



April 6, 2017

FOUNDATION INVESTIGATION AND DESIGN REPORT

Centreline Culvert Replacement - Highway 112
STA 21+845, Township of Otto
Ministry of Transportation, Ontario
G.W.P. 5105-12-00; W.P. 5428-15-01

Submitted to:

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REPORT

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Table of Contents

PART A – FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION.....	1
3.0 INVESTIGATION PROCEDURES	1
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS	3
4.1 Regional Geology	3
4.2 General Overview of Local Subsurface Conditions	4
4.3 Culvert at STA 21+845	4
4.3.1 Asphalt.....	5
4.3.2 Embankment Fill	5
4.3.3 Peat.....	5
4.3.4 Silt and Sand to Sand and Gravel.....	5
4.3.5 Clayey Silt.....	6
4.3.6 Silt.....	6
4.3.7 Bedrock / Refusal.....	6
4.3.8 Groundwater Conditions	7
4.3.9 Analytical Testing of Creek Water.....	8
5.0 CLOSURE.....	8

PART B – FOUNDATION DESIGN REPORT

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS.....	9
6.1 General.....	9
6.2 Consequence and Site Understanding Classification	9
6.3 Foundations for Culvert Replacement	10
6.3.1 Foundation Options.....	10
6.3.2 Founding Elevations and Frost Protection Requirements	10
6.3.2.1 Corrugated Steel Pipe Culvert Replacement	10
6.3.2.2 Concrete Pipe Culvert Replacement.....	10
6.3.2.3 Precast Box Culvert Replacement	10



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

6.3.2.4	Open Footing Culvert Replacement.....	11
6.3.3	Factored Geotechnical Resistances	11
6.3.3.1	Corrugated Steel Pipe (CSP) Culvert Replacement	11
6.3.3.2	Concrete Pipe Culvert Replacement.....	11
6.3.3.3	Precast Box Culvert Replacement	12
6.3.3.4	Open Footing Culvert Replacement.....	12
6.3.4	Resistance to Lateral Loads / Sliding Resistance	12
6.4	Embankment Stability and Settlement	12
6.4.1	Stability	13
6.4.1.1	Methods.....	13
6.4.1.2	Parameter Selection	13
6.4.1.3	Results of Analysis	13
6.4.2	Settlement.....	13
6.4.2.1	Methods.....	13
6.4.2.2	Parameter Selection	14
6.4.2.3	Results of Analysis	14
6.5	Lateral Earth Pressures for Design.....	15
6.6	Construction Considerations.....	15
6.6.1	Temporary Roadway Protection and Cofferdams	15
6.6.2	Sloughing of Temporary Side Slopes.....	16
6.6.3	Rock Excavation and Blasting.....	17
6.6.4	Sub-Excavation and Replacement below Culvert Bedding	17
6.6.5	Embankment Fill Placement	17
6.6.6	Embankment Platform Widening.....	18
6.6.7	Culvert Bedding and Backfill	18
6.6.7.1	Corrugated Steel Pipe Culvert	19
6.6.7.2	Concrete Pipe Culvert.....	19
6.6.7.3	Precast Box Culvert.....	19
6.6.7.4	Open Footing Culvert.....	20
6.6.8	Erosion Protection.....	20
6.6.9	Temporary Culvert Extension.....	20



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

6.6.10	Surface Water and Groundwater Control	21
6.6.11	Recommendations for Construction Materials Based on Analytical Testing	21
6.6.11.1	Potential for Sulphate Attack	21
6.6.11.2	Potential for Corrosion	22

7.0 CLOSURE.....	22
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REFERENCES

TABLES

Table 1	Summary of Existing Culvert Details
Table 2	Comparison of Foundation Alternatives for Culvert Replacement
Table 3	Factored Ultimate and Serviceability Geotechnical Resistances for Culvert Replacement Options
Table 4	Resistance to Lateral Loads/Sliding Resistance for Culvert Replacement Options
Table 5	Summary of Foundation Engineering Parameters
Table 6	Summary of Stability Analysis
Table 7	Summary of Settlement Analysis

FIGURES

Figure 1A and 1B	Site Photographs
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DRAWINGS

Drawing 1	Borehole Locations and Soil Strata
Drawing 2	Soil Strata

APPENDICES

Appendix A Record of Boreholes

Lists of Symbols and Abbreviations	
Lithological and Geotechnical Rock Description Terminology	
Record of Boreholes	C2-1 to C2-9
Record of Drillholes	C2-1 to C2-4 and C2-6
Record of DCPTs	C2-DCPT-1 to C2-DCPT-3

Appendix B Geotechnical Laboratory Test Results

Table B1	Summary of Point Load Tests on Rock Samples
Figure B1	Grain Size Distribution – Gravelly Sand to Sand and Gravel (FILL)
Figure B2	Grain Size Distribution – Silt and Sand
Figure B3	Plasticity Chart – Clayey Silt
Figure B4	Grain Size Distribution – Silt
Figure B5A and B5B	Bedrock Core Photographs
Figure B6	Unconfined Compression Test (UC) – Borehole C2-1, Run No. 2

Appendix C Analytical Test Results



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

Appendix D

Stability Analysis Figures

Figure D1	Stability Analysis: 3 m Embankment Widening – West Side (Temporary)
Figure D2	Stability Analysis: Median/Internal Side Slopes with Grade Lowering (East Slope)
Figure D3	Stability Analysis: Median/Internal Side Slopes with Grade Lowering (West Slope)
Figure D4	Stability Analysis: Final Embankment

Appendix E

Non-Standard Special Provisions

NSSP	Obstructions
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PART A

**FOUNDATION INVESTIGATION REPORT
CENTRELINE CULVERT REPLACEMENT – HIGHWAY 112
STA 21+845, TOWNSHIP OF OTTO
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 5105-12-00; W.P. 5428-15-01**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by MMM Group Limited (MMM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide Foundation Engineering services for the replacement of the centreline culvert at STA 21+845 on Highway 112 in the Township of Otto, approximately 8 km south of Kirkland Lake, Ontario.

The Terms of Reference and 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 culverts 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 culvert at STA 21+845 on Highway 112 which has been identified for replacement. The foundation engineering services associated with the other culverts for Work Order / Assignment #2 are presented in separate reports.

2.0 SITE DESCRIPTION

The centreline culvert requiring replacement is located at approximately STA 21+845 on Highway 112 in the Township of Otto, approximately 8 km south of Kirkland Lake, Ontario. The existing culvert is a 910 mm wide by 610 mm high open footing structure covered with up to approximately 6 m of embankment fill. Details of the culvert are also summarized in Table 1 following the text of this report.

In general, the topography in the area of the culvert consists of rolling surface topography with 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 and DCPT locations advanced for the culvert investigation, including through the existing Highway 112 embankment, varies between Elevation 321.5 m and 315.1 m, referenced to Geodetic datum. Figure 1 contains photographs of the ground surface conditions at/near the culvert location.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the foundation investigation associated with the culvert at STA 21+845 was carried out between May 31 and June 3, 2016, during which time a total of six boreholes, three hand excavations and three Dynamic Cone Penetration Test (DCPT) were advanced at, or in the immediate vicinity of, the culvert alignment as summarized in Table 1 and shown on Drawing 1.

The field investigation was carried out using a truck-mounted CME55 drill rig and portable drilling equipment supplied and operated by Landcore Drilling of Sudbury, Ontario. Hand excavations were carried out at selection locations by Golder personnel.

The boreholes drilled by the truck-mounted CME55 drill rig were advanced through the overburden using 152 mm diameter solid stem augers and wash boring techniques using NW size casing. The boreholes completed with the portable equipment were advanced through the overburden using NQ and HQ size casing with wash boring techniques. Boreholes that were completed with rock coring were advanced with an NQ size core barrel. In



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

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.

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

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 and bedrock core samples. The soil and bedrock core samples were identified in the field, placed in appropriate containers, labelled and transported to Golder's Mississauga geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO Laboratory Standards and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. One Unconfined Compression (UC) test and six point load strength index tests were carried on selected bedrock core 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.

Classification of the rock mass quality of the bedrock with respect to the Rock Quality Designation (RQD) is described based on Table 3.10 of the Canadian Foundation Engineering Manual (CFEM)¹. Classification of the bedrock core samples with respect to strength from point load tests and unconfined compression test is described based on Table 3.5 of CFEM¹. The degree of weathering of the bedrock samples (i.e. fresh to slightly weathered – W1 to W2) and the strength classification of the intact rock mass based on field identification (i.e. strong – R4) are described in accordance with the International Society for Rock Mechanics (ISRM)² standard classification system.

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

¹ Canadian Geotechnical Society. (2006). Canadian Foundation Engineering Manual, 4th Edition.

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



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

Culvert Location	Borehole/DCPT	Location		Ground Surface Elevation (m)	Depth (m)
		Northing (m) / Latitude (°)	Easting (m) / Longitude (°)		
STA 21+845 (Township of Otto)	C2-1	532043.7 / 48.069212	376983.6 / -80.031327	316.5	4.6*
	C2-2	5326048.2 / 48.069252	376994.7 / -80.031176	320.1	11.8*
	C2-3	5326057.2 / 48.069330	377010.4 / -80.030965	315.1	5.6*
	C2-4	5326081.9 / 48.069556	376977.3 / -80.031404	321.5	6.8*
	C2-5	5326071.7 / 48.069467	376964.6 / -80.031577	316.2	1.1
	C2-6	5326033.1 / 48.069116	376993.3 / -80.031198	316.9	1.9*
	C2-7 (Hand Excavation)	5326028.6 / 48.069075	376995.5 / -80.031169	318.2	0.1
	C2-8 (Hand Excavation)	5326025.9 / 48.069051	376996.8 / -80.031152	319.6	0.0
	C2-9 (Hand Excavation)	5326064.4 / 48.069396	377009.0 / -80.030982	315.1	0.2
	C2-DCPT-1	5326055.0 / 48.069316	376968.8 / -80.031523	315.6	4.0
	C2-DCPT-2	5326066.4 / 48.069419	376965.1 / -80.031570	315.5	2.8
	C2-DCPT-3	5326076.1 / 48.069506	376962.3 / -80.031607	317.1	1.1

Note: * Includes between 1.6 m and 3.6 m length of bedrock coring.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Highway 112 is located in the Abitibi Uplands physiographic region, within the James region of the Canadian Shield as delineated by the Geomorphic Systems of North America³. 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 knobs⁴.

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

⁴ 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.



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

Highway 112 crosses four main assemblages or batholiths associated with the southern Abitibi Greenstone Belt⁵: 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 by 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 and Drillhole sheets and the laboratory test sheets in Appendices A and B, respectively. The results of the in situ field testing (i.e. SPT 'N'-values) as presented in 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 in the culvert area consists of a surficial layer of peat (at the toe of the highway embankment) or embankment fill (within the highway embankment), underlain by deposit of loose silt and sand to sand to sand and gravel, trace organics, which is in turn underlain by deposits of stiff clayey silt and loose silt. The overburden deposits are underlain by granite bedrock. 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 Culvert at STA 21+845

The plan/profiles along the centreline and along the west side of the highway embankment and a cross-section across the highway embankment in the area of the existing culvert at STA 21+845 showing the borehole locations and interpreted stratigraphy are shown on Drawings 1 and 2. The height of the embankment at this location is between about 5 m and 6 m and the existing culvert is about 25 m long. A total of six boreholes, three hand excavations and three DCPT's were completed to investigate the subsurface conditions at the culvert location: three boreholes/hand excavations (Borehole C2-1, C2-3 and C1-9) were advanced near the ends of the existing culvert; one borehole (Borehole C2-2) was advanced through the Highway 112 southbound lane roadway embankment, south of the existing culvert alignment; two boreholes (Boreholes C2-4 and C2-5) and three DCPT's (C2-DCPT-1 to C2-DCPT-3) were advanced north of the existing culvert, west of the centreline of Highway 112

⁵ 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.



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

and at the toe of the embankment; and three boreholes/hand excavations (C2-6 to C2-8) were advanced south of the existing culvert at the west toe of the existing embankment.

4.3.1 Asphalt

An approximately 100 mm thick layer of asphalt was encountered at ground surface in Boreholes C2-2 and C2-4.

4.3.2 Embankment Fill

Embankment fill, approximately 3.5 m and 5.5 m thick was encountered below the asphalt in Boreholes C2-2 and C2-4 at Elevations 320.0 m and 321.4 m, respectively, a 1.1 m thick layer of fill was also encountered at ground surface in Borehole C2-5 at the toe of the embankment at Elevation 316.2 m. Borehole C2-5 was terminated in the fill upon split-spoon refusal (bouncing) on inferred bedrock. The embankment fill consists of a 1.8 m and 1.6 m thick upper layer of gravelly sand to sand and gravel and a 3.7 m and 1.8 m thick layer of rock fill consisting of cobbles ranging in size from 80 mm to 300 mm in diameter, in the respective boreholes. The fill layer at the toe of the embankment consists of sand and gravel. The size of the cobbles/boulders were estimated by coring through areas where the augers encountered refusal.

The SPT 'N'-values measured within the gravelly sand to sand and gravel fill deposit range from 2 blows to 33 blows per 0.3 m of penetration, indicating a very loose to dense relative density. SPT 'N'-values of 100 blows per 0.08 m and 33 blows per 0.2 m of penetration was measured within the gravelly sand fill but are considered not representative of the relative density as the split-spoon sampler was bouncing on the underlying rock fill and inferred bedrock. SPT 'N'-values measured within rock fill are provided on the Record of Borehole sheets; however they may not be representative as the spoon was noted to have been advancing between cobble and boulder size material during the SPT drives..

The natural water contents measured on eight samples of the gravelly sand to sand and gravel fill range from about 3 per cent to 13 per cent.

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

4.3.3 Peat

A 0.2 m to 0.8 m thick deposit of peat was encountered at ground surface in Boreholes C2-3, C2-6 and C2-9. The peat typically contains some sand, trace silt and trace gravel. Borehole C2-9 was terminated within the peat deposit due to refusal on the underlying bedrock.

A SPT 'N'-value of 5 blows per 0.3 m of penetration was measured within the peat deposit indicating a loose relative density.

4.3.4 Silt and Sand to Sand and Gravel

A 0.6 m to 1.4 m thick deposit of silt and sand to sand and gravel (comprised of silt and sand, sand, and sand and gravel) was encountered at ground surface (Elevation 316.5 m) in Borehole C2-1, below the embankment fill in



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

Borehole C2-2 at a depth of 5.6 m below ground surface (Elevation 314.5 m) and below the peat at a depth of 0.8 m below ground surface (Elevation 314.4 m) in Borehole C2-3. Trace organics were noted to be present within the deposit in Borehole C2-1 and a 0.1 m thick layer of cobbles was encountered underlying the silt and sand deposit.

