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DRAFT REPORT ON

Preliminary Foundation Investigation and Design Proposed Culvert Replacement Site No. 32-110c and 32-141c Stoney Creek at Highway 35 Township of Ops, Ontario W.P. 4106-00-01

Submitted to:

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REPORT



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PART A

**PRELIMINARY FOUNDATION INVESTIGATION
PROPOSED CULVERT REPLACEMENT
SITES 32-110C & 32-141C
STONE CREEK, HIGHWAY 35
TOWNSHIP OF OPS, ONTARIO
W.P. 4106-00-01**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Dillon Consulting Limited (Dillon) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations associated with numerous culvert and bridge replacements and/or rehabilitations at various locations in the Eastern Region of Ontario as part of the 23 Structures MEGA 3 project.

This report presents the results of the preliminary foundation investigation conducted for the replacement of two structural culverts located at Site No 32-110c and 32-141c, which are constructed at the crossing of Stoney Creek and Highway 35, about 0.6 km north of Tower Road, in the Township of Ops, Ontario (WP 4106-00-01).

The purpose of the preliminary foundation investigation was to assess the subsurface conditions for the proposed culvert replacement by drilling 4 boreholes and carrying out in-situ testing and laboratory testing on selected soil samples.

The terms of reference for the original scope of work are outlined in the MTO's Request for Proposal (RFP) dated August 2012.

The work was carried out in accordance with Golder's Quality Control Plan dated December 2012.



2.0 SITE DESCRIPTION

The two existing culverts (Site No. 32-110c and 32-141c) are located at the crossing of Stoney Creek and Highway 35, about 0.6 km north of Tower Road in the Township of Ops (City of Kawartha Lakes), Ontario.

The two culverts are located side by side at the site. Culvert 32-141c was built in 1902 and is perpendicular to the highway alignment. This first culvert is an open-footing non-rigid frame concrete structure measuring about 6 m in width and 22 m in length. Culvert 32-110c was built in 1955 with an approximately 45 degree skew with the highway centreline. This newest culvert is a twin cell sectional plate, corrugated steel pipe arch structure. Each cell has a span of about 3.4 m and are about 28 m in length. The existing culvert locations are shown on Drawing 1.

At this location, Stoney Creek flows in about an East to West direction. It is understood that the inverts are at about Elevation 249 m, and that the water level in the culverts was at about Elevation 250 m in September of 2016.

The existing pavement grade at the culvert location is at about Elevation 252.7 m and very little cover exists above the culverts (i.e., 0.6 to 1.3 m). In this area Highway 35 is 1 lane wide in each direction (i.e., 2-lane highway). The existing embankment slopes at the culvert locations about 2.0 to 2.5 m in height and are sloped at about 2 to 3 horizontal to 1 vertical (2H:1V to 3H:1V). The existing embankments are performing well and appear stable.

It is understood that no significant widening or grade raise is planned at the site as part of the culvert replacement project. It is understood that the culvert will potentially be replaced in one single stage using a full closure of the highway, and that traffic would be detoured during construction.



3.0 INVESTIGATION PROCEDURES

The subsurface investigation was carried out for the culvert replacement between November 28 and December 2, 2016, at which time 4 boreholes (numbered 16-101 to 16-104, inclusive) were advanced at the locations shown on Drawing 1. The boreholes were advanced as follows:

- Boreholes 16-101 and 16-102 were advanced using a 200 mm inside diameter (I.D.) continuous-flight hollow-stem augers on a truck-mounted drill rig, supplied and operated by CCC Geotechnical and Environmental Drilling Ltd. (CCC) of Ottawa, Ontario. Boreholes 16-101 and 16-102 were advanced to depths of about 13 m below the existing ground surface in the overburden.
- Boreholes 16-103 and 16-104 were advanced using portable drilling equipment, supplied and operated by CCC. Boreholes 16-103 and 16-104 were advanced to depths of about 6.6 and 7.9 m, respectively, below the existing ground surface in the overburden.

Soil samples in the boreholes were generally obtained at vertical intervals of about 0.60 to 0.76 m, using a 50-mm outer diameter split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures.

A monitoring well was installed in Borehole 16-104 to monitor the groundwater level at the site. The well consists of a 30 mm diameter rigid PVC pipe with a 1.5 m long slotted screen section, installed within silica sand backfill and sealed by a section of bentonite pellet backfill. The water level in the monitoring well was measured on December 7, 2016, some 5 days after drilling was complete.

