February 22, 2017

FOUNDATION INVESTIGATION AND DESIGN REPORT

Structural Culvert Replacement - Highway 112 Unnamed Creek Culvert, Site No. 47-415/C Ministry of Transportation, Ontario G.W.P. 5105-12-00; W.P. 5427-15-01

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MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 5105-12-00; W.P. 5427-15-01

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by MMM Group Limited (MMM) on behalf of Ministry of Transportation, Ontario (MTO) to provide Foundation Engineering services for the replacement of the Unnamed Creek structural culvert at STA 23+975 on Highway 112 in the Township of Otto (MTO Structure Site No. 47-415/C), approximately 6 km south of Kirkland Lake, Ontario.

The Terms of Reference and the Scope of Work for the foundation investigation are outlined in MTO's Work Order / Assignment #2, dated March 2016. Golder's proposal for the foundation engineering services associated with the structural culvert is contained in Golder's letter addressed to MMM, dated April 13, 2016. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated May 25, 2016.

This report addresses the investigation carried out for the Unnamed Creek culvert at STA 23+975 on Highway 112 which has been identified for replacement. The foundation investigation and design associated with the centreline culverts for Work Order / Assignment #2 are presented in separate reports.

2.0 SITE DESCRIPTION

The structural culvert at Unnamed Creek requiring replacement is located at approximately STA 23+975 on Highway 112 in the Township of Otto, approximately 6 km south of Kirkland Lake, Ontario. The existing culvert is a 3.1 m wide by 2.5 m high open footing structure located within an approximately 4 m high fill embankment. Details of the culvert are summarized in Table 1 following the text of this report.

In general, the topography in the area of the culvert consists of a relatively flat lacustrine plain used for agricultural purposes. Sparse clusters of trees and brush are present along Unnamed Creek in the creek bed which creates a local depression within an otherwise flat landscape. Beyond the immediate area of the culvert the surface topography is rolling and has sparsely to densely populated treed areas and numerous bedrock outcrops separated by valleys which generally contain agricultural land or swamps containing slow flowing to standing water, various types of vegetation and organic soils. The developed area directly adjacent to Highway 112 is primarily used for residential purposes and agriculture. The ground surface at the borehole locations advanced for the culvert investigation, including through the existing Highway 112 embankment, varies between Elevation 283.4 m and 279.8 m, referenced to Geodetic datum. Figure 1 contains photographs of the culvert location.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the foundation investigation associated with the Unnamed Creek culvert at STA 23+975 was carried out between June 2 and 7, 2016, during which time a total of six boreholes were advanced at, or in the immediate vicinity of the culvert alignment as summarized in Table 1 and as shown in plan on Drawing 1.

The field investigation was carried out using a truck-mounted CME55 drill rig and portable drilling equipment which were supplied and operated by Landcore Drilling of Sudbury, Ontario.

The boreholes drilled by the truck-mounted CME55 drill rig were advanced through the overburden using 152 mm diameter solid stem augers, 203 mm outer diameter hollow stem augers, NQ size casing with wash boring techniques and NQ coring. The boreholes completed by the portable equipment were advanced through the overburden using HQ size casing with wash boring techniques. In general, soil samples were obtained at intervals of depth of about 0.75 m and 1.5 m using a 50 mm outside diameter (O.D.) split-spoon sampler operated by an automatic hammer on the drill rig, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586). Boreholes advanced by portable equipment employed a full-weight hammer lifted manually and dropped from the SPT height. In situ field vane testing, using a MTO standard "N"-vane (ASTM D2573), was carried out in the cohesive soils, where appropriate, to measure the undrained shear strength of the deposit.

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

A sample of creek water was obtained at the culvert location on June 12, 2016 and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters including pH, resistivity, conductivity, sulphates and chlorides. The results of the analytical testing are included in Appendix C.

The fieldwork was observed by members of Golder's engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined the soil samples. The soil samples were identified in the field, placed in appropriate containers, labelled and transported to our Mississauga geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO Laboratory Standards and/or ASTM Standards, as appropriate. Classification testing (water content, organic content, Atterberg limits, grain size distribution) and a consolidation test were carried out on selected soil samples. The results of the laboratory testing are summarized on the Record of Borehole sheets in Appendix A and presented in the laboratory test figures in Appendix B.

The borehole locations were surveyed in the field relative to a fixed marker on site. The as-drilled borehole locations, in stations and offsets, were measured in reference to the applicable marker and from existing site features and were subsequently converted into MTM NAD 83 (Zone 12) coordinates in AutoCAD. Borehole elevations were surveyed by a member of our technical staff in reference to the centreline of Highway 112 and the existing culvert and were subsequently converted to Geodetic elevations using topographic information provided by MTO. The borehole locations and elevations are given on the Record of Borehole sheets and shown on Drawings 1 and 2. The borehole locations, ground surface elevations and drilled depths are summarized below.

Culvert Location	Borehole	Location		Ground Surface Elevation (m)	Depth of Borehole / DCPT (m)
		Northing (m) / Latitude (°)	Easting (m) / Longitude (°)		
STA 23+975 (Township of Otto)	C3-1	5327881.0 / 48.085852	375949.3 / -80.044898	279.8	11.0
	C3-2	5327882.8 / 48.085866	375962.0 / -80.044728	283.4	18.3
	C3-3	5327893.0 / 48.085954	375993.1 / -80.044309	280.1	9.7

Culvert Location	Borehole	Location		Ground Surface Elevation (m)	Depth of Borehole / DCPT (m)
		Northing (m) / Latitude (º)	Easting (m) / Longitude (º)		
	C3-4	5327895.1 / 48.085980	375932.7 / -80.045119	280.3	7.6 / 12.0
	C3-5	5327902.5 / 48.086046	375940.8 / -80.045009	283.4	15.9 / 17.6
	C3-6	5327860.4 / 48.085662	375981.7 / -80.044466	283.1	16.6 / 17.3

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Highway 112 is located in the Abitibi Uplands physiographic region, within the Canadian Shield as delineated by the *Geomorphic Systems of North America*[1]. The Abitibi Uplands generally slopes towards Hudson Bay and is typically characterized by low broad hills with gently sloping, rolling or undulating topography and subdued relief. This region is underlain by massive, mainly crystalline rocks covered by Quaternary glaciolacustrine, glaciofluvial, and till deposits, as well as more recent organic deposits within the depressions between bedrock knobs[2].

Highway 112 crosses four main assemblages, or batholiths, associated with the southern Abitibi Greenstone Belt[3]: Round Lake Batholith; Catharine-Pacaud assemblage; Boston assemblage and Temiskaming assemblage. The southern end of the highway, where it meets the TransCanada Highway is located within the granodioritic Round Lake Batholith. The highway trends north passing through the Catharine-Pacaud and Boston assemblages which are characterized by mafic to intermediate grey to green basalt flows with felsic to silicious banding and plagioclase phenocrysts and metavolcanic to metasedimentary basalts, cherts and conglomerates, respectively. The northern end of Highway 112 contains the Temiskaming assemblage, characterized by clastic metasedimentary rocks, primarily cherts (jasper) and sandstones. This area contains multiple faults and deformations associated within the Larder-Cadillac shear zone which generally runs along Highway 11 in the area where it intersects with Highway 112.

4.2 General Overview of Local Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil and bedrock samples, are presented on the Record of Borehole sheets and the laboratory test sheets in Appendices A and B,

[1] Graf, W. L. (1987). *Geomorphic systems of North America*. Geological Society of America, Inc.: Boulder, Colorado.

[2] Ministry of Northern Development and Mines, Ontario (MNDMO). (2016). *OGSEarth:* Quaternary Geology [Electronic Map]. 1:1,000,000. Retrieved July 28, 2016 from OGSEarth. Queen's Printer for Ontario, 2016.

[3] Jackson, S. L. and Fyon, J. A. (1991). The western Abitibi subprovince in Ontario; in Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 1, p.405-482.

respectively. The results of the in-situ field tests (i.e. SPT 'N'-values and field vane undrained shear strengths) as presented on the Record of Borehole Sheets and in Section 4.3 are uncorrected. The stratigraphic boundaries shown on the Record of Boreholes sheets are inferred from non-continuous sampling, observations of drilling progress and in situ testing and are approximate. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

The stratigraphy at the borehole locations at the culvert site consists of surficial layers of peat or embankment fill, underlain by a deposit of soft to stiff clayey silt to clay, which contains trace organic near surface. The clayey silt to clay deposit is underlain by a deposit of compact to dense sand and gravel, which is separated from the clayey silt to clay deposit by a silt layer at one borehole location. A detailed description of the subsurface conditions at the culvert crossing is provided in the following section of this report. Where relatively significant thicknesses of overburden were encountered, the various soil types are described in detail for each main deposit or stratum.

4.3 Unnamed Creek Culvert (STA 23+975)

The plan/profile along the centreline of the existing Unnamed Creek culvert at STA 23+975 showing the borehole locations and interpreted stratigraphy as well as a profile on the highway embankment crest and a cross section of the embankment to the north of the culvert are shown on Drawings 1 and 2. The height of the embankment at the culvert location is between about 3.5 m to 4.0 m and the existing culvert is about 27.5 m long. A total of three boreholes and were completed to investigate the subsurface conditions at the culvert location: two boreholes (Borehole C3-1 and C3-3) were advanced near the ends of the existing culvert and one borehole (Borehole C3-2) was advanced through the Highway 112 southbound lane roadway embankment on the north side of the existing culvert alignment. An additional three boreholes (Boreholes C3-4 to C3-6) were advanced at the west toe and crest of the existing highway embankment to investigate the subsurface conditions at the proposed embankment widening location.

4.3.1 Asphalt

An approximately 100 mm and 90 mm layer of asphalt was encountered at ground surface in Boreholes C3-2 and C3-5, respectively.

4.3.2 Embankment Fill

Embankment fill approximately 3.0 m and 3.7 m thick was encountered below the asphalt at Elevation 283.4 m in Boreholes C3-5 and C3-2, respectively. A 0.2 m thick layer of sand fill containing trace organics was also encountered at ground surface in Borehole C3-6. The embankment fill consists of sandy silt, sand, gravelly sand and sand and gravel, generally becoming finer in gradation with depth. Cobbles were inferred to be present within the fill from auger grinding between depths of 2.0 m and 3.1 m (Elevation 281.4 m and 280.3 m) in Borehole C3-2. Approximately 0.1 m diameter cobbles were noted to be present in the sandy silt fill cuttings brought to surface by the augers in Borehole C3-5 between depths of about 2.4 m and 2.7 m (Elevation 281.0 m and 280.7 m).

The SPT 'N'-values measured within the embankment fill deposit range between 3 blows and 16 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

The natural water content measured on four samples of the sand to sand and gravel portion of the deposit is between about 4 per cent and 5 per cent. The natural water content measured on a sample of the sandy silt, containing trace organics, is about 20 per cent.

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

4.3.3 Peat and Organic Silty Clay

A 0.3 m to 0.5 m thick surficial deposit of peat was encountered in Boreholes C3-1, C3-3 and C3-4 between Elevation 280.3 m and 279.8 m. A 0.8 m thick layer of organic silty clay was encountered below the embankment fill in Borehole C3-2 at Elevation 279.7 m.

A SPT 'N'-value of 2 blows per 0.3 m of penetration was measured within the organic silty clay deposit, suggesting a soft consistency.

The natural water content and organic content measured on a sample of the organic silty clay is about 94 per cent and 19 per cent, respectively.

4.3.4 Clayey Silt to Clay

A 9.3 m to 16.4 m thick deposit of clayey silt to clay was encountered underlying the near surface non-cohesive interlayer between Elevation 282.9 m and 278.2 m in all of the boreholes advanced at the culvert site. In Boreholes C3-1 and C3-2, the upper 1.9 m and 0.7 m of the deposit consists of a sandy gravelly silt clay containing trace organics in the respective boreholes. In addition, a 0.1 m thick layer of sand and gravel, some silt was encountered within the silty clay deposit at Elevation 279.3 m in Borehole C3-3. In general, boreholes advanced within the extent of the creek bed contained trace organics within the upper 0.5 m to 1.3 m of the deposit.

The measured SPT 'N'-values within the clayey silt to clay deposit generally range between 0 blows (weight of rods/hammer) to 2 blows per 0.3 m of penetration. SPT 'N'-values between 4 blows and 9 blows per 0.3 m of penetration were measured in the upper portion of the deposit. Field vane tests carried out within the deposit measured undrained shear strengths ranging from about 20 kPa to 54 kPa and sensitivities between 2 and 9. The vane undrained shear strength results indicate that the deposit has a soft to stiff consistency.

The natural water content measured on 30 samples of the clayey silt to clay deposit ranges between about 31 per cent and 67 per cent. The natural water content measured on a sample of the sand and gravel interlayer within the non-cohesive deposit is about 17 per cent.

The results of grain size distribution tests completed on 13 samples of the clayey silt to clay deposit are shown on Figures B2A and B2B in Appendix B.

Atterberg limits tests were carried out on 18 samples of the cohesive deposit and measured liquid limits ranging from about 27 per cent to 53 per cent, plastic limits ranging from 15 per cent to 20 per cent and plasticity indices ranging from 8 per cent to 33 per cent. The test results, which are plotted on a plasticity chart on Figure B3 in Appendix B, indicate that the material tested ranges from a clayey silt of low plasticity to clay of high plasticity.

A laboratory consolidation test was carried out on one specimen of the clayey silt to silty clay component of the deposit obtained from a Shelby tube sample in Borehole C3-1. A preconsolidation stress of about 75 kPa was estimated from the void ratio versus logarithmic pressure plot and from the total work versus pressure plot. A bulk unit weight of about 16 kN/m^3 and a specific gravity of about 2.73 were measured on the consolidation test specimen. Details of the test results are shown on Figure B4 in Appendix B and are summarized below.

Borehole (Sample No.)	Sample Depth / Elevation	σ_{vo}' (kPa)	σ_p' (kPa)	σ_p' - σ_{vo}' (kPa)	OCR	C_c	C_r	e_o	c_v* (cm^2/s)
C3-1 (S-1)	3.9 m / 275.9 m	30	75	45	2.5	0.59	0.19	1.72	2.5 x 10 $^{-3}$

Note: * For stress range of 20 kPa ≤ σ'_v ≤ 155 kPa

Where:
- σ_{vo}' is the effective overburden stress in kPa
- σ_{vo}' is the preconsolidation stress in kPa
- OCR is overconsolidation ratio
- e_o is initial void ratio
- C_c is the compression index
- C_r is the recompression index
- c_v is the coefficient of consolidation in cm^2/s

4.3.5 Silt to Silty Sand / Sand and Gravel

A non-cohesive deposit comprised of silt to silty sand and/or sand and gravel deposit was encountered below the clayey silt to clay deposit. The non-cohesive deposit(s) range from a 0.1 m to 0.7 m thick layer of silt to silty sand which was encountered above the sand and gravel and below the clayey silt to clay deposit at Elevation 270.5 m and 268.2 m in Boreholes C3-3 and C3-2, respectively; Borehole C3-3 was terminated within the silty sand layer. A 1.1 m and 2.4 m thick sand and gravel component of the deposit was encountered below the silt to silty sand layer in Borehole C3-2 and below the clayey silt to clay deposit in Borehole C3-5 at Elevations 267.5 m and 268.6 m, respectively. Borehole C3-5 was terminated within the sand and gravel deposit. Cobbles between 0.1 m and 0.2 m diameter were encountered within the sand and gravel deposit below a depth of 16.8 m (Elevation 251.4 m) in Borehole C3-2 and were inferred to be present in Borehole C3-4 by auger grinding below a depth of 14.8 m (Elevation 268.6 m).

A SPT 'N'-value of 1 blow per 0.3 m of penetration was measured within the silt component of the silty sand to silt layer, indicating a very loose relative density. SPT 'N'-values between 22 blows and 48 blows per 0.3 m of penetration were measured within the sand and gravel deposit, indicating a compact to dense relative density. SPT 'N'-values of 100 blows per 0.08 m of penetration and 100 blows per 0.05 m of penetration were measured at borehole refusal in Boreholes C3-3 and C3-2, respectively.

The natural water content measured on a sample of the sand and gravel deposit was about 7 per cent.

