



July 2014

FOUNDATION INVESTIGATION AND DESIGN REPORT

**Culvert Replacement, Gibbings Drainage Works
Highway 8, Site No. 12-392/C, Station 15+890
Contract 2 Structure Replacements and Rehabilitation
GWP 3040-11-00
Ministry of Transportation, West Region**

Submitted to:

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REPORT



Report Number: 12-1132-0163-2000-R01

Geocres No.: 40P11-20

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TABLE I - Comparison of Structure Alternatives for Replacement Culvert

LIST OF ABBREVIATIONS

LIST OF SYMBOLS

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FIGURE 1 - Key Plan

DRAWING 1 - Borehole Locations and Soil Strata

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APPENDIX A

Laboratory Test Data

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PART A

FOUNDATION INVESTIGATION REPORT

**CULVERT REPLACEMENT, GIBBINGS DRAINAGE WORKS
HIGHWAY 8, SITE NO. 12-392/C, STATION 15+890
CONTRACT 2 STRUCTURE REPLACEMENTS AND REHABILITATION
GWP 3040-11-00
MINISTRY OF TRANSPORTATION - WEST REGION**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Stantec Consulting Ltd. (Stantec) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the detail design work for GWP 3040-11-00. The project involves the detail design for the replacement and rehabilitation of several structures along multiple highways in Southern Ontario.

This report addresses the proposed replacement of the culvert at Gibbings Drainage Works (Site 12-392/C) at Station 15+890 on Highway 8 southeast of Clinton, Ontario in Huron County.

The purpose of the foundation investigation is to determine the subsurface conditions at the location of the proposed structure replacement by drilling boreholes and carrying out in situ testing and laboratory testing on selected samples. The terms of reference for the scope of work are outlined in the MTO's Request for Proposal and in Golder's proposal P2-1132-0163 dated February 25, 2013. The work was carried out in accordance with our Quality Control Plan for Foundation Engineering dated March 26, 2013.



2.0 SITE DESCRIPTION

The subject culvert is situated at Station 15+890 on Highway 8, approximately 0.3 kilometres southeast of Sanctuary Line in Hullett Township, Huron County, Ontario. The villages of Clinton and Seaforth are 5.8 kilometres northwest and 7.8 kilometres southeast of the site, respectively. The location of the culvert is shown on the Key Plan, Figure 1.

This section of Highway 8 is currently a two lane undivided highway with paved shoulders at the culvert location. It is generally oriented northwest-southeast in the vicinity of the subject site but for the purposes of this report, Highway 8 is assumed to be oriented east-west as indicated by current signage. The creek flow direction in the culvert is from south to north beneath Highway 8. The existing culvert is a concrete open rigid frame (RFO) structure with the following characteristics:

Dimensions (m)	Obvert Elevation (m)		Construction
	Lt ¹	Rt ¹	
3.10 x 1.52 x 33.53	288.06	288.15	RFO

NOTE: 1. When facing the direction of increasing chainage, Lt and Rt are defined as Left and Right of centreline, respectively.

The banks of the drainage channel upstream and downstream of the culvert are grass covered and the channel flows through fields adjacent to Highway 8. Site photographs are provided in Appendix B.

The culvert is situated in a rural agricultural area. Ground surface elevations in the vicinity of the culvert site range from about 287.5 to 293 metres.

2.1 Site Geology

The project area is located within the Horseshoe Moraines physiographic region. This region is characterized by morainic ridges composed of pale brown, hard, calcareous, fine-textured till with a moderate degree of stoniness.¹ The quaternary geological mapping indicates that surficial soils consist of Rannoch Till consisting of silt to sandy silt till deposits.² Geological mapping also indicates that the underlying bedrock consists of medium brown microcrystalline limestone of the Dundee Formation of the Hamilton Group of Middle Devonian age.³ The bedrock surface at the site is at about elevation 268.0 metres, with an estimated overburden thickness of about 20 metres.⁴

¹ Chapman, L.J., and Putnam, D.F., 1984: Physiography of Southern Ontario; Ontario Geological Survey, Special Volume 2, 270p. Accompanied by Map. P.2715 (coloured), scale 1:600,000.

² Cooper, A.J., Fitzgerald, W.D. and Clue, Jack. 1977: Quaternary Geology of the Seaforth Area. Southern Ontario; Ontario Geological Survey Prelim. Map P.1233, scale 1:50,000.

³ Sanford B.V., 1969: Geology Toronto-Windsor Area, Ontario; Ontario Geological Survey of Canada Map 1263A, Scale 1:250,000.

⁴ Karrow, P.F. 1964: Bedrock Topography Series. Goderich-Seaforth Sheet, Ontario Department of Mines Preliminary Map No.P.297, Scale 1:50,000.



3.0 INVESTIGATION PROCEDURES

The field work for the investigation was carried out on July 9, 2013, during which time 3 boreholes were drilled at the locations shown on the Borehole Location Plan, Drawing 1. Borehole 215 was drilled in the southbound shoulder since it was difficult to access the area at the inlet. The boreholes were drilled using track-mounted CME 75 drilling equipment supplied and operated by a specialist drilling contractor. Samples of the overburden were typically obtained at depth intervals of 0.75 metres using 50 millimetre outside diameter split spoon sampling equipment in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586).

The recorded SPT N values are noted on the Record of Borehole sheets. The SPT resistance, or N value, is defined as the number of blows required by a 63.5 kilogram hammer dropped from a height of 760 millimetres to drive a split-spoon sampler a distance of 300 millimetres after an initial 150 millimetres of penetration. The results of the SPT testing as presented on the Record of Borehole sheets, Drawing 1 and in Section 4 are unmodified (not standardized for hammer efficiency, borehole diameter, rod length, etc.). The samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 40 millimetres. Therefore, particles or objects that may exist within the soils that are larger than this dimension will not be sampled or represented in the grain size distributions.

Groundwater conditions in the boreholes were observed throughout the drilling operations and a standpipe piezometer was installed in borehole 214 as indicated on the corresponding Record of Borehole sheet. The boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 903 (as amended).

The field work was monitored on a full-time basis by experienced members of our staff who located the boreholes in the field, monitored the drilling, sampling, and in situ testing operations and logged the boreholes. The samples were identified in the field, placed in labelled containers, and transported to our London laboratory for further examination and testing. Index and classification tests, consisting of water content determinations, Atterberg limits and grain size distribution analyses, were carried out on selected samples. The results of the testing are shown on the Record of Borehole sheets and in Appendix A.

The as-drilled borehole locations and ground surface elevations are shown on the Record of Borehole sheets and on Drawing 1. The table below summarizes the coordinates, ground surface elevations, and depths of the boreholes.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
213	4 828 303	387 401	287.88	8.08
214	4 828 290	387 403	290.37	11.13
215	4 828 281	387 396	290.36	11.13



4.0 SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the in situ testing and the laboratory testing carried out on selected samples, are given on the attached Record of Borehole sheets following the text of this report and in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous samples and observations of drilling resistance and, therefore, may represent transitions between soil types rather than exact planes of geological change. Further, the subsurface conditions will vary between and beyond the borehole locations.

The boreholes drilled at the site generally encountered the existing pavement structure or topsoil overlying variable fill materials which were, in turn, underlain in sequence by silt, clayey silt, silty clay, sandy silt and clayey silt till.

The locations and elevations of the boreholes, together with the interpreted stratigraphic profile, are shown on Drawing 1. A detailed description of the subsurface conditions encountered in the boreholes is provided on the Record of Borehole sheets and is summarized in the following sections.

4.2 Soil Conditions

4.2.1 Pavement Structure

Asphaltic concrete pavement was encountered at ground surface in boreholes 214 and 215. The asphaltic concrete pavement was 60 millimetres thick in both boreholes.

Pavement granular base materials were encountered beneath the asphalt in boreholes 214 and 215. The granular base materials were about 120 and 180 millimetres thick, respectively. Pavement granular subbase material was encountered beneath the granular base in borehole 214. The granular subbase material was about 280 millimetres thick. It was not possible to discern the pavement subbase layer at borehole 215.

4.2.2 Topsoil

Topsoil was encountered at the ground surface in borehole 213 and beneath the fill in borehole 215 at elevation 287.5 metres. The topsoil layers were about 0.3 and 0.4 metres in total thickness. A water content of about 36 per cent was measured in the buried topsoil.

Materials designated as topsoil in this report were classified solely based on visual and textural evidence. Testing of organic content or for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.