The SPT 'N'-values measured within the silt and sand to sand and gravel deposit range from 5 blows to 8 blows per 0.3 m of penetration, indicating a loose relative density. A SPT 'N'-value of 100 blows per 0.28 m of penetration was measured in Borehole C2-2, however it may not be representative due to the presence of a cobble.

A natural water content of 22 percent was measured on one sample of the silt and sand.

The result of a grain size distribution test completed on one sample of silt and sand component of the deposit is shown on Figure B2 in Appendix B.

4.3.5 Clayey Silt

A 1.3 m thick deposit of clayey silt was encountered below the sand deposit in Borehole C2-2 at a depth of 6.2 m below ground surface (Elevation 313.9 m). The clayey silt deposit contains trace sand and trace gravel. Silt seams were observed in the clayey silt deposit.

A SPT 'N'-value of 14 blows per 0.3 m of penetration was measured within the clayey silt deposit, suggesting a stiff consistency.

A natural water content of 36 per cent was measured on a sample of the clayey silt.

An Atterberg limits test carried out on a sample of the clayey silt measured a liquid limit of 34 per cent, a plastic limit of 17 per cent and a plasticity index of about 17 per cent. The result of the Atterberg limits test, which is plotted on a plasticity chart on Figure B3 in Appendix B, indicates that the material is a clayey silt of low plasticity.

4.3.6 Silt

A 1.2 m thick deposit of silt was encountered below the clayey silt in Borehole C2-2 at a depth of 7.5 m below ground surface (Elevation 312.6 m). The deposit contains traced sand and trace to some clay. Clayey silt seams were observed in the silt deposit.

A SPT 'N'-value of 6 blows per 0.3 m of penetration was measured within the silt deposit, indicating a loose relative density.

The natural water content measured on one sample of the silt was about 26 per cent.

The results of a grain size distribution test completed on one sample of the silt deposit is shown on Figure B4 in Appendix B.

4.3.7 Bedrock / Refusal

Bedrock was encountered (and cored) in Boreholes C2-1 to C2-4 and C2-6. Refusal to further split-spoon advancement on inferred bedrock was encountered in Borehole C2-5. The bedrock surface was also encountered in two hand excavations (Boreholes C2-7 and C2-8). Refusal to DCPT advancement was encountered in



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

C2-DCPT-1 to C2-DCPT-3 on the inferred underlying bedrock. The depths to bedrock and the corresponding bedrock surface elevations are summarized below.

Borehole/DCPT	Depth to Bedrock Surface (m)	Bedrock Surface Elevation (m)
C2-1	1.0	315.5
C2-2	8.7	311.4
C2-3	2.2	312.9
C2-4	3.6	317.9
C2-5	1.1*	316.6*
C2-6	0.3	315.0
C2-7 (Hand Excavation)	0.1	318.1
C2-8 (Hand Excavation)	0.0	319.6
C2-9 (Hand Excavation)	0.2	314.9
C2-DCPT-1	4.0*	311.6*
C2-DCPT-2	2.8*	312.7*
C2-DCPT-3	1.1*	316.0*

Note: * Inferred from refusal to further split-spoon or DCPT advancement.

Based on review of the bedrock core samples, the bedrock consists of coarse grained, non-porous, granite. The bedrock is described as fresh and strong. The bedrock descriptions are shown on the Record of Drillhole sheets in Appendix A and the rock core samples are shown on the photographs in Figures B5A and B5B.

The Total Core Recovery (TCR) and Solid Core Recovery (SCR) of samples recovered are between 86 per cent and 100 per cent and between 6 per cent and 100 per cent, respectively. The Rock Quality Designation (RQD) based on the borehole data ranges from 24 per cent to 100 per cent, indicating a rock mass of very poor, but generally poor, to excellent quality as per Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006).

An Unconfined Compression (UC) test performed on a core sample of the bedrock from Borehole C2-1 measured an uniaxial compressive strength (UCS) of about 70 MPa. Point load strength index tests were carried out on six selected samples of the bedrock core. The corrected point load strength index values (Is_{50}), for both the axial and diametral tests, range between about 5.0 MPa and 11.0 MPa, as shown in Table B1 in Appendix B.

Based on the laboratory UC and point load index test results, the bedrock is classified as strong (R_4 , $50 \text{ MPa} < \text{UCS} < 100 \text{ MPa}$) to extremely strong (R_6 , $Is_{50} > 10 \text{ MPa}$) as per Table 3.5 of CFEM (2006). The UC test results are presented in Figure B6 in Appendix B.

4.3.8 Groundwater Conditions

Details of the groundwater levels observed in the open boreholes are summarized on the Records of Borehole sheets in Appendix A. A summary of the measured groundwater levels in the open boreholes upon completion of drilling/rock coring are presented below.



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

Borehole	Ground Surface Elevation (m)	Depth Below Ground Surface to Water Level (m)	Groundwater Level Elevation (m)	Date	Notes
C2-1	316.5	0.2	316.3	June 1, 2016	Open Borehole
C2-2	320.1	5.6	314.5	May 31, 2016	Open Borehole
C2-3	315.1	0.0	315.1	June 3, 2016	Open Borehole
C2-4	321.5	3.5	318.0	June 1, 2016	Open Borehole
C2-5	316.2	0.0	316.2	June 2, 2016	Open Borehole
C2-6	316.9	Dry	-	June 2, 2016	Open Borehole
C2-7	318.2	Dry	-	June 2, 2016	0.1 m deep Hand Excavation
C2-8	319.6	N/A	N/A	June 2, 2016	Bedrock Outcrop
C2-9	315.1	Dry	-	June 3, 2016	0.2 m deep Hand Excavation

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.

4.3.9 Analytical Testing of Creek Water

Analytical testing was carried out on a sample of creek water taken from the culvert site to assess the corrosivity and concrete degradation potential from the creek water/groundwater for the new culvert structure. The results from the specialist analytical laboratory are presented in Appendix C and are summarised below:

Parameter	Test Result
Water Resistivity	7,900 ohm-cm
Water Conductivity	130 μ mho/cm
Sulphate Concentration	Less than 1.0 mg/L
Chloride Concentration	24 mg/L
Water pH	7.11

5.0 CLOSURE

Messrs. Shane Albert and Dave Marmor, EIT, supervised the borehole investigation program. This report was prepared by Mr. Ted Beadle, P.Eng. and was reviewed by Mr. Pierre-Philippe Levasseur, P.Eng, a senior geotechnical engineer with Golder. Mr. Jorge M.A. Costa, P.Eng., a Senior Consultant to Golder and Designated MTO Foundations Contact, conducted an independent quality control review of this report.



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

Report Signature Page

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PART B

**FOUNDATION DESIGN REPORT
CENTRELINE CULVERT REPLACEMENT – HIGHWAY 112
STA 21+845, TOWNSHIP OF OTTO
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 5105-12-00; W.P. 5428-15-01**



6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the proposed replacement of the open footing culvert at STA 21+845 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 open footing culvert at STA 21+845 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 the temporary embankments required for staged construction, and provides recommendations for stable embankment geometry and embankment fill materials that may be required as a means to reduce culvert settlements and to improve embankment stability (if necessary). The report also addresses potential construction concerns and geotechnical issues associated with the culvert replacement and temporary embankments associated with staged construction, sub-excavating soft/organic materials and placement of new fill materials.

It is understood that the replacement culvert will be a 525 mm diameter Corrugated Steel Pipe (CSP) constructed at the same alignment as the existing culvert and with the upstream (east end) and downstream (west end) inverts at about Elevations 315.0 m and 314.4 m respectively. In addition, it is understood that the replacement of the existing culvert by staged construction will require a combination of an embankment widening of up to 3 m on the west side of the existing embankment and an approximately 1.5 m grade lowering and staged construction to facilitate the culvert replacement. There is no permanent grade raise as part of the culvert replacement.

6.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the 2014 Canadian Highway Bridge Design Code and its Commentary (CHBDC, S6-14, 2014), 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 (2014) have been used for design, as indicated in Sections 6.3 and 6.4 below.

6.3 Foundations for Culvert Replacement

6.3.1 Foundation Options

A CSP 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 have been provided for the various culvert alternatives although it is understood that the proposed replacement culvert will be a 525 mm diameter CSP.

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, concrete pipe, precast box as well as cast-in-place open footing structure are provided in the following sections. From a foundation perspective, a CSP culvert is considered to be the preferred replacement alternative, given the relatively small size of the replacement structure.

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). As a result of the minimum depth at which the footings would have to be constructed as required for frost protection and the variability in the bedrock surface elevation along the culvert alignment, excavations up to about 3 m deep below the invert may be required to construct the footings on the bedrock, and up to about 5 m of bedrock excavation may be required in placed to construct the footing on a relatively level bedrock subgrade. 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 (compacted granular fill on the loose native silt and sand to sand gravel deposit), at 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.

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 (compacted granular fill on the native silt and sand to sand gravel deposit), at 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.

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 (on the native silt and sand to sand gravel deposit), at 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.

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 (on granite bedrock and mass concrete over bedrock), at 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.

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 (2014) and its *Commentary*.

6.3.4 Resistance to Lateral Loads / Sliding Resistance

Resistance to lateral forces / sliding resistance between the base of the CSP, concrete pipe or box culvert, or strip footings for the open footing culverts, and the subgrade should be calculated in accordance with Section 6.10.5 of the CHBDC (2014). Table 4, following the text of this report, provides the coefficients of friction ($\tan \delta$) between the base of the 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 a combination of temporary embankment widening up to 3 m on the west side of Highway 112 as well as grade lowering are being evaluated for staged construction. The purpose of the temporary embankment widening and an approximately 1.5 m grade lowering is to maintain traffic on the existing roadway during the replacement works without the need for temporary roadway protection systems.

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



6.4.1 Stability

6.4.1.1 Methods

Limit equilibrium slope stability analyses for the temporary and permanent embankments 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, target minimum factors of safety of 1.3 and 1.5 have been used for the design of the embankment slopes for temporary and permanent conditions 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 parameters 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 each site was assumed to be at ground surface at the toes of the embankment, consistent with the level at which it was encountered in boreholes advanced during the site investigation and observations of surface water on site.

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

6.4.1.3 Results of Analysis

The results of the stability analysis for the temporary and final embankment geometry are summarized in Table 6 and shown on Figures D1 to D4 in Appendix D. At this site, the minimum FoS for deep seated global failure of the temporary embankment widening and for the grade lowering geometry of the temporary stage embankment, as well as for the final embankment geometry, is equal to or greater than 1.3 in short-term conditions, and 1.5 in long-term conditions.

6.4.2 Settlement

6.4.2.1 Methods

To estimate the magnitude of expected settlement of the temporary embankment widening and final reconstructed embankment, analysis was carried out at the critical section, corresponding to the thickest soil deposits at STA 21+845. Settlement analyses were carried out using the commercially available program Settle^{3D} (version 4.0), developed by Rocscience Inc. The settlement analyses assume that all organics and other



deleterious materials (i.e. peat, and rootlets) are removed from the footprint of the temporary embankment widening prior to construction.

6.4.2.2 *Parameter Selection*

The simplified stratigraphy and the associated unit weights and strengths employed for the estimation of settlement of the foundation soils of the temporary widening and final embankment are presented in Table 5. The immediate compression of the non-cohesive overburden soils were modelled by estimating an elastic modulus of deformation based on the SPT 'N'-values and using correlations proposed by Bowles (1984) and Kulhawy and Mayne (1990). These estimated values were compared with the typical range of expected values for similar soil types, as outlined in CHBDC (2014) and adjusted, as appropriate. The consolidation settlement parameters of the cohesive deposits was assessed using empirical correlations proposed in literature by Koppula (1986), Terzaghi and Peck (1967), Kulhawy and Mayne (1990) and Azzouz et al. (1976).

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

For the purpose of the settlement analysis, the groundwater level was assumed to be at ground surface at the toe of the embankment, which is consistent with the level at which it was encountered in boreholes advanced during the site investigation and observations of surface water on site.

6.4.2.3 *Results of Analysis*

Based on the settlement analysis, the total factored settlement of the foundation soils due to the 3.0 m temporary embankment widening on the west side of the existing embankment is estimated to be about 20 mm. This settlement is estimated to be comprised of about 15 mm of factored immediate settlement due to the compression of the non-cohesive deposits and about 5 mm of factored primary settlement within the cohesive deposit. Based on the average coefficient of consolidation (c_v) of about $5 \times 10^{-3} \text{ cm}^2/\text{s}$ estimated for the cohesive deposit and the imposed loading conditions, and assuming a two way drainage of approximately 1.3 m thick cohesive deposit, it is estimated that about 90 per cent of the factored primary consolidation settlement will be completed in about 10 days.

Given that there is a minor platform widening (i.e. 1 m on each side) with no grade raise of the final embankment, the existing fill below the existing culvert invert level as well as native overburden is not expected to experience additional load as a result of the culvert replacement and as such, the settlement of the foundation soils below the culvert is estimated to be less than 25 mm.

The results of the foundation soil settlement analysis for the temporary widening, grade lowering and final embankment at the critical section are summarized in Table 7.

The magnitude of short-term and long-term post-construction settlement associated with the rock fill was estimated in accordance with the MTO Foundations Guideline (September 2010). Given that the height of embankment is between approximately 5.5 m and 6 m at the culvert location, if rock fill is to be used for up to 4.5 m of the reconstruction of the embankment, it is estimated that the short-term post-construction (1 year after embankment construction) factored settlement will be about 35 mm and the long-term post-construction factored settlement of



the rock fill will be about 5 mm. The results of the rock fill settlement analysis for the final embankment are summarized in Table 7.

6.5 Lateral Earth Pressures for Design

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 Roadway Protection and Cofferdams

The temporary excavations for the culvert replacement will be made through the existing embankment fill, comprised of gravelly sand and rock fill, and into native overburden soils, which typically are comprised of firm



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

peat, loose silt and sand to sand and gravel, stiff clayey silt and loose silt, over granite bedrock. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. According to OHSA, the existing fill and native overburden soils would be classified as Type 3 soils. Provided that proper groundwater control is in place, temporary open-cut excavations through the embankment fill and native overburden soils should be made with side slopes inclined no steeper than 1H:1V.