The result of a grain size distribution test completed on a sample of the sand and gravel is shown on Figure B5 in Appendix B.

4.3.6 Refusal

Refusal to further split-spoon and casing advancement was encountered within the clayey silt to silty clay deposit and silty sand layer in Boreholes C3-1 and C3-3 at depths of 11.0 m (Elevation 268.1 m) and 9.7 m (Elevation 270.4 m), respectively. Refusal to split-spoon advancement was encountered in Borehole C3-2 within the sand and gravel deposit at a depth of 18.3 m (Elevation 265.1 m). DCPT's advanced from the bottom of Boreholes C3-4 and C3-5 encountered refusal at depths of 12.0 m and 17.6 m (Elevations 268.3 m and 265.8 m), respectively.

4.3.7 Groundwater Conditions

The water level was measured in Boreholes C3-1 to C3-6 upon completion of drilling operations at depths between 0 m (at ground surface) and 3.2 m below ground surface, ranging from Elevations 282.1 m to 277.1 m. The water level at the site is expected to fluctuate seasonally in response to changes in precipitation and snow melt, and is expected to be higher during the spring and periods of precipitation.

4.3.8 Analytical Testing of Creek Water

The results of an analytical test on a sample of creek water taken from culvert site is provided in Appendix C. The suite of parameters tested include pH, sulphate, chloride, resistivity and conductivity.

5.0 CLOSURE

Messrs. Shane Albert and Dave Marmor, EIT, supervised the borehole investigation program. This report was prepared by Ms. Madison Kennedy, B.A.Sc., and was reviewed by Mr. Christopher Ng, P.Eng., a senior geotechnical engineer and an Associate of Golder. Mr. Jorge Costa, P.Eng., a Senior Consultant with Golder and Designated MTO Foundations Contact conducted an independent quality control review of this report.

Report Signature Page

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PART B

FOUNDATION DESIGN REPORT
STRUCTURAL CULVERT REPLACEMENT – HIGHWAY 112
UNNAMED CREEK CULVERT, SITE NO. 47-415/C
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 5105-12-00; W.P. 5427-15-01

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the proposed replacement of the Culvert Site No. 47-415/C at STA 23+975 on Highway 112. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the investigation. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess the feasible foundation alternatives and carry out the design of the culvert foundations. The foundation investigation report, discussion and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part A of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

Golder Associates Ltd. (Golder) was retained by MMM Group Limited (MMM) on behalf of the MTO to provide recommendations on the foundation aspects of the detail design for the replacement of the existing centerline culvert at STA 23+975 on Highway 112 in the Township of Otto.

This report presents geotechnical resistances for design of the replacement culvert as well as the results of stability and settlement analyses associated with embankment reconstruction, and provides recommendations for stable embankment geometry and embankment fill materials that may be required as a means to reduce culvert embankment settlements and to improve embankment stability (if necessary). The report also addresses potential construction concerns and geotechnical issues associated with culvert construction, sub-excavating soft/organic materials and placement of new fill materials.

We understand that the proposed replacement culvert will be a 3.0 m wide by 2.4 m high by 27.7 m long concrete box structure with upstream (east end) and downstream (west end) inverts at Elevations 279.3 m and 279.2 m, respectively, and the culvert alignment will remain unchanged. In addition, there is no embankment grade raise or widening associated with the culvert replacement. Further, it is also understood that the replacement of the culvert will be carried out under full closure of Highway 112 and that temporary embankment widening or grade lowering will not be required. In the event that a different type of culvert is considered as the replacement option, a comparison between different types of culverts is presented in Table 2 and discussed in Section 6.3.

6.2 Consequence and Site Understanding Classification

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

6.3 Culvert/Foundation Types for Culvert Replacement

6.3.1 Culvert/Foundation Options

A CSP (corrugated steel pipe) culvert, concrete pipe culvert, precast box culvert, and cast-in-place open footing culvert are all feasible alternatives for the replacement of the existing culvert. Foundation recommendations are provided below for these feasible alternative culvert types although it is understood that the proposed replacement culvert will be a 3.0 m wide by 2.4 m high precast box structure.

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

6.3.2 Founding Elevations and Frost Protection Requirements

6.3.2.1 Corrugated Steel Pipe Culvert Replacement

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

6.3.2.2 Concrete Pipe Culvert Replacement

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

6.3.2.3 Precast Box Culvert Replacement

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

6.3.2.4 Open Footing Culvert Replacement

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

6.3.3 Factored Geotechnical Resistances

6.3.3.1 Corrugated Steel Pipe (CSP) Culvert Replacement

A CSP culvert placed on the properly prepared subgrade (i.e. compacted granular fill on soft to firm clayey silt to clay deposit), at or below the founding elevation recommended in Table 3, should be designed based on the recommended factored ultimate geotechnical resistance at Ultimate Limit State (ULS) and the factored serviceability geotechnical resistance at Serviceability Limit State (SLS) for 25 mm of settlement, as given in Table 3. These recommendations are based on a 3 m diameter CSP culvert.

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

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

6.3.3.2 Concrete Pipe Culvert Replacement

A concrete pipe culvert placed on the properly prepared subgrade (i.e. compacted granular fill on soft to firm clayey silt to clay deposit), at or below the founding elevation recommended in Table 3, should be designed based on the recommended factored ultimate geotechnical resistance at ULS and the factored serviceability geotechnical resistance at SLS for 25 mm of settlement, as given in Table 3. These recommendations are based on a 3 m diameter concrete pipe culvert.

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

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

6.3.3.3 Precast Box Culvert Replacement

A precast box culvert placed on the properly prepared subgrade (i.e. compacted granular fill on soft to firm clayey silt to clay deposit), at or below the founding elevation recommended in Table 3, should be designed based on the recommended factored ultimate geotechnical resistance at ULS and the factored serviceability geotechnical resistance at SLS for 25 mm of settlement, as given in Table 3. These recommendations are based on a 3 m wide by 2.4 m high by 27.7 m long concrete box culvert.

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

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

6.3.3.4 Open Footing Culvert Replacement

Strip footings placed on the properly prepared subgrade (i.e. soft to firm clayey silt to clay deposit), at or below the founding elevation recommended in Table 3, should be designed based on the factored ultimate geotechnical resistance at ULS and the factored serviceability geotechnical resistance at SLS for 25 mm of settlement, as given in Table 3. These recommendations are based on an assumed footing width of 0.6 m.

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

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

6.3.4 Resistance to Lateral Loads / Sliding Resistance

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

6.4 Embankment Stability and Settlement

It is understood that there are no changes to the final grade and embankment geometry of Highway 112 associated with this culvert replacement and that the culvert replacement will be carried out under the full close of the highway.

The results of stability and settlement analysis for the temporary excavation and final embankment geometry are presented in the following sections.

6.4.1 Stability

6.4.1.1 Methodology

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

6.4.1.2 Parameter Selection

For the non-cohesive soils present at this site, the effective stress parameters employed in the analysis were estimated from empirical correlations based on the results of the in situ Standard Penetration Tests (SPT). The correlations proposed by Peck et al (1974) and U.S. Navy (1986) were employed and the results were adjusted by engineering judgment based on precedent experience in similar soils. The strength parameters for organic deposits were assessed based on engineering judgement and data from soils of the same classification. The simplified stratigraphy, parameters and associated strengths and unit weights employed for the existing and new fill material as well as the native overburden deposits encountered at the culvert site used in the analysis are summarized in Table 5, following the text of this report.

For the purpose of the stability analysis, the groundwater level at was assumed to be at the level at which it was encountered in the boreholes advanced during the site investigation.

6.4.1.3 Results of Analysis

The results of the stability analysis for the temporary excavation and final embankment geometry at the critical sections at the culvert site are summarized in Table 6. At this site, the FoS for the temporary excavation and final embankment geometry is equal to or greater than 1.3 and 1.5, respectively.

6.4.2 Settlement

6.4.2.1 Settlement of Foundation Soils

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

These settlements are immediate and are expected to occur relatively quickly (i.e. during construction) in response to the embankment construction.

6.5 Lateral Earth Pressures

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

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

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

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

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

6.6 Construction Considerations

6.6.1 Temporary Excavation and Roadway Protection

The temporary excavations for the culvert replacement will be made through the existing embankment fill and into native overburden soils, which typically are comprised of soft organic silty clay, sand and gravel and soft to firm sandy gravelly clayey silt to clayey silt to clay. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. According to OHSA, the existing fill and native overburden soils would be classified as Type 3 and Type 4 soils, respectively. Provided that proper groundwater control is in place, temporary open-cut excavations through the embankment fill and native overburden soils should be made with side slopes inclined no steeper than 1H:1V and 3H:1V, respectively.

If a temporary protection system is required, a sheet pile shoring system or a soldier pile and lagging system may be used for support of the excavation.

Temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). The lateral movement of the temporary shoring should meet Performance Level 2 as specified in OPSS.PROV 539.

The selection and design of the protection system is the responsibility of the Contractor. The support systems may be designed using the parameters provided in Table 5.

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

Design of the temporary support system should include an evaluation of base stability, soil squeezing stability and the hydraulic uplift stability as defined in the Canadian Foundation Engineering Manual (CFEM, 2006). Further, the native soil (i.e. clayey silt to clay) at this site is sensitive to disturbance from driving operations for pile installation which should be considered in the design, installation and removal of the temporary protection system.

Consideration could be given to either partial or full removal of the temporary protection system upon completion of construction or each stage of construction (as required). Where possible, full removal of the temporary protection system should be considered to mitigate potential impediments to future rehabilitation/reconstruction work at the culvert site. However, where the temporary protection system penetrates into cohesive soils, there is a potential risk that full removal will result in a void within the soil column due to adhesion along the sheet pile (or H-pile) walls (CFEM, 2006). Given the founding depth of the proposed culvert replacement at this site, it is anticipated that the temporary protection system will be installed into the cohesive clayey silt to clay deposit. There is little to no risk of pile adhesion within the granular embankment fill, however if the temporary protection system, as designed and installed by the Contractor, extends into the cohesive deposit, there is a potential risk of adhesion which should be re-evaluated after pile installation depending on the depth of penetration. For piles installed to a toe Elevation 278.3 m or lower, penetrating greater than 1 m into the clayey silt to clay deposit consideration will need to be given to only partial depth removal.

6.6.2 Sub-Excavation and Replacement below Culvert Bedding

Prior to the placement of any bedding material or backfill, all organic soils should be stripped from the plan limits of the proposed works. Given the design invert elevations of the replacement culverts summarized in Table 3, excavation of the embankment fill, organic material and native overburden soils up to about 4.5 m below existing ground surface will be required. Where excavation below the proposed culvert foundation level is required to remove disturbed/unsuitable material or the existing culvert footings, replacement backfill consisting of OPSS.PROV 1010 Granular 'B' should be used.

The culvert subgrade, if comprised of native material, or the excavation base following sub-excavation, should be inspected, to ensure that all organic soils or other unsuitable materials have been removed in accordance with OPSS.PROV 421 (Pipe Culvert Installation in Open Cut) for a concrete pipe or CSP culvert, OPSS 422 (Precast Reinforced Concrete Box Culverts) for a precast box culvert and OPSS 902 (Excavating and Backfilling Structures) for a cast-in-place open footing culvert. Following inspection, the sub-excavated area should be backfilled with granular material meeting OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II and placed and compacted in accordance with OPSS.PROV 501 (Compacting) to at least 98 per cent of the Standard Proctor maximum dry density of the material.

Taking into consideration that backfill/bedding will be placed on the native clayey silt to clay deposit, it is recommended that a non-woven geotextile be placed between the subgrade soils and the bottom of the backfill/bedding. The geotextile should meet the specification for OPSS 1860 (Geotextiles) Class II and have a Filtration Opening Size (FOS) not greater than 212 μm.

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

6.6.3 Culvert Bedding and Backfill

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

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

Culvert bedding should be placed on a properly prepared subgrade whether comprised of native material or sub-excavation backfill. The bedding, cover and backfill should be placed in lifts not exceeding 200 mm in loose thickness, and compacted to at least 95 per cent of the Standard Proctor maximum dry density of the material as specified in OPSS.PROV 501 (Compacting).

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

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

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

6.6.3.1 Corrugated Steel Pipe Culvert

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

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

6.6.3.2 Concrete Pipe Culvert

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

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

6.6.3.3 Precast Box Culvert

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

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

6.6.3.4 Open Footing Culvert

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

6.6.4 Subgrade Protection

The cohesive overburden soils exposed at the founding level will be susceptible to disturbance from construction traffic and/or ponded water. To limit the effect of this disturbance, a concrete working slab could be placed on the subgrade if the concrete for the footings, or the box culvert, is not placed within four hours after preparation, inspection and approval of the subgrade. The minimum thickness of the concrete working slab should be 100 mm and the concrete should have a 28-day compressive strength of not less than 20 MPa. A sample NSSP to address this requirement is included in Appendix D.

6.6.5 Erosion Protection

Provision should be made for scour and erosion protection at the culvert location. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring), or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall should be provided at the upstream end of the CSP, concrete pipe and precast box culvert. If a clay seal is adopted, the clay material should meet the requirements of OPSS.PROV 1205 (Clay Seal), and the seal should be a minimum 1 m thick if constructed of natural clay or soil-bentonite mix, and extend from a depth of 1 m below the scour level for a CSP, concrete pipe or precast box culvert, and from the ground surface immediately adjacent to an open footing culvert, to a minimum horizontal distance of 2 m on either side of the culvert inlet opening and to a minimum vertical height equivalent to the high water level, including along the embankment slopes.

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

6.6.6 Surface Water and Groundwater Control

For excavations extending to or below the surface water or groundwater levels at the time of construction, groundwater inflows may occur through the relatively permeable sand and gravel layer directly below the existing culvert. Therefore, control of groundwater may be necessary to allow for construction to be carried out in dry conditions. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade. Dewatering of all excavations should be carried out in accordance with OPSS 517 (Dewatering).

Surface water and groundwater control could be in the form of a sheet-pile cut off wall or cofferdam advanced to an appropriate depth to control groundwater inflow and to prevent base heaving of the foundation subgrade. Alternatively, a sand bag and/or bladder cofferdam system could be used, but the design of/measures to control groundwater inflow and protection of excavations is the responsibility of the Contractor.

Depending on the surface water level and flow conditions and groundwater levels at the time of construction, water flow could be diverted and/or pumped from behind a cofferdam; however, if construction dewatering pumping volumes are anticipated to exceed 50 m^3/day, an Environmental Activity Section Registry (EASR) will be required as per the recently introduced changes to the Environmental Protection Act by the Ontario Ministry of the Environment and Climate Change (MOECC).