4.2.3 Fill

Granular fill materials were encountered beneath the pavement structure in boreholes 214 and 215 from elevations 289.9 to 290.1 metres. The granular fill materials were 0.2 to 0.4 metres thick.



Layers of cohesive fill materials were encountered beneath the granular fill material in boreholes 214 and 215 at elevation 289.7 metres and beneath the buried topsoil in borehole 215 at elevation 287.2 metres. The cohesive fill material was 0.5 to 3.0 metres thick with N values of 4 to 50 blows per 0.3 metres. The cohesive fill material had water contents of 12 to 33 per cent.

4.2.4 Silt

Layers of loose to compact silt were encountered beneath the topsoil in borehole 213 at elevation 287.5 metres and beneath the fill and clayey silt in borehole 215 at elevations 286.7 and 285.6 metres, respectively. The silt was 0.3 to 2.5 metres thick. The silt had measured N values of 8 to 14 blows per 0.3 metres and water contents of about 17 to 22 per cent. Grain size distribution curves for two samples of the silt are provided on Figure A-1 in Appendix A.

4.2.5 Clayey Silt

A stratum of firm to stiff clayey silt was encountered beneath the silt layers in boreholes 213 and 215 from elevations 285.0 to 285.9 metres and beneath the sandy silt in borehole 214 at elevation 285.6 metres. The clayey silt was 0.3 to 2.0 metres thick. Measured N values for the clayey silt layers were 8 to 13 blows per 0.3 metres. Water contents of the samples ranged from 16 to 25 per cent.

The clayey silt is of low plasticity based on the Atterberg limits determinations carried out on samples obtained during standard penetration testing. The plastic limits ranged from 13 to 18 per cent, the liquid limits from 23 to 34 per cent, and the plasticity indices from 11 to 16 per cent. The Atterberg limits data for the clayey silt are presented on Figure A-5 and grain size distribution curves for samples of the clayey silt are provided on Figure A-2.

4.2.6 Silty Clay

A layer of stiff silty clay was encountered at elevation 284.2 metres beneath the clayey silt in borehole 213. The silty clay was 0.8 metres thick. The silty clay had a measured N value of 8 blows per 0.3 metres.

4.2.7 Sandy Silt

Loose sandy silt was encountered beneath the silty clay in borehole 213 at elevation 283.5 metres and beneath the fill in borehole 214 at elevation 286.7 metres. The sandy silt layers were 0.8 to 1.2 metres thick with measured N values of 5 to 9 blows per 0.3 metres. The sandy silt had water contents of 12 to 20 per cent. The gradation of a representative sample of sandy silt is presented on Figure A-3.



4.2.8 Clayey Silt Glacial Till

Layers of firm to very stiff clayey silt glacial till were encountered beneath the sandy silt in borehole 213 at elevation 282.7 metres and beneath the clayey silt in boreholes 214 and 215 at elevations 283.7 and 283.4 metres, respectively. All boreholes were terminated in the clayey silt till after exploring the layer for 2.9 to 4.4 metres. Measured N values for the clayey silt till layers ranged from 7 to 16 blows per 0.3 metres. Water contents of the samples ranged from 12 to 13 per cent. Cobbles were encountered in the glacial till in boreholes 214 and 215. The presence of cobbles and boulders should be expected in this glacial deposit.

The clayey silt till is of low plasticity based on the Atterberg limits determinations carried out on samples obtained during standard penetration testing. The plastic limits varied between 11 and 12 per cent, the liquid limit between 17 and 18 per cent, and the plasticity indices between 5 and 6 per cent. The Atterberg limits data for the clayey silt till are presented on Figure A-5. Grain size distribution curves for samples of the clayey silt till are provided on Figure A-4.

4.3 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling and a groundwater observation standpipe was installed in borehole 214. Installation details are provided on the corresponding Record of Borehole sheet following the text of this report. Groundwater was encountered in all boreholes at depths of 1.4 to 3.7 metres or between elevations 286.5 and 286.7 metres. A summary of the encountered and measured groundwater levels is provided in the table below.

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Elevation (m)	Measured Groundwater Level Elevation (m)		
			September 4, 2013	April 30, 2014	July 25, 2014
213	287.88	286.5	-	-	-
214	290.37	286.7	287.05	287.97	287.05
215	290.36	286.7	-	-	-

The above-noted encountered water levels are not considered to be representative of the long-term, stabilized groundwater conditions. The corresponding water level in the watercourse was measured at elevation 286.6 metres on July 9, 2013 and at elevation 286.8 metres on April 30, 2014. On September 4, 2013 the water level in the groundwater observation standpipe installed in borehole 214 was about 3.3 metres below the roadway surface or at about elevation 287.1 metres. On April 30, 2014 the water level in the groundwater observation standpipe installed in borehole 214 was about 2.4 metres below the roadway surface or at about elevation 287.9 metres. On July 25, 2014 the water level in the groundwater observation standpipe installed in borehole 214 was about 3.3 metres below the roadway surface or at about elevation 287.1 metres.

Based on the observed groundwater levels, the surrounding topography, and water levels in the drain, the inferred groundwater level has been assumed to be elevation 288.0 metres for design purposes. The groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring snow melt conditions and will be influenced by flows in the watercourse.



5.0 MISCELLANEOUS

The investigation was carried out using equipment supplied and operated by Aardvark Drilling Inc., an Ontario Ministry of Environment licensed well contractor. The field operations were supervised by Mr. Brett Thorner, E.I.T. under the direction of Mr. David J. Mitchell, the Site Investigation Field Manager. The laboratory testing was carried out at Golder Associates' London laboratory under the direction of Mr. Chris M. Sewell. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories for testing Types C and D aggregates. This report was prepared by Mr. Brett Thorner, E.I.T. under direction of Ms. Dirka U. Prout, P.Eng. and reviewed by Mr. W. Michael Kellestine, P.Eng., a Principal with Golder Associates. Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment conducted an independent quality review of the report.

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PART B

FOUNDATION DESIGN REPORT

**CULVERT REPLACEMENT, GIBBINGS DRAINAGE WORKS
HIGHWAY 8, SITE NO. 12-392/C, STATION 15+890
CONTRACT 2 STRUCTURE REPLACEMENTS AND REHABILITATION
GWP 3040-11-00
MINISTRY OF TRANSPORTATION - WEST REGION**



6.0 ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides recommendations on the foundation aspects of the design of the replacement culvert at Gibbings Drainage Works (Site 12-392/C), located at Station 15+890 on Highway 8 in the Township of Hullett in Huron County, Ontario.

The recommendations are based on interpretation of the factual data obtained from the boreholes advanced at this site. The interpretation and recommendations are intended to provide the designers with sufficient information to design the proposed culvert foundations. As such, where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, and scheduling.

The existing culvert is a 33.5 metre long rigid frame open footing concrete structure with a 3.1 metre span, a 1.5 metre high opening, and invert elevations of 286.6 and 286.5 metres at the outlet and inlet, respectively. The existing culvert has approximately 2.0 metres of fill cover.

6.2 Replacement Culvert

Based on information provided by Stantec, it is understood that consideration is being given to replacing the existing culvert with a new 3.0 by 2.1 metre concrete box culvert, a 3.0 by 2.4 metre concrete open footing culvert or a 4.5 by 2.4 metre concrete open footing culvert. The 4.5 metre wide alternative includes leaving the existing footings in place during construction of the new footings for environmental reasons. It has been indicated by Stantec that the concrete box culvert is the preferred structural alternative and may be pre-cast or cast-in-place (CIP). No grade raise is proposed at this location. A comparison of the various culvert types is presented in Table I following the report text.

6.2.1 Foundations

The subsurface conditions encountered during the investigation generally consisted of the existing pavement structure overlying variable embankment fill materials and buried topsoil to about elevation 286.7 metres, overlying interlayered silt, sandy silt, clayey silt and silty clay to elevations of 282.7 to 283.7 metres. A layer of firm to stiff clayey silt till was encountered in each borehole at depth. The inferred groundwater level is at elevation 288.0 metres. The water level in the watercourse was about elevation 286.6 metres at the time of the investigation.

The culvert replacement should be designed to withstand the appropriate vertical weight of fill and traffic loading. It is not necessary to found a box culvert at the standard depth for frost protection purposes as these types of structures are tolerant of small magnitude movements related to freeze-thaw cycles, should these occur. A box or open footing culvert should, however, be founded below any existing fill and surficial organic materials.