Given the relatively shallow depth to bedrock and the presence of rock fill within the embankment, it will not be possible to install sheet pile shoring. A soldier pile and lagging system may be used for support of the excavation, but may require pre-drilling to facilitate installation of the soldier piles. In addition, where bedrock is present at shallow depth below ground surface, if the soil cover does not have sufficient depth to provide lateral resistance, the use of rakers and tie-backs will be required to provide lateral support, or the soldier piles would have to be socketed into bedrock. The Contractor should be alerted to the presence of these obstructions; an example Non-Standard Special Provision (NSSP) to be included in the Contract Documents is presented in Appendix E.

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

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

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

Consideration could be given to either partial or full removal of the temporary protection 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.

6.6.2 Sloughing of Temporary Side Slopes

Given that the embankment fill is heterogeneous in composition and the angle of internal friction of the material(s) is variable, sloughing of the temporary 1 horizontal to 1 vertical (1H:1V) embankment slopes may occur during construction. If sloughing of the surficial/near surface slope material(s) should occur, consideration could be given to the placement of a surficial layer of granular fill on the temporary embankment slope to prevent further sloughing. Alternatively, consideration could also be given to flattening the temporary side slopes to 1.5 horizontal to 1 vertical (1.5H:1V) to reduce the potential for sloughing of the temporary slopes during construction. Barriers along the temporary 1H:1V embankment slopes should be positioned to provide as much separation distance as practical



from the edge of the embankment crest. Further, visual monitoring of the embankment side slopes for signs of sloughing/instability should be carried out on a regular basis.

6.6.3 Rock Excavation and Blasting

It should be noted that the bedrock at the site is classified as strong (R4) to extremely strong (R6) and as such, bedrock excavation would likely have to be carried out using line drilling and pre-shearing techniques to minimize blasting damage to the rock (i.e. shatter and over-break) and provide better control over the configuration of the founding surface. The overall slope of the rock face may be formed vertically, or near vertically (i.e. 0.25H:1V). In addition, following excavation, it will be necessary to remove all loose, shatter and/or fractured rock within the footprint of the foundations and to ensure that the founding bedrock surface is cleaned and protected such that the integrity of the rock is maintained.

The use of explosives should follow the specifications outlined in OPSS.PROV 120 (Use of Explosives). The rock excavation operations should be carried out in accordance with OPSS.PROV 206 (Grading).

6.6.4 Sub-Excavation and Replacement below Culvert Bedding

Prior to the placement of any bedding material or granular fill, all organic soils and soft material should be stripped from the plan limits of the proposed works. For temporary embankment widening to the west of the existing embankment, all loose/soft materials should be sub-excavated to Elevation 313 m or bedrock, from STA 21+840 to STA 21+875. The loose/soft material should be removed using construction procedures in accordance with OPSS.PROV 209 (Embankments over Swamps and Compressible Soils). Given the proposed culvert founding elevations of the replacement culvert summarized in Table 3, excavation of the embankment fill, organic material and native overburden soils up to about 7.1 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 should consist of OPSS.PROV 1010 Granular 'B' Type II material.

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.

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).

6.6.5 Embankment Fill Placement

Prior to the placement of any granular fill or rock fill for the embankment widening, all organic soils should be stripped from the plan limits of the proposed works. Placement of granular fill and rock fill for the construction of



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

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

The up to 4 m high staged embankment, which will be incorporated into the final construction of permanent embankment, may be constructed at a 1 horizontal to 1 vertical (1H:1V) median/internal side slope. The final embankment should be constructed at 1.25 horizontal to 1 vertical (1.25H:1V) side slopes.

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

6.6.6 Embankment Platform Widening

In accordance with the requirements of MTO Northern Region Engineering Directive NRE 98-200, Northern Region Embankment Design Guidelines, the reconstruction of the embankment should include an allowance for platform widening to accommodate settlements during and after construction, as well as to allow for future and pavement overlay, so that the minimum standard shoulder widths are maintained if future grade adjustments on the embankment are required. Given the small magnitude of settlement estimated to occur during and after construction, the minimum required embankment platform widening is 1 m per side.

6.6.7 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	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.



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 OPSS 208.010 (Benching of Earth Slopes) to integrate the new fill into the existing embankment fill along the cut faces. Where the culvert is to be placed within a rock fill embankment or rock fill is to be used as backfill, it is recommended that a non-woven geotextile be placed between the rock fill, and the granular bedding, backfill and cover. The geotextile should meet the specification for OPSS 1860 (Geotextiles) Class II and have a Filtration Opening Size (FOS) not greater than 150 µm.

Inspection and field density testing should be carried out by 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.

6.6.7.1 *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).

6.6.7.2 *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).

6.6.7.3 *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 OPSS 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).

6.6.7.4 *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).

6.6.8 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 and downstream ends 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 culvert 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 seal on the embankment slope.

6.6.9 Temporary Culvert Extension

A temporary culvert extension will be required to provide surface water passage/drainage below the temporary embankment widening. The temporary culvert extension may consist of a precast concrete culvert (box or pipe) or corrugated steel pipe (CPS) culvert. Bedding recommendations for the temporary culvert extension should be in accordance with the corresponding OPSS and/or OPSD, as outlined in Section 6.6.6, depending on the type of temporary culvert extension chosen.

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



6.6.10 Surface Water and Groundwater Control

Groundwater control will be required as the foundation excavation will extend below the existing ground surface for the removal of organic and overburden soils prior to placement of the culvert, and for installation of the cast-in-place culvert footings. For excavations extending to or below the groundwater level at the time of construction, groundwater inflows should be expected due to the relatively permeable silt to silt and sand to sand and gravel subgrade and fractured bedrock (near surface bedrock with a relatively low RQD). Therefore, control of groundwater will be necessary to allow for construction to be carried out in dry conditions. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade. Dewatering of all excavations should be carried out in accordance with OPSS 517 (Dewatering).

If required, temporary shoring and groundwater control could be in the form of a cofferdam advanced to an appropriate depth to control groundwater inflow and to prevent base heaving of the foundation subgrade. As noted in Section 6.6.1, due to the shallow depth to bedrock at the culvert site, sheet pile installation may not be feasible. Alternatively, a sand bag and/or bladder cofferdam system could be considered; however, additional pumping may be required to maintain a dry excavation as groundwater seepage may occur through the relatively permeable embankment fill, silt to silt and sand to sand and gravel subgrade soils and fractured bedrock.

Depending on the surface water level and flow conditions and groundwater levels at the time of construction, water flow could be diverted and/or pumped from behind a cofferdam. However, if construction dewatering pumping volumes are anticipated to exceed 50 m³/day, an Environmental Activity Section Registry (EASR) will be required as per the Environmental Protection Act by the Ontario Ministry of the Environment and Climate Change (MOECC). A permit to take water (PTTW) would be required if construction dewatering pumping volumes exceed 400 m³/day.

6.6.11 Recommendations for Construction Materials Based on Analytical Testing

The results of an analytical test on one sample of creek water are summarized in Section 4.3.9 and presented in Appendix C. The potential for deterioration of concrete due to sulphate attack and corrosion of steel elements are discussed in the following sections. It is the responsibility of the designer to determine the appropriate construction materials, including the exposure class and ensuring that all aspects of CSA A23.1-14 Section 4.1.1 "Durability Requirements" are followed when designing concrete components and protection of steel elements.

6.6.11.1 Potential for Sulphate Attack

The analytical test results were compared to CSA A23.1-14 Table 3 ("*Additional requirements for concrete subjected to sulphate attack*") for the potential sulphate attack on concrete. The sulphate concentration measured in the creek water sample is less than 0.0001 per cent (<1 mg/L), which is below the exposure class of S-3 (Moderate). Therefore, based on the single sample of creek water tested, when the designer is selecting the exposure class for the structure, the effects of sulphates from within the creek water around the culvert may not need to be considered.



6.6.11.2 *Potential for Corrosion*

The water sample tested exhibited a pH of 7.11 and a resistivity of 7,900 ohm-cm. According to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to culvert durability as it is less than 8.0. The resistivity is greater than 6,000 ohm-cm, which indicates that the soil corrosiveness is very low ($10,000 > R > 6,000$ ohm-cm), as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). However, the culvert will be located under the roadway shoulder and will be exposed to de-icing salt. Therefore, concrete should be designed for a “C” type exposure class as defined by CSA A23.1-14 Table 1 and consideration should be given to providing corrosion protection to reinforcing elements. All culverts should be designed with consideration given to Table 7.1 of the MTO Gravity Pipe Design Guidelines (2014).

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.



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

Report Signature Page

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FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

ASTM International:

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

Ontario Water Resources Act:

Ontario Regulation 331/13 Amendment to Revised Regulations of Ontario 1990, Regulation 903

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 120	Construction Specifications for the Use of Explosives
OPSS.PROV 206	Construction Specifications for Grading
OPSS.PROV 209	Construction Specifications for Embankments over Swamps and Compressible Soils
OPSS.PROV 401	Construction Specifications for Trenching, Backfilling and Compacting
OPSS.PROV 421	Construction Specifications for Pipe Culvert Installation in Open Cut
OPSS 422	Construction Specifications for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS.PROV 501	Construction Specifications for Compacting
OPSS 517	Construction Specifications for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Construction Specifications for Temporary Protection Systems
OPSS 902	Construction Specifications for Excavating and Backfilling – Structures
OPSS.PROV 1002	Material Specifications for Aggregates - Concrete
OPSS.PROV 1010	Material Specifications for Aggregates – Base, Subbase, Select Subgrade, Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

Commercial Software:

Slide (Version 6.0) by Rocscience Inc

Settle^{3D} (Version 4.0) by Rocscience Inc



TABLES



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

Table 1: Summary of Existing Culvert Details

Culvert Location (Township)	Culvert ID	Approximate Height of Embankment ¹	Existing Culvert			Approximate Invert Elevation ²		Boreholes	Dynamic Cone Penetration Tests
			Type	Approximate Dimension	Approximate Length	Upstream	Downstream		
STA 21+845 (Otto)	C2	Up to about 6 m	Open Footing	910 mm span by 610 mm high	25.7 m	315.0 m (East End)	314.4 m (West End)	6 Boreholes (C2-1 to C2-6) 3 Hand Excavations (C2-7 to C2-9)	3 DCPTs (C2-DCPT-1 to C2-DCPT-3)

- 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 Drainage and Hydrology Report for the Replacement of Four Centreline Culverts on Highway 112 and Highway 650, W.P. 5427 15-01, prepared by MMM, dated November 2016.

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Checked By: CN
Reviewed By: JMAC



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

Table 2: Comparison of Foundation Alternatives for Culvert Replacement

Replacement Alternatives	Advantages	Disadvantages	Risks/Consequences
Corrugated Steel Pipe (CSP) Culvert	<ul style="list-style-type: none"> Minimizes the depth of excavation, excavation support and dewatering requirements compared to cast-in-place open footing culvert. Culvert construction using CSP pipes is expected to be the fastest, resulting in the shortest duration for dewatering and surface water pumping, where required. More tolerant of total and differential settlement than precast and cast-in-place open footing culverts. 	<ul style="list-style-type: none"> Dewatering is required to carry out construction 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/outlet ends to mitigate potential for scour around/under the 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). 	<ul style="list-style-type: none"> Some risk of disturbance of the loose sand deposit under the culvert during construction.
Concrete Pipe Culvert	<ul style="list-style-type: none"> Minimizes the depth of excavation, excavation support and dewatering requirements compared to cast-in-place open footing culvert. Compared to cast-in-place open footings, the use of concrete pipe segments is expected to allow for faster construction, resulting in shorter duration for dewatering and surface water pumping, where required. More tolerant of total and differential settlement than a cast-in-place open footing culvert. Will have a longer lifespan than a culvert of CSP construction. 	<ul style="list-style-type: none"> A concrete pipe culvert will require slightly longer duration for construction as compared to the construction of a CSP culvert. Dewatering is required to carry out construction 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/outlet ends to mitigate potential for scour around/under the culvert. Proper compaction of backfill material under the haunches and to the springline is difficult. 	<ul style="list-style-type: none"> Some risk of disturbance of the loose sand deposit under the culvert during construction.



FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

Table 2: Comparison of Foundation Alternatives for Culvert Replacement

Replacement Alternatives	Advantages	Disadvantages	Risks/Consequences
Precast Box Culvert	<ul style="list-style-type: none"> Minimizes the depth of excavation, excavation support and dewatering requirements compared to cast-in-place open footing culvert. Compared to cast-in-place open footings, the use of 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 than a cast-in-place open footing culvert. Will have a longer lifespan than a culvert of CSP construction. Easier to place/compact backfill compared to a pipe culvert. Box culvert of similar span width and height as a CSP or concrete pipe culvert can accommodate higher flows. 	<ul style="list-style-type: none"> A precast box culvert will require longer duration for construction than a CSP and a concrete pipe culvert. Cut-off wall or clay blanket may be required at inlet/outlet ends to mitigate potential for scour around/under the culvert. 	<ul style="list-style-type: none"> Some risk of disturbance of the loose sand deposit under the culvert during construction.
Cast-In-Place Open Footing Culvert	<ul style="list-style-type: none"> Provides a relatively higher bearing capacity due to the depth of embedment of footings and /or the footings being founded on bedrock. 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 or bedrock, as applicable. 	<ul style="list-style-type: none"> Deeper excavations, excavation support and dewatering requirements compared to other culvert types; Up to 5 m of bedrock excavation will be required to construct footings at the founding elevation on bedrock. Mass concrete will be required in areas where soil has been excavated below the founding elevation to reduce loading stress concentrations on the footing. Additional time will be required to implement a dewatering system for the construction of footings in-the-dry. A cast-in-place open footing culvert is less tolerant of total and differential settlement. 	<ul style="list-style-type: none"> High risk of disturbance of the loose silt deposit under the culvert during construction. Culvert joints may be required to accommodate total and differential settlement (if applicable)

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FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

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	Approximate Founding Elevation (Upstream / Downstream) ¹	Founding Condition ²	Factored Geotechnical Axial Resistance at ULS ³	Factored Serviceability Geotechnical Resistance at SLS for 25 mm of Settlement ³
STA 21+845 (Otto)	315.0 m / 314.4 m (East / West)	Corrugated Steel Pipe (CSP)	525 mm diameter by 25.7 m long	314.7 m / 314.1 m (East / West)	Compacted Granular Fill over Sand / Stiff Clayey Silt	450 kPa	350 kPa
		Concrete Pipe Culvert	525 mm diameter by 25.7 m long	314.7 m / 314.1 m (East / West)	Compacted Granular Fill over Sand / Stiff Clayey Silt	450 kPa	350 kPa
		Precast Box	525 mm wide by 525 mm high by 25.7 m long	314.7 m / 314.1 m (East / West)	Compacted Granular Fill over Sand / Stiff Clayey Silt	450 kPa	350 kPa
		Cast-In-Place Open Footing	0.6 m wide footings by 25.7 m long	312.6 m / 312.0 m (East / West)	Bedrock or Mass Concrete on Bedrock	10,000 kPa	N/A
			1.2 m wide footings / 25.7 m long	312.6 m / 312.0 m (East / West)	Bedrock or Mass Concrete on Bedrock	10,000 kPa	N/A

- Notes:
1. Culvert invert elevations are estimated based on the Drainage and Hydrology Report for the Replacement of Four Centreline Culverts on Highway 112 and Highway 650, W.P. 5427-15-01, prepared by MMM, dated November 2016
 2. A minimum 0.3 m thick compact granular pad is required over the bedrock to reduce loading stress concentrations on the pipe culverts, precast box culverts and cast-in-place footings.
 3. The factored ultimate geotechnical resistance at ULS and factored serviceability geotechnical resistance at SLS for 25 mm of settlement are estimated based on the assumed culvert dimensions. The geotechnical resistances should be reviewed if the founding elevation and/or the footing/base width differ from those given above.
 4. The factored serviceability geotechnical resistance at SLS for 25 mm of settlement will be greater than the factored ultimate geotechnical resistance at ULS and as a result, the SLS condition does not apply; the estimated settlement for the factored ULS resistance is less than 25 mm.