7.0 CLOSURE

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

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ASTM International:

ASTM D1586	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
ASTM D2573	Standard Test Method for Field Vane Shear Test in Saturated Fine-Grained Soils

Ontario Occupational Health and Safety Act:

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

Ontario Provincial Standard Drawing:

OPSD 208.010	Benching of Earth Slopes
OPSD 802.010	Flexible Pipe Embedment and Backfill
OPSD 802.031	Rigid Pipe Bedding, Cover and Backfill, Type 3 Soil – Earth Excavation
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 3090.100	Foundation, Frost Penetration Depths for Northern Ontario

Ontario Provincial Standard Specification:

OPSS.PROV 401	Trenching, Backfilling and Compacting)
OPSS.PROV 421	Pipe Culvert Installation in Open Cut)
OPSS 422	Construction Specifications for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS.PROV 501	Construction Specifications for Compacting

OPSS 517	Construction Specifications for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Construction Specifications for Temporary Protection Systems
OPSS 902	Construction Specifications for Excavating and Backfilling – Structures
OPSS.PROV 1002	Material Specifications for Aggregates - Concrete
OPSS.PROV 1010	Material Specifications for Aggregates – Base, Subbase, Select Subgrade, Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
OPSS 1860	Material Specification for Geotextiles

Ontario Water Resources Act:

Ontario Regulation 903 Wells (as amended)

Commercial Software:

Slide (Version 6.0) by Rocscience Inc

TABLES

Table 1: Summary of Existing Culvert Details

Culvert Location (Township)	Culvert ID (Site No.)	Approximate Height of Embankment [1]	Existing Culvert			Approximate Invert Elevation [2]		Boreholes
			Type	Approximate Dimension	Approximate Length	Upstream End of Culvert	Downstream End of Culvert	
STA 23+975 (Otto)	C3 (47-415C)	Up to about 4 m	Open Footing	3.1 m wide by 2.5 m high	27.5 m	279.3 m (East)	279.1 m (West)	6 Boreholes (C3-1 to C3-6)

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

2. Culvert invert elevations are estimated based on the top of culvert surveys and culvert dimensions provided by MTO.

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

Table 2: Comparison of Culvert Replacement Options

Replacement Alternatives	Advantages	Disadvantages	Risks/Consequences
Corrugated Steel Pipe (CSP) Culvert	■ Minimizes the depth of excavation, excavation support and dewatering requirements compared to cast-in-place open footing culvert. ■ Culvert construction using CSP pipes is expected to be the fastest, resulting in the shortest duration for dewatering and surface water pumping, where required. ■ More tolerant of total and differential settlement if a change in embankment geometry or a grade raise is required at the culvert site than cast-in-place open footings.	■ Dewatering would be required if excavation extends below the groundwater level and construction is to be carried out in-the-dry to allow for placement and compaction of backfill around the culvert. ■ Cut-off wall or clay blanket may be required at inlet to mitigate potential for scour under culvert. ■ Proper compaction of backfill material under the haunches and to the springline is difficult. ■ Will have a shorter lifespan than a concrete structure (concrete pipe, precast box or open footing culvert). ■ Much larger structure(s) may be required to accommodate design flows as compared to a box or open footing culvert of similar span width and height.	■ Some risk of disturbance of the soft to firm sandy gravelly silty clay and soft to firm clayey silt to silty clay deposits under the culvert during construction.
Concrete Pipe Culvert	■ Minimizes the depth of excavation, excavation support and dewatering requirements compared to cast-in-place open footing culvert. ■ Compared to cast-in-place open footings, the use of concrete pipe segments is expected to allow for faster construction, resulting in shorter duration for dewatering and surface water pumping, where required. ■ More tolerant of total and differential settlement if a change in embankment geometry or a grade raise is required at the culvert site than cast-in-place open footings. ■ Will have a longer lifespan than a culvert of CSP construction.	■ A concrete pipe culvert will require slightly longer duration for construction as compared to the construction of a CSP culvert. ■ Dewatering/unwatering would be required if the excavation extends below the groundwater level and construction is to be carried out in-the-dry to allow for placement and compaction of backfill around the culvert. ■ Cut-off wall or clay blanket may be required at inlet to mitigate potential for scour under culvert. ■ Proper compaction of backfill material under the haunches and to the springline is difficult. ■ Much larger structure(s) may be required to accommodate design flows as compared to a box or open footing culvert of similar span width and height.	■ Some risk of disturbance of the soft to firm sandy gravelly silty clay and soft to firm clayey silt to silty clay deposits under the culvert during construction.

Table 2: Comparison of Culvert Replacement Options

Replacement Alternatives	Advantages	Disadvantages	Risks/Consequences
Precast Box Culvert	■ Minimizes the depth of excavation, excavation support and dewatering requirements compared to cast-in-place open footing culvert. ■ Compared to cast-in-place open footings, the use of precast box segments is expected to allow for faster construction, resulting in shorter duration for dewatering and surface water pumping. ■ More tolerant of total and differential settlement from the embankment widening, or if a grade raise is required, at the culvert site than cast-in-place open footings. ■ Will have a longer lifespan than a culvert of CSP construction. ■ Easier to place/compact bedding/cover backfill compared to a CSP or concrete pipe culvert. ■ If required, bedding and backfill can be placed in wet conditions. ■ Box culvert of similar span width and height as a CSP or concrete pipe culvert can accommodate higher flows.	■ A precast box culvert will require longer duration for construction than a CSP and a concrete pipe culvert. ■ Cut-off wall or clay blanket usually required at inlet to mitigate potential for scour under culvert.	■ Some risk of disturbance of the soft to firm sandy gravelly silty clay and soft to firm clayey silt to silty clay deposits under the culvert during construction.

Table 2: Comparison of Culvert Replacement Options

Replacement Alternatives	Advantages	Disadvantages	Risks/Consequences
Cast-In-Place Open Footing Culvert	■ Provides a relatively higher bearing capacity due to the depth of embedment of footings. ■ Will have a longer lifespan than a culvert of CSP construction. ■ Open footing culvert of similar span width and height as a CSP or concrete pipe culvert can accommodate higher flows. ■ Excavation of the existing culvert footings may be reused to accommodate the new footings, provided such excavation extends to below the depth of frost penetration.	■ Deeper excavations, excavation support and dewatering requirements compared to other culvert types (footing are founded below the depth of frost penetration); ■ Additional time will be required to implement a dewatering system for the construction of footings in-the-dry. ■ A cast-in-place open footing culvert is less tolerant of total and differential settlement.	■ High risk of disturbance of the soft to firm sandy gravelly silty clay and soft to firm clayey silt to silty clay deposits under the culvert during construction. ■ Culvert joints may be required to accommodate total and differential settlement (if applicable)

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

Culvert Location (Township)	Proposed Invert Elevation [1] (Upstream / Downstream)	Culvert Type	Culvert Dimensions [1]	Approximate Founding Elevation (Upstream / Downstream)	Founding Condition	Factored Ultimate Geotechnical Resistance at ULS [2]	Factored Serviceability Geotechnical Resistance at SLS for 25 mm of Settlement [2]
STA 23+975 Site No. 47-415/C (Otto)	279.3 m / 279.2 m (East / West)	Corrugated Steel Pipe (CSP)	3 m diameter by 27.7 m long	279.0 m / 278.9 m	Compacted Granular Fill on Soft to Firm Clayey Silt to Clay	100 kPa	75 kPa
		Concrete Pipe Culvert	3 m diameter by 27.7 m long	279.0 m / 278.9 m	Compacted Granular Fill on Soft to Firm Clayey Silt to Clay	100 kPa	75 kPa
		Precast Box	3 m wide by 2.4 m high by 27.7 m long	279.0 m / 278.9 m	Compacted Granular Fill on Soft to Firm Clayey Silt to Clay	100 kPa	75 kPa
		Cast-In-Place Open Footing	0.6 m wide footings / 3 m span by 2.4 m high by 27.7 m long	276.9 m / 276.8 m	Soft to Firm Clayey Silt to Clay	110 kPa	95 kPa

Notes: 1. Culvert invert elevations and dimensions were provided by MTO on October 26, 2016.

2. The factored ultimate geotechnical resistances at ULS and factored serviceability geotechnical resistances at SLS for 25 mm of settlement are estimated based on the culvert dimensions indicated in the table. The geotechnical resistances should be reviewed if the founding elevation and/or the footing/base diameter/width differ from those given above.

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

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

Culvert Type	Interface Material	Coefficient of Friction ($\tan \delta$)
Corrugated Steel Pipe Culvert (CSP)	Compacted Granular Fill (Bedding)	0.55
Concrete Pipe Culvert	Compacted Granular Fill (Bedding)	0.40
Pre Cast Box Culvert	Compacted Granular Fill (Bedding)	0.40
Cast In Place Open Footing Culvert	Soft to Firm Clayey Silt to Clay	0.30

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

Table 5: Summary of Foundation Engineering Parameters

Culvert Designation	Culvert Location (Township)	Stratigraphic Unit	Top Elevation (m)	Thickness (m)	γ' (kN/m^3)	ϕ' (°)	c' (kPa)	S_u (kPa)	σ_p' (kPa)	e_o	C_c	C_r	E' (MPa)	c_v (cm^2/s)	Coefficient of Earth Pressure		
															Active, K_a	At Rest, K_o	Passive, K_p
C3 Site No. 47-415/C	Highway 112 STA 23+975 (Otto)	New Granular Embankment Fill	-	-	21	34	-	-	-	-	-	-	150	-	0.28	0.44	3.54
		Existing Very Loose to Compact Sandy Silt to Sand Fill	283.4 – 283.1	0.2 – 3.6	20	32	-	-	-	-	-	-	10	-	0.31	0.47	3.25
		Soft Organic Silty Clay	~ 279.7	~ 0.8	16	27	-	20	-	-	-	-	-	-	0.38	0.54	2.66
		Soft to Firm Sandy Gravelly Silty Clay	279.7 – 279.3	0.7 - 1.9	16	30	-	20	75	1.0	0.65	0.09	-	2.5 x 10^{-3}	0.33	0.50	3.00
		Soft to Firm Clayey Silt to Silty Clay to Clay	282.9 – 278.2	8.7 – 17.1	16	30	-	20 – 40	75	1.0	0.65	0.09	-	2.5 x 10^{-3}	0.33	0.50	3.00
		Very Loose Silt	~ 286.0	~ 0.4	19	30	-	-	-	-	-	-	10	-	0.33	0.50	3.00
		Compact to Dense Sand and Gravel	268.6 – 267.5	2.4 – ~2.8	21	34	-	-	-	-	-	-	80	-	0.28	0.44	3.54

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

Table 6: Summary of Stability Analysis

Culvert ID Culvert Location (Township)	Stability Analysis [1]				
	Condition	Analysis	Slope Profile	Embankment at Critical Section	Minimum Factor of Safety [3]
C3 23+975 Site No. 47-415/C (Otto)	Temporary Excavation	North Cut	1H:1V	4.4 m	≥ 1.3
		South Cut	1H:1V	4.4 m	≥ 1.3
	Final Embankment	East Slope	1.5H:1V [2]	3.6 m	≥ 1.5
		West Slope	1.5H:1V [2]	3.6 m	≥ 1.5

Note:
1. Stability analysis was carried out using total stress (undrained) parameters for cohesive deposits and Mohr-Coulomb (drained) parameters for non-cohesive deposits.
2. Embankment side slopes are based on surface topography information provided by MTO on June 29, 2016
3. The minimum FoS is based on a deep-seated, global trial failure surface that would impact the operation of the highway.

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

FIGURES

West side of Highway 112 at STA 23+975 (Township of Otto) Culvert Outlet, looking southeast. June 4, 2016.

PROJECT
Detail Design for Replacement of Structural Culvert – Highway 112
GWP 5105-12-00; WP 5427-15-01

TITLE
Site Photographs
Unnamed Creek Culvert, Site No. 47-415/C - Highway 112

Golder Associates

PROJECT No. 1530157			FILE No. ----		
DESIGN	MCK	Aug16	SCALE	NTS	REV.
CADD	-- --				
CHECK	CN	Aug 16	**FIGURE 1A**		
REVIEW	JMAC	Aug 16			

REVISION DATE: February 3, 2017 BY: MCK Project: 1531057

East side of Highway 112 at STA 23+975 (Township of Otto) Culvert Inlet, looking southwest. June 6, 2016.

PROJECT	**Detail Design for Replacement of Structural Culvert – Highway 112 GWP 5105-12-00; WP 5427-15-01**
TITLE	**Site Photographs Unnamed Creek Culvert, Site No. 47-415/C - Highway 112**

Golder Associates

PROJECT No. 1530157			FILE No. ----		
DESIGN	MCK	Aug16	SCALE	NTS	REV.
CADD	-- --				
CHECK	CN	Aug 16	**FIGURE 1B**		
REVIEW	JMAC	Aug 16			

DRAWINGS

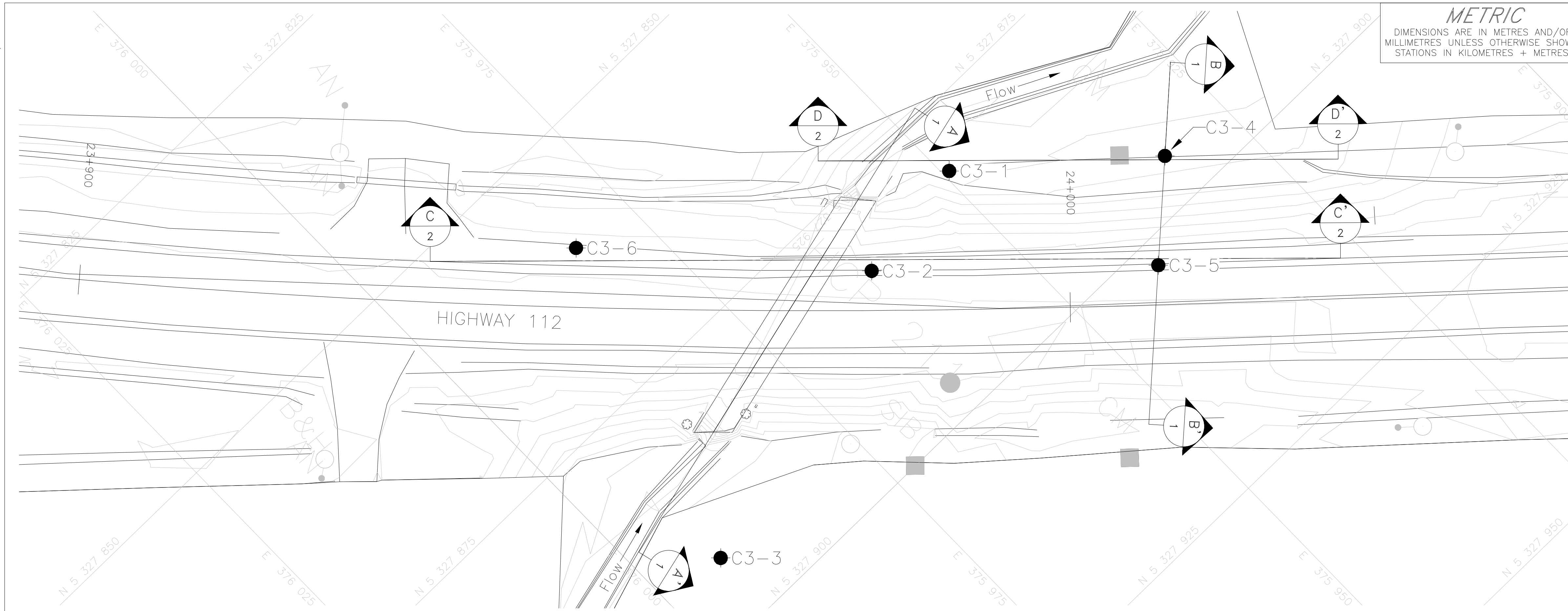
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5427-15-01