The boreholes were backfilled with bentonite pellets, mixed with native soils in the overburden. The site conditions were restored following completion of work.

The field work was supervised by a member of Golder's technical staff, who located the boreholes, supervised the drilling, sampling and in-situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled, and transported to Golder's laboratory in Ottawa for further examination. Index and classification tests consisting of grain size distribution, Atterberg limit, organic content and water content testing were carried out on selected soil samples. All of the laboratory tests were carried out to MTO and/or ASTM standards as appropriate.

The borehole locations and ground surface elevations were surveyed by Golder Associates. The boreholes and locations, including MTM NAD83 northing and easting coordinates and ground surface elevations referenced to Geodetic datum, are summarized in the following table and are shown on Drawing 1.

Borehole Number	Borehole Location	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)
16-101	On roadway, southbound lanes, north of proposed culvert	4904891.0	368476.0	252.7
16-102	On roadway, southbound lanes, south of proposed culvert	4904866.7	368485.4	252.7
16-103	Toe of slope, west end of the proposed culvert	4904883.1	368469.8	251.7
16-104	Toe of slope, east end of the proposed culvert	4904917.2	368482.9	250.5



4.0 SITE GEOLOGY AND STRATIGRAPHY

4.1 Regional Geological Conditions

As delineated in *The Physiography of Southern Ontario*¹, the study area lies within the physiographic region known as the Schomberg Clay Plains.

The Schomberg Clay Plains region consists of three large areas (i.e., near Schomberg, Newmarket and north of Lake Scugog) covering an estimated 1,200 km². The region contains deep deposits of stratified clay and silt over a drumlinized till plain. The Stoney Creek site falls within the area to the north of Lake Scugog, which overlies a flat till plain, resembling more to a typical lake plain than the other two areas of the region. The average depth of the clay deposits is about 4 to 5 m.

4.2 Site Stratigraphy

As part of the subsurface investigation at this site, four boreholes were advanced. A soil stratigraphy section projected along the centreline of the proposed culvert area is shown on Drawing 1.

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation, together with the results of the in-situ and laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole and Drillhole sheets in Appendix A and on Figures B1 to B5 and in Table B1 in Appendix B.

The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions at the locations of the proposed culvert replacement consist of a layer of roadway embankment fill or topsoil underlain by organic materials, sand and gravel, silty sand or clayey sand overlying a deposit of silty clay over glacial till.

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

4.2.1 Pavement Structure and Embankment Fill

The pavement structure of the highway was penetrated within the westbound shoulder at Boreholes 16-101 and 16-102. At the borehole locations, the pavement structure at the shoulder consists of about 60 and 150 mm of asphaltic concrete, respectively. The asphaltic concrete is underlain by about 0.3 m of sand, and crushed stone and asphalt, respectively.

Embankment fill was encountered beneath the pavement structure, generally consisting of sand and gravel. The embankment fill was fully penetrated to depths of about 3.8 and 2.6 m below the ground surface (i.e., Elevations 248.9 and 250.1 m) in Boreholes 16-101 and 16-102, respectively.

¹ Chapman, L.J. and D.F. Putnam. *The Physiography of Southern Ontario*, Ontario Geological Survey Special Volume 2, Third Edition, 1984. Accompanied by Map P.2715, Scale 1:600,000.



Standard penetration test N values for the embankment fill ranged from about 13 to 20 blows per 0.3 m of penetration, indicating a compact state of packing. One higher blow count of greater than 74 was encountered within the fill at Borehole 16-102, reflecting a very dense state of packing. This higher blow count could reflect the presence of rock fill rather than the state of packing of the fill. Obstructions (e.g., crushed rock or cobbles and boulder sized particles) should be anticipated.

The results of grain size distribution testing carried out on two samples of the embankment fill are provided on Figure B1. The measured natural water contents of seven samples of the fill range from 2 to 22 percent.

4.2.2 Topsoil and Organic Material (Peat, Organic Silt and Silty Sand with Organic Matter)

A surficial topsoil layer was encountered at Borehole 16-104, with a thickness of about 80 mm.