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FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

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)	0.35
Concrete Pipe Culvert	Compacted Granular Fill (Bedding)	0.40
Precast Box Culvert	Compacted Granular Fill (Bedding)	0.40
Cast-In-Place Open Footing Culvert	Bedrock or Mass Concrete over Bedrock	0.70

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FOUNDATION REPORT - CENTRELINE CULVERT
REPLACEMENT - HIGHWAY 112 STA 21+845

Table 5: Summary of Foundation Engineering Parameters

Culvert Designation	Culvert Location (Township)	Stratigraphic Unit	Top Elevation (m)	Thickness (m)	γ' (kN/m ³)	ϕ' (°)	c' (kPa)	S_u (kPa)	σ_p' (kPa)	e_o	C_c	C_r	m_v (kPa ⁻¹)	E' (MPa)	c_v (cm ² /s)	Coefficient of Earth Pressure		
																Active, K _a	At Rest, K _o	Passive, K _p
C2	Highway 112 STA 21+845 (Otto)	New Rock Fill	-	-	20	40	-	-	-	-	-	-	-	150	-	0.21	0.36	4.60
		Existing Compact to Dense Gravelly Sand Fill	321.4 – 320.0	1.7 – 1.8	21	32	-	-	-	-	-	-	-	50	-	0.31	0.47	3.25
		Existing Rock Fill	319.8 – 318.2	1.8 – 3.7	20	40	-	-	-	-	-	-	-	150	-	0.21	0.36	4.60
		Loose Silt and Sand to Sand to Sand and Gravel	316.5 – 314.4	0.6 – 1.4	21	31	-	-	-	-	-	-	-	10	-	0.32	0.48	3.12
		Stiff Clayey Silt	~ 313.9	~ 1.3	19	30	-	50	-	-	-	-	1 x 10 ⁻⁴	-	5 x 10 ⁻³	0.33	0.50	3.00
		Loose Silt	~ 312.6	~1.2	19	30	-	-	-	-	-	-	-	5	-	0.33	0.50	3.00

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Table 6: Summary of Stability Analysis

Culvert ID Culvert Location (Township)	Stability Analysis ¹					Figure Number
	Condition	Embankment	Slope Profile	Embankment Height at Culvert Location	Minimum Factor of Safety ²	
C2 STA 21+845 (Otto)	3.0 m Embankment Widening – West Side (Temporary) ³	West Slope	1.5H:1V	5.5 m	≥ 1.3	D1
	Median/Internal Side Slopes with Grade Lowering (Temporary)	East Slope	1H:1V ⁴	Up to 4 m	≥ 1.3	D2
		West Slope	1H:1V ⁴	Up to 4 m	≥ 1.3	D3
	Final Embankment	East Slope	1.25H:1V	6 m	≥ 1.5	D4
		West Slope	1.25H:1V	5.5 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. The minimum FoS is based on a deep seated, global trial failure surface that would impact the operation of the highway.
 3. Where embankment widening is required, benching of the existing embankment side slope should be carried out in accordance with OPSD 208.010 (Benching of Earth Slopes).
 4. For temporary 1H:1V side slopes, surficial sloughing may occur which may require maintenance. If sloughing occurs during construction, consideration could be given to the placement of a surficial layer of granular fill on the temporary embankment slope or flattening slopes to 1.5H:1V inclination to mitigate against further sloughing.

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FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 21+845

Table 7: Summary of Settlement Analysis

Culvert ID Culvert Location (Township)	Construction Stage	Estimated Factored Immediate Settlement of Foundation Soils	Estimated Factored Consolidation Settlement of Foundation Soils ¹	Estimated Factored Settlement of Embankment Fills	Estimated Total Factored Settlement
C2 STA 21+845 (Otto)	3.0 m Embankment Widening – West Side (Temporary)	15 mm	5 mm	< 5 mm (Granular Fill)	20 mm
	Final Embankment	10 mm	5 mm	< 5 mm (Granular Fill) < 35 mm (Rock Fill) ²	< 20 mm (Granular Fill) < 50 mm (Rock Fill) ²

Notes: 1. About 90 per cent of the factored primary consolidation settlement is estimated to be completed in about 10 days.

2. Rock fill settlements assume 4.5 m of rock fill are placed for embankment reconstruction.

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Reviewed By: JMAC




FIGURES



East side of Highway 112 at STA 21+845 (Township of Otto) Culvert, looking west. June 5, 2016.


REVISION DATE: February 2, 2017 BY: MCK Project: 1531057

PROJECT		Detail Design for Replacement of 3 Centreline Culverts – Highway 112			
		GWP 5105-12-00; WP 5428-15-01			
TITLE		Site Photographs			
		Culvert STA 21+845 (Township of Otto)			
		Highway 112			
		PROJECT No. 1530157		FILE No. ----	
		DESIGN	TWB	Sep 6	SCALE NTS REV.
		CADD	-- --		
		CHECK	PPL	Sep 6	
		REVIEW	JMAC	Sep 6	
					FIGURE 1A



West side of Highway 112 looking south towards Culvert C2 at STA 21+845 (Township of Otto). June 2, 2016.

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

PROJECT		Detail Design for Replacement of 3 Centreline Culverts – Highway 112				
		GWP 5105-12-00; WP 5428-15-01				
TITLE		Site Photographs				
		Culvert STA 21+845 (Township of Otto)				
		Highway 112				
		PROJECT No. 1530157			FILE No. ----	
		DESIGN	TWB	Sep 6	SCALE	NTS
		CADD	-- --			REV.
		CHECK	PPL	Sep 6	FIGURE 1B	
		REVIEW	JMAC	Sep 6		



**FOUNDATION REPORT - CENTRELINE CULVERT
REPLACEMENT - HIGHWAY 112 STA 21+845**

DRAWINGS



**Golder
Associates**



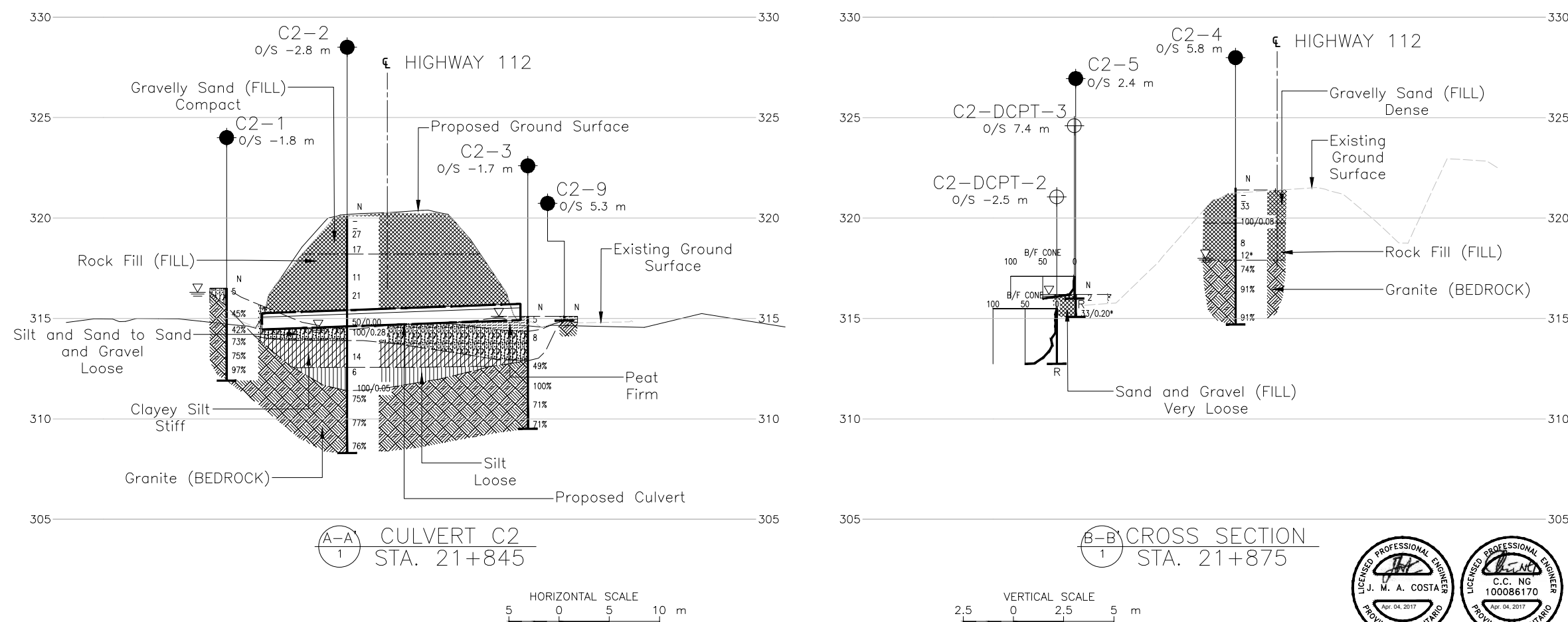
	Borehole – Current Investigation
	Dynamic Cone Penetration Test – Current Investigation
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
	WL upon completion of drilling

REFERENCE

NOTES

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

NO.	DATE	BY	REVISION		
Geocres No. 42A-112					
HWY. 112		PROJECT NO. 1531057		DIST. .	
SUBM'D. TWB	CHKD. TWB	DATE: 4/4/2017		SITE: .	
DRAWN: MR	CHKD. CN	APPD. JMAM		DWG. 1	



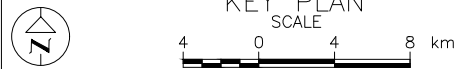
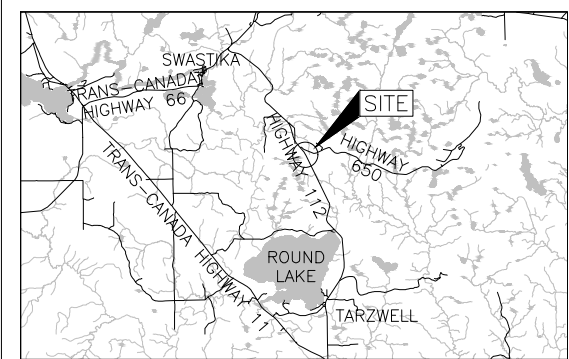
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5428-15-01

HIGHWAY 112
CULVERT STA. 21+845

SOIL STRATA

SHEET



LEGEND

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

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
C2-1	316.5	5326043.7	376983.6
C2-2	320.1	5326048.2	376994.7
C2-3	315.1	5326057.2	377010.4
C2-4	321.5	5326081.9	376977.3
C2-5	316.2	5326071.7	376964.6
C2-6	316.9	5326033.1	376993.3
C2-7	318.2	5326028.6	376995.5
C2-8	319.6	5326025.9	376996.8
C2-9	315.1	5326064.4	377009.0
C2-DCPT-1	315.6	5326055.0	376968.8
C2-DCPT-2	315.5	5326066.4	376965.1
C2-DCPT-3	317.1	5326076.1	376962.3

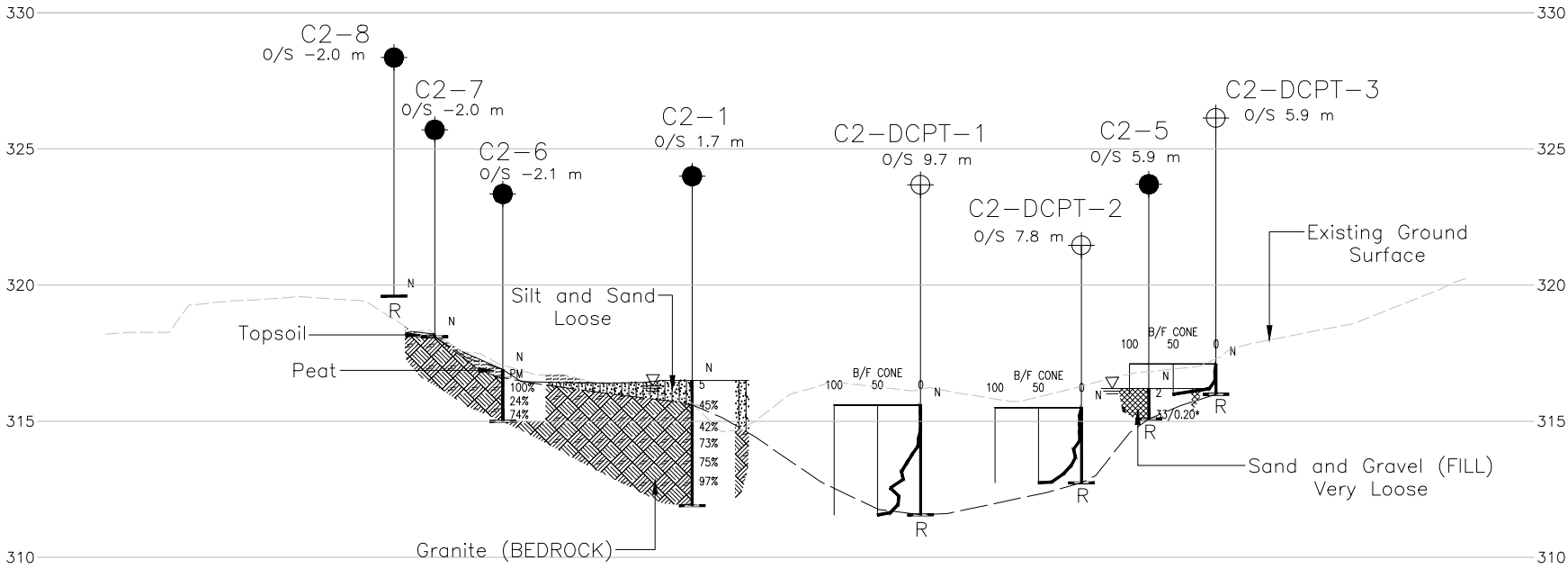
REFERENCE

Base plan, culvert section and surface data provided in digital format by MTO, drawing file no. "b04490112002.dwg", dated May, 2016, received June 29, 2016.