Based on the soil conditions encountered at the borehole locations, and assuming that the design culvert invert elevations will be similar to those of the existing culvert at about elevation 286.5 metres, the replacement box culvert will encounter the loose to compact silt below the groundwater level at the approximate design foundation elevation. It is expected that the relatively thin layer of silt will be very susceptible to disturbance, not easily dewatered and problematic from a foundation and construction perspective. A non-standard special provision (NSSP) should be included in the contract documents describing the problems that may be encountered due to the type of material and groundwater conditions.

Therefore, it is recommended that the silt soils at the design foundation level be removed and replaced with Ontario Provincial Standard Specifications (OPSS) Granular B Type II. There is a possibility that wet conditions may be present after subexcavation of the silty materials. Use of Type II is therefore preferred since it can be compacted more effectively under moist to wet conditions. The granular fill should be uniformly placed and compacted. Spread footings for open footing culverts may be founded on the stiff clayey silt at elevation 285.2 metres at the inlet and elevation 285.1 metres at the outlet.

Any observed fill or organic materials should be removed to the native soils. Any low areas should be brought to design grade using lean concrete fill or well graded compacted granular materials.

Geotechnical Resistances

The compacted granular fill and the stiff clayey silt are suitable for support of the proposed culvert replacement. A factored geotechnical resistance at Ultimate Limit States (ULS) of 225 kilopascals (kPa) and a geotechnical reaction at Serviceability Limit States (SLS) of 150 kPa may be used for design purposes provided that foundations have a minimum width of 0.5 metres and that the subgrade has been properly prepared (see Section 6.6). In the case of a 0.9 metre wide footing, a factored geotechnical resistance of 250 kPa at ULS and a geotechnical reaction of 175 kPa may be used for design. The SLS values correspond to a maximum of 25 millimetres of total settlement for new culvert construction.

Frost Treatment and Scour Protection

Frost treatment in the form of a frost taper symmetrical about the culvert centreline must be provided in accordance with Ontario Provincial Standard Drawing (OPSD) 803.010 for a box or open footing culvert. The design frost penetration depth for this area is 1.4 metres below ground surface. Foundations for open footing culverts must be provided with frost protection in the form of a minimum depth of soil cover equivalent to the frost depth or a comparable thermal alternative. The culvert base should be adequately protected against scour as noted in Section 1.9.5.2 of the Canadian Highway Bridge Design Code (CHBDC). Scour protection for the culvert backfill, bedding, and stream bank should be provided to protect the roadway, approach embankments and culvert approaches.



Resistance to Lateral Forces/Sliding Resistance

The resistance to lateral forces/sliding resistance between the base of the replacement box culvert and the bedding or concrete open footing and native soils should be calculated in accordance with Section 6.7.5 of the CHBDC.

In accordance with the CHBDC Section 6.7.5, a factor of 0.8 is applied in the equation to calculate the factored horizontal geotechnical resistance, H_{ri} or H_{rs} , as follows:

$$H_{ri} = 0.8A'c' + 0.8V\tan\delta > H_f \text{ (for box culverts)}$$

$$H_{rs} = 0.8A'c' + 0.8V\tan\phi' > H_f \text{ (for open footing culverts)}$$

where:

A'	-	effective contact area, square metres
c'	=	Nil
$\tan \delta$	-	coefficient of friction for interface between box culvert base and bedding/levelling pad
$\tan \phi'$	-	coefficient of internal friction for soil close to the underside of the spread/strip footing
V	-	unfactored vertical force, kilonewtons
H_f	-	unfactored horizontal load, kilonewtons

The factored horizontal resistance may be calculated using the following parameters in the following table:

Structure	Interaction	Angle of Friction, δ (degrees)	Coefficient of Friction, $\tan \delta$	Angle Of Internal Friction, ϕ' (degrees)	Coefficient of Internal Friction, $\tan \phi'$
CIP Box or Open Footing Culvert	CIP concrete on native clayey silt	-	-	28	0.55
Precast Box Culvert	Pre-cast concrete on Granular A bedding/levelling pad	30	0.58	-	-

6.2.2 Bedding

For precast box culverts, bedding should be placed above a properly prepared subgrade from which all frozen, soft, uncompacted fill, organic materials, or other deleterious materials have been removed. Subexcavated material below the design subgrade elevation should be replaced with compacted OPSS Granular B Type II. It is recommended that the box culvert units be placed on a minimum thickness of 300 millimetres of OPSS Granular A bedding material and a minimum 75 millimetre thick levelling course consisting of uncompacted Granular A or fine aggregates as specified in MTO Special Provision (SP) 422S01.



6.2.3 Backfill and Cover

Backfill, cover, and construction of the frost taper (backfill transition) should be completed in accordance with OPSD 803.010 for a concrete box or open footing culvert. The excavation for the culvert replacement should exceed the culvert dimensions by at least one metre on each side to promote good workmanship and effective compaction of the fill.

The backfill should consist of free-draining, non-frost susceptible granular materials such as OPSS Granular A or Granular B Type III, which is more readily available than Type II in this area. The granular backfill should have less than 5 per cent passing the 0.075 millimetre sieve, placed and compacted in accordance with OPSS 501. All bedding, backfill, and cover materials should be placed in accordance with OPSS 501 and 902 and SP 422S01.

Heavy compaction equipment should not be used immediately adjacent to the walls and roof of the culvert. The height of backfill adjacent to the culvert walls should be maintained equal on both sides of the structure during all stages of backfill placement with one side not exceeding the other by more than 500 millimetres.

6.2.4 End Treatments and Camber

If a box culvert is selected, end treatments in the form of cut-off walls at the inlet and outlet through the silt layer should be provided in accordance with Clause 1.9.5.6 of the CHBDC. An outlet filter is not recommended unless the head difference between the culvert inlet and outlet is high. No grade raise is proposed as part of the culvert replacement and relatively low cover is proposed for the replacement culvert; therefore it is not necessary to provide a camber.

6.3 Liquefaction Potential and Seismic Analysis

6.3.1 Seismic Parameters

The site is located near the Town of Clinton in southern Ontario. According to Table A.3.1.1 of the CHBDC, the zonal acceleration ratio, A , applicable to this site is 0.00. The corresponding acceleration related seismic zone, Z_a , is 0. Based on the site stratigraphy, the soil profile type is categorized as Type I with a seismic site response coefficient, S , of 1.0 based on the CHBDC criteria.

The importance category of the replacement culvert is "other" based on the current version of the CHBDC. The corresponding seismic performance zones (SPZ) to this importance category is 1. Structural culverts situated in SPZ 1 need not be analyzed for seismic loads. However, design forces for restraining elements and support lengths must meet the minimum requirements as outlined in CHBDC Clause 4.4.5.1. It should be noted that the MTO views culverts with spans greater than 3 metres as being similar to bridges. The designer should ensure that the selected culvert design meets the seismic requirements for buried structures as outlined in Clause 7.5.5 of the CHBDC.



6.3.2 Seismic Hazard Assessment

A preliminary screening of the soil stratigraphy was conducted using the procedure outlined in the Federal Highway Administration recommended procedures⁵ and Canadian Foundation Engineering Manual (CFEM). A detailed evaluation of the liquefaction potential of the foundation soils is not considered warranted.

6.4 Lateral Earth Pressures for Design

The lateral pressures acting on the proposed culvert will depend on the type and method of placement of the backfill materials, on the nature of the soil behind the backfill, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure, and on the drainage conditions behind the walls.

The following recommendations are made concerning the design of the walls in accordance with the current CHBDC. It should be noted that these design recommendations and parameters assume level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free-draining granular fill meeting the specifications of OPSS Granular A, Granular B Type II, or Granular B Type III, but with less than 5 per cent passing the 0.075 millimetre sieve should be used as backfill behind the walls. The fill should be compacted in loose lifts not greater than 200 millimetres in thickness. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill.
- A compaction surcharge equal to 12 kPa should be included in the lateral earth pressures for the structural design in accordance with CHBDC Figure 6.6.
- If the wall support does not allow lateral yielding (such is typically the case for a rigid concrete box culvert), at-rest earth pressures should be assumed for geotechnical design. The granular fill should be placed in a zone with a width equal to at least 1.4 metres behind the culvert walls (Case (a) from commentary on CHBDC Figure C6.20).
- For Case (a), the restrained case, which is typical for box culvert walls, the pressures are based on the existing embankment fill materials, assuming a Select Subgrade Material (SSM) is used, and the following parameters (unfactored) may be used:

Soil unit weight: 19 kN/m³

Coefficients of lateral earth pressure:
'At rest' or restrained, K_0 0.53

⁵ Federal Highway Administration (FHWA). (1997). "Design Guidance: Geotechnical Earthquake Engineering For Highways. Volume I – Design Principles." *Geotechnical Engineering Circular No. 3*. FHWA-SA-97-076, Washington, D.C.