Peat and/or organic silt was encountered at ground surface at Borehole 16-103 and beneath the topsoil/fill at Boreholes 16-102 and 16-104. The peat was fully penetrated, having a thickness of about 0.3 to 1.2 m, extending down to Elevations of 249.8 to 250.5 m. SPT 'N' values obtained within this material were about 4 to 7 blows per 0.3 m of penetration indicating a loose state of packing.

A 0.7 m silty sand layer was encountered beneath the organic silt at Boreholes 16-103 containing organic matter. This layer extends down to about Elevation 249.8 m. The result of one SPT test within this material gave an N value of about 2 blows per 0.3 m of penetration indicating a very loose state of packing.

The results of the organic content testing on one sample from each of boreholes 16-102 to 16-104 are presented in Table A1 in Appendix A. The measured organic contents in these materials range from about 4 to 9 percent. The measured natural water contents of five samples of the organic materials range from 25 to 82 percent.

4.2.3 Sand and Gravel

A layer of sand and gravel, containing organic material, was encountered below the peat at borehole 16-104 at a depth of about 0.6 m below the ground surface. The sand and gravel at this location is about 1.2 m thick, extending down to Elevation 248.7 m. The measured standard penetration test N values in this layer were 5 and 6 blows per 0.3 m of penetration, indicating a loose consistency. The measured natural water content of one sample of the sand and gravel was 13 percent.

4.2.4 Silty Clay to Clayey Silt to Silt

A deposit of stratified clay and silt exists at boreholes 16-101 (below the fill), 16-102 and 16-103 (below the organic material) and 16-104 (below the sand and gravel). This deposit was fully penetrated and extends down to depths of about 5.3 to 8.4 m below the existing ground surface (i.e., Elevation ranging from 243.8 to 246.4 m).

A layer of clayey silt to silt was encountered below the fill at Borehole 16-101 at a depth of about 3.8 m below the ground surface. The clayey silt to silt at this location is about 1.5 m thick, extending down to Elevation 247.4 m. The result of two standard penetration tests in this layer gave N values of 4 blows per 0.3 m of penetration. The results of grain size distribution testing carried out on one sample of the clayey silt to silt are provided on Figure B2. The measured natural water content of one sample of the silt was 20 percent.



Asides from this siltier layer at Borehole 16-101, the stratified deposit consists mainly of silty clay to clayey silt throughout the boreholes. The upper portion of the silty clay to clayey silt has been weathered to form a grey brown crust. The weathered layer ranges from about 1.6 to 3.4 m in thickness. Standard penetration tests carried out within the weathered crust gave 'N' values ranging from 5 to 17 blows per 0.3 m of penetration, indicating a generally stiff to very stiff consistency.

The unweathered portion of the silty clay to clayey silt is grey brown to grey in colour. This layer was fully penetrated and varied from about 1.3 to 2.3 m in thickness. The measured standard penetration test N values within the unweathered material ranged between about 2 to 9 blows per 0.3 m of penetration, indicating a firm to very stiff consistency.

The results of grain size distribution testing carried out on six samples of the stratified silty clay to clayey silt are provided on Figure B3. The results of Atterberg limit testing on ten samples of the weathered deposit gave plasticity indices ranging widely from about 7 to 43 percent and liquid limits ranging from about 21 to 62 percent, as shown on Figure B4, indicating the layered deposits varying in plasticity from low to high. The measured natural water content of the stratified clay and silt deposits ranges from 22 to 37 percent.

4.2.5 Till

A deposit of glacial till was encountered beneath the silty clay to clayey silt at depths of about 5.3 to 8.4 m below the existing ground surface (i.e., Elevation ranging from 243.8 to 246.4 m). The till generally consists of a heterogeneous mixture of gravel, cobbles, and boulders in a matrix of silty sand with trace clay. A higher gravel content was encountered in the till in Borehole 16-102.

The till was not fully penetrated at the boreholes locations but was proven to extend to depths of about 6.6 to 13.0 m below the existing ground surface (i.e., Elevations 239.8 to 245.2 m). Standard penetration test 'N' values of 9 to 'in excess of' 100 blows per 0.3 m of penetration were measured in the glacial till, indicating a loose to very dense state of packing. Although the higher 'N' values could reflect the presence of cobbles and boulders in the till deposit, rather than the state of packing of the soil matrix.