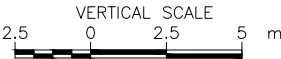
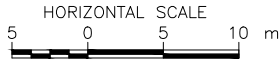
NOTES

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.



PROFILE
STA. 21+800 TO 21+900



NO.	DATE	BY	REVISION
Geocres No. 42A-112			
HWY. 112	PROJECT NO. 1531057		DIST. .
SUBM'D. TWB	CHKD. TWB	DATE: 4/4/2017	SITE: .
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

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

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

Notes: 1
2

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



LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N :

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

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive Soils

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

(b) Cohesive Soils Consistency

	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	
0 to 5	Trace
5 to 12	Trace to Some (or Little)
12 to 20	Some
20 to 30	(ey) or (y)
over 30	And (non-cohesive (cohesionless)) or With (cohesive)

Example

Trace sand
Trace to some sand
Some sand
Sandy
Sand and Gravel
Silty Clay with sand / Clayey Silt with sand



LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERING STATE

Fresh: no visible sign of weathering

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

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

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

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

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

BEDDING THICKNESS

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

JOINT OR FOLIATION SPACING

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

GRAIN SIZE

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

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

CORE CONDITION

Total Core Recovery (TCR)

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

Solid Core Recovery (SCR)

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

Rock Quality Designation (RQD)

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

DISCONTINUITY DATA

Fracture Index

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

Dip with Respect to Core Axis

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

Description and Notes

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

Abbreviations

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

PROJECT		1531057		RECORD OF BOREHOLE No C2-1				SHEET 1 OF 1				METRIC					
W.P.		5428-15-01		LOCATION		N 5326043.7; E 376983.6 MTM ZONE				ORIGINATED BY SA							
DIST		HWY 112		BOREHOLE TYPE		Portable Equipment, HQ Casing (Manual Hammer)				COMPILED BY MR							
DATUM		Geodetic		DATE		June 1, 2016				CHECKED BY MK							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
316.5	GROUND SURFACE						20	40	60	80	100	20	40	60		GR SA SI CL	
0.0	SILT and SAND, trace to some clay, trace to some gravel, containing organics and cobbles Loose		1	SS	5											10 48 36 6	
315.6	Brown to grey Moist to wet																
1.0	COBBLES GRANITE (BEDROCK)		1	RC	REC 86%											RQD = 45%	
	Bedrock cored from depths of 0.9 m to 4.6 m.		2	RC	REC 100%											RQD = 42%	
	For bedrock coring details refer to Record of Drillhole C2-1.		3	RC	REC 100%											RQD = 73%	
			4	RC	REC 100%											RQD = 75%	
			5	RC	REC 100%											RQD = 97%	
311.9	END OF BOREHOLE																
4.6	NOTES: 1. Water level in open borehole at a depth of 0.2 m below ground surface (Elev. 316.3 m) upon completion of drilling. 2. Geographic Coordinates: Latitude: 48.069212 Longitude: -80.031327																

PROJECT: 1531057

RECORD OF DRILLHOLE: C2-1

SHEET 1 OF 1

LOCATION: N 5326043.7 ;E 376983.6

DRILLING DATE: June 1, 2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: Portable Equipment

DRILLING CONTRACTOR: Landcore Drilling Inc.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	FLUSH	JN - Joint FLT - Fault SH - Shear VN - Vein CJ - Conjugate	BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage	PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular	PO - Polished K - Slickensided SM - Smooth RO - Rough VR - Very Rough	MB - Mechanical Break BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.	NOTES								
								RECOVERY	R.Q.D. %	FRACT. INDEX PER 0.25 m	B Angle	DIP w.r.t. CORE AXIS	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY K, cm/sec	Diametral Point Load Index (MPa)	RMC -Q AVG		
								TOTAL CORE %	SOLID CORE %								10 ⁰	10 ¹	10 ²		
1	NQ RC NW Casing	Continued from Record of Borehole C2-1 COBBLES Fresh, pink, coarse grained, non-porous, strong GRANITE		315.60 0.90 1.04	1																
2					2																
3					3																
4					4																
5					5																
5		END OF DRILLHOLE		311.90 4.60																	
6																					
7																					
8																					
9																					
10																					

UCS = 70.5 MPa

DEPTH SCALE

1 : 50



LOGGED: SA

CHECKED: MK

PROJECT		1531057		RECORD OF BOREHOLE No C2-2				SHEET 1 OF 1		METRIC						
W.P.		5428-15-01		LOCATION		N 5326048.2; E 376994.7 MTM ZONE		ORIGINATED BY		DM						
DIST		HWY 112		BOREHOLE TYPE		CME 55, 152 mm Diameter Solid Stem Augers, NW Casing		COMPILED BY		MR						
DATUM		Geodetic		DATE		May 31, 2016		CHECKED BY		MK						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
320.1	GROUND SURFACE						20	40	60	80	100					
0.9	ASPHALT (100 mm)		1	AS	-											
	Gravelly sand, trace to some silt (FILL)		2	AS	-											
	Compact Brown Moist		3A													
			3B	SS	27											
318.2	Rock fill (FILL)		4	SS	17											
1.9																
			5	SS	11											
			6	SS	21											
			7	SS	50/0.00											
314.5	SAND, some silt		8	SS	100/0.20											
5.6	Brown Wet															
313.9	- cobble at a depth of 5.9 m															
6.2	CLAYEY SILT, trace sand, trace gravel, containing silt seams		9	SS	14											
	Stiff Grey Wet															
312.6	SILT, trace sand, trace to some clay, containing clayey silt seams		10	SS	6											
7.5	Loose Grey Wet															
311.4	GRANITE (BEDROCK)		11		100/0.05											
8.7	Bedrock cored from depths of 8.7 m to 11.8 m.		1	RC	REC 99%											
	For bedrock coring details refer to Record of Drillhole C2-2.		2	RC	REC 100%											
			3	RC	REC 100%											
308.3	END OF BOREHOLE															
11.8	NOTE:															
	1. Water level in open borehole at a depth of 5.6 m below ground surface (Elev. 314.5 m) upon completion of drilling.															
	2. Geographic Coordinates:															
	Latitude: 48.069252															
	Longitude: -80.031176															

PROJECT: 1531057

RECORD OF DRILLHOLE: C2-2

SHEET 1 OF 1

LOCATION: N 5326048.2 ;E 376994.7

DRILLING DATE: May 31, 2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 55

DRILLING CONTRACTOR: Landcore Drilling Inc.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	FLUSH	JN - Joint FLT - Fault SH - Shear VN - Vein CJ - Conjugate BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular PO - Polished K - Slickensided SM - Smooth RO - Rough VR - Very Rough MB - Mechanical Break BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.										NOTES	
								RECOVERY		R.Q.D. %	FRACT. INDEX PER 0.25 m	DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY K, cm/sec	Diametral Point Load Index (MPa)	RMC -Q AVG	
								TOTAL CORE %	SOLID CORE %			B Angle	DIP w.r.t CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Ja		
9	NQ RC NW Casing	Continued from Record of Borehole C2-2		311.40															
		Fresh, pink, coarse grained, non-porous, strong GRANITE		8.70	1														5.0 MPa (Axial) 8.3 MPa
10					2														
11					3														
12		END OF DRILLHOLE		308.30															
13				11.80															
14																			
15																			
16																			
17																			
18																			

DEPTH SCALE

1 : 50



LOGGED: DM

CHECKED: MK

PROJECT		1531057		RECORD OF BOREHOLE No C2-3				SHEET 1 OF 1				METRIC					
W.P.		5428-15-01		LOCATION		N 5326057.2; E 377010.4 MTM ZONE				ORIGINATED BY SA							
DIST		HWY 112		BOREHOLE TYPE		Portable Equipment, NQ Casing (Manual Hammer)				COMPILED BY MR							
DATUM		Geodetic		DATE		June 3, 2016				CHECKED BY MK							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
315.1	GROUND SURFACE						20	40	60	80	100	W _p	W	W _L			
0.0	PEAT (Fibrous), some sand, trace to some silt Firm Brown Moist to wet		1	SS	5												
314.4																	
0.8	- 280 mm diameter cobble encountered at a depth of 0.6 m SAND and GRAVEL, some silt, containing organics Loose Brown Wet		2	SS	8												
312.9																	
2.2	GRANITE (BEDROCK) Bedrock cored from depths of 2.2 m to 5.6 m. For bedrock coring details refer to Record of Drillhole C2-3.		1	RC	REC 100%											RQD = 49%	
			2	RC	REC 100%											RQD = 100%	
			3	RC	REC 100%											RQD = 71%	
			4	RC	REC 95%											RQD = 71%	
309.5	END OF BOREHOLE																
5.6	NOTES: 1. Water level in open borehole at ground surface (Elev. 315.1 m) upon completion of drilling. 2. Geographic Coordinates: Latitude: 48.069330 Longitude: -80.030965																

PROJECT: 1531057

RECORD OF DRILLHOLE: C2-3

SHEET 1 OF 1

LOCATION: N 5326057.2 ;E 377010.4

DRILLING DATE: June 3, 2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: Portable Equipment

DRILLING CONTRACTOR: Landcore Drilling Inc.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN																NOTES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
						RECOVERY			R.Q.D. %	FRACT. INDEX PER 0.25 m	DISCONTINUITY DATA						HYDRAULIC CONDUCTIVITY K, cm/sec	Diametral Point Load Index (MPa)	RMC -Q AVG																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
						FLUSH	TOTAL CORE %	SOLID CORE %			B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
																				JN - Joint FLT - Fault SH - Shear VN - Vein CJ - Conjugate	BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage		PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular	PO - Polished K - Slickensided SM - Smooth RO - Rough VR - Very Rough	MB - Mechanical Break BR - Broken Rock																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
		Continued from Record of Borehole C2-3		312.90																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						

9.3 MPa (Axial)
10.8 MPa

DEPTH SCALE

1 : 50




LOGGED: SA

CHECKED: MK

PROJECT		RECORD OF BOREHOLE No C2-4				SHEET 1 OF 1		METRIC									
W.P. 5428-15-01		LOCATION N 5326081.9; E 376977.3 MTM ZONE				ORIGINATED BY DM											
DIST _____ HWY 112		BOREHOLE TYPE CME 55, 152 mm Diameter Solid Stem Augers, NW Casing				COMPILED BY MR											
DATUM Geodetic		DATE June 1, 2016				CHECKED BY MK											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
321.5	GROUND SURFACE																
0.0	ASPHALT (100 mm)		1	AS	-												
	Gravelly sand, trace to some silt, trace clay, containing cobbles (FILL)		2	AS	-												
	Dense Brown Moist		3	SS	33												30 61 7 2
319.8	Rock fill (FILL)		4	SS	100/0.08*												
1.8																	
			5	SS	8												
			6	SS	12**												
317.9	GRANITE (BEDROCK)																
3.6	Bedrock cored from depths of 3.6 m to 6.8 m. For bedrock coring details refer to Record of Drillhole C2-4.		1	RC	REC 97%												RQD = 74%
			2	RC	REC 100%												RQD = 91%
			3	RC	REC 100%												RQD = 91%
314.7	END OF BOREHOLE																
6.8	NOTES: 1. Water level in open borehole at a depth of 3.5 m below ground surface (Elev. 318.0 m) upon completion of drilling. * N-value may not be representative; split-spoon bouncing on Rock Fill below. ** N-Vaule may not be representative; split-spoon angled due to sloping rock. 2. Geographic Coordinates: Latitude: 48.069556 Longitude: -80.031404																

PROJECT		RECORD OF BOREHOLE No C2-5				SHEET 1 OF 1		METRIC								
W.P. 1531057		LOCATION N 5326071.7; E 376964.6 MTM ZONE				ORIGINATED BY SA										
DIST _____ HWY 112		BOREHOLE TYPE Portable Equipment (Manual Hammer)				COMPILED BY MR										
DATUM Geodetic		DATE June 2, 2016				CHECKED BY MK										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
316.2	GROUND SURFACE						20	40	60	80	100	W _p	W	W _L		
0.0	Sand and gravel, trace to some silt, trace clay, containing organics and rootlets (FILL) Very loose Brown Wet		1	SS	2											
315.1			2	SS	33/0.20							○				33 53 11 3
1.1	END OF BOREHOLE															
NOTES: 1. Water level in open borehole at a ground surface (Elev. 316.2 m) upon completion of drilling. * Split-spoon bouncing. 2. Geographic Coordinates: Latitude: 48.069467 Longitude: -80.031577																

PROJECT		1531057		RECORD OF BOREHOLE No C2-6				SHEET 1 OF 1		METRIC									
W.P.		5428-15-01		LOCATION		N 5326033.1; E 376993.3 MTM ZONE		ORIGINATED BY		SA									
DIST		HWY 112		BOREHOLE TYPE		Portable Equipment, HQ Casing (Manual Hammer)		COMPILED BY		MR									
DATUM		Geodetic		DATE		June 2, 2016		CHECKED BY		MK									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)	
316.9	GROUND SURFACE							20	40	60	80	100							
0.0	PEAT (Fibrous), trace gravel, some sand		1	CS	-	316													
316.6	Brown Moist		1	RC	REC 100%														RQD = 100%
0.3	GRANITE (BEDROCK)		2	RC	REC 100%														RQD = 24%
	Bedrock cored from depths of 0.3 m to 1.9 m.		3	RC	REC 96%														RQD = 74%
315.0	For bedrock coring details refer to Record of Drillhole C2-6.																		
1.9	END OF BOREHOLE																		
NOTE:																			
1. Geographic Coordinates:																			
Latitude: 48.069116																			
Longitude: -80.031198																			

PROJECT: 1531057

RECORD OF DRILLHOLE: C2-6

SHEET 1 OF 1

LOCATION: N 5326033.1 ;E 376993.3

DRILLING DATE: June 2, 2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: Portable Equipment

DRILLING CONTRACTOR: Landcore Drilling Inc.