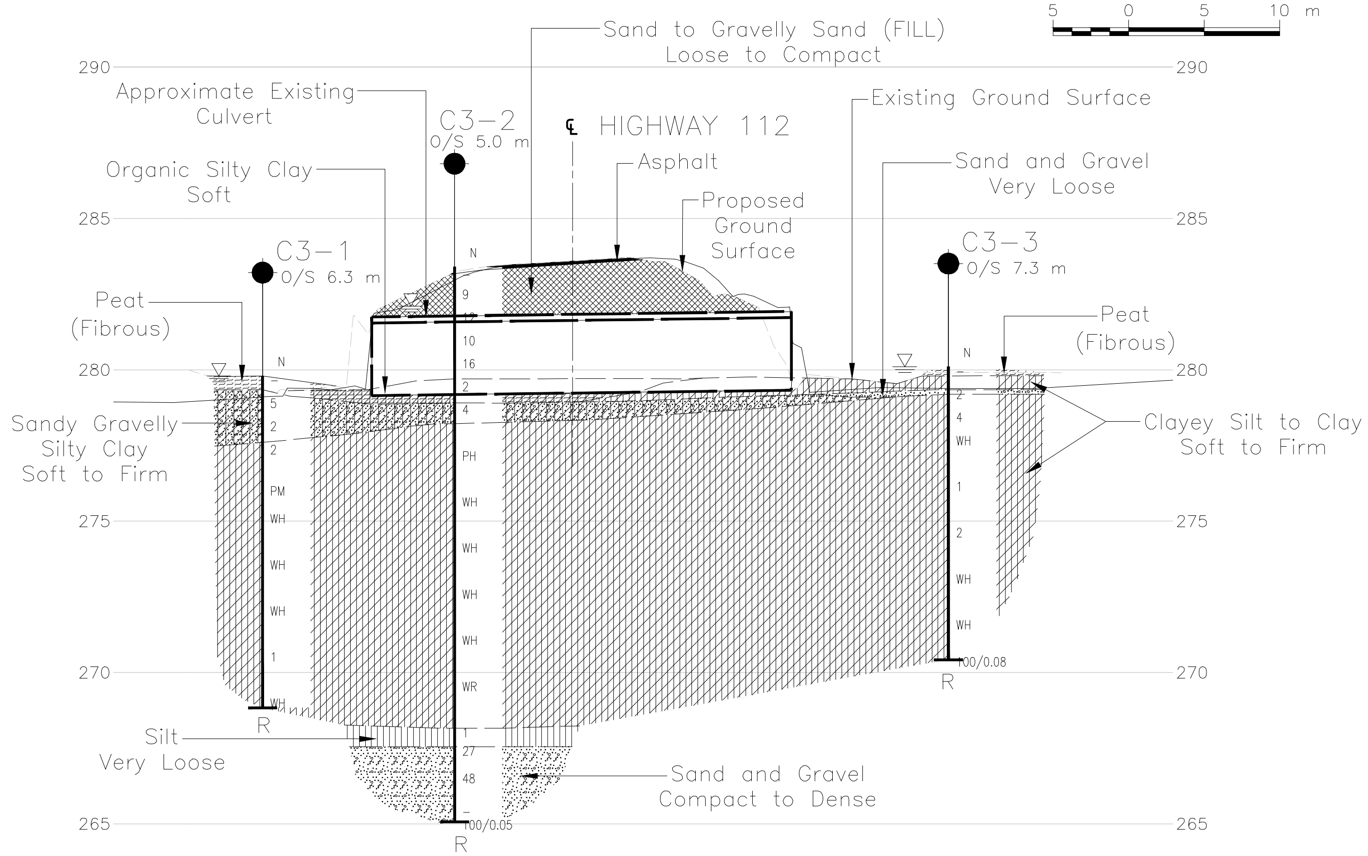
SHEET

HIGHWAY 112
STRUCTURAL CULVERT STA. 23+975
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates

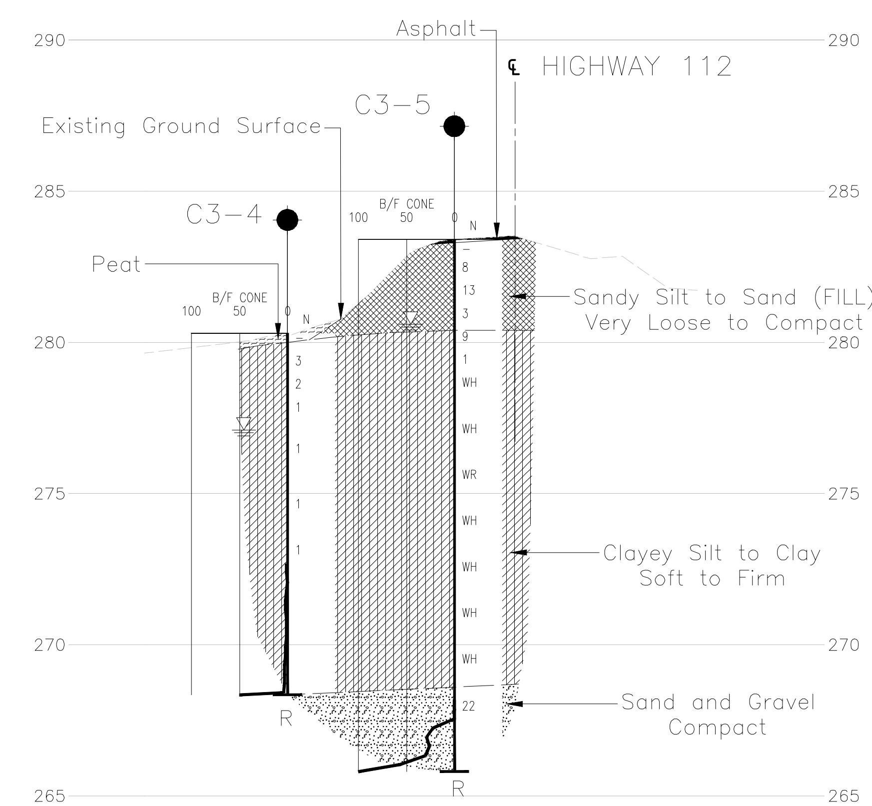


PLAN
SCALE
5 0 5 10 m



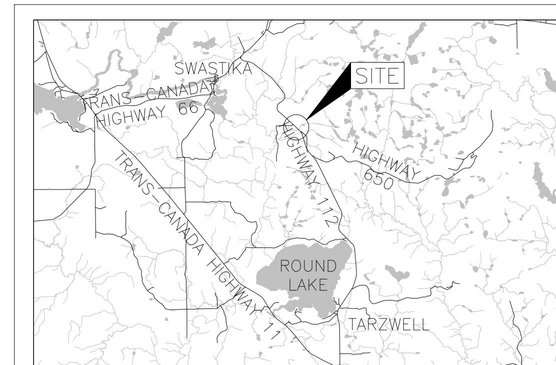
A-A' 1 CENTRELINE PROFILE
STA. 23+975

HORIZONTAL SCALE
5 0 5 10 m



B-B' 1 CROSS-SECTION B-B'
(EMBANKMENT WIDENING)

VERTICAL SCALE
2.5 0 2.5 5 m



KEY PLAN
SCALE
4 0 4 8 km

LEGEND

- ● Borehole – Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- ▽ WL upon completion of drilling
- R Refusal to Further Penetration

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
C3-1	279.8	5327881.0	375949.3
C3-2	283.4	5327882.8	375962.0
C3-3	280.1	5327893.0	375993.1
C3-4	280.3	5327895.1	375932.7
C3-5	283.4	5327902.5	375940.8
C3-6	283.1	5327860.4	375981.7

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 plan, culvert section and surface data provided in digital format by MTO, drawing file no. "b04490112004.dwg", dated May, 2016, received June 29, 2016.

LICENSED PROFESSIONAL ENGINEER J. M. A. COSTA Feb. 22, 2017 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER C.C. NG 100086170 Feb. 22, 2017 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 42A-110

HWY. 112	PROJECT NO. 1531057		DIST.
SUBM'D. MCK	CHKD. MCK	DATE: 8/4/2016	SITE: 47-415/C
DRAWN: MR	CHKD. CN	APPD. JMAC	DWG. 1

MINISTRY OF TRANSPORTATION, ONTARIO

PLOT DATE: February 21, 2017

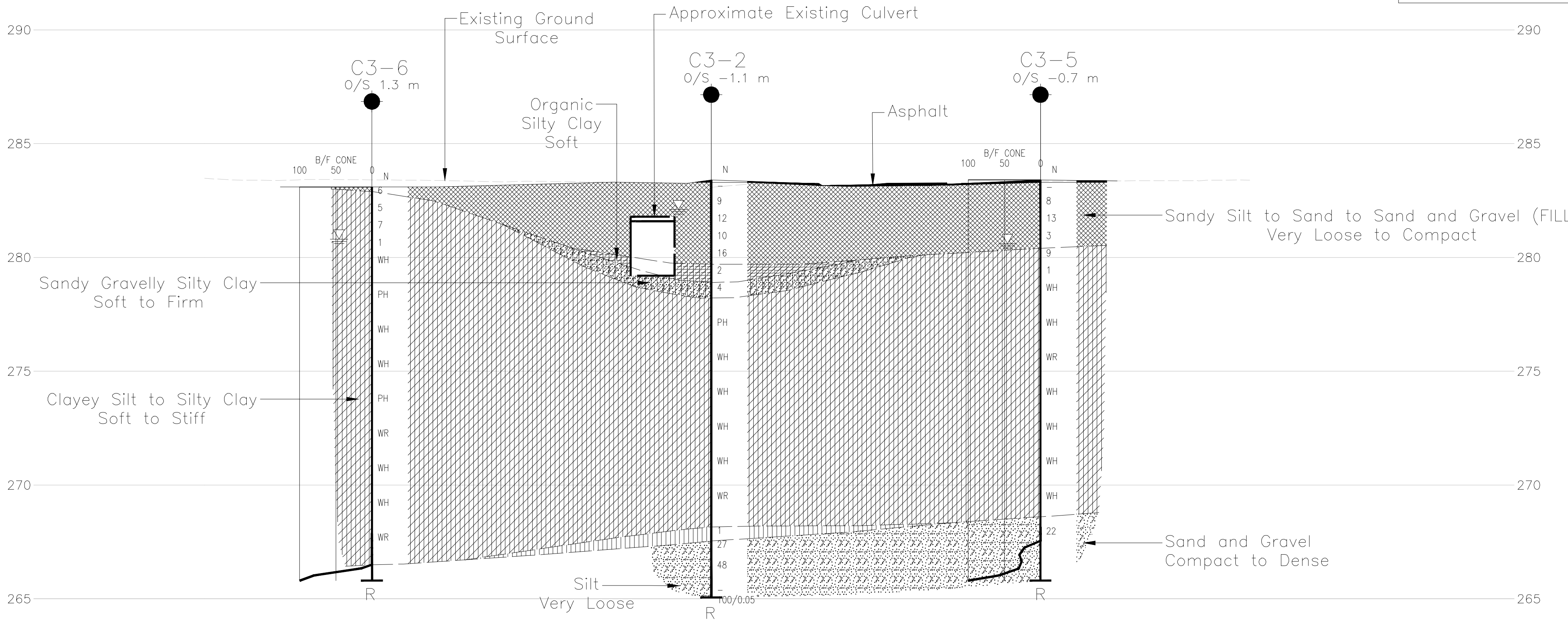
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5427-15-01

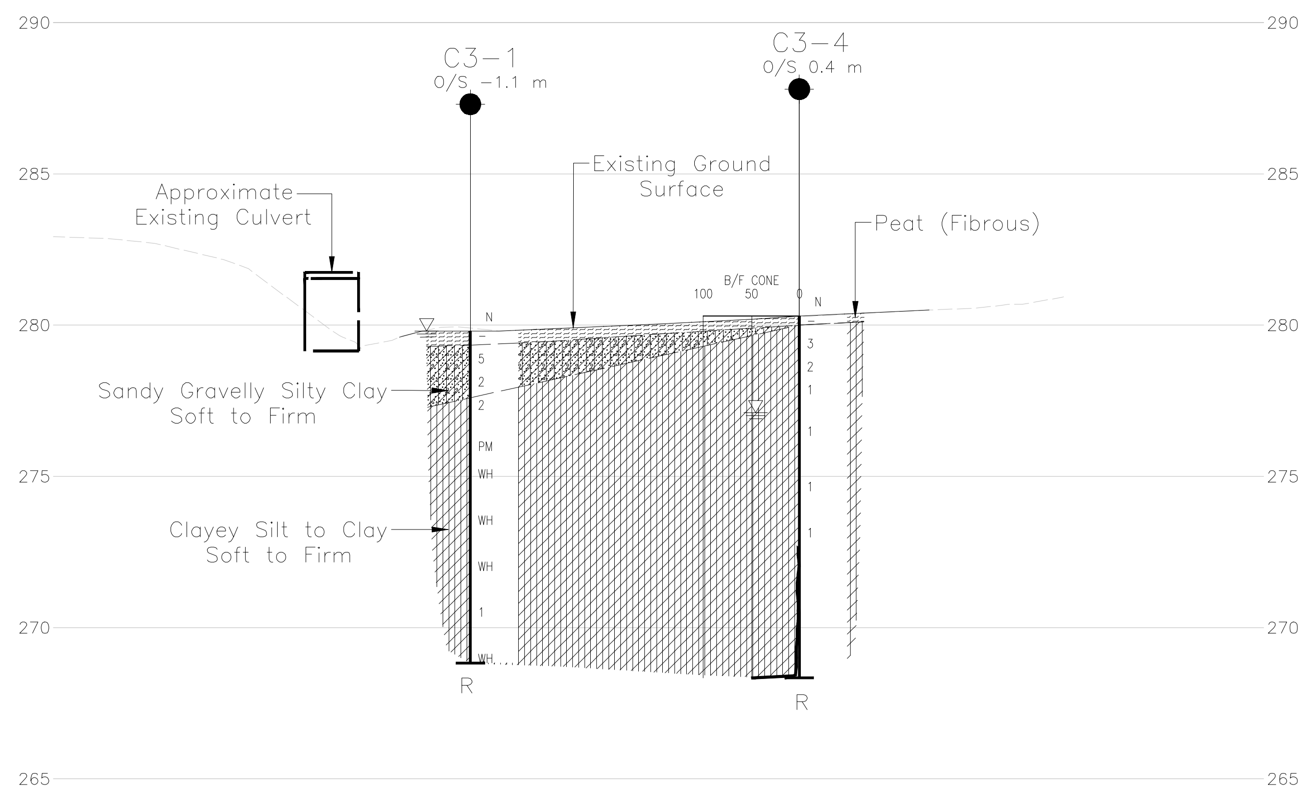
HIGHWAY 112
STRUCTURAL CULVERT STA. 23+975
SOIL STRATA

SHEET

Golder Associates



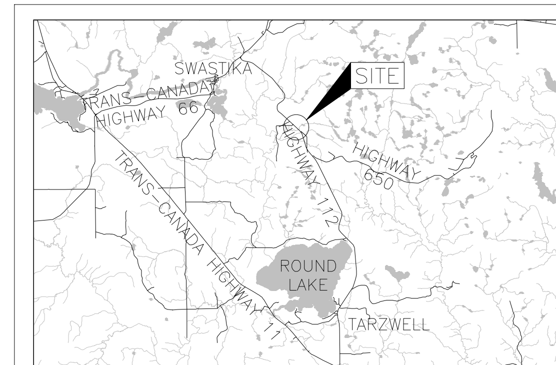
PROFILE C-C' (EMBANKMENT CREST)



PROFILE D-D' (EMBANKMENT TOE)

HORIZONTAL SCALE 5 0 5 10 m

VERTICAL SCALE 2.5 0 2.5 5 m



KEY PLAN
SCALE 4 0 4 8 km

LEGEND

- ● Borehole – Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- ▽ WL upon completion of drilling
- R Refusal to Further Penetration

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
C3-1	279.8	5327881.0	375949.3
C3-2	283.4	5327882.8	375962.0
C3-3	280.1	5327893.0	375993.1
C3-4	280.3	5327895.1	375932.7
C3-5	283.4	5327902.5	375940.8
C3-6	283.1	5327860.4	375981.7

NOTES

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NO.	DATE	BY	REVISION

Geocres No. 42A-110

HWY. 112		PROJECT NO. 1531057	DIST.
SUBM'D. MCK	CHKD. MCK	DATE: 8/4/2016	SITE: 47-415/C
DRAWN: MR	CHKD. CN	APPD. JMAC	DWG. 2

APPENDIX A

Record of Boreholes

LIST OF SYMBOLS

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

I. GENERAL

Symbol	Description
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

Symbol	Description
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
$\sigma_1, \sigma_2, \sigma_3$	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

Symbol	Description
$\rho(\gamma)$	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)

Symbol	Description
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

Symbol	Description
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)

Symbol	Description
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

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

Notes: 1 $\tau = c' + \sigma' \tan \phi'$
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 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

RECORD OF BOREHOLE No C3-1

SHEET 1 OF 1 — METRIC

PROJECT 1531057			
W.P. 5427-15-01	LOCATION N 5327881.0; E 375949.3	ORIGINATED BY SA
DIST	HWY 112	BOREHOLE TYPE Portable Equipment, HQ Casing (Manual Hammer)	COMPILED BY MR
DATUM Geodetic	DATE June 4, 2016	CHECKED BY MK/ACK

ELEV / DEPTH (m)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	Water Content (%)	Unit Weight γ (kN/m³)	GR	SA	SI	CL
279.8	GROUND SURFACE									
0.0	PEAT (Fibrous), some sand	1	SS	-						
279.3 / 0.5	Sandy Gravelly SILTY CLAY, trace organics; Soft to firm; Grey; Wet	2	SS	5						
		3	SS	2	○		21	28	19	32
277.6 / 2.2	CLAYEY SILT to SILTY CLAY; Soft to firm; Grey; Wet	4	SS	2	w_P–w_L, ○					
		S-1	TO	PM	w_P–w_L	16.0				
		5	SS	WH	○		0	0	33	67
		6	SS	WH	w_P–w_L, ○					
		7	SS	WH						
		8	SS	1	w_P–w_L, ○					
268.8 / 11.0	END OF BOREHOLE; SPLIT-SPOON AND CASING REFUSAL	9	SS	WH						