The results of grain size distribution testing carried out on two samples of the till are provided on Figure B5. The measured natural water contents of seven samples of the fill range from 7 to 12 percent.

4.2.6 Groundwater Conditions

The groundwater level in the monitoring well in Borehole 16-104 was measured on December 7, 2016, some five days after borehole completion. The groundwater level measured in the well is summarized in the table below.

Borehole	Ground Surface Elevation (m)	Water Level Depth (m)	Water Level Elevation (m)
16-104	250.5	1.1	249.4

It should be noted that groundwater levels in the area are subject to fluctuations both seasonally and with precipitation events.



5.0 CLOSURE

The field operations were supervised by Mr. Doug Grylls, under the direction of Ms. Kim Lesage, P.Eng. This preliminary foundation investigation report was prepared by Ms. Kim Lesage, P.Eng. and reviewed by Mr. Fintan Heffernan, P.Eng., the designated MTO contact for this project.

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PART B

**PRELIMINARY FOUNDATION DESIGN
PROPOSED CULVERT REPLACEMENT
SITES 32-110C & 32-141C
STONE CREEK, HIGHWAY 35
TOWNSHIP OF OPS, ONTARIO
W.P. 4106-00-01**



6.0 DISCUSSION AND PRELIMINARY ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides preliminary foundation design recommendations for the proposed replacement of the existing Stoney Creek culverts along Highway 35. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this preliminary subsurface investigation. The discussion and preliminary recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to carry out the preliminary design of the foundations for the replacement structure. Further investigation and analysis will be required during detail design.

Where comments are made on construction, they are provided to highlight those aspects that could affect the future detail design of the project, and for which special provisions may be required in the Contract Documents. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

The replacement culvert will be along the highway in the general area of the existing culvert alignments (as shown on Drawing 1), on a similar skew to existing culvert 32-110c but pushed slightly north, so that the inlet coincides with the inlet of existing culvert 32-141c. It is understood that the proposed culvert will be about 26 m long. The proposed invert level will be at about Elevation 249 m with a level profile. It is understood that the existing grades of Highway 35 will be maintained and that the embankment side slopes will be generally sloped at about 2H:1V.

It is currently understood that the culvert will be replaced in a single stage using a full closure of the highway, and that traffic would be detoured during construction.

6.2 Foundation Options

Based on the subsurface conditions, only shallow foundation options have been considered in sufficient detail for preliminary design for the replacement of the existing Stoney Creek culverts. It is not considered to be a practical or economical option to support the new culvert on deep foundations because the shallow subsoils will provide adequate bearing resistance and settlement performance given that the Highway 35 grade will likely not be raised and that no major widening of the roadway is currently planned.

A summary of the advantages and disadvantages associated with each shallow foundation option is provided below, and a comparison of the alternative foundation options based on advantages, disadvantages, constructability and relative costs is provided in Table 1 following the text of this report.

- **Concrete box culvert founded on the native stratified stiff clay and silt:** A box culvert could be considered for the culvert replacement provided it is founded on or within the native stratified clay and silt. Relatively lower geotechnical resistances would apply for the compressible native clay soils with potential for some settlement of the culvert. However, the foundation loads would be distributed over a larger area, resulting in lower foundation stress levels, and therefore reduced settlement magnitudes. A two-cell box culvert would likely be required to meet the flow requirements and profile constraints at the site. It is expected that temporary protection systems and/or cofferdams would be required during excavation and construction. A precast culvert would be preferred over a cast-in-place culvert for this option because it would likely be easier and quicker to install, and require less construction time and, therefore, less disruption to traffic.



- **Rigid frame open footing culvert founded on the native stratified stiff clay and silt:** A rigid frame open footing culvert could also be considered for the culvert replacement, provided it is founded on the native stratified clay and silt. The settlements for this type of culvert would be larger than those for a closed box culvert, if founded on the native overburden soils, due to the higher concentration of foundation stresses below the footings. It is also expected that a temporary protection system and/or cofferdams would be required during excavation and construction. As above, a precast culvert would be preferred over a cast-in-place culvert for this option.

Based on the above considerations, the preferred option from a geotechnical/foundations perspective is to replace the two existing culverts with a precast concrete two-cell box culvert founded on the native stratified clay and silt.