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	FLUSH	RECOVERY				R.Q.D. %	FRACT. INDEX PER 0.25 m	DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY K, cm/sec			Diametral Point Load Index (MPa)	RMC -Q AVG	NOTES							
									TOTAL CORE %	SOLID CORE %	B Angle	DIP w.r.t. CORE AXIS			TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	10 10 10 10	10 10 10 10											
	JN - Joint FLT - Fault SH - Shear VN - Vein CJ - Conjugate																				BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage				PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular		PO - Polished K - Slickensided SM - Smooth RO - Rough VR - Very Rough		MB - Mechanical Break BR - Broken Rock		
	NOTE: For additional abbreviations refer to list of abbreviations & symbols.																														
1	NQ RC NW Casing	Continued from Record of Borehole C2-6		316.60	1																										
		0.30																													
2		END OF DRILLHOLE		315.00																											
1.90																															
3																															
4																															
5																															
6																															
7																															
8																															
9																															
10																															

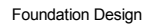
DEPTH SCALE

1 : 50



LOGGED: SA

CHECKED: MK



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



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

GTA-MTO 001 S:\CLIENTS\MTO\HWY_112\02_DATA\GINT\HWY_112.GPJ GAL-GTA.GDT 24/03/17



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



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



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

GTA-MTO 001 S:\CLIENTS\MTO\HWY_112\02_DATA\GINT\HWY_112.GPJ GAL-GTA.GDT 24/03/17

PROJECT <u>1531057</u>		RECORD OF DCPT No C2-DCPT-3		SHEET 1 OF 1		METRIC	
W.P. <u>5428-15-01</u>		LOCATION <u>N 5326076.1; E 376962.3 MTM ZONE</u>		ORIGINATED BY <u>SA</u>			
DIST <u> </u> HWY <u>112</u>		BOREHOLE TYPE <u>Portable Equipment, Dynamic Cone Penetration Test (Manual Hammer)</u>		COMPILED BY <u>MR</u>			
DATUM <u>Geodetic</u>		DATE <u>June 2, 2016</u>		CHECKED BY <u>MK</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			W _p	W	W _L		
								○ UNCONFINED + FIELD VANE				WATER CONTENT (%)			
						● QUICK TRIAXIAL × REMOULDED									
317.1	GROUND SURFACE						317								
0.0	Dynamic Cone Penetration Test (DCPT)														
316.0															
1.1	END OF DCPT REFUSAL TO FURTHER PENETRATION (50 Blows / 0.20 m) (HAMMER BOUNCING) NOTE: NOTE: 1. Geographic Coordinates: Latitude: 48.069506 Longitude: -80.031607														



APPENDIX B

Geotechnical Laboratory Test Results

TABLE B1
SUMMARY OF POINT LOAD TESTS ON ROCK SAMPLES

PROJECT NO. 1531057						
DATE July, 2016						
Borehole Number	Run Number	Sample Depth (m)	Sample Elevation (m)	Bedrock Description	Test Type	Is (50mm) (MPa)
C2-2	1	8.8	311.3	Granite	Axial	5.0
C2-2	1	9.0	311.1	Granite	Diametral	8.3
C2-3	1	2.8	312.3	Granite	Axial	9.3
C2-3	1	2.9	312.2	Granite	Diametral	10.8
C2-4	1	3.9	317.8	Granite	Diametral	11.0
C2-4	1	4.0	317.7	Granite	Axial	7.1

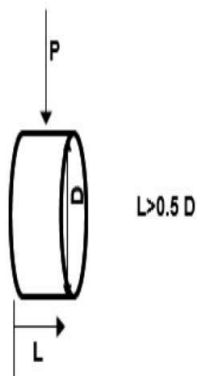
⁽¹⁾ $I_{s50} \times C$ (actual value will have to be confirmed by UCS testing), from ISRM ("Suggested Methods for Determining Point Load Strength", International Society for Rock Mechanics Commission on Testing Methods, Int. J. Rock. Mech. Min. Sci. and Geomechanical Abstr., Vol 22, No. 2 1985, pp. 51-60.

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

DIAMETRAL SPECIMEN SHAPE REQUIREMENTS

note: Diametral tests are perpendicular to core axis

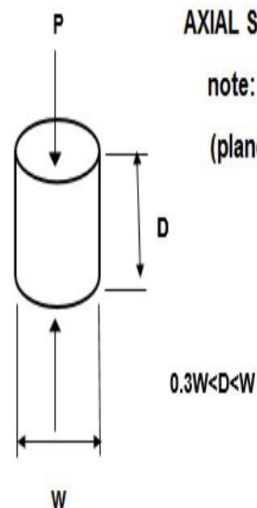
(planes of weakness)



AXIAL SPECIMEN SHAPE REQUIREMENTS

note: Axial tests are parallel to core axis

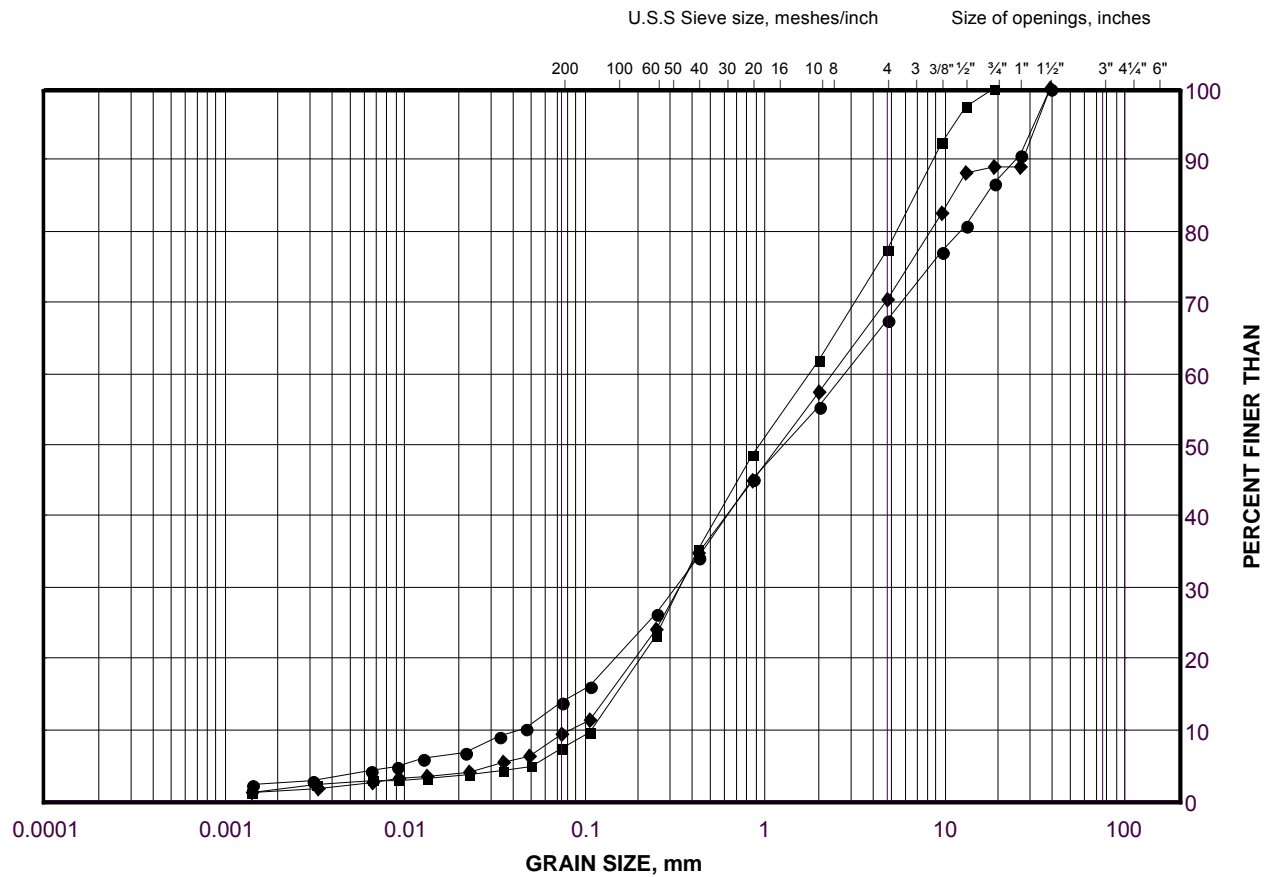
(planes of weakness)



GRAIN SIZE DISTRIBUTION

Gravelly Sand to Sand and Gravel (FILL)

FIGURE B1



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C2-5	2	315.2
■	C2-2	2	319.4
◆	C2-4	3	320.4

Project Number: 1531057

Checked By: TWB

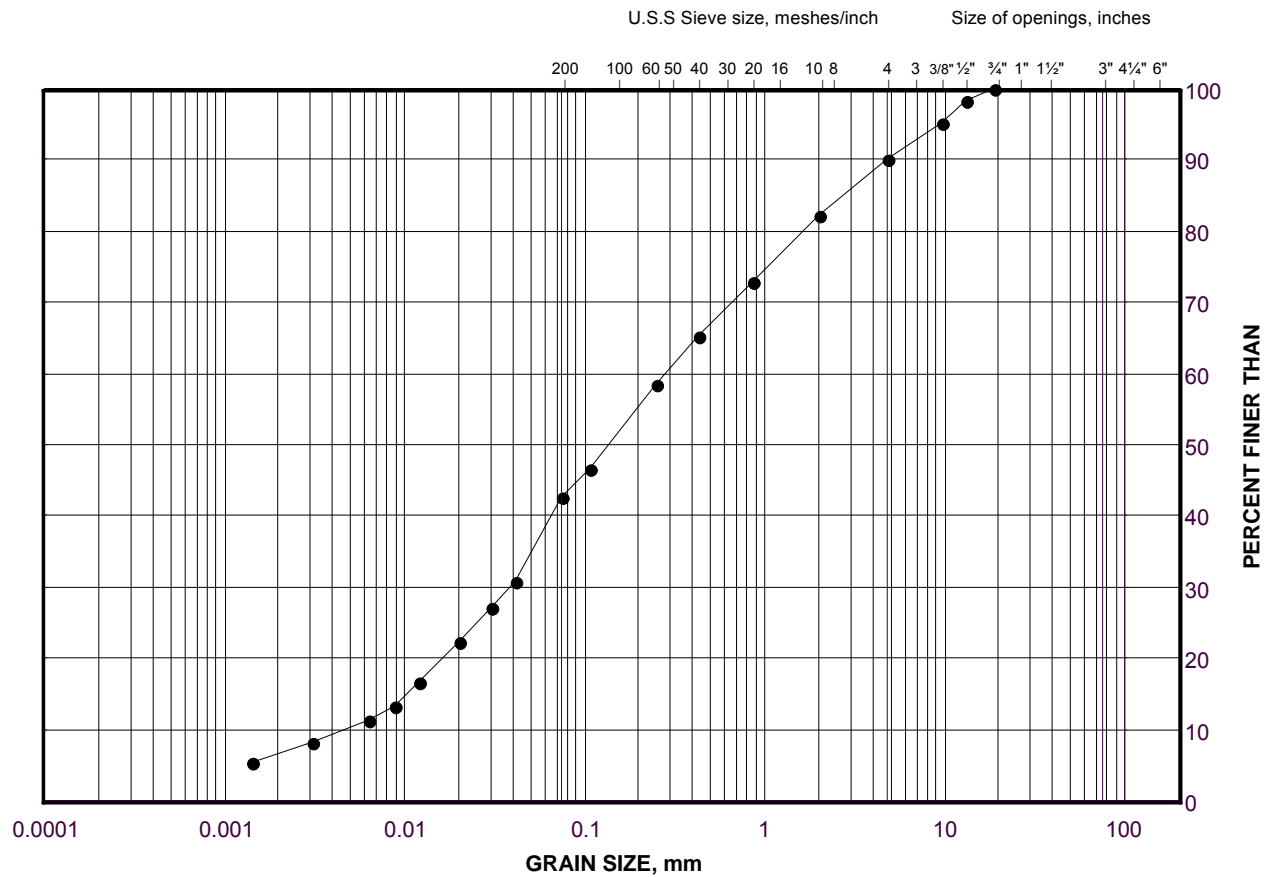
Golder Associates

Date: 17-Aug-16

GRAIN SIZE DISTRIBUTION

Silt and Sand

FIGURE B2



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

LEGEND

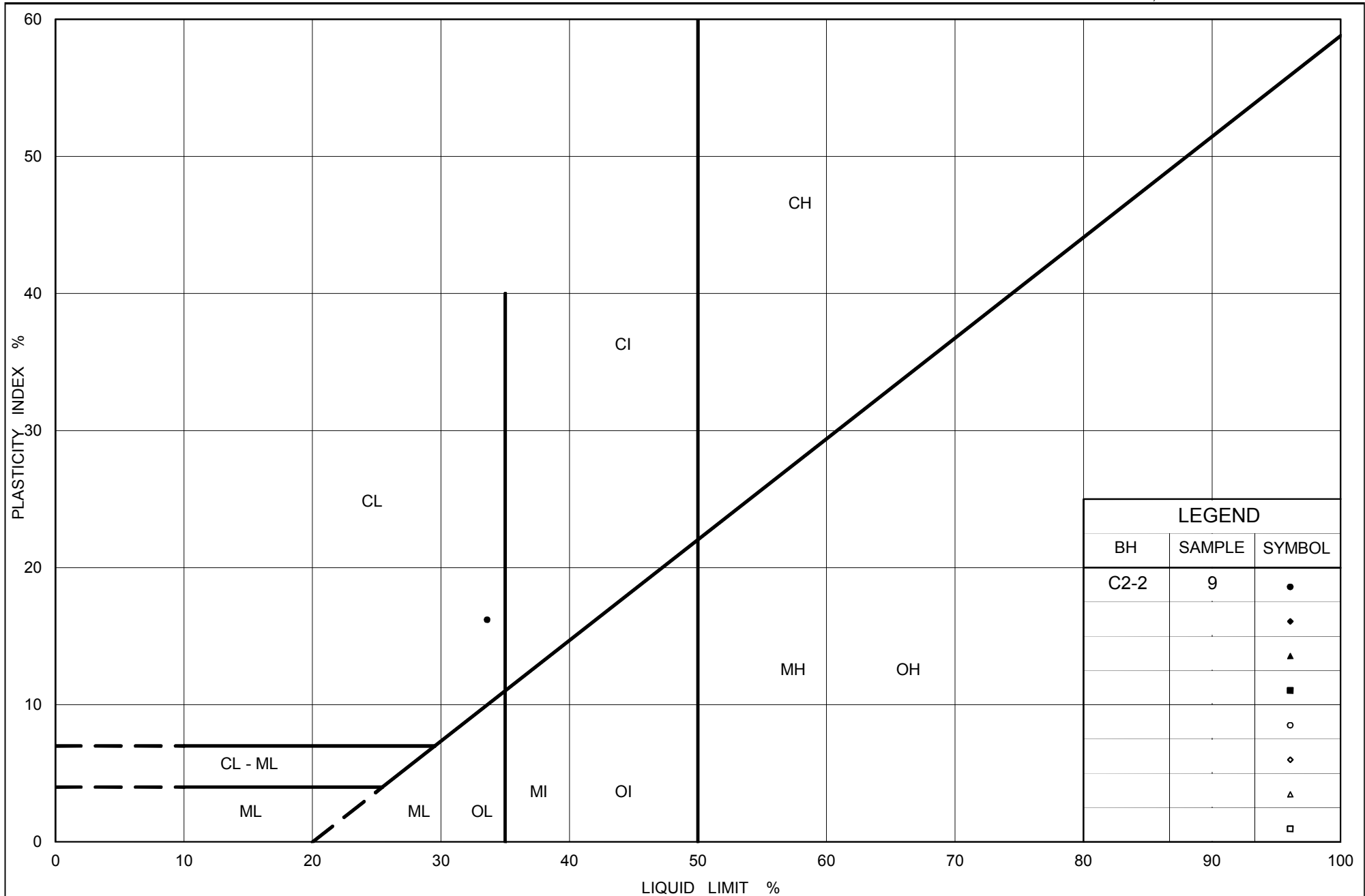
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	C2-1	1	316.2