6.5 Construction Considerations

6.5.1 Foundation Preparation

Care should be taken during construction to avoid disturbance of the subgrades prior to constructing foundations for the replacement culvert. All existing fill and any topsoil, organics, and soft or loose soils should be stripped from the proposed founding areas prior to placement of base materials. Subgrade preparation should be performed and monitored in accordance with OPSS 902 and as modified by these recommendations.

If a precast box culvert is to be founded on the native silts, special precautions are to be taken during construction. It is probable that the silts and sandy silt deposits at about elevation 286 metres will require subexcavation and replacement due to the likelihood of significant disturbance and groundwater inflow during construction. Foundations for open footing culverts should be constructed as soon as possible after inspection and approval of the subgrade. The clayey silt to silty clay subgrade is susceptible to disturbance from excessive foot traffic and moisture. If construction of the footings is to be delayed by 24 hours or more, the subgrade must be protected by a 100 millimetre thick working slab consisting of concrete having a 28-day compressive strength of 20 megapascals. A NSSP should be included in the contract documents to outline the need for a working slab if construction of the footings is delayed.

It is recommended that the footing excavations be carried out such that the final 0.5 metres of excavation is completed with a Quality Verification Engineer (QVE) experienced in geotechnical engineering on site. The prepared excavation bases should be inspected by the QVE and granular base materials or a working slab (if necessary) should be placed immediately after inspection to protect the founding materials. The QVE should assess the foundation conditions to determine if sub-excavation of unsuitable material is required. Sub-excavation and placement of compacted fill should be carried out under the direction of the QVE.

6.5.2 Erosion and Scour Protection

Erosion and scour protection for the culvert inlet and outlet should be provided, as appropriate. Consideration could be given to using suitable non-woven geotextile and rip-rap, as required, to provide erosion protection based on hydraulic requirements. Temporary erosion protection and sedimentation control measures should be implemented in accordance with OPSS 805. Rip-rap treatment at the culvert outlet should be provided in accordance with OPSD 810.010. In addition, sediment control such as silt fences and erosion control blankets will be required during construction.

6.6 Excavations and Groundwater Control

Excavations will extend through the existing pavement structure, fill, and topsoil and terminate either in the underlying silt and sandy silt or the clayey silt. It is anticipated that excavation for the culvert replacement will proceed below the groundwater level of elevation 288.0 metres. It will be difficult to dewater the sandy silt and silt using sumps and other gravity methods and it is recommended these materials be subexcavated to the underlying stiff silty clay or clayey silt and replaced to facilitate construction.

Surficial water seepage into the excavations should be expected and will be heavier during periods of sustained precipitation. Surface water runoff should be directed away from the excavations at all times. The existing



culvert flows will need to be diverted/piped during construction. The appropriate NSSP should be included in the contract documents to alert the contractor about the need for adequate control of surface and groundwater flows.

Temporary open cut slopes within the fill materials and silts should be maintained no steeper than 1 horizontal to 1 vertical and localized sloughing and ground movements should be expected. All excavations should be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects. The fill materials, buried topsoil and silt and sandy silt below the groundwater level would be classified as Type 3 soils.

6.7 Staging and Temporary Roadway Protection

It is understood that a single lane is to remain open to traffic during construction; therefore, replacement of the existing culvert will need to be conducted in stages using a signalized single lane. Temporary support systems could consist of cantilevered soldier piles and lagging or steel sheet piles. The contractor should be prepared for the presence of cobbles and boulders within the clayey silt till at and below elevation 284 metres which may impede installation of the steel sheet piles.

Excavation support systems should be designed and constructed in accordance with OPSS 539 and the design should limit the lateral movement of the temporary shoring system to meet Performance Level 2. The contractor is responsible for the complete detailed design of the protection system.

Where the support to the wall is provided by anchors or rakers, the wall design should be based on a triangular earth pressure distribution using the design parameters given below. The raker/anchor support must be designed to accommodate the loads applied from pressures and surcharge pressures from area, line, or point loads as well as the impact of sloping ground behind the system. Passive toe restraint to the soldier piles may be determined using a triangular pressure distribution acting over an equivalent width equal to three times the pile socket diameter.

The unfactored triangular earth pressure distribution (p' in kN/m^2 ; increasing with depth) can be calculated as follows:

$$p' = K_a (H - h_w) \gamma + K_a (\gamma - \gamma_w) h_w + \gamma_w h_w + K_a q$$

where H = the height of the excavation at any point in metres

K_a = active coefficient of earth pressure

γ = soil unit weight

γ_w = unit weight of water or 9.8 kN/m^3

q = surcharge for traffic and other loading

h_w = height of groundwater level above excavation base/water level to be taken as elevation 288.0 metres

The support systems may be designed using the parameters provided in the table below. These parameters are provided to assist with design for the unfactored ultimate resistance and loading conditions and may not result in



a temporary support design that adequately controls ground and structure displacements. Achieving adequate displacement control in accordance with the MTO performance criteria may require designs that result in a system that is stiffer than might otherwise be required based on the soil parameters provided in the table below.

Soil Type	Coefficient of Earth Pressure			Internal Angle of Friction (degrees)	Bulk Unit Weight γ (kN/m ³)	Effective Unit Weight γ' (kN/m ³)
	Active, K_a	At Rest, K_o	Passive, K_p			
Fill	0.36	0.53	2.8	28	19	9.0
Sandy Silt	0.36	0.53	2.8	28	19	9.0
Silt	0.38	0.55	2.67	27	18.5	8.5
Clayey Silt	0.36	0.53	2.8	28	19	9.0
Clayey Silt Till	0.33	0.50	3.0	30	20	10.0

The earth pressure coefficients identified above may be applied assuming a horizontal ground surface behind the retaining structure. Where the ground surface behind the retaining structure is sloped, the earth pressure coefficients provided in the table above must be increased.



7.0 MISCELLANEOUS

This section of the report was prepared by Mr. Brett Thorner, E.I.T. under the direction of the Project Engineer Ms. Dirka U. Prout, P.Eng. and reviewed by Mr. W. Michael Kellestine, P.Eng., a Principal with Golder Associates. Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment, conducted an independent quality review of the report.

GOLDER ASSOCIATES LTD.

Dirka U. Prout, P.Eng.

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

BT/DUP/WMK/AMH/FJH/cr

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n:\active\2012\1132 - geo\1132-0100\12-1132-0163 stantec-fdns-mega culverts-3011-e-0041\ph 2000-gwp 3040-11-00\rpts\r01 - site 12-392 (gibbings)\1211320163-2000-r01 jul 30 14 (final) part a&b fdns repl clvrt 12-392-c (gibbings drainage).docx

TABLE I

COMPARISON OF STRUCTURE ALTERNATIVES FOR REPLACEMENT CULVERT

Gibbings Drainage Works, Site 12-392, Station 15+890, Highway 8
 Structure Replacements and Rehabilitation
 GWP 3040-11-00

FOUNDATION OPTION	FEASIBILITY	ADVANTAGES	DISADVANTAGES	ESTIMATED COSTS	RISKS/ CONSEQUENCES
Precast box culvert founded on stiff clayey silt or compacted granular fill	<ul style="list-style-type: none"> • Feasible • Preferred technical alternative 	<ul style="list-style-type: none"> • Least expensive option due to shallower excavation compared to the open footing option and use of precast elements • Allows for most rapid construction compared to the two other alternatives since there is no wait for concrete to cure • Suitable for corrosive environments • Can be more readily installed during cold weather conditions 	<ul style="list-style-type: none"> • If floor is thin and poorly reinforced, it may crack and heave • During high flows, the concrete floor can be undermined • Susceptible to defects/leakage at joints 	<ul style="list-style-type: none"> • Low 	<ul style="list-style-type: none"> • Relatively low risk • Improper alignment or transition between stream and culvert may lead to problems with scour
CIP box culvert founded on stiff clayey silt or compacted granular fill	<ul style="list-style-type: none"> • Feasible 	<ul style="list-style-type: none"> • Intermediate in cost between a pre-cast box and CIP open footing culvert • Less excavation required compared to an open footing culvert • Suitable for corrosive environments • Culvert design can be customized in the field for high stress or load conditions or other site- 	<ul style="list-style-type: none"> • If floor is thin and poorly reinforced, it may crack and heave • During high flows, the concrete floor can be undermined • More expensive compared to precast box option due to increased labour associated with concrete formwork • Special curing 	<ul style="list-style-type: none"> • Low to Moderate 	<ul style="list-style-type: none"> • Relatively low risk • Improper alignment or transition between stream and culvert may lead to problems with scour