6.3 Culvert Foundation Options

6.3.1 Concrete Box Culvert

6.3.1.1 Founding Level and Bedding

It is not necessary to found the box culvert at the standard depth for frost protection purposes as box structures are tolerant of small magnitude movements related to freeze-thaw cycles should these occur. The box culvert should, however, be founded below any existing fill and surficial soils containing organic matter (i.e., below about Elevation 248.7 based on the borehole data).

The bedding and/or leveling pad requirements for a box culvert replacement should be in accordance with Ontario Provincial Standard Specification (OPSS) 422 (*Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut*) for concrete box culverts. It is recommended that the box culvert segments be placed on a minimum thickness of 300 mm of granular bedding material meeting OPSS.PROV 1010 (*Aggregates-Base, Subbase, Select Subgrade, And Backfill Material*) Granular A or Granular B Type II. A geotextile should also be placed below the granular bedding to protect it from disturbance during placement of the granular fill and to provide a proper filter to the silty subgrade. The geotextile should consist of a woven Class II geotextile as per OPSS 1860 (*Geotextiles*).

It is understood that the culvert will be founded at about the same elevation as the existing culverts (i.e., about Elevation 248.0 to 248.5 m), and therefore the box culvert replacement will be typically founded on the stiff to very stiff weathered silty clay to clayey silt to silt (below any embankment fill, topsoil, organics, and soft or loose soils). The subgrade will be susceptible to disturbance and degradation on exposure to water and construction traffic. As an alternative to the placement of a minimum 300 mm thick layer of Granular A, a 100 mm thick concrete working slab could be placed on the subgrade within the culvert footprint, to protect the subgrade from such degradation. The working slab should be placed within four hours after inspection and approval of the subgrade.

The footing subgrade should be inspected by a Quality Verification Engineer (QVE) in accordance with OPSS 902 (*Excavating and Backfilling – Structures*). Further discussion regarding subgrade preparation and protection is provided in Section 6.8.3.

6.3.1.2 Geotechnical Resistances

For a box culvert founded at the elevations provided in Section 6.3.1.1, within the native stratified stiff clay and silt, a factored geotechnical resistance at Ultimate Limit States (ULS) of 175 kPa and a geotechnical resistance at Serviceability Limit States (SLS) for 25 mm of settlement of 100 kPa may be used for preliminary design purposes.



These preliminary geotechnical resistances are provided for loads applied perpendicular to the surface of the footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.10.4 of the *Canadian Highway Bridge Design Code (CHBDC 2014)* and its *Commentary*.

The preliminary geotechnical resistance values provided above will have to be re-evaluated and modified as necessary during detail design.

6.3.2 Rigid Frame Open Footing Culvert

6.3.2.1 Founding Level and Frost Protection Requirements

Strip footings for an open footing culvert replacement, and for any associated concrete wing walls/retaining walls should be founded on the native stratified clay and silt.

As per Ontario Provincial Standard Drawing (OPSD) 3090.101 (*Foundation Frost Depths for Southern Ontario*), the frost penetration depth in the area is 1.6 m. Therefore, the footings should be provided with a minimum of 1.6 m of earth cover below the lowest surrounding grade to provide adequate protection against frost penetration. The open footing founding elevation should therefore be at about Elevation 247.4 m or lower, based on an invert level of Elevation 249.0 m.

Where the subgrade for the culvert and/or associated wall footings consists of native soils, it will be susceptible to disturbance and degradation on exposure to water and construction traffic. It is recommended that a 100 mm thick concrete working slab be placed within four hours following inspection and approval of the subgrade, to protect the subgrade from softening.

The footing subgrade should be inspected by a Quality Verification Engineer (QVE) in accordance with OPSS 902 (*Excavating and Backfilling – Structures*). Further discussion regarding subgrade preparation and protection is provided in Section 6.8.3.

6.3.2.2 Geotechnical Resistance

Strip footings placed on the properly prepared subgrade should be designed based on the following preliminary factored geotechnical resistances at ULS and geotechnical resistances at SLS.

Footing Width	Factored Geotechnical Resistance at ULS	Geotechnical Resistance at SLS*
Up 1.5 m	175 kPa	100 kPa

Note: * For 25 mm of total settlement for the given footing width.

The structural engineer must verify that the selected footing width is sufficient to resist overturning. The ULS resistance and settlement are dependent on the footing size, configuration and applied loads; the preliminary geotechnical resistances should, therefore, be reviewed if the selected footing width or founding elevation differs significantly from those given above.