Elevation scale: 279, 278, 277, 276, 275, 274, 273, 272, 271, 270, 269

Field vane sensitivity values plotted (+): 2, 6, 4, 4, 3, 3

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

REMARKS & GRAIN SIZE DISTRIBUTION (%)

NOTES:

1. Water level at ground surface upon completion of drilling.

2. Geographic Coordinates:

Latitiude: 48.085852
Longitude: -80.044898

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

RECORD OF BOREHOLE No C3-2

SHEET 1 OF 2 **METRIC**

PROJECT 1531057

W.P. 5427-15-01 LOCATION N 5327882.8; E 375962.0 ORIGINATED BY DM

DIST HWY 112 BOREHOLE TYPE CME 55, 152 mm O.D. Solid Stem Augers, NW Casing, Wash bore, NQ Coring COMPILED BY MR

DATUM Geodetic DATE June 2, 2016 CHECKED BY MK/ACK

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa (+ FIELD VANE, sensitivity)	WATER CONTENT (%)	UNIT WEIGHT	GR	SA	SI	CL
283.4	GROUND SURFACE												
0.0	ASPHALT (100 mm)												
0.1	Sand, trace to some gravel to gravelly, trace to some silt (FILL) Loose to compact Brown Moist	1	AS	-		283							
		2	SS	9	∇	282							
		3	SS	12									
	- Auger grinding between depths of 2.0 m and 2.1 m	4	SS	10		281				11	85	4	0
	- Auger grinding between depths of 2.9 m and 3.1 m	5	SS	16		280							
279.7 / 3.7	Organic SILTY CLAY Soft Grey to black Wet	6	SS	2		279		94.3		OC = 19%			
278.9 / 4.5	Sandy Gravelly SILTY CLAY, trace to some gravel Very loose Grey Wet; - Casing grinding at a depth of 4.1 m	7	SS	4									
278.2 / 5.2	CLAYEY SILT to SILTY CLAY Soft to firm Grey Wet					278	8; 4						
		8	TO	PH		277	6; 5						
		9	SS	WH		276				0	0	36	64
						275	7; 4						
		10	SS	WH		274	6; 5						
		11	SS	WH		273 / 272	6; 4			0	0	41	59
		12	SS	WH		271 / 270	4; 5						
		13	SS	WR		269	5			0	1	49	50

Continued Next Page

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

RECORD OF BOREHOLE No C3-2

SHEET 2 OF 2 **METRIC**

PROJECT 1531057
W.P. 5427-15-01 LOCATION N 5327882.8; E 375962.0 ORIGINATED BY DM
DIST HWY 112 BOREHOLE TYPE CME 55, 152 mm O.D. Solid Stem Augers, NW Casing, Wash bore, NQ Coring COMPILED BY MR
DATUM Geodetic DATE June 2, 2016 CHECKED BY MK/ACK

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	PLASTIC LIMIT / WATER CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
268.2 15.2	SILT, some sand, some gravel; Very loose; Grey; Wet	14	SS	1	268		
267.5 15.9	SAND and GRAVEL, trace silt; Compact to dense; Pink and black; Wet	15	SS	27	267	○	65 30 4 1
	- cobbles 0.1 m to 0.2 m in diameter encountered below a depth of 16.8 m (Elev. 251.4 m)	16	SS	48	266		
		17	RC	-			
265.1 18.3	END OF BOREHOLE SPLIT-SPOON REFUSAL	18	SS	100/0.05			

NOTES:

1. Water level in open borehole at a depth of 1.3 m (Elev. 282.1 m) upon completion of drilling.

2. Geographic Coordinates:

Latitiude: 48.085866
Longitude: -80.044728

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

Golder Associates

RECORD OF BOREHOLE No C3-3

SHEET 1 OF 1

METRIC

PROJECT 1531057

W.P. 5427-15-01 — LOCATION N 5327893.0; E 375993.1 — ORIGINATED BY SA

DIST ___ HWY 112 — BOREHOLE TYPE Portable Equipment, HQ Casing (Manual Hammer) — COMPILED BY MR

DATUM Geodetic — DATE June 6 and 7, 2016 — CHECKED BY MK/ACK

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
280.1	GROUND SURFACE				
0.0	PEAT (Fibrous), trace to some sand	1	SS	-	
279.8 / 0.3	SILTY CLAY, some sand, trace gravel, trace organics, Brown to grey, Moist				
279.3 / 0.9	SAND and GRAVEL, some silt, Grey, Wet	2A / 2B	SS	2	
	SILTY CLAY, Soft to firm, Grey, Wet	3	SS	4	
		4	SS	WH	
		5	SS	1	0 1 31 68
		6	SS	2	0 2 36 62
		7	SS	WH	
		8	SS	WH	
270.5 / 9.7	Silty SAND, Grey, Wet	9	SS	100/0.08	

Elevation scale: 280, 279, 278, 277, 276, 275, 274, 273, 272, 271

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

Field vane sensitivities (top to bottom): 2, 5, 4, 3, 2, 4, 3, 5, 3, 3

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

UNIT WEIGHT γ kN/m³

END OF BOREHOLE
SPLIT-SPOON AND CASING REFUSAL

NOTES:

1. Water level at ground surface upon completion of drilling.

2. An additional borehole was advanced about 1 m west of Borehole C3-3 to a depth of 2.4 m to carry out vanes.

3. Geographic Coordinates:

Latitiude: 48.085954
Longitude: -80.044309

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

PROJECT 1531057

RECORD OF BOREHOLE No C3-4

SHEET 1 OF 1

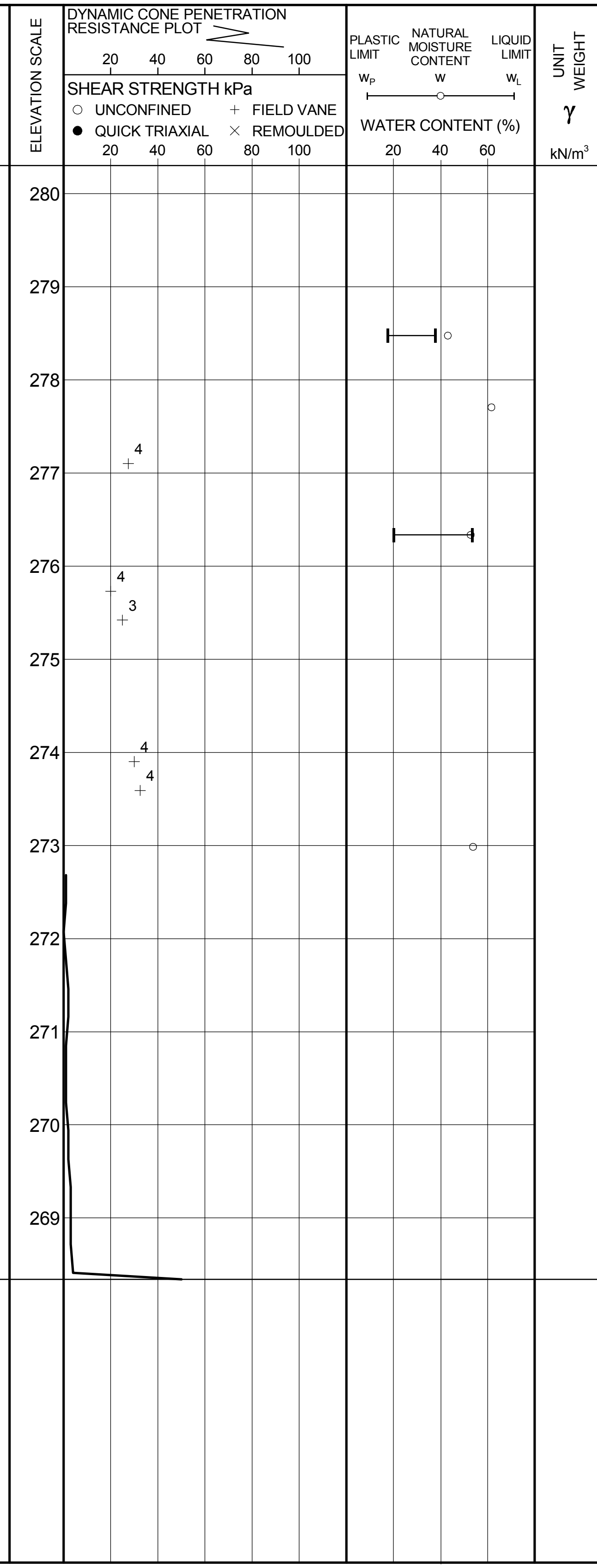
METRIC

W.P. 5427-15-01 LOCATION N 5327895.1; E 375932.7 ORIGINATED BY SA

DIST HWY 112 BOREHOLE TYPE Portable Equipment, HQ Casing (Manual Hammer) COMPILED BY MR

DATUM Geodetic DATE June 6, 2016 CHECKED BY MK/ACK

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
280.3	GROUND SURFACE					
280.0 / 0.0	PEAT (Fibrous), some sand Dark brown Moist	1	SS	-		
279.7 / 0.6	CLAYEY SILT, some sand, trace organics and rootlets Brown Moist	2	SS	3		
	SILTY CLAY to CLAY, trace to some sand, trace organics to a depth of 1.4 m Soft to firm Grey Wet	3	SS	2		0 10 33 57
		4	SS	1		
					▽ (Elev. 277.1)	
		5	SS	1		0 1 24 75
		6	SS	1		
		7	SS	1		
272.7 / 7.6	Dynamic Cone Penetration Test (DCPT)					
268.3 / 12.0	END OF DCPT REFUSAL TO FURTHER PENETRATION (50 Blows / 0.08 m) (HAMMER BOUNCING) NOTES: 1. Water level in open borehole at a depth of 3.2 m below ground surface (Elev. 277.1 m) upon completion of drilling. 2. Geographic Coordinates: Latitiude: 48.085980 Longitude: -80.045119					



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

Golder Associates

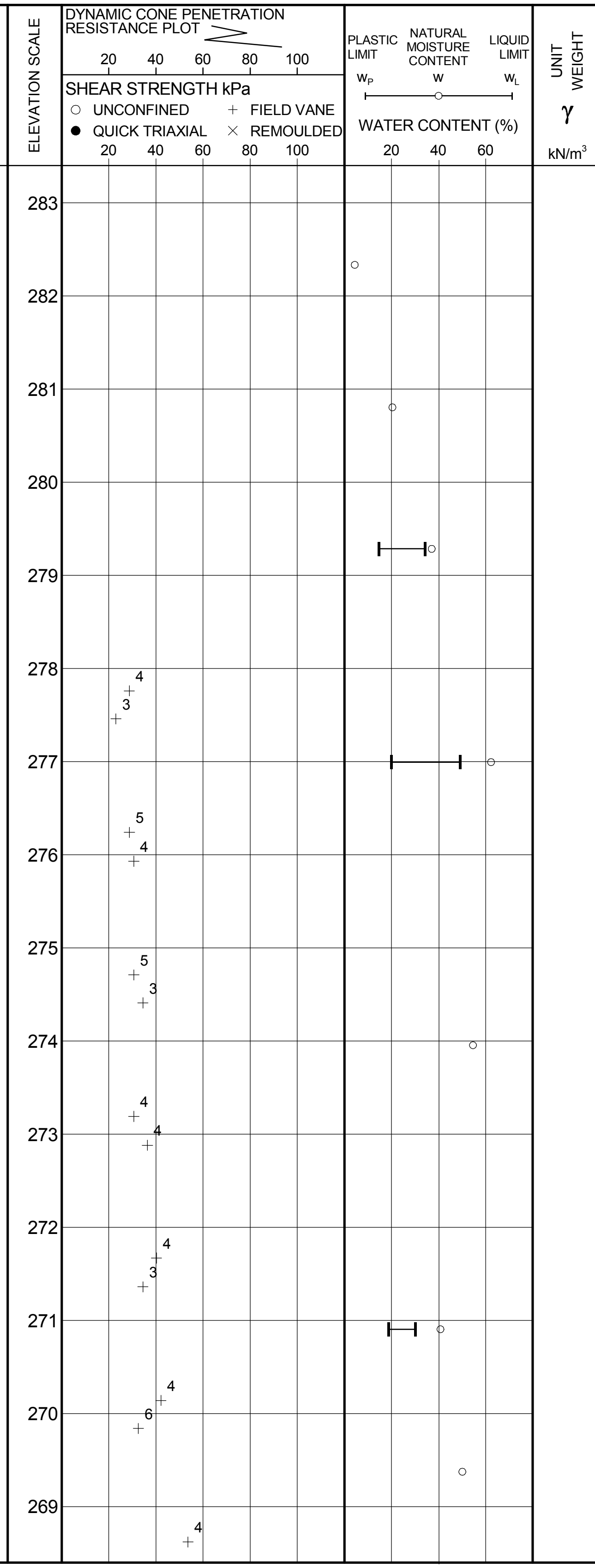
Foundation Design

RECORD OF BOREHOLE No C3-5

SHEET 1 OF 2 **METRIC**

PROJECT 1531057			
W.P. 5427-15-01	LOCATION N 5327902.5; E 375940.8		ORIGINATED BY DM
DIST ___ HWY 112	BOREHOLE TYPE CME 55, 152 mm O.D. Solid Stem Augers; 203 mm O.D. Hollow Stem Augers		COMPILED BY MR
DATUM Geodetic	DATE June 4, 2016		CHECKED BY MK/ACK

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
283.4	GROUND SURFACE					
0.0	ASPHALT (90 mm)					
0.1	Sand, trace gravel to sand and gravel, trace silt (FILL) Loose to compact Brown Moist	1	AS	-		
		2	SS	8		4 91 3 2
		3	SS	13		
281.2 / 2.2	Sandy silt, some gravel, trace clay, trace organics (FILL) Very loose Brown Wet - Cobbles 0.1 m diameter encountered at depths between 2.4 m to 2.7 m	4	SS	3	▽	15 25 56 4
280.4 / 3.0	CLAYEY SILT to SILTY CLAY, trace to some sand, trace organics to a depth of 4.4 m Soft to firm Brown to grey Wet	5	SS	9		
		6	SS	1		
		7	SS	WH		
		8	SS	WH		0 1 27 72
		9	SS	WR		
		10	SS	WH		
		11	SS	WH		
		12	SS	WH		
		13	SS	WH		0 1 56 43
268.6 / 14.8						



Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No C3-5

SHEET 2 OF 2

METRIC

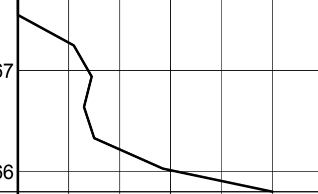
PROJECT 1531057

W.P. 5427-15-01 LOCATION N 5327902.5; E 375940.8 ORIGINATED BY DM

DIST HWY 112 BOREHOLE TYPE CME 55, 152 mm O.D. Solid Stem Augers; 203 mm O.D. Hollow Stem Augers COMPILED BY MR

DATUM Geodetic DATE June 4, 2016 CHECKED BY MK/ACK

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	SAND and GRAVEL, some silt Compact Grey Wet		14	SS	22		268				
267.5 15.9	- Auger grinding below a depth of 14.8 m END BOREHOLE Dynamic Cone Penetration Test (DCPT)						267				
265.8 17.6	END OF DCPT REFUSAL TO FURTHER PENETRATION (100 Blows / 0.25 m) (HAMMER BOUNCING)						266				



NOTES:

1. Water level in open borehole at a depth of 2.8 m below ground surface (Elev. 280.6 m) upon completion of drilling.

2. Geographic Coordinates:

Latitiude: 48.086046
Longitude: -80.045009

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

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

Foundation Design

Golder Associates

RECORD OF BOREHOLE No C3-6

SHEET 1 OF 2

METRIC

PROJECT 1531057
W.P. 5427-15-01
LOCATION N 5327860.4; E 375981.7
ORIGINATED BY DM
DIST HWY 112
BOREHOLE TYPE CME 55, 152 mm Diameter Solid Stem Augers, NW Casing, Wash boring
COMPILED BY MR
DATUM Geodetic
DATE June 3, 2016
CHECKED BY MK/ACK