Project Number: 1531057

Checked By: TWB

Golder Associates

Date: 17-Aug-16



LEGEND		
BH	SAMPLE	SYMBOL
C2-2	9	•
		◊
		▲
		■
		◦
		◈
		△
		◻



Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt

Figure No. B3

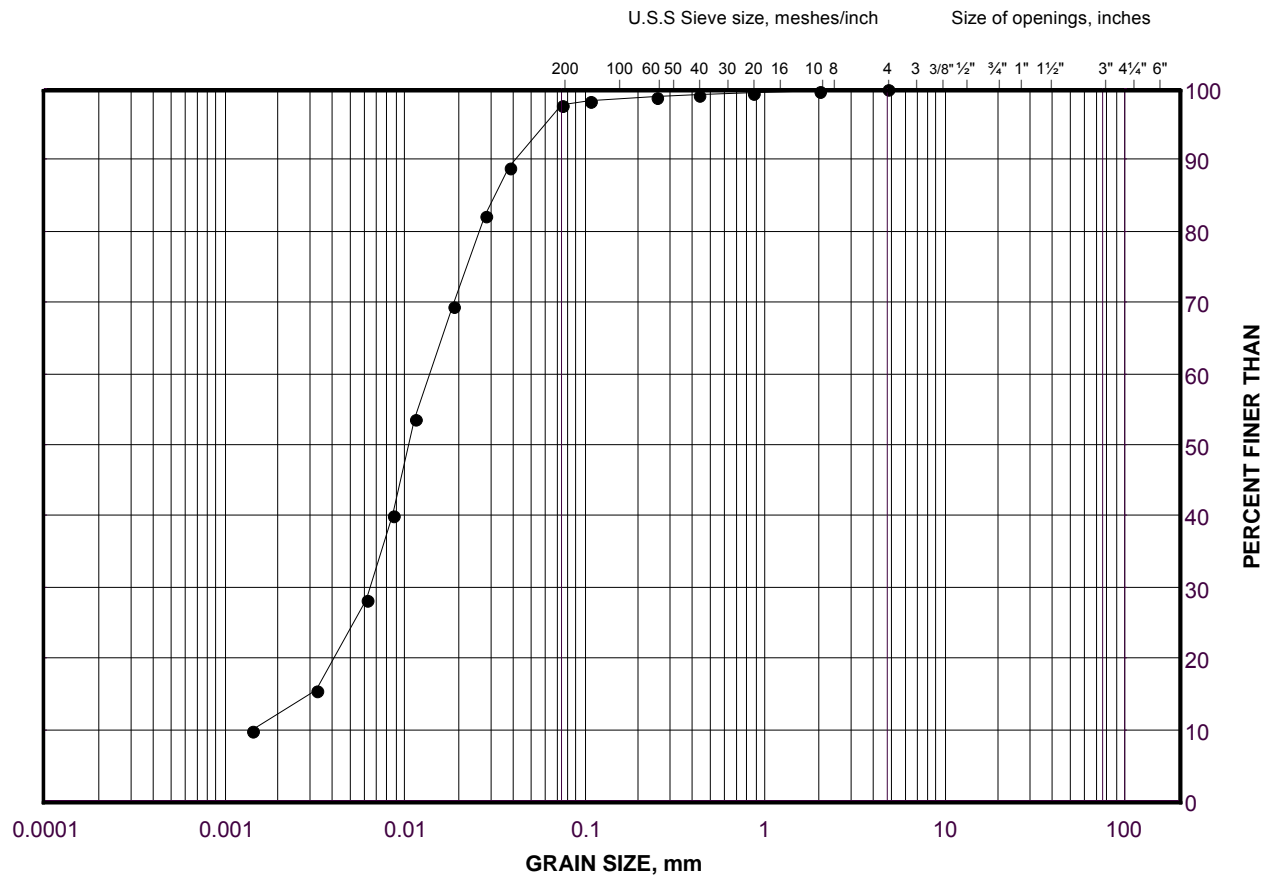
Project No. 1531057

Checked By: TWB

GRAIN SIZE DISTRIBUTION

Silt

FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	C2-2	10	312.2

Project Number: 1531057

Checked By: TWB

Golder Associates

Date: 17-Aug-16

Borehole C2-1



Box 1: 0.90 m – 4.60 m

Borehole C2-2

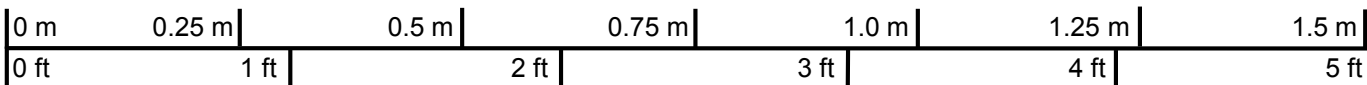


Box 1: 8.70 m – 11.80 m

Borehole C2-3



Box 1: 2.20 m – 5.60 m



Scale

PROJECT **Detail Design for Replacement of 3 Centreline Culverts and 1 Structural Culvert – Highway 112 WP 5428-15-01**

TITLE **Bedrock Core Photographs – Highway 112 Borehole C2-1, C2-2 and C2-3**



PROJECT No. 1531057			FILE No. ----		
DESIGN	TWB	SEP 6	SCALE	NTS	REV.
CADD	--		FIGURE B5A		
CHECK	PPL	SEP 6			
REVIEW	JMAC	SEP 6			

Borehole C2-4

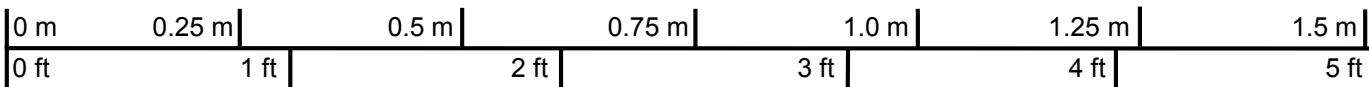


Box 1: 3.60 m – 6.80 m

Borehole C2-6



Box 1: 0.30 m – 1.90 m



Scale

PROJECT **Detail Design for Replacement of 3 Centreline Culverts and 1 Structural Culvert – Highway 112 WP 5428-15-01**

TITLE **Bedrock Core Photographs – Highway 112 Borehole C2-4 and C2-6**



PROJECT No. 1531057			FILE No. ----		
DESIGN	TWB	SEP 6	SCALE	NTS	REV.
CADD	--		FIGURE B5B		
CHECK	PPL	SEP 6			
REVIEW	JMAC	SEP 6			

UNCONFINED COMPRESSION TEST (UC)**Figure B6****SAMPLE IDENTIFICATION**

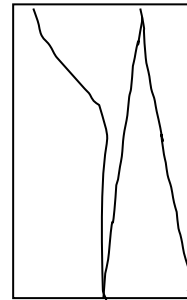
PROJECT NUMBER	1531057	RUN NUMBER	Run 2
PROJECT NAME	MMM/5015-E-0003/LV Retainer NE	SAMPLE DEPTH, m	1.65-1.80
BOREHOLE NUMBER	C2-1	DATE:	2016-07-19

TEST CONDITIONS

MACHINE SPEED, mm/min	N/A	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.26

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	9.61	WATER CONTENT, (specimen) %	0.15
SAMPLE DIAMETER, cm	4.25	UNIT WEIGHT, kN/m ³	25.40
SAMPLE AREA, cm ²	14.20	DRY UNIT WT., kN/m ³	25.37
SAMPLE VOLUME, cm ³	136.47	SPECIFIC GRAVITY	-
WET WEIGHT, g	353.66	VOID RATIO	-
DRY WEIGHT, g	353.13		

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

STRAIN AT FAILURE, %	N/A	COMPRESSIVE STRENGTH, MPa	70.5
----------------------	-----	---------------------------	------

REMARKS:

Checked By: MCK

Golder Associates



APPENDIX C

Analytical Test Results

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	Date		Date Analyzed	Laboratory Method	Reference
	Quantity	Extracted			
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.

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 (SO ₄)	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								

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 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

GENERAL COMMENTS

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

Package 1	9.3°C
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Results relate only to the items tested.

QUALITY ASSURANCE REPORT

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

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% 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).

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.

<div style="display: flex; justify-content: space-between;"> <div> Maxxam <small>A Maxxam Analytics International Corporation o/a Maxxam Analytics</small> <small>6740 Campbell Road, Mississauga, Ontario Canada L5N 2L8 Tel (905) 817-5700 Toll-Free (800) 563-6266 Fax (905) 817-5777 www.maxxam.ca</small> </div> <div> CHAIN OF CUSTODY RECORD </div> </div>												
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_Guido@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 #: HWY 112 Sampled By: S.A. + D.M.			Laboratory Use Only: Maxxam Job #: _____ Bottle Order #: _____ COC #: _____ 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						ANALYSIS REQUESTED (PLEASE BE SPECIFIC)				Turnaround Time (TAT) Required: Please provide advance notice for rush projects		
Regulation 153 (2011) <input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Medium/Fine <input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse <input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/Other <input type="checkbox"/> For RSC <input type="checkbox"/> Table _____			Other Regulations <input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw <input type="checkbox"/> Reg 558 <input type="checkbox"/> Storm Sewer Bylaw <input type="checkbox"/> MISA Municipality _____ <input type="checkbox"/> PWQO <input type="checkbox"/> Other _____			Special Instructions _____			Field Filtered (please circle): Metals / Hg / Cr-VI Chloride & Sulphate Conductivity, Resistivity and pH		Regular (Standard) TAT: <small>(will be applied if Rush TAT is not specified)</small> Standard TAT = 5-7 Working days for most tests. Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.	
Include Criteria on Certificate of Analysis (Y/N)? _____								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						# of Bottles	Comments	
1	C1	June 12/16	11:00AM	Surface Water						1	small pottle (~3" deep) NOT Flowing	
2	C2	June 12/16	10:45AM	"						1		
3	C3	June 12/16	7:50AM	"						1		
4	C4	June 12/16	7:40AM	"						1		
5												
6												
7												
8												
9												
10												
* RELINQUISHED BY: (Signature/Print) [Signature] Shane Albert		Date: (YY/MM/DD) 16/06/13	Time 11:35am	RECEIVED BY: (Signature/Print) [Signature] Bradley Frappier YR KUSAT NAZ		Date: (YY/MM/DD) 16/06/13	Time 11:35	# jars used and not submitted _____	Time Sensitive _____	Laboratory Use Only Temperature (°C) on Receipt: 9, 10, 9°C Custody Seal: Present <input checked="" type="checkbox"/> Intact <input type="checkbox"/> Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>		
<small>* 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</small>												