COMPARISON OF STRUCTURE ALTERNATIVES FOR REPLACEMENT CULVERT

FOUNDATION OPTION	FEASIBILITY	ADVANTAGES	DISADVANTAGES	ESTIMATED COSTS	RISKS/ CONSEQUENCES
		specific requirements <ul style="list-style-type: none"> • Can be constructed with far fewer joints than a precast box culvert 	requirements for cold weather work		
CIP open footing culvert with spread footings founded on stiff clayey silt or compacted granular fill	<ul style="list-style-type: none"> • Feasible 	<ul style="list-style-type: none"> • Higher costs compared to box culvert options • Suitable for corrosive environments • Culvert design can be customized in the field for high stress or load conditions or other site-specific requirements • Can be constructed with far fewer joints than a precast box culvert • Most suitable where maintenance of fish and/or wildlife passage and preservation of the natural stream bed is a priority 	<ul style="list-style-type: none"> • More expensive compared to both box culvert options due to increased labour associated with concrete formwork and deeper excavation required to provide frost protection for footings • Footings may be susceptible to scour and undermining especially at inlet • Additional excavation below groundwater level • Additional dewatering effort 	<ul style="list-style-type: none"> • Moderate 	<ul style="list-style-type: none"> • Relatively low to moderate risk • Improper alignment or transition between stream and culvert may lead to problems with scour • Option with foundations most susceptible to damage by scour

- NOTES:
1. Qualitative estimates are based on 2014 construction costs and are intended to provide a comparison between alternatives rather than actual construction costs.
 2. Table to be read in conjunction with accompanying report.

Prepared By: BT
 Checked By: AMH

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

III. SOIL DESCRIPTION

(a) Cohesionless Soils

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

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.) split spoon sampler for a distance of 300 mm (12 in.)

Consistency

	<u>kPa</u>	<u>psf</u>
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

(b) Cohesive Soils

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.

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.

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
F	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

(a) Index Properties

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

(a) Index Properties (continued)

w	water content
w_l	liquid limit
w_p	plastic limit
I_p	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_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

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

- Notes:** 1 $\tau = c' + \sigma' \tan \phi'$
 2 shear strength = (compressive strength)/2
 * density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

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

RECORD OF BOREHOLE No 214

1 OF 1

METRIC

PROJECT 12-1132-0163
W.P. 3040-11-00 LOCATION N 4828289.9 , E 387403.1 ORIGINATED BY BT
DIST HWY 8 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY AMG/LMK
DATUM GEODETIC DATE July 9, 2013 CHECKED BY

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											
								<div><div></div><div>20406080100</div></div>											
								<div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div>					WATER CONTENT (%)						
								<div><div>20406080100</div></div>					<div><div>102030</div></div>						
290.37	GROUND SURFACE																		
0.06	ASPHALT																		
0.18	FILL, granular base																		
0.46	Brown																		
0.70	FILL, granular subbase																		
	Brown		1	SS	10														
	FILL, silty sand																		
	Brown																		
	FILL, clayey silt, trace to some topsoil, trace sand, trace gravel, trace roots, with cobbles		2	SS	11														
	Firm to stiff																		
	Dark brown																		
			3	SS	5														
			4	SS	4														
286.71																			
3.66	SANDY SILT, trace to some clay		5	SS	9														
	Loose																		
	Grey																		
285.55			6	SS	8														
4.82	CLAYEY SILT, trace sand, trace gravel																		
	Stiff		7	SS	12														
	Grey																		
			8	SS	8														
283.66																			
6.71	CLAYEY SILT TILL, some sand, trace gravel, with cobbles		9	SS	10														
	Stiff to very stiff																		
	Grey		10	SS	11														
			11	SS	16														

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

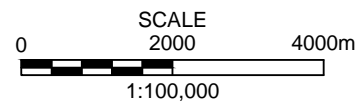
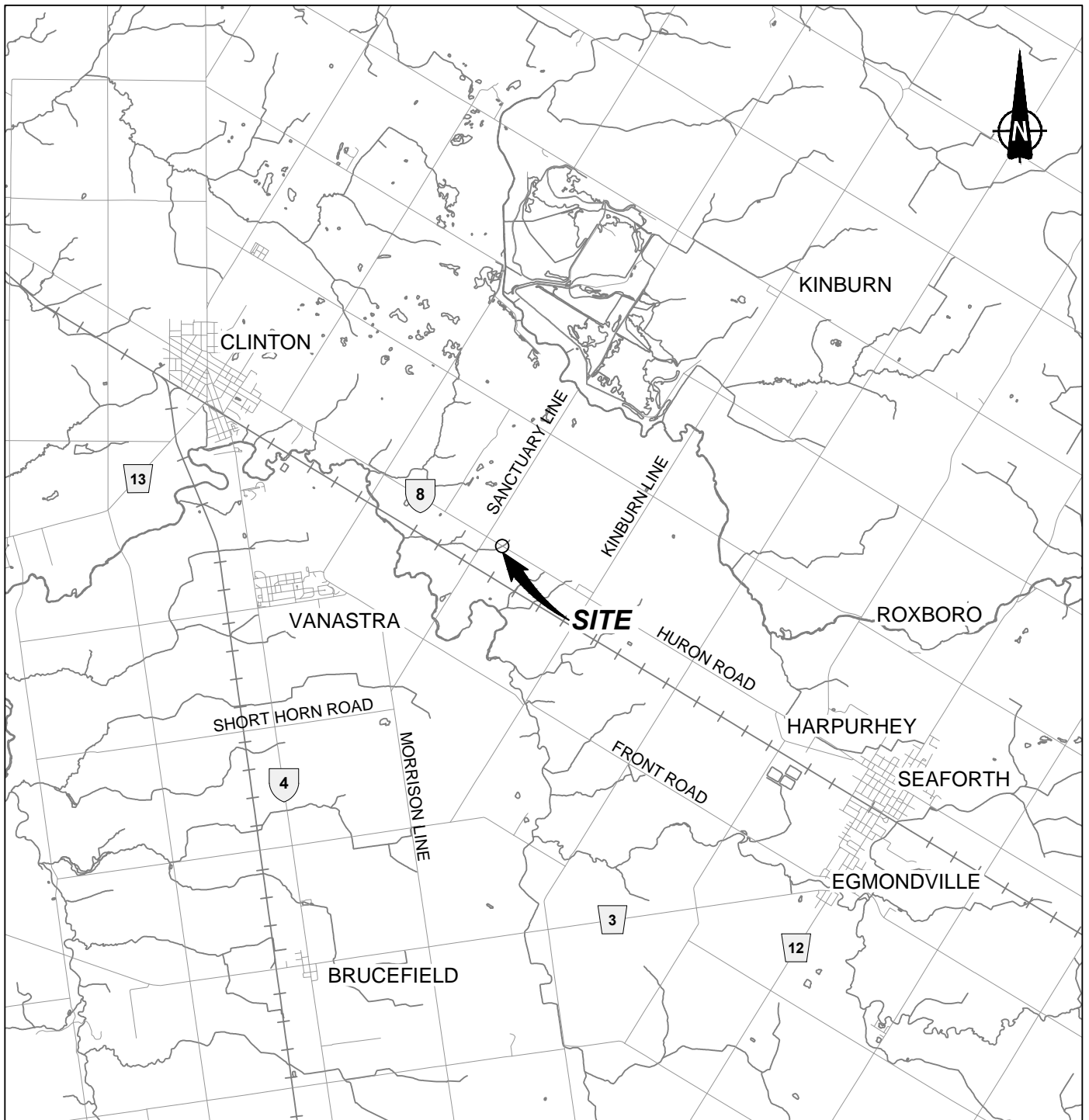
METRIC

ORIGINATED BY BT

COMPILED BY AMG/LMK

CHECKED BY _____

[illegible]



REFERENCE

PLAN BASED ON CANMAP STREETFILES V.2008.5.