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
283.1	GROUND SURFACE					
0.0	Sand, trace gravel, trace silt, trace organics (FILL) Brown Moist	1A 1B 1C	SS	6		
0.2	CLAYEY SILT to CLAY, trace sand Soft to stiff Light brown Moist	2	SS	5		
		3	SS	7	∇	
		4	SS	1		0 3 37 60
	- Becoming grey and wet below a depth of 3.0 m (Elev. 280.1 m)	5	SS	WH		
		6	TO	PH		
		7	SS	WH		
		8	SS	WH		
		9	TO	PH		
		10	SS	WR		0 1 34 65
		11	SS	WH		
		12	SS	WH		

Field vane sensitivity values plotted (from top): 9, 6, 5, 3, 5, 5, 8, 5, 6, 5, 4, 5, 4, 4, 6

Elevation scale: 283, 282, 281, 280, 279, 278, 277, 276, 275, 274, 273, 272, 271, 270, 269

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

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No C3-6

METRIC

PROJECT 1531057

W.P. 5427-15-01 LOCATION N 5327860.4; E 375981.7 ORIGINATED BY DM

DIST HWY 112 BOREHOLE TYPE CME 55, 152 mm Diameter Solid Stem Augers, NW Casing, Wash boring COMPILED BY MR

DATUM Geodetic DATE June 3, 2016 CHECKED BY MK/ACK

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × 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
	--- CONTINUED FROM PREVIOUS PAGE ---										
	CLAYEY SILT to CLAY, trace sand Soft to stiff Light brown Moist		13	SS	WR		268 267 266	+5 (field vane); +5; +4			
266.5 16.6	END OF BOREHOLE Dynamic Cone Penetration Test (DCPT)										
265.8 17.3	END OF DCPT REFUSAL TO FURTHER PENETRATION (100 Blows / 0.25 m) (HAMMER BOUNCING)										

NOTES:

1. Water level in open borehole at a depth of 2.3 m below ground surface (Elev. 280.8 m) upon completion of drilling.

2. Geographic Coordinates:

Latitiude: 48.085662
Longitude: -80.044466

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

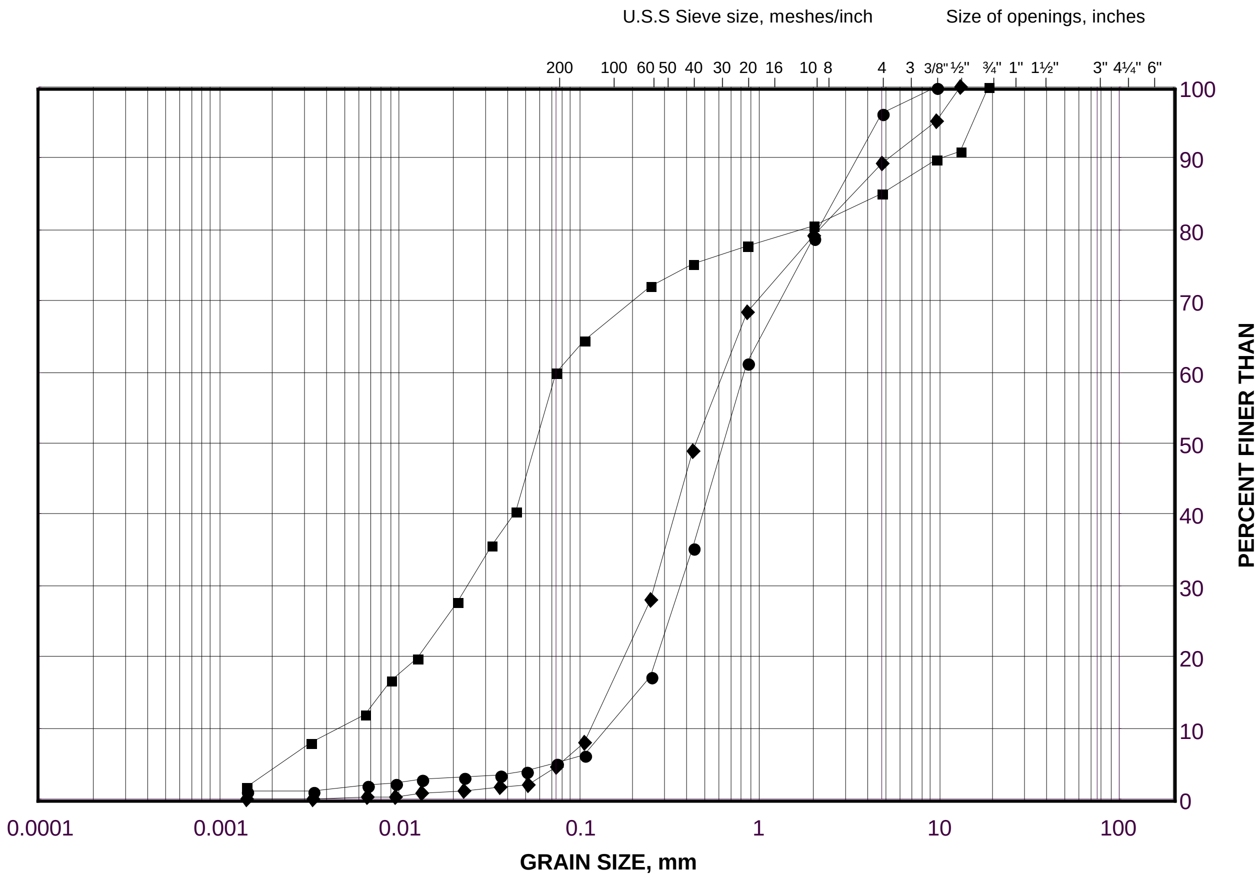
APPENDIX B

Laboratory Results

GRAIN SIZE DISTRIBUTION

Sandy Silt to Sand (FILL)

FIGURE B1



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C3-5	2	282.3
■	C3-5	4	280.8
◆	C3-2	4	280.8

Project Number: 1531057

Checked By: MCK

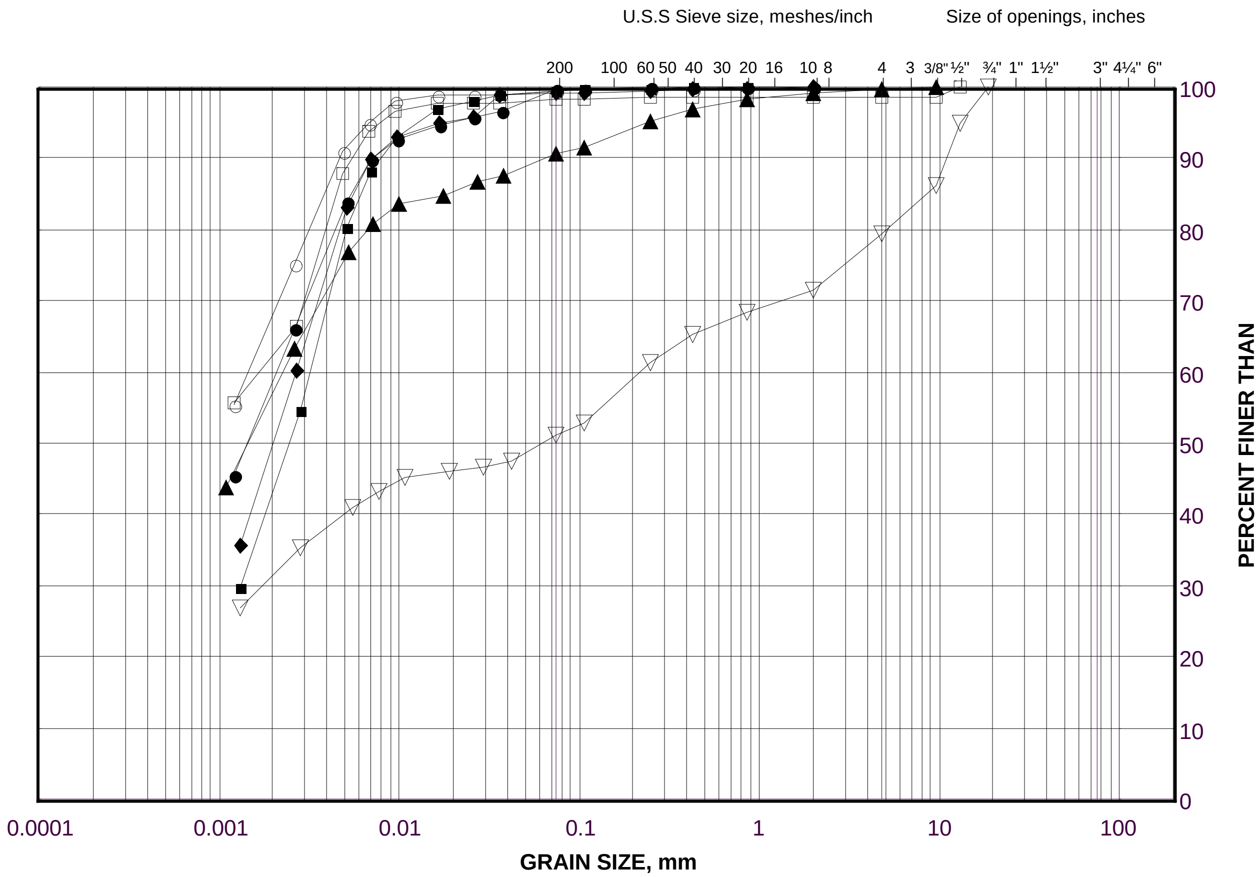
Golder Associates

Date: 07-Sep-16

GRAIN SIZE DISTRIBUTION

Clayey Silt to Sandy Gravelly Silty Clay
to Silty Clay

FIGURE B2A



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C3-2	11	272.4
■	C3-5	13	269.4
◆	C3-2	13	269.4
▲	C3-4	3	278.5
▽	C3-1	3	278.0
❍	C3-3	5	276.0
□	C3-3	6	274.5

Project Number: 1531057

Checked By: MCK

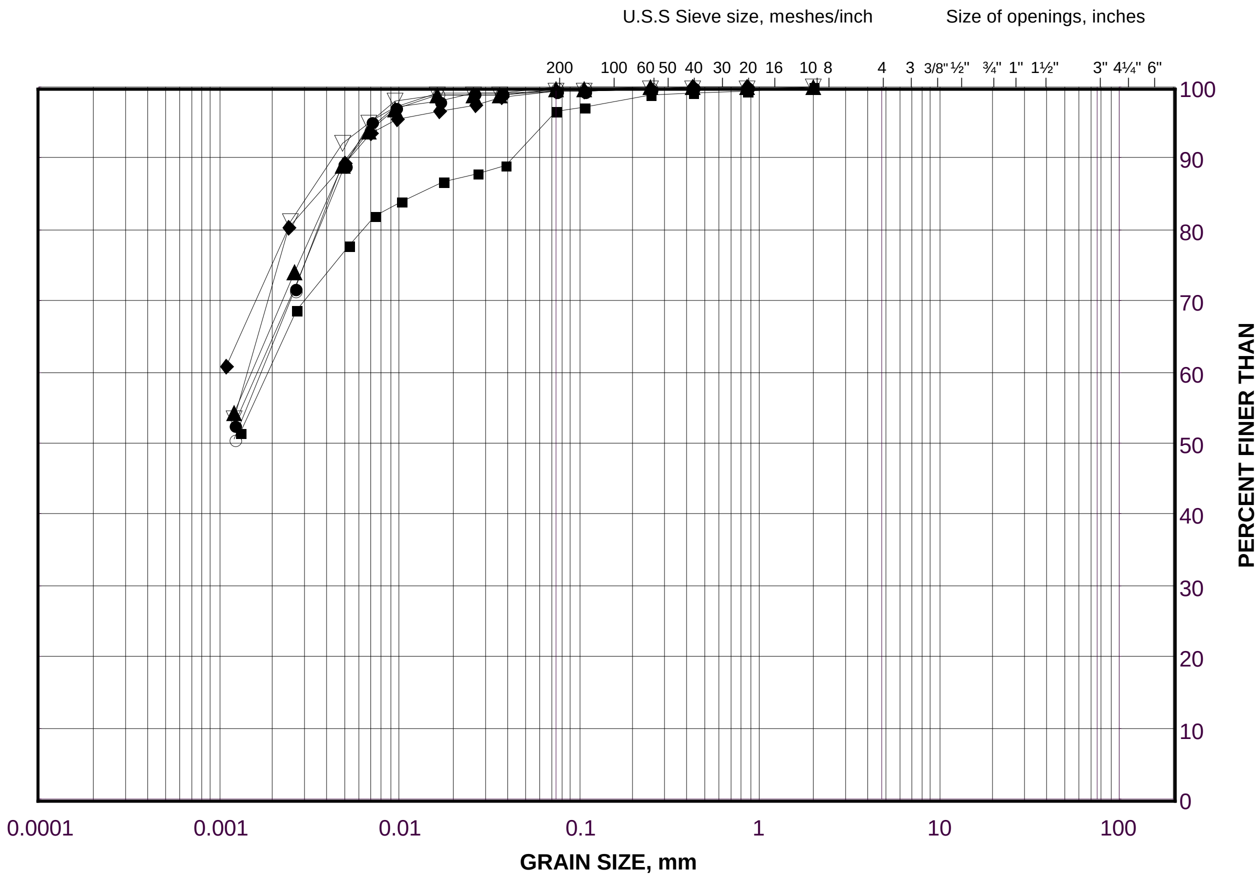
Golder Associates

Date: 17-Aug-16

GRAIN SIZE DISTRIBUTION

Silty Clay to Clay

FIGURE B2B



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

LEGEND

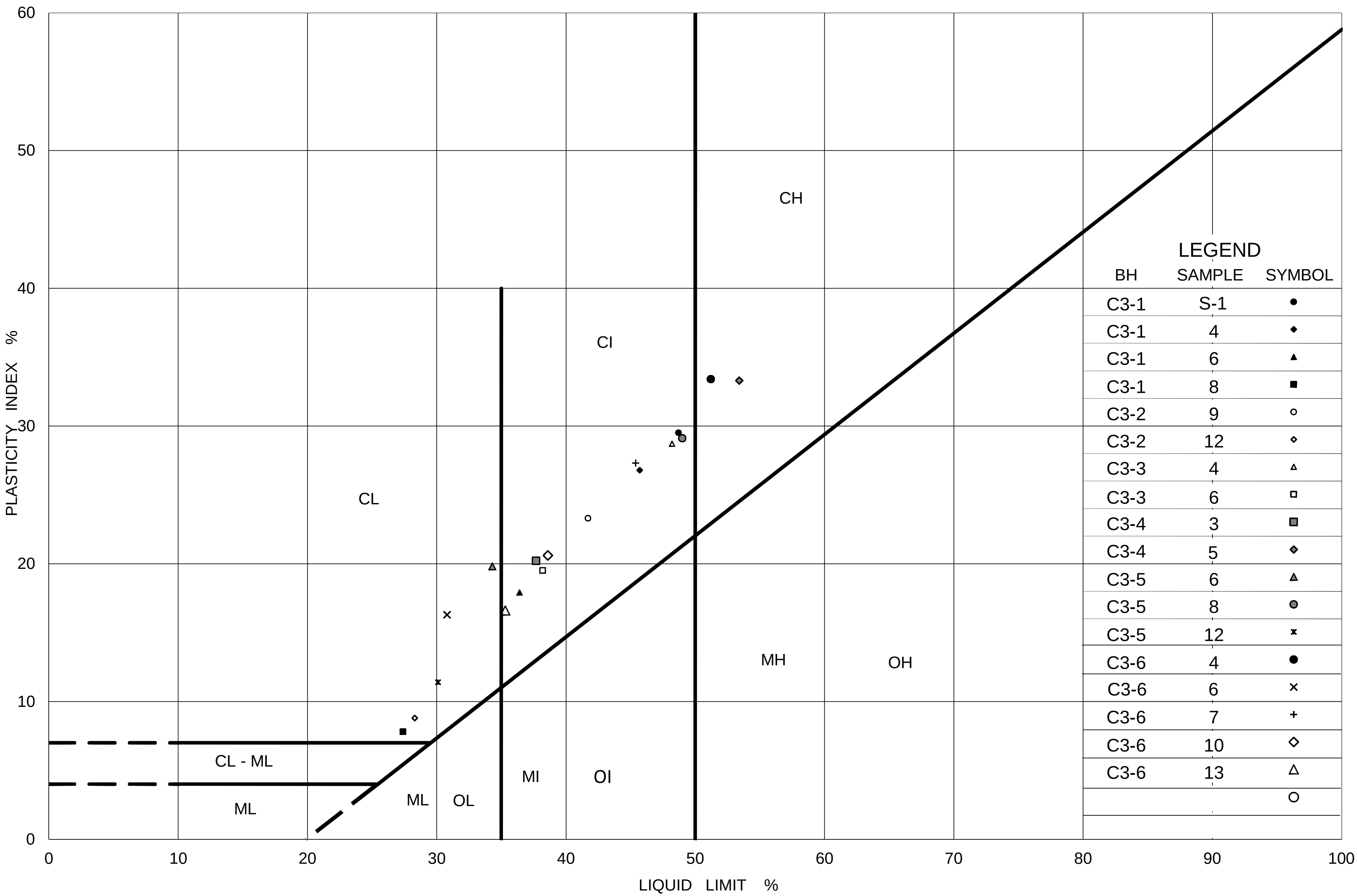
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C3-6	10	272.1
■	C3-6	4	280.5
◆	C3-4	5	276.3
▲	C3-1	5	274.9
▽	C3-5	8	277.0
❍	C3-2	9	275.5