These preliminary geotechnical resistances are provided for loads applied perpendicular to the surface of the footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.10.4 of the *Canadian Highway Bridge Design Code (CHBDC 2014)* and its *Commentary*.

The preliminary geotechnical resistance values provided above will have to be re-evaluated and modified as necessary during detail design.



6.4 Settlement

The replacement culvert will be founded on the native stratified silt and clay. Provided the SLS geotechnical resistance for the culvert are limited to the values provided in Section 6.3, then the total and differential culvert settlements should be minimal (i.e., less than about 25 and 15 mm, respectively). Most of this settlement will consist of the recompression of the native material and will occur during construction.

If higher resistances are required, consideration could be given to carry out consolidation testing as part of the detailed design to better characterize the compressibility of the clay deposit.

It is understood that no major embankment widening is required as part of this project and therefore the anticipated total and differential settlements of the culvert should be negligible.

6.5 Culvert Backfill and Erosion Protection

Backfill, cover and construction of the frost taper (backfill transition) for concrete box culverts should be completed in accordance with OPSS 422 (*Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut*) and/or OPD 803.010 (*Backfill and Cover for Concrete Culverts*).

Backfill to culvert walls should consist of granular fill meeting the requirements of OPSS.PROV 1010 Granular A or Granular B Type II. The backfill should be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*). The fill depth during placement should be maintained equal on both sides of the culvert walls, with one side not exceeding the other by more than 500 mm. The culvert should be designed for the full overburden pressure and live load assuming that the embankment fill has a unit weight of 22 kN/m³ for Granular A and 21 kN/m³ for Granular B Type II or select earth fill above and/or surrounding the culvert.

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 culvert replacement.

If the flow velocities are sufficiently high, provision should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert inlet and outlet. The requirements for the design of erosion protection measures for the culvert inlet should be assessed by the hydraulic design engineer. As a minimum, rip-rap treatment for the culvert outlet should be consistent with the standard Treatment Type A presented in OPD 810.010 (*Rip-Rap Layout for Sewer and Culvert Outlets*), with the rip-rap placed up to the toe of slope level, in combination with the cut-off measures noted above.

6.6 Embankment Construction and Stability

It is understood that reconstruction of the highway embankment sideslopes will be required following the removal of the existing culverts and construction of the new culvert. The embankments are (and will be) about 3 m in height relative to the original ground surface and are planned to be sloped at about 2H:1V for granular fill below the flatter pavement structure. The subsurface conditions beneath the embankment reconstruction areas are expected to typically consist of fill and native organic soils overlying shallow bedrock. Any topsoil, peat/organic matter or softened/loosened soils should be stripped from below the embankment widening areas prior to placement of any new fill materials in the embankment toe/sideslope areas.



The fill for the new embankment areas adjacent to the culvert should be placed and compacted in accordance with OPSS.PROV 206 (*Grading*) and OPSS.PROV 501 (*Compacting*). Benching of the existing embankment should be carried out to “key in” the new fill materials, in accordance with OPSD 208.010 (*Benching of earth slopes*). Commonly in embankment widening construction, the fill material cut from the existing embankment side slope for creation of these benches is re-used for the embankment widening below/adjacent to each bench area; any fill containing organic matter should be wasted. Additional fill for construction of the embankment above the level of the original ground surface could consist of clean earth fill, granular fill or rock fill.

Replacement of topsoil and seeding or pegged sod is recommended to be provided on the surface of the reconstructed embankment slopes to reduce surface water erosion.

For the soil conditions at the culvert and the embankment height, the embankment will have an adequate factor of safety against both static and seismic slope instability (i.e., greater than 1.3 under static conditions, and 1.1 under seismic conditions).

6.7 Retaining Walls

It is understood that wingwalls or header walls, up to 4.5 m in height, will be constructed parallel to the highway to limit the length and impacts to the water course. The walls for the culvert replacement could consist of gabion walls, concrete gravity walls, and reinforced soil system wall (RSS). A concrete gravity wall could consist of pre-cast elements or be CIP; however, pre-cast wingwalls are preferred for compatibility with pre-cast culverts. Although somewhat labour intensive to construct, installation of gabion walls will be more economical, rapid, and require less excavation and disruption to traffic than most other wall types. The choice of retaining wall system will depend on the desired appearance, the anticipated costs, performance and on other considerations such as constructability.