NOTE

THIS DRAWING IS TO BE READ IN CONJUNCTION
WITH ACCOMPANYING TEXT.

PROJECT

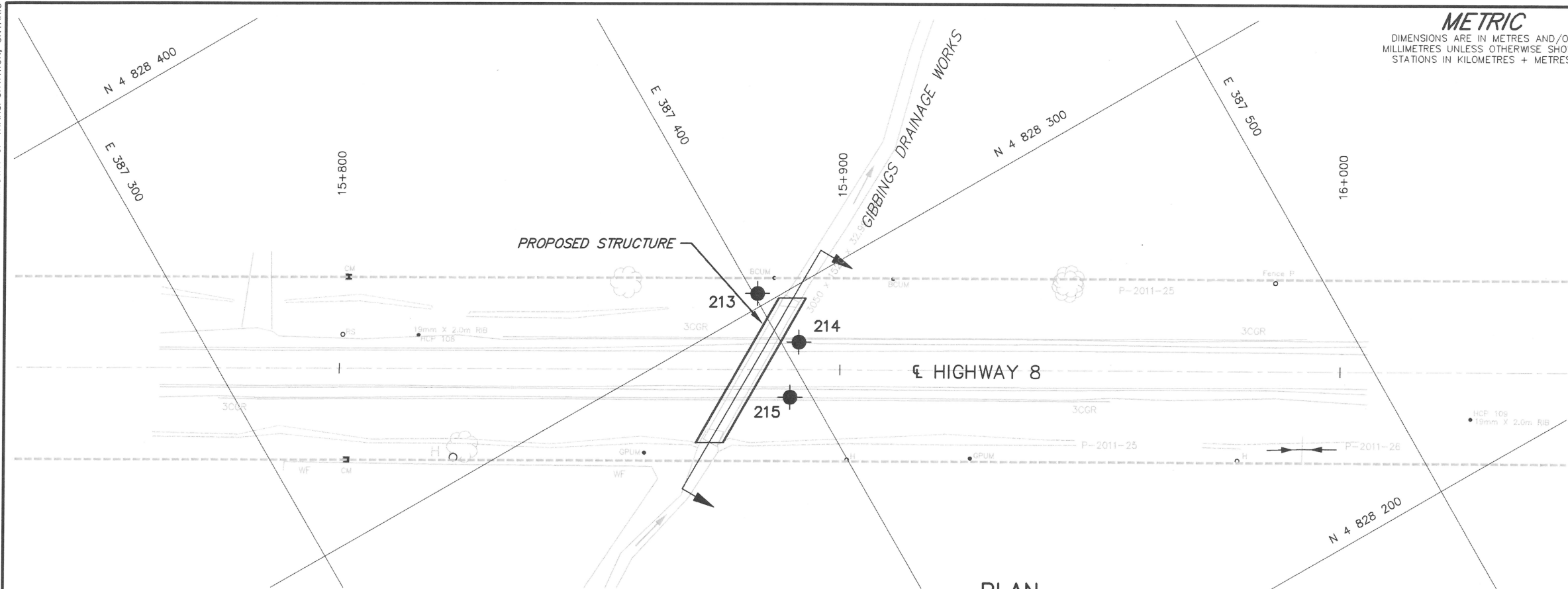
GIBBINGS DRAINAGE WORKS, SITE 12-392/C
STATION 15+890, HIGHWAY 8
GWP 3040-11-00

TITLE

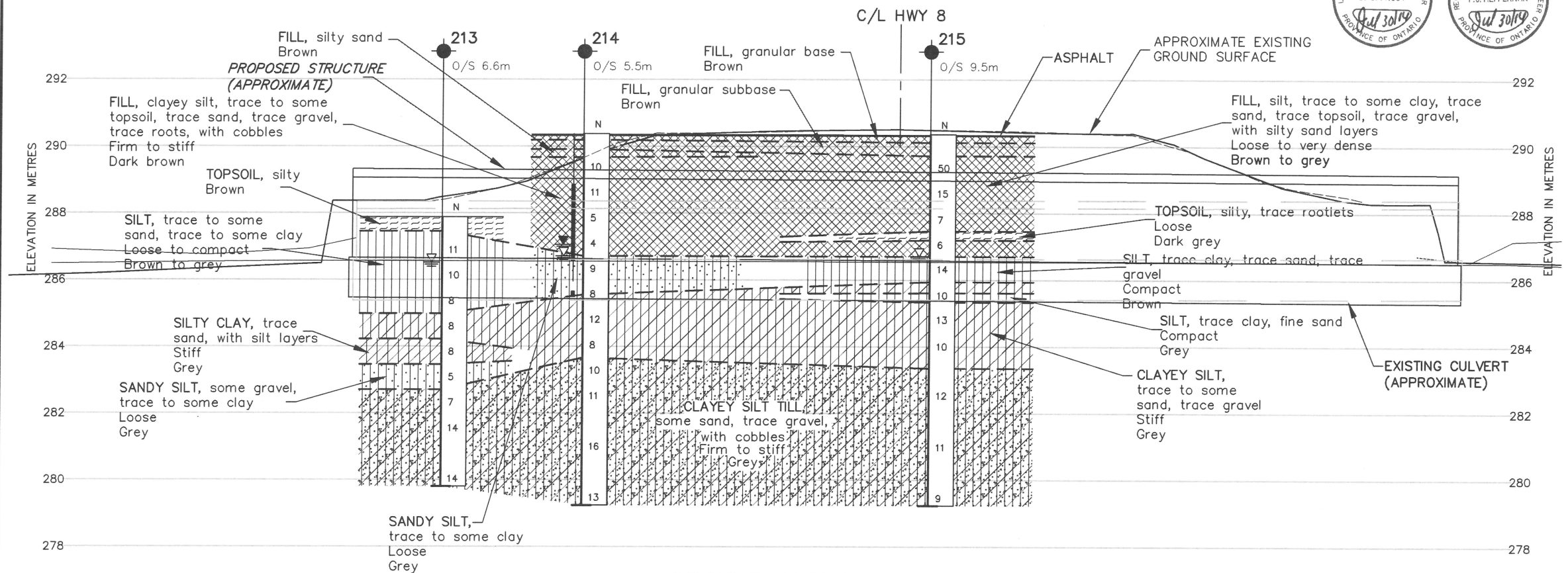
KEY PLAN



PROJECT No. 12-1132-0163		FILE No. 1211320163-2000-F01001	
CADD	LMKWDF	Apr. 04/14	SCALE AS SHOWN
CHECK			REV. 0
			FIGURE 1



PLAN

SCALE
10 0 10 m

PROFILE ALONG C/L CULVERT

HORIZONTAL SCALE
2 0 2 m
VERTICAL SCALE
2 0 2 m**METRIC**
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.CONT No.
WP No. 3040-11-00

SHEET

GIBBINGS DRAINAGE WORKS
STATION 15+890, HIGHWAY 8
STRUCTURE REPLACEMENTS AND REHABILITATION
BOREHOLE LOCATIONS AND SOIL STRATA**Golder Associates Ltd.**
LONDON, ONTARIO, CANADA

KEY PLAN

SCALE IN KILOMETRES
0 2 4

LEGEND

- Borehole - Current Investigation
- Seal
- Standpipe
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL measured on July 25, 2014
- WL encountered during drilling

No.	ELEVATION	CO-ORDINATES (MTM NAD83 ZONE 11)	
		NORTHING	EASTING
213	287.88	4 828 302.5	387 400.7
214	290.37	4 828 289.9	387 403.1
215	290.36	4 828 281.3	387 396.2

NOTES

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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