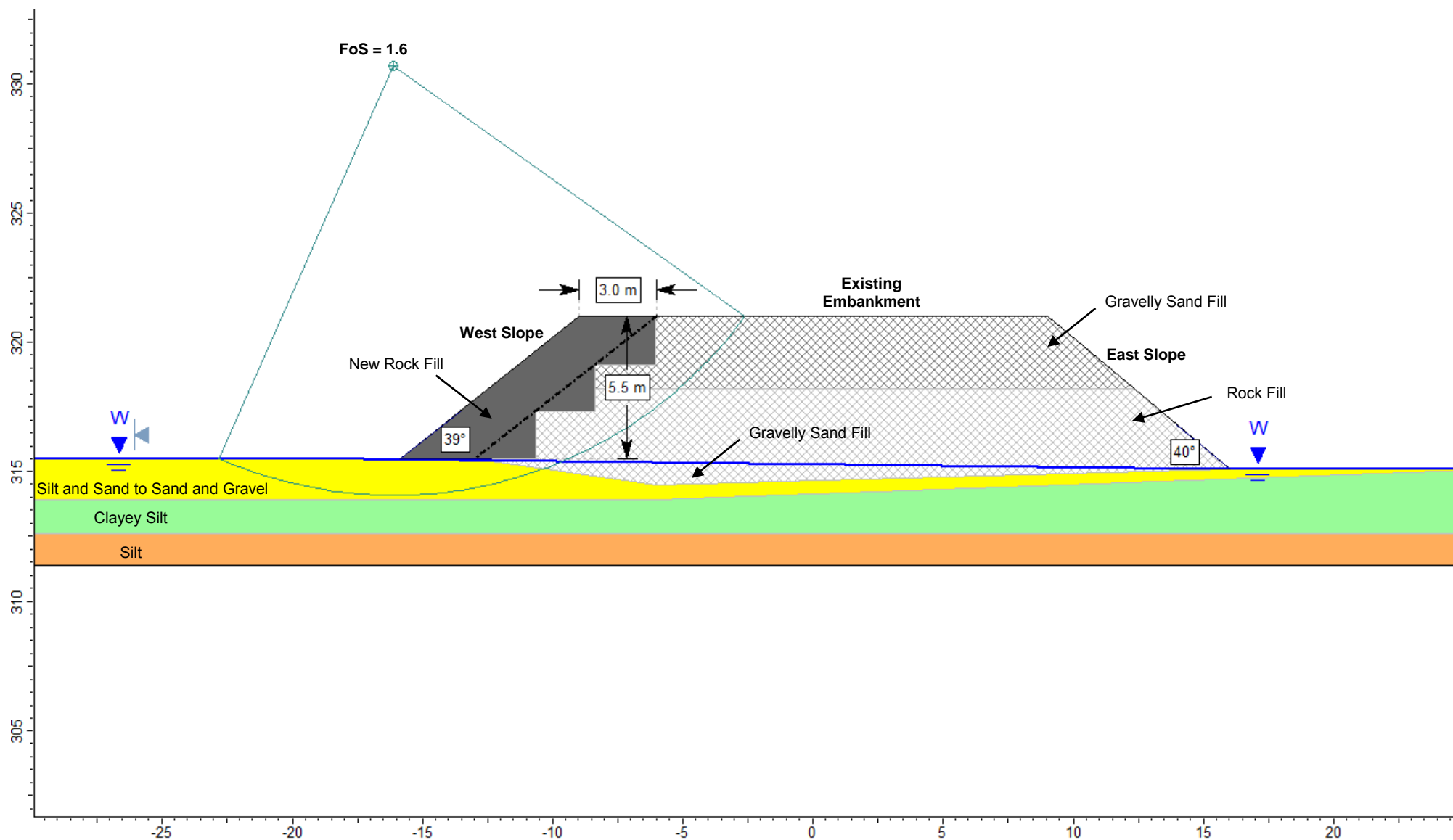
APPENDIX D

Stability Analysis Figures



Stability Analysis: 3 m Embankment Widening – West Side (Temporary)

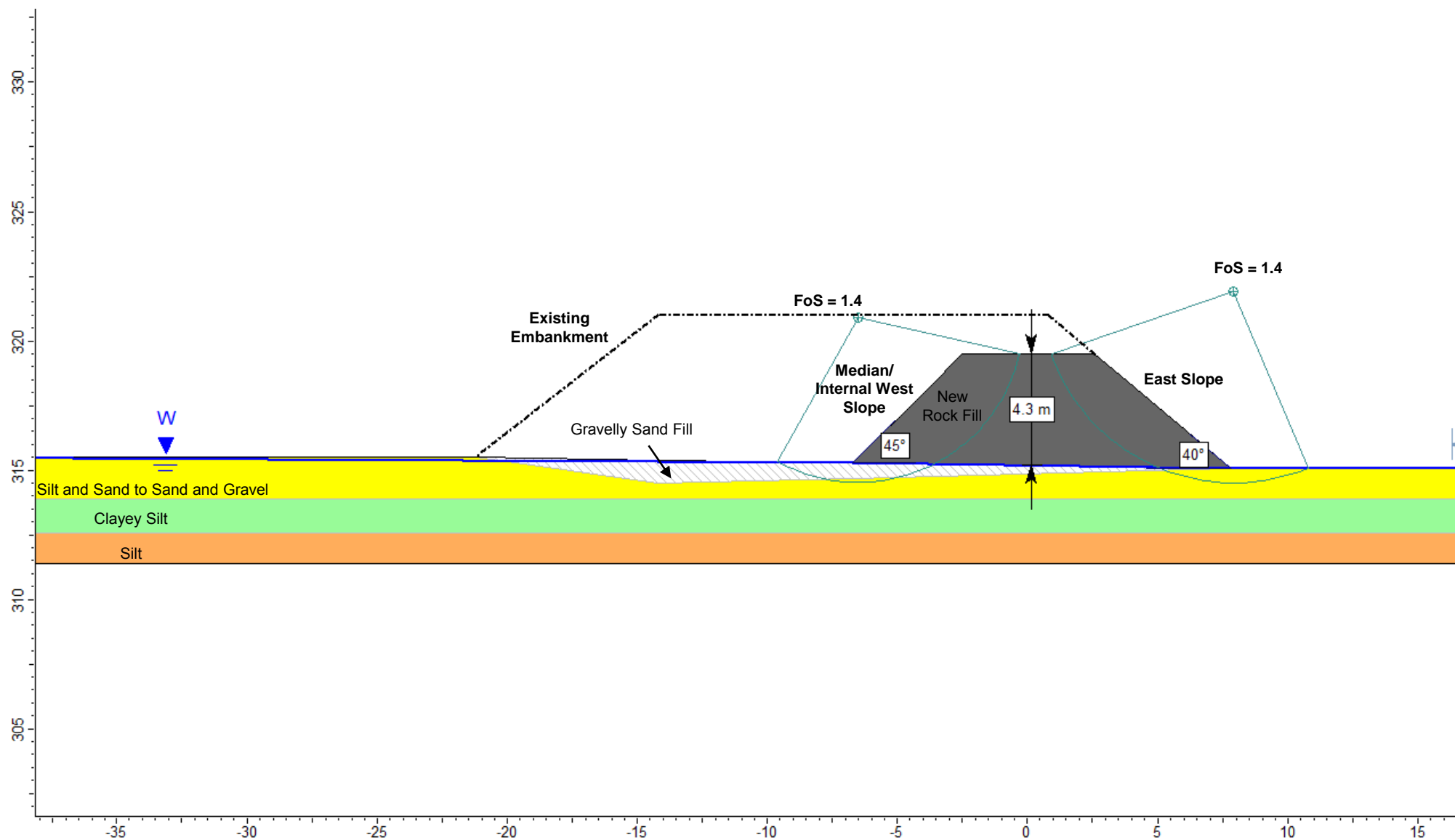
Figure D1





Stability Analysis: Median/Internal Side Slopes with Grade Lowering (East Slope)

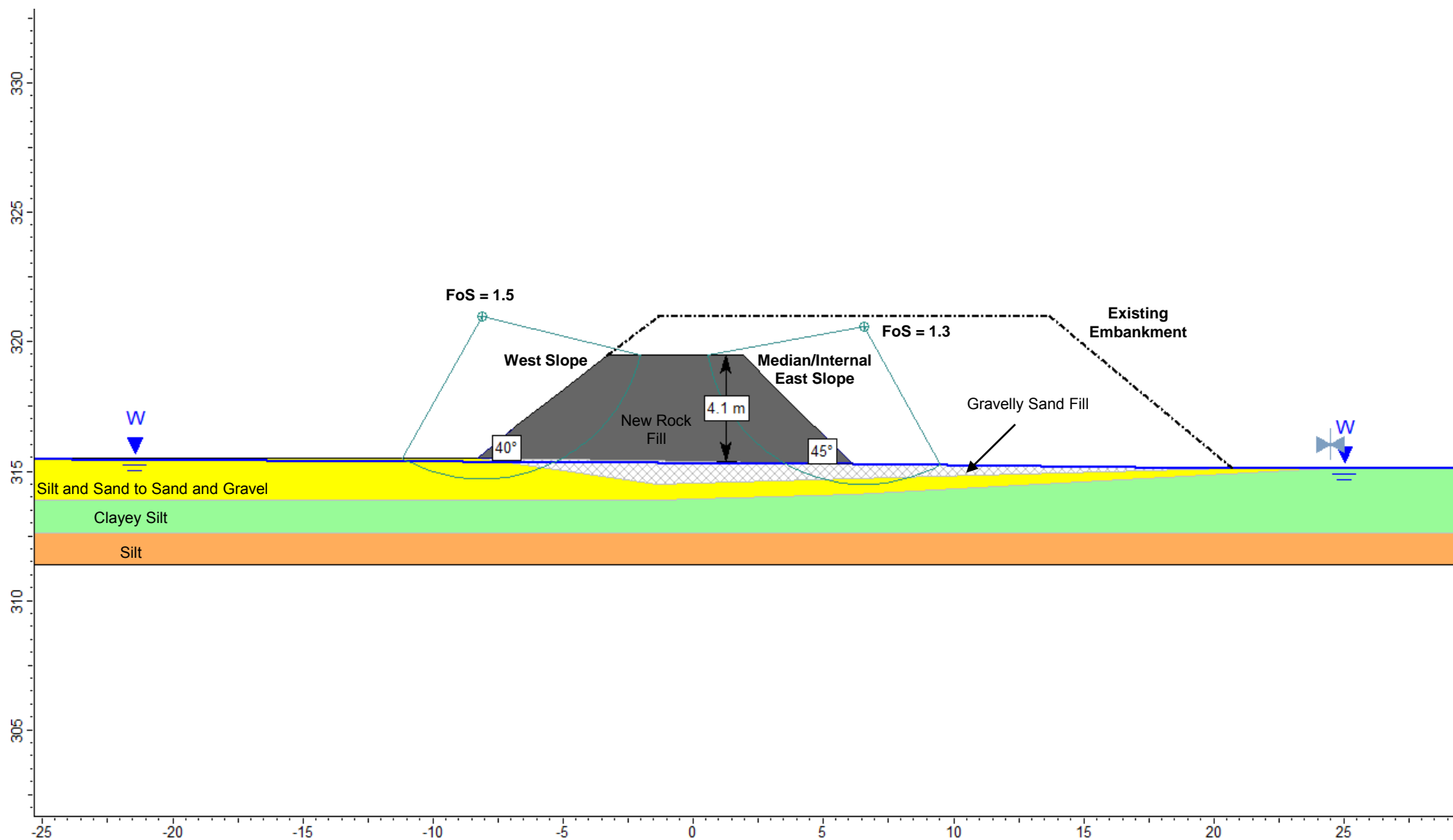
Figure D2





Stability Analysis: Median/Internal Side Slopes with Grade Lowering (West Slope)

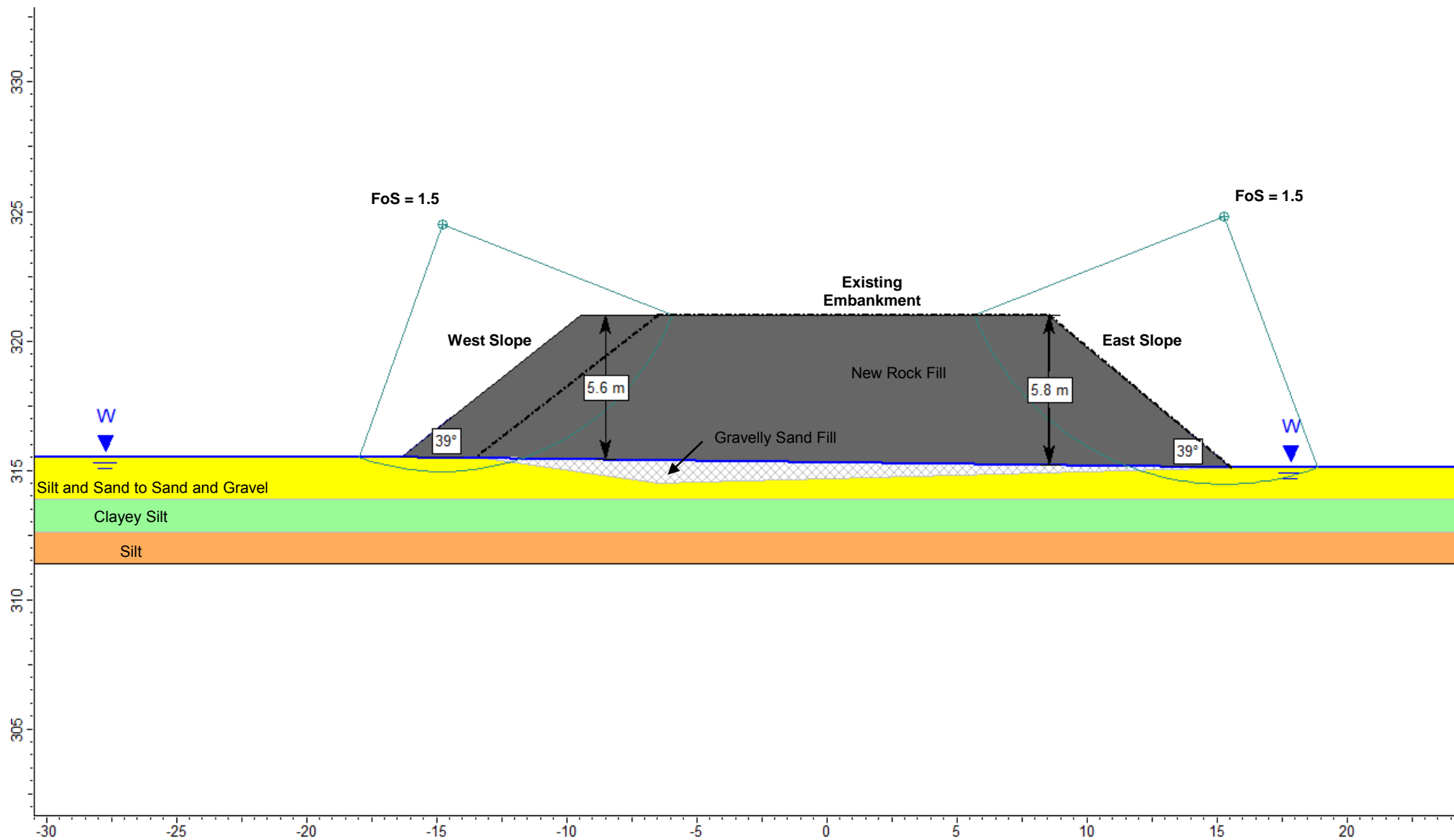
Figure D3





Stability Analysis: Final Embankment

Figure D4





APPENDIX E

Non-Standard Special Provisions

OBSTRUCTIONS - Item No.

Non-Standard Special Provision

At Culvert C2 (Highway 112 STA 21+845, Township of Otto) rock fill was encountered in the embankment fill between Elevations 319.8 m and 318.2 m. In addition, bedrock and/or cobbles over bedrock were encountered between Elevations 315.6 m and 311.4 m at or in the vicinity of the culvert. Consideration of the presence of these obstructions must be made in the selection of the appropriate equipment and procedures for sub-excavation, and installation of temporary roadway protection systems and cofferdams through this material for culvert construction.

BASIS OF PAYMENT

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

END OF SECTION

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

For more information, visit golder.com

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