Project Number: 1531057

Checked By: MCK

Golder Associates

Date: 17-Aug-16



Ministry of Transportation

Ontario

PLASTICITY CHART
Clayey Silt to Clay

Figure No. B3

Project No. 1531057

Checked By: MCK

CONSOLIDATION TEST SUMMARY
ASTM D2435/D2435M

FIGURE B4

SAMPLE IDENTIFICATION

Project Number	1531057	Sample Number	S-1
Borehole Number	C3-1	Sample Depth, m	3.66-4.12

TEST CONDITIONS

Test Type	Laboratory Standard	Load Duration, hr	24
Oedometer Number	6		
Date Started	7/08/2016		
Date Completed	7/24/2016		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m^3	16.02
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	9.86
Area, cm^2	31.64	Specific Gravity, measured	2.73
Volume, cm^3	60.02	Solids Height, cm	0.699
Water Content, %	62.43	Volume of Solids, cm^3	22.11
Wet Mass, g	98.04	Volume of Voids, cm^3	37.91
Dry Mass, g	60.36	Degree of Saturation, %	99.4

TEST COMPUTATIONS

Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	1.897	1.715	1.897				
5.80	1.880	1.690	1.888	205	3.69E-03	1.57E-03	5.68E-07
10.66	1.872	1.678	1.876	487	1.53E-03	8.89E-04	1.33E-07
20.38	1.863	1.665	1.867	194	3.81E-03	4.88E-04	1.82E-07
39.82	1.843	1.637	1.853	154	4.73E-03	5.26E-04	2.44E-07
78.56	1.810	1.590	1.826	577	1.23E-03	4.53E-04	5.44E-08
155.83	1.600	1.289	1.705	2160	2.85E-04	1.43E-03	4.01E-08
310.60	1.455	1.083	1.528	1882	2.63E-04	4.92E-04	1.27E-08
619.87	1.358	0.944	1.407	1084	3.87E-04	1.65E-04	6.27E-09
1237.17	1.268	0.814	1.313	844	4.33E-04	7.73E-05	3.28E-09
2475.27	1.189	0.702	1.228	614	5.21E-04	3.35E-05	1.71E-09
1237.17	1.203	0.721	1.196				
310.60	1.242	0.778	1.223				
78.67	1.284	0.837	1.263				
20.61	1.322	0.891	1.303				
5.93	1.349	0.931	1.336				

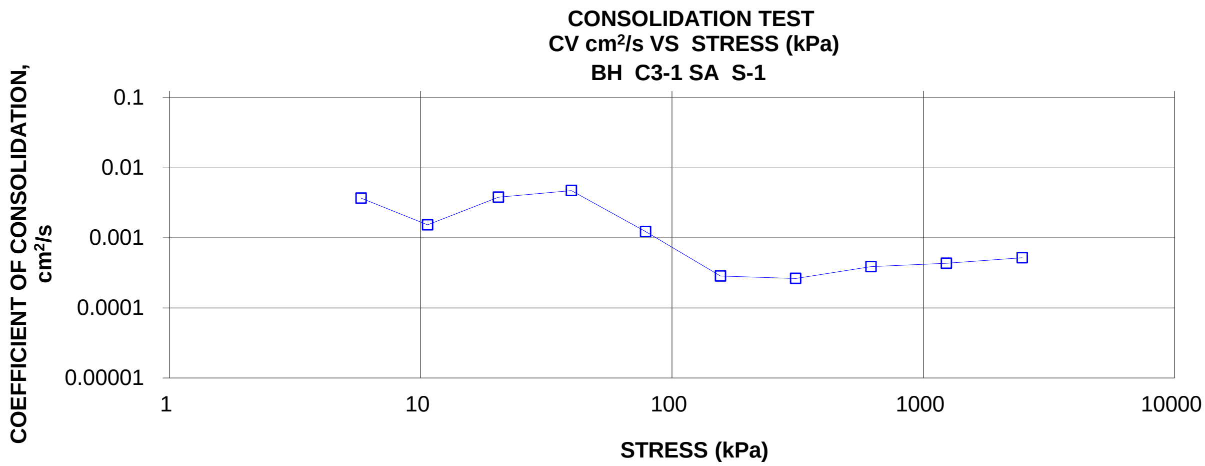
Note:
Consolidation loading and unloading schedule assigned by the client.
k calculated using cv based on t_{90} values.

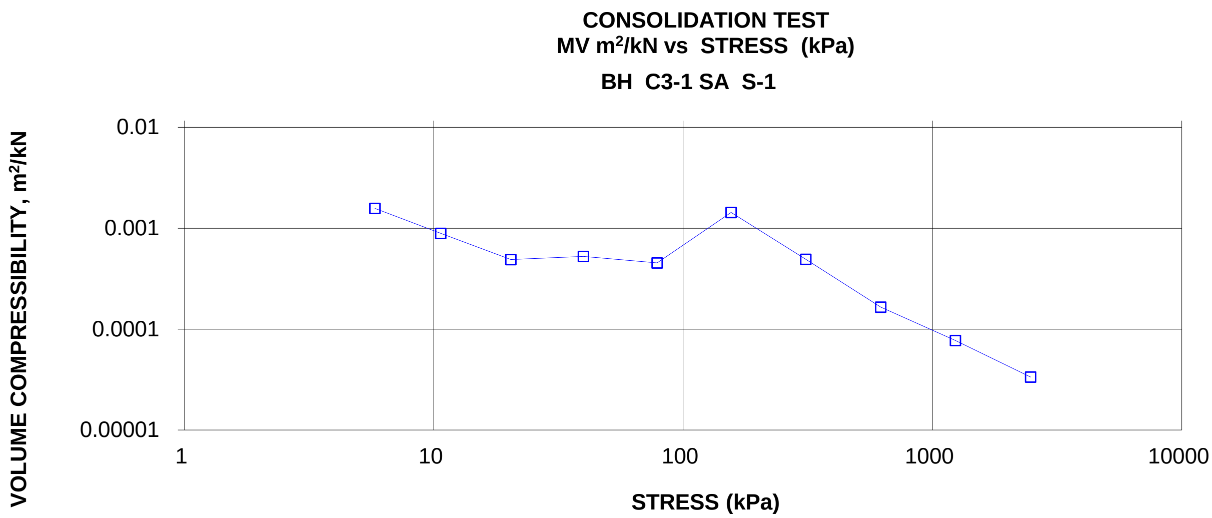
SAMPLE DIMENSIONS AND PROPERTIES - FINAL

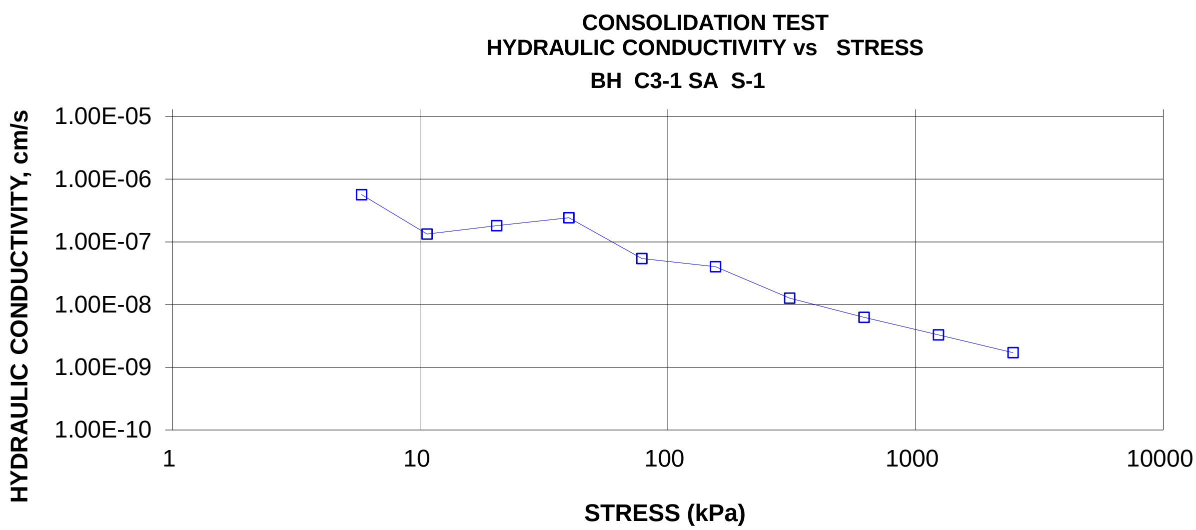
Sample Height, cm	1.35	Unit Weight, kN/m^3	18.28
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	13.87
Area, cm^2	31.64	Specific Gravity, measured	2.73
Volume, cm^3	42.69	Solids Height, cm	0.699
Water Content, %	31.86	Volume of Solids, cm^3	22.11
Wet Mass, g	79.59	Volume of Voids, cm^3	20.58
Dry Mass, g	60.36		