6.7.1 Retaining Wall Options

6.7.1.1 Gabion Walls

Construction of gabion walls is geotechnically feasible at the site. Gabion walls require the least amount of space behind the wall. Gabion walls do not require an embedment depth equivalent to the frost depth provided it is founded on a granular pad of 300 mm compacted thickness and the foundations have adequate embedment to provide a stable structure. Advantages of gabion walls compared to more rigid structures include the ability to accommodate differential settlements, dissipation of the energy of flowing water, and are free-draining provided an adequate filter is placed behind the wall. Gabion walls can be constructed relatively quickly with minimal equipment and materials. The life expectancy of a gabion wall can be extended by utilizing PVC-coated galvanized steel baskets. Gabion walls are to be constructed in accordance with OPSS.PROV 512 (*Installation of Gabions*).

6.7.1.2 Reinforced Concrete Gravity

Construction of reinforced concrete gravity walls is geotechnically feasible. Compared to a concrete toe wall or RSS walls, footings for gravity walls must be constructed with a frost cover of 1.6 m. This may result in a longer foundation construction time compared to a pre-cast concrete toe wall or RSS wall, particularly if CIP walls are erected. Groundwater control will likely be required since footing excavations will be advanced below the groundwater level.



6.7.1.3 RSS Walls

If the heights of the wingwalls will be relatively low, RSS walls utilizing an interlocking block system and geogrid reinforcement is a geotechnically feasible alternative. Retained Soil System walls are proprietary systems which are to be designed by the supplier and constructed in accordance with their specifications. The internal stability of the mechanically-reinforced soil walls should be verified by the RSS supplier/designer. If a RSS block system wall is selected, the geotechnical aspects of the global stability of the detailed retaining wall design should be reviewed prior to construction. Depending on the design approach selected, an embedment depth equivalent to the frost depth may not be required for foundations of an RSS block system wall. This wall type can be constructed relatively quickly and inexpensively using small equipment.

6.7.2 Retaining Wall Foundations

It is anticipated that the retaining walls would be founded at Elevations between about 247 and 248 m, depending on the wall type and location. At this elevation the retaining walls would be founded within the native stratified stiff clay and silt (below any embankment fill, topsoil, organics, and soft or loose soils). A factored geotechnical resistance at ULS of 200 kPa and a geotechnical reaction at SLS of 125 kPa may be used for preliminary design purposes, for footings up to 1.2 m in width. The walls should be structurally separate from the culvert to accommodate some differential settlement.

The walls should be structurally separate from the culvert to accommodate some differential settlement.

Gabion walls may be founded directly on a 300 mm thick compacted Granular A pad. If required, a granular levelling course approximately 75 mm in thickness may be placed on the founding strata for gabion walls. Non-woven geotextile is to be placed between the gabions and the backfill in accordance with OPSS.PROV 512 (*Installation of Gabions*), OPSS 1860 (*Geotextiles*), and the manufacturer's specifications.

Cast-in-place reinforced concrete gravity walls founded on concrete strip footings must be provided with a frost cover of 1.6 metres below the adjacent ground or thermal equivalent.

RSS walls may be designed such that the facing blocks are constructed on a levelling pad. The levelling pad should be constructed using a minimum of 300 mm of Granular A. As noted previously, depending on the design selected by the RSS supplier, it may not be necessary to provide 1.6 m of earth cover or thermal equivalent for frost protection. However the foundations must have adequate embedment to provide a stable structure. Typically the embedment depth, defined as the distance between the top of the levelling pad and the top of the adjoining finished grade, is a minimum of 500 mm.

All wingwall foundations must be protected against scour as noted in the CHBDC (2014) Section 1.9.5.

6.8 Construction Considerations

The following sections identify future construction issues that should be considered at this stage as they may impact the planning and preliminary design as well as the future detail design. Where applicable, Non-Standard Special Provisions (NSSP) should be developed during detail design for incorporation into the Contract Documents.



6.8.1 Groundwater and Surface Water Control

Control of the surface water and groundwater will be necessary for the construction of the replacement culvert, to allow excavation and foundation construction to be carried out in dry conditions.