REFERENCE

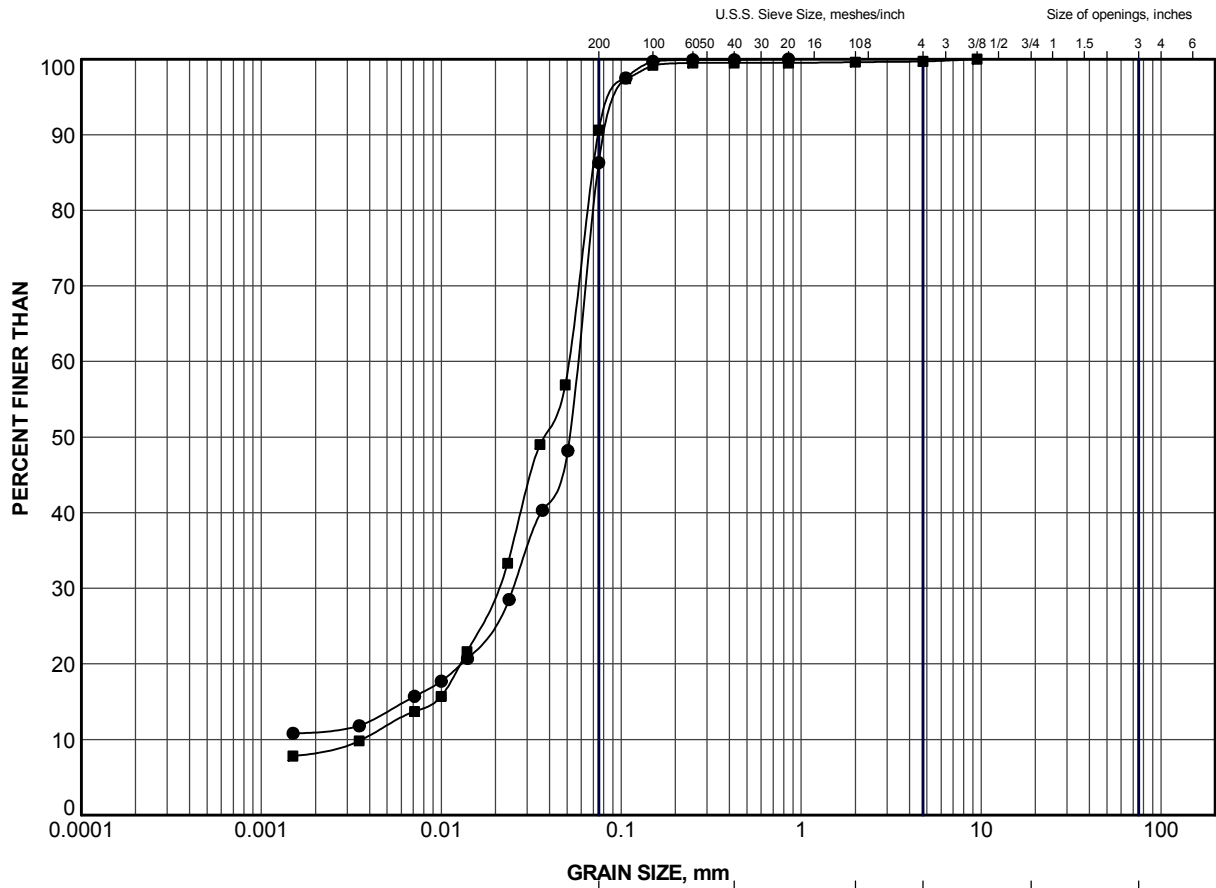
Base plans provided by Stantec.

NO.	DATE	BY	REVISION
Geocres No.	40P11-20		
HWY.	8	PROJECT NO.	12-1132-0163
SUBM'D.	BT	CHKD.	DUP
DRAWN:	WDF	CHKD.	WMK
DATE:	July 28/14	APPD.	FJH
DIST.	12-392/C	DWG.	1



APPENDIX A

Laboratory Test Data



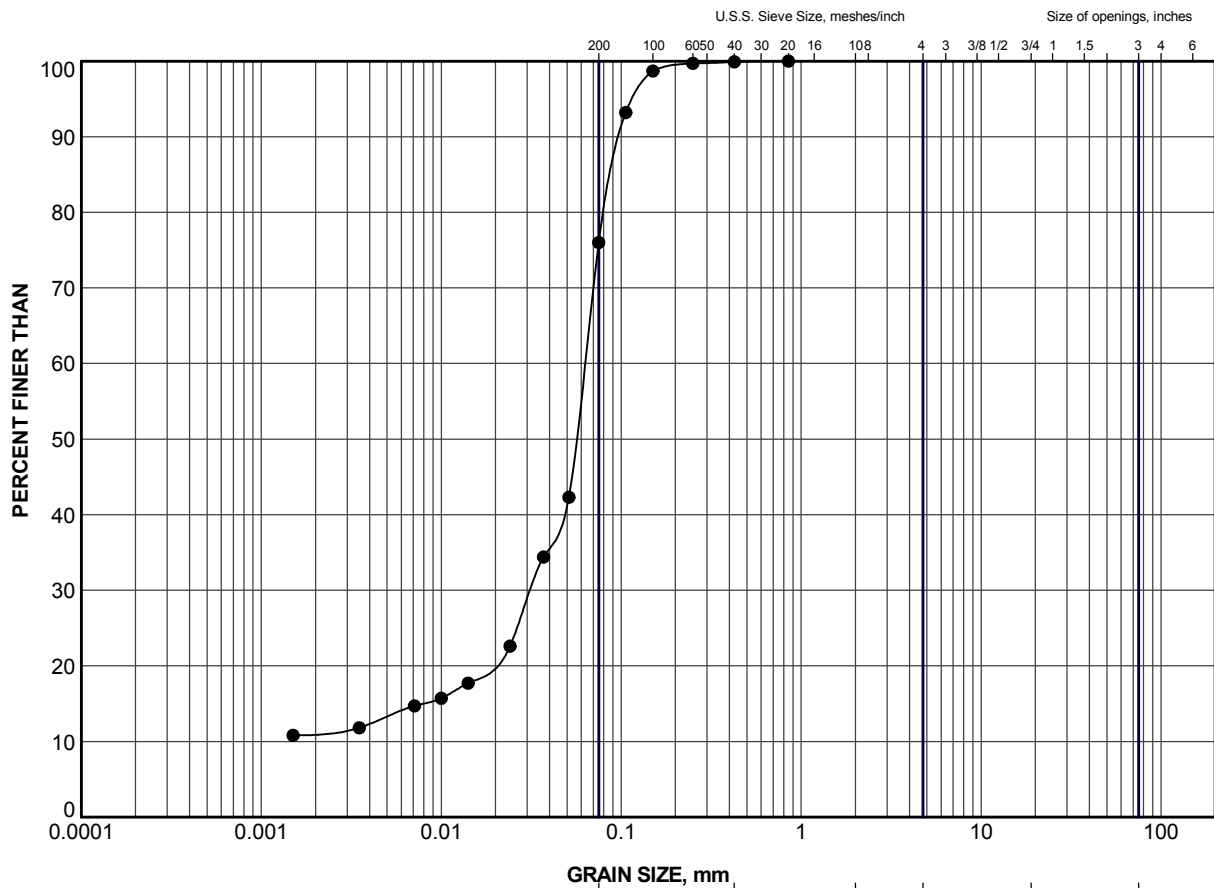
CLAY AND SILT	GRAVEL SIZE, mm						Cobble Size
	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	213	2	286.1
■	215	5	286.3

PROJECT				GIBBINGS DRAINAGE WORKS, SITE 12-392/C STATION 15+890, HIGHWAY 8 GWP 3040-11-00			
TITLE				GRAIN SIZE DISTRIBUTION SILT			
PROJECT No.		12-1132-0163		FILE No. 1211320163-2000-F010A1			
DRAWN		LMK		Nov 15/13		SCALE N/A REV.	
CHECK						FIGURE A-1	