CONSOLIDATION TEST SUMMARY

FIGURE B4







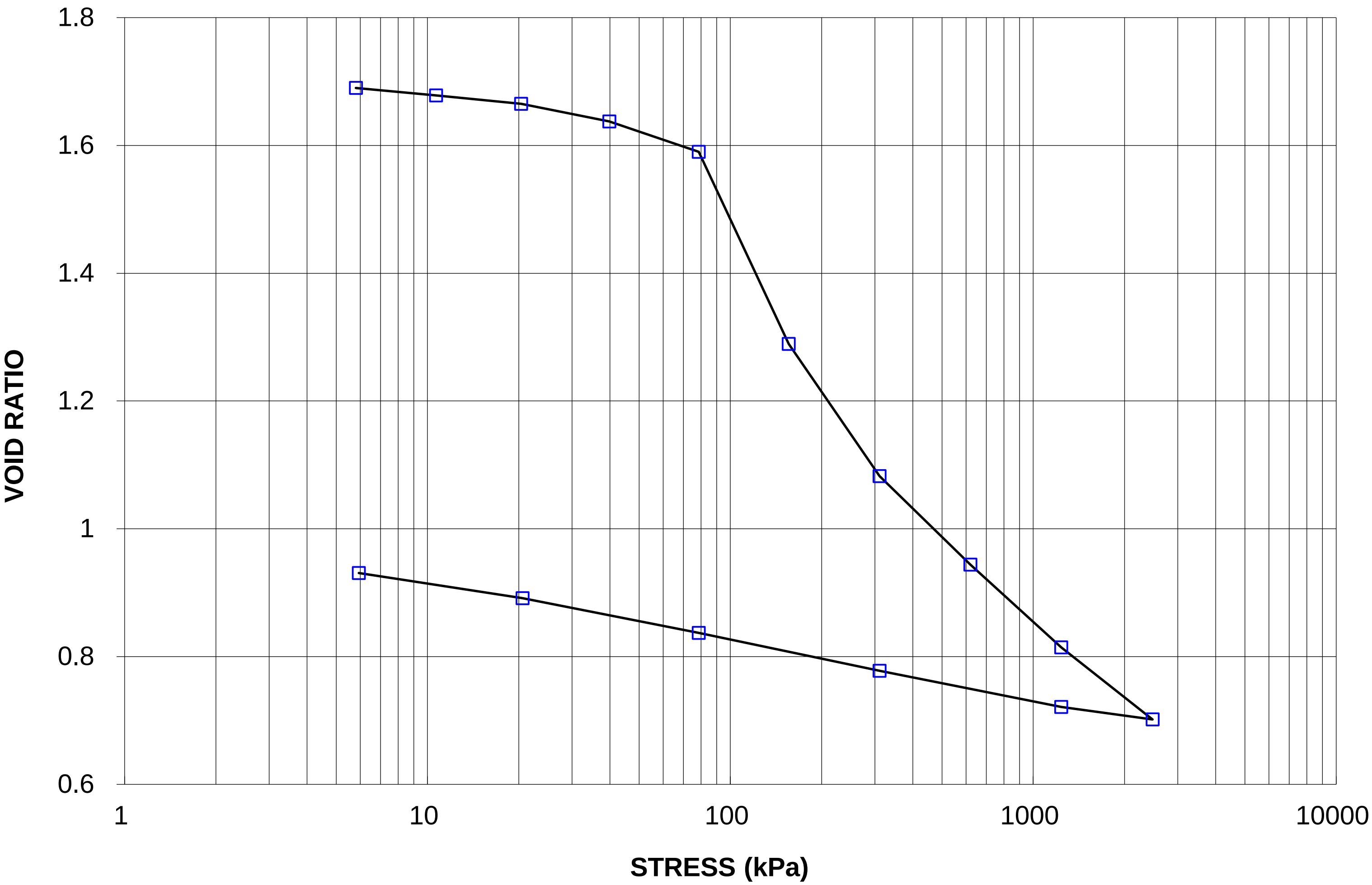
Project No. 1531057

Prepared By: LH

Golder Associates

Checked By: MCK

CONSOLIDATION TEST
VOID RATIO vs STRESS
BH C3-1 SA S-1

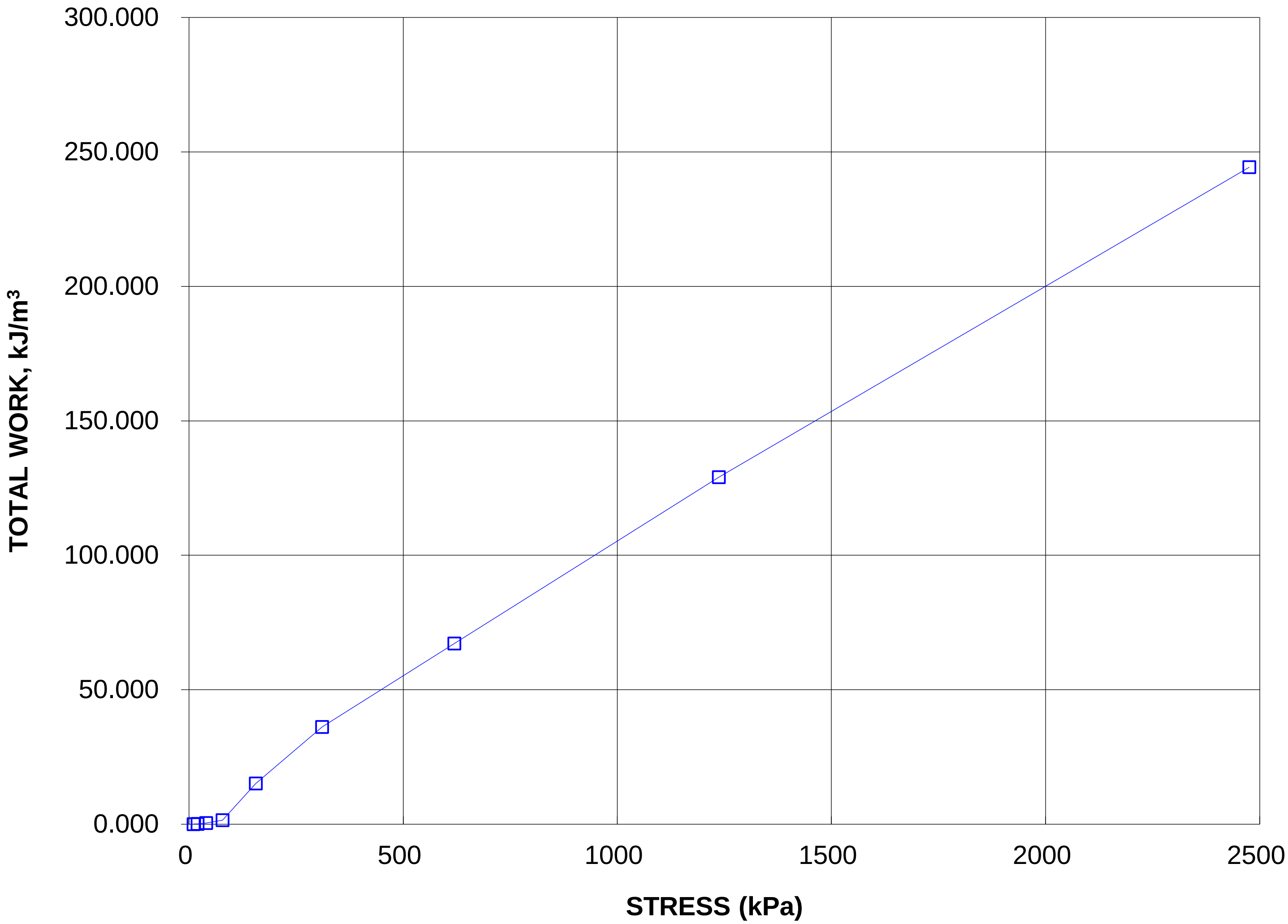


Golder Associates

Checked By: MCK

CONSOLIDATION TEST
VOID RATIO VS LOG STRESS

CONSOLIDATION TEST
TOTAL WORK, kJ/m³ vs STRESS
BH C3-1 SA S-1



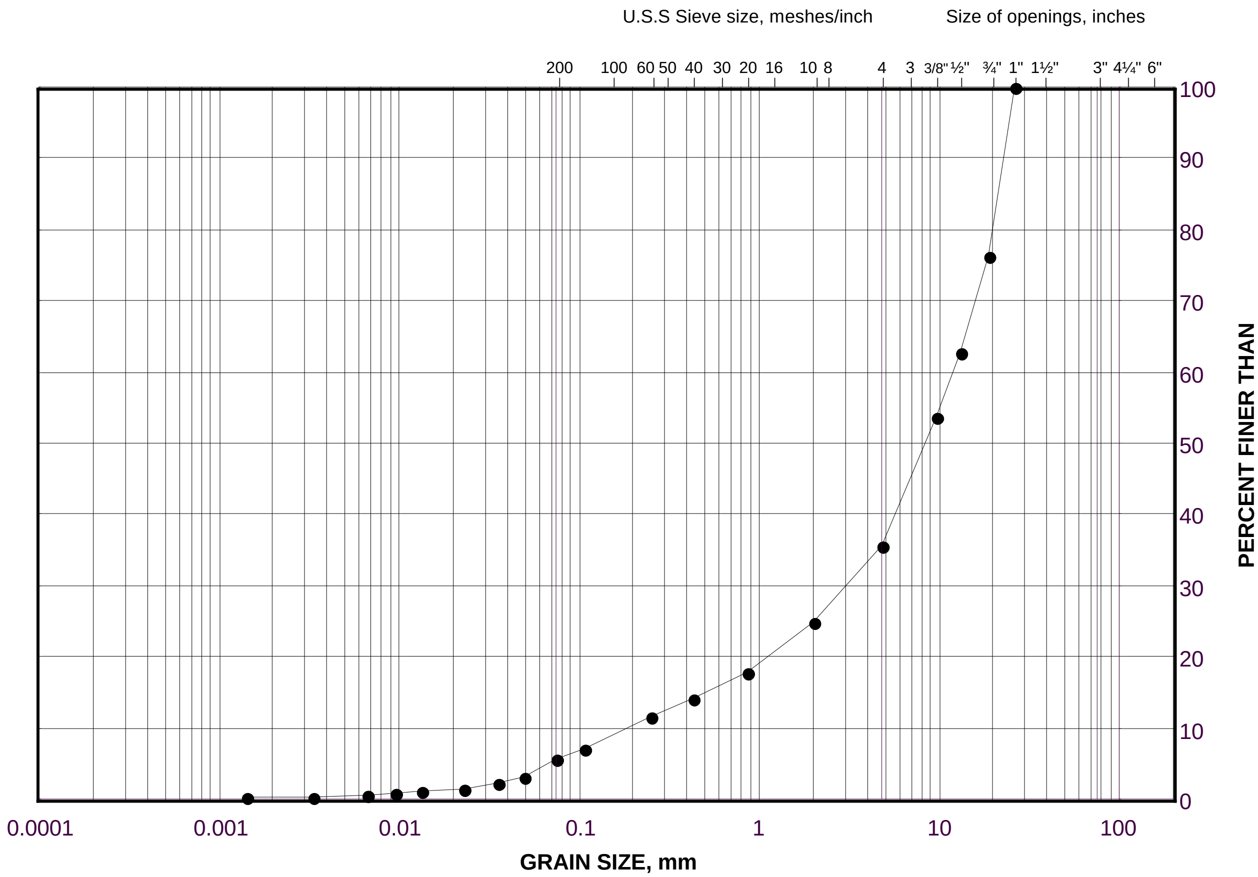
Project No. 1531057
Prepared By: LH
Checked By: MCK

Golder Associates

CONSOLIDATION TEST
TOTAL WORK VS STRESS

FIGURE B4
Sheet 4 of 4

GRAIN SIZE DISTRIBUTION Sand and Gravel	FIGURE B5



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C3-2	15	267.2

Project Number: 1531057

Checked By:MCK

Golder Associates

Date: 17-Aug-16

APPENDIX C

Analytical Testing Results

Maxxam
A Bureau Veritas Group Company

Your Project #: 1531057
Site Location: LV RETAINER NER ASSIGN#2, HWY 112
Your C.O.C. #: 565300-01-01

Attention:Chris Ng

Golder Associates Ltd
Mississauga - Standing Offer
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2016/06/20
Report #: R4035051
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B6C1265
Received: 2016/06/13, 11:35

Sample Matrix: Water
Samples Received: 4

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride by Automated Colourimetry	4	N/A	2016/06/16	CAM SOP-00463	EPA 325.2 m
Conductivity	4	N/A	2016/06/16	CAM SOP-00414	SM 22 2510 m
pH	4	N/A	2016/06/16	CAM SOP-00413	SM 4500H+ B m
Resistivity of Water	4	2016/06/14	2016/06/17	CAM SOP-00414	SM 22 2510 m
Sulphate by Automated Colourimetry	4	N/A	2016/06/16	CAM SOP-00464	EPA 375.4 m

Remarks:

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

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

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

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Ema Gitej, Senior Project Manager
Email: EGitej@maxxam.ca
Phone# (905)817-5829
==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam
A Bureau Veritas Group Company

Maxxam Job #: B6C1265
Report Date: 2016/06/20

Golder Associates Ltd
Client Project #: 1531057
Site Location: LV RETAINER NER ASSIGN#2, HWY 112
Sampler Initials: SA

RESULTS OF ANALYSES OF WATER

Maxxam ID		CNJ774	CNJ775	CNJ776	CNJ777			
Sampling Date		2016/06/12 11:00	2016/06/12 10:45	2016/06/12 07:45	2016/06/12 07:40			
COC Number		565300-01-01	565300-01-01	565300-01-01	565300-01-01			
	UNITS	C1	C2	C3	C4	RDL	QC Batch	MDL
Calculated Parameters								
Resistivity	ohm-cm	21000	7900	28000	7000		4538726	
Inorganics								
Conductivity	umho/cm	48	130	36	140	1.0	4541542	0.20
pH	pH	6.72	7.11	7.16	7.46		4541543	
Dissolved Sulphate (SO4)	mg/L	<1.0	<1.0	<1.0	<1.0	1.0	4541170	0.10
Dissolved Chloride (Cl)	mg/L	2.0	24	1.3	15	1.0	4541163	0.30

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Maxxam Job #: B6C1265
Report Date: 2016/06/20

Golder Associates Ltd
Client Project #: 1531057
Site Location: LV RETAINER NER ASSIGN#2, HWY 112
Sampler Initials: SA

TEST SUMMARY

Maxxam ID: CNJ774
Sample ID: C1
Matrix: Water

Collected: 2016/06/12
Shipped:
Received: 2016/06/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride by Automated Colourimetry	KONE	4541163	N/A	2016/06/16	Alina Dobreanu
Conductivity	AT	4541542	N/A	2016/06/16	Yogesh Patel
pH	AT	4541543	N/A	2016/06/16	Yogesh Patel
Resistivity of Water		4538726	2016/06/17	2016/06/17	Automated Statchk
Sulphate by Automated Colourimetry	KONE	4541170	N/A	2016/06/16	Deonarine Ramnarine

Maxxam ID: CNJ775
Sample ID: C2
Matrix: Water

Collected: 2016/06/12
Shipped:
Received: 2016/06/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride by Automated Colourimetry	KONE	4541163	N/A	2016/06/16	Alina Dobreanu
Conductivity	AT	4541542	N/A	2016/06/16	Yogesh Patel
pH	AT	4541543	N/A	2016/06/16	Yogesh Patel
Resistivity of Water		4538726	2016/06/17	2016/06/17	Automated Statchk
Sulphate by Automated Colourimetry	KONE	4541170	N/A	2016/06/16	Deonarine Ramnarine

Maxxam ID: CNJ776
Sample ID: C3
Matrix: Water

Collected: 2016/06/12
Shipped:
Received: 2016/06/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride by Automated Colourimetry	KONE	4541163	N/A	2016/06/16	Alina Dobreanu
Conductivity	AT	4541542	N/A	2016/06/16	Yogesh Patel
pH	AT	4541543	N/A	2016/06/16	Yogesh Patel
Resistivity of Water		4538726	2016/06/17	2016/06/17	Automated Statchk
Sulphate by Automated Colourimetry	KONE	4541170	N/A	2016/06/16	Deonarine Ramnarine

Maxxam ID: CNJ777
Sample ID: C4
Matrix: Water

Collected: 2016/06/12
Shipped:
Received: 2016/06/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride by Automated Colourimetry	KONE	4541163	N/A	2016/06/16	Alina Dobreanu
Conductivity	AT	4541542	N/A	2016/06/16	Yogesh Patel
pH	AT	4541543	N/A	2016/06/16	Yogesh Patel
Resistivity of Water		4538726	2016/06/17	2016/06/17	Automated Statchk
Sulphate by Automated Colourimetry	KONE	4541170	N/A	2016/06/16	Deonarine Ramnarine

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

GENERAL COMMENTS

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

Package 1	9.3°C

Results relate only to the items tested.

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Maxxam Job #: B6C1265
Report Date: 2016/06/20

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 1531057
Site Location: LV RETAINER NER ASSIGN#2, HWY 112
Sampler Initials: SA

			Matrix Spike		SPIKED BLANK		Method Blank		RPD	
QC Batch	**Parameter**	**Date**	**% Recovery**	**QC Limits**	**% Recovery**	**QC Limits**	**Value**	**UNITS**	**Value (%)**	**QC Limits**
4541163	Dissolved Chloride (Cl)	2016/06/16	NC	80 - 120	101	80 - 120	<1.0	mg/L	0.024	20
4541170	Dissolved Sulphate (SO4)	2016/06/16	NC	75 - 125	104	80 - 120	<1.0	mg/L	4.3	20
4541542	Conductivity	2016/06/16			102	85 - 115	<1.0	umho/cm	1.9	25
4541543	pH	2016/06/16			101	98 - 103			1.2	N/A

N/A = Not Applicable

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

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

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

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

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VALIDATION SIGNATURE PAGE

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

Cristina Carriere

Cristina Carriere, Scientific Services

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

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Maxxam — IMMEDIATE TEST

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CHAIN OF CUSTODY RECORD

Page 1 of 1

INVOICE TO:
Company Name: #1326 Golder Associates Ltd
Attention: Central Acct:1112, 1113, 1118
Address: 6925 Century Ave Suite 100, Mississauga ON L5N 7K2
Tel: (905) 567-4444 Fax: (905) 567-6561
Email: Catherine_Guiao@golder.com, Rachel_Benjamin@gol

REPORT TO:
Company Name:
Attention:
Address:
Tel: Fax:
Email:

PROJECT INFORMATION:
Quotation #: B52596
P.O. #:
Project: 1531057
Project Name: LV Retainer NER Assign#2
Site #: HWY112
Sampled By: S.A + D.M

Laboratory Use Only:
Maxxam Job #:
Bottle Order #: 565300
COC #: C#565300-01-01
Project Manager: Ema Gitej

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY

Regulation 153 (2011): Table 1 / Table 2 / Table 3 / Table ___; Res/Park / Ind/Comm / Agri/Other; Medium/Fine / Coarse / For RSC

Other Regulations: CCME / Reg 558 / MISA / PWQO / Other; Sanitary Sewer Bylaw / Storm Sewer Bylaw; Municipality ______

Special Instructions:

Include Criteria on Certificate of Analysis (Y/N)? ______

ANALYSIS REQUESTED (PLEASE BE SPECIFIC): Field Filtered (please circle): Metals / Hg / Cr VI; Chloride & Sulphate; Conductivity, Resistivity and pH

Turnaround Time (TAT) Required:
Please provide advance notice for rush projects
Regular (Standard) TAT: [X]
(will be applied if Rush TAT is not specified)
Standard TAT = 5-7 Working days for most tests.
Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.
Job Specific Rush TAT (if applies to entire submission)
Date Required: Time Required:
Rush Confirmation Number: (call lab for #)

#	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Field Filtered	Chloride & Sulphate	Conductivity, Resistivity and pH	# of Bottles	Comments
1		C1	June 12/16	11:00AM	Surface Water		X	X	1	*Small puddle (~3" deep) NOT Flowing
2		C2	June 12/16	10:45AM	"		X	X	1	
3		C3	June 13/16	7:50AM	"		X	X	1	
4		C4	June 13/16	7:40AM	"		X	X	1	
5										
6										
7										
8										
9										
10										

Received in Sudbury

13-Jun-16 11:35
Ema Gitej
B6C1265
GK1 ENV-1107

RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted
Shane Albert	16/06/13	11:35am	Bradley Frappier	2016/06/13	11:35	
			NUSRAT MAZ	2016/06/14	11:00	

Laboratory Use Only: Time Sensitive; Temperature (°C) on Receipt: 9, 10, 9°C; Custody Seal Present: No ✓; Intact

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

SAMPLES MUST BE KEPT COOL (< 10° C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

White: Maxxam Yellow: Client

2/5/4

Maxxam Analytics International Corporation o/a Maxxam Analytics

APPENDIX D

Non-Standard Special Provisions

WORKING SLAB – Item No.

Non-Standard Special Provision

The subgrade soils for the culvert foundation may be susceptible to disturbance and loosening from construction traffic and ponded water.

Where precast box culverts or open footing culverts are used, if the culvert is not placed on the prepared subgrade within four hours of its inspection and approval, a concrete working slab of 20 MPa compressive strength at 28-days with minimum thickness of 100 mm, shall be placed on the foundation subgrade. A minimum 75 mm thick uncompacted levelling pad consisting of Granular 'A' material (OPPS.PROV 1010) or concrete fine aggregate (meeting the grading requirements specified in OPSS.PROV 1002) shall be provided on top of the concrete working slab.

BASIS OF PAYMENT

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

END OF SECTION

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

For more information, visit golder.com

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