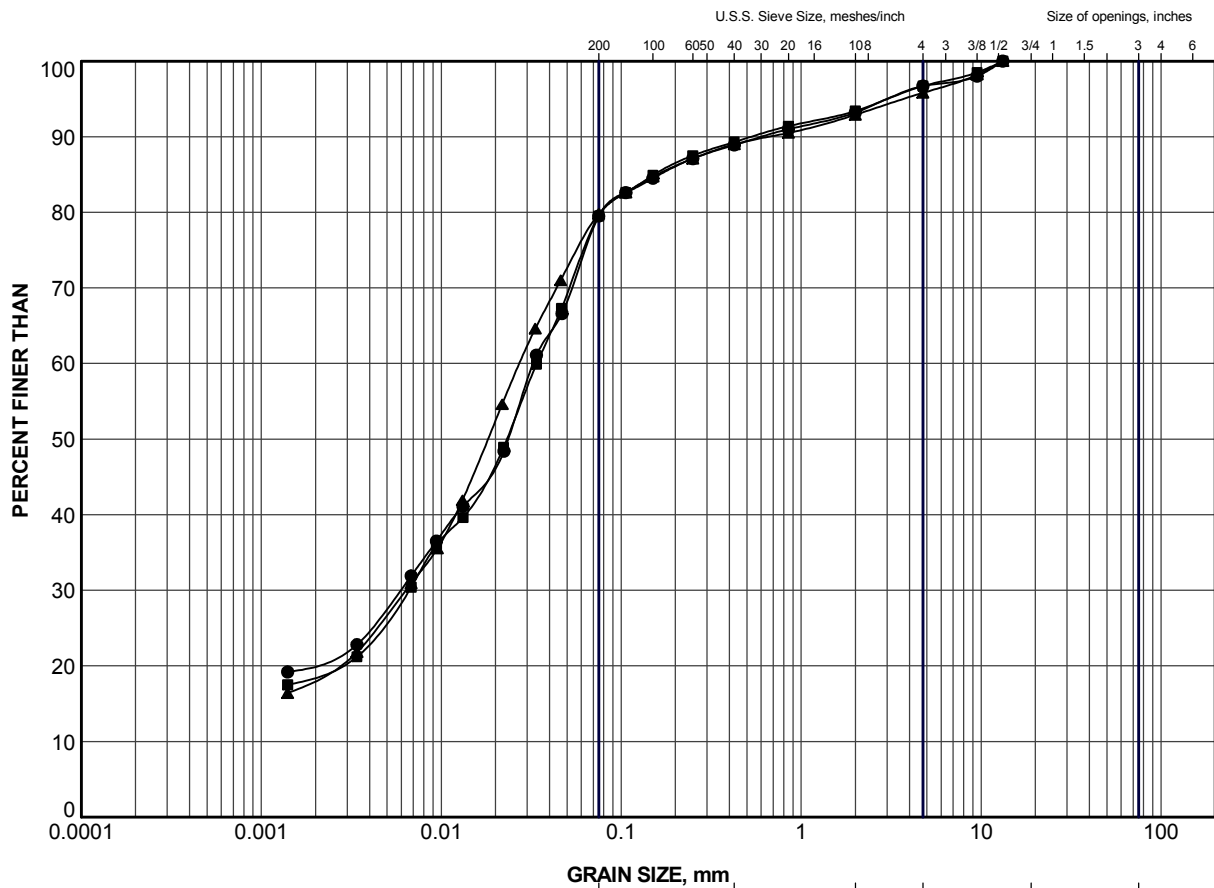


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	214	5	286.3

PROJECT				GIBBINGS DRAINAGE WORKS, SITE 12-392/C STATION 15+890, HIGHWAY 8 GWP 3040-11-00			
TITLE				GRAIN SIZE DISTRIBUTION SANDY SILT			
PROJECT No.		12-1132-0163		FILE No. 1211320163-2000-F010A3			
DRAWN		LMK		Nov 15/13		SCALE N/A REV.	
CHECK						FIGURE A-3	
 Golder Associates LONDON, ONTARIO							

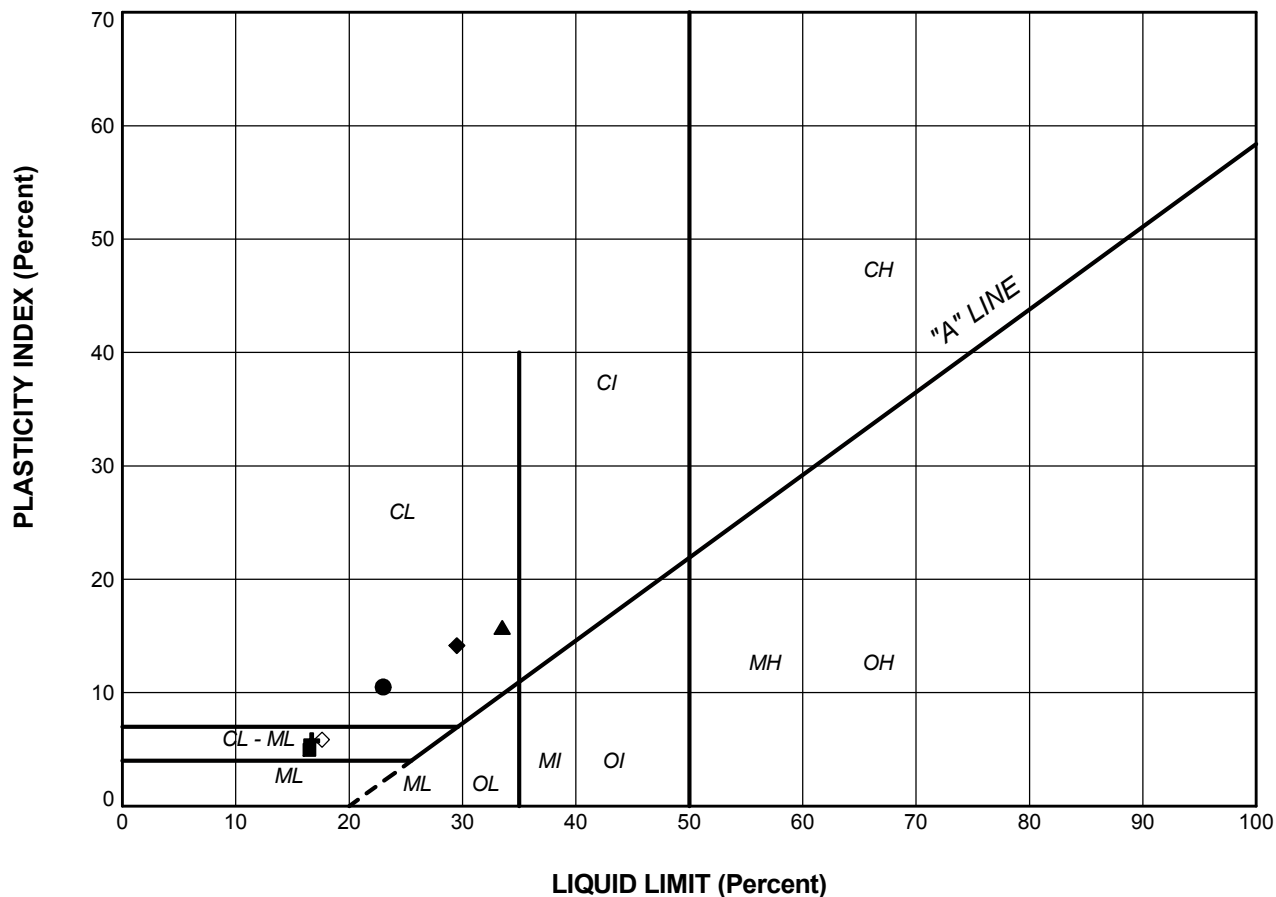


LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	213	7	282.3
■	214	10	282.5
▲	215	9	282.5

PROJECT				GIBBINGS DRAINAGE WORKS, SITE 12-392/C STATION 15+890, HIGHWAY 8 GWP 3040-11-00			
TITLE				GRAIN SIZE DISTRIBUTION CLAYEY SILT TILL			
PROJECT No.		12-1132-0163		FILE No. 1211320163-2000-F010A4			
DRAWN		LMK		Nov 15/13		SCALE N/A REV.	
CHECK						FIGURE A-4	





LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
CLAYEY SILT					
●	213	4	23.0	12.5	10.5
▲	214	7	33.5	17.8	15.8
◆	215	7	29.5	15.4	14.2
CLAYEY SILT TILL					
■	213	7	16.5	11.6	5.0
⊕	214	10	16.7	11.0	5.8
◇	215	9	17.6	11.8	5.9

PROJECT			GIBBINGS DRAINAGE WORKS, SITE 12-392/C STATION 15+890, HIGHWAY 8 GWP 3040-11-00		
TITLE			PLASTICITY CHART		
PROJECT No.		12-1132-0163	FILE No. 1211320163-2000-F010A5		
DRAWN	LMK	Nov 15/13	SCALE	N/A	REV.
CHECK			FIGURE A-5		





APPENDIX B

Site Photographs



APPENDIX B PHOTOGRAPHS



Photograph 1: North elevation (inlet) of Gibbings Drainage Works Site 12-392/C.



Photograph 2: South elevation (outlet).



APPENDIX B PHOTOGRAPHS



Photograph 3: Highway 8 looking east from north shoulder at Culvert Site 12-392/C.

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