Some groundwater inflow into the excavations should be expected. It should be possible to handle the groundwater inflow by pumping from well filtered sumps established in the floor of the excavations. Due to the layered nature of the clay and silt deposits at the site, there is potential for the foundation excavations to intersect water-bearing silt layers; in this case, additional subexcavation may be required if groundwater pumping from filtered sumps cannot maintain the subgrade in “dry” conditions for foundation construction.

Depending on the flow at the time of construction, the surface water flow could be passed through one of the existing culverts, through the culvert area by means of a temporary pipe, or diverted by pumping from behind a temporary cofferdam.

Surface water should be directed away from the excavation area, to prevent ponding of water that could result in disturbance and weakening of the sensitive clay and silt subgrade soils; further discussion on this aspect is provided in Section 6.8.3.

6.8.2 Excavation and Temporary Protection Systems

Temporary excavations for the culvert will be made through the existing fill, organic matter, sand and gravel, silt, and silty clay to clayey silt. 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. The existing fill and loose sand and gravel above the water table, and weathered silty clay to clayey silt would be classified as Type 3 soil based on the OHSA. The organic deposits together with the fill and native materials below the water table (except the weathered silty clay crust) would be classified as Type 4 soil. According to OHSA, excavations that extend to, or into, Type 3 soils should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V) and excavations in Type 4 soils should be sloped no steeper than 3H:1V.

If 3H:1V open cut excavation side slopes cannot be accommodated, then a temporary protection system (i.e., temporary excavation shoring) will be required. Where shoring is required, the support system should be designed and constructed by the contractor in accordance with OPSS.PROV 539 (*Temporary Protection Systems*). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539.

A conventional shoring system for these conditions could consist of soldier piling and lagging or interlocking steel sheet piling supported against lateral movement using walers, tie backs and/or internal struts/braces. Interlocking steel sheet piling would aid in groundwater control. The design of that system is the responsibility of the contractor.

6.8.3 Subgrade Protection

All embankment fill, topsoil, organics, and soft or loose soils (including sand and gravel containing organic matter, as encountered in Borehole 16-104) should be removed from below the proposed founding elevations and wasted or reused as landscaping fill, as required. Subgrade preparation should be performed and monitored in accordance with OPSS 902 (*Excavating and Backfilling – Structures*). The cleaned excavation base should be inspected by a QVE qualified in geotechnical engineering prior to pouring the footings for the rigid frame open footing culvert or placing granular bedding for the box culvert.



The sensitive clayey silt to silty clay subgrade will be susceptible to disturbance and degradation on exposure to water and construction traffic. It is recommended that a minimum 300 mm thick layer of OPSS.PROV 1010 Granular A be placed below the base slab on the subgrade to form a bedding layer for the box culvert segments, and to limit the degradation of the sensitive clayey subgrade. The bedding should be placed within four hours after inspection and approval of the subgrade to limit such degradation. A Class II woven geotextile (per OPSS 1860) should also be placed on the subgrade to protect it from disturbance during placement of the granular fill and to provide a proper filter to the silty subgrade.

As an alternative to the placement of a minimum 300 mm thick layer of OPSS.PROV Granular A, a 100 mm thick concrete working slab could be placed on the subgrade within the box culvert or footing footprint, to protect the subgrade from such degradation. In the case of a box culvert, a 75 mm thick layer of OPSS.PROV 1010 Granular A or concrete fine aggregate meeting the gradation requirements set out in OPSS.PROV 1002 (*Aggregates – Concrete*) should be placed on top of the concrete mat to provide a “levelling pad” for the box culvert replacement. The working slab should be placed within four hours after inspection and approval of the subgrade.

6.8.3.1 Existing Services

A number of underground utilities exist in the area of the culvert, including Enbridge Gas Distribution (Enbridge) high pressure gas mains to the south and east of the proposed culvert footprint.

As a preliminary guideline, provided that settlement-sensitive services/utilities are not present beneath any new embankment fill (or within the zone of influence of any new embankment loading), the construction of the new culvert would likely not have a measurable impact on these utilities. Further analysis should be carried out during detail design for any settlement-sensitive utilities that are within the proposed excavation/backfill footprint.

6.9 Recommendations for Further Work in Detail Design

Additional boreholes could be required during the future detail design stage of investigation, to further assess and/or confirm the subsurface conditions and the preliminary recommendations provided in this report, as follows:

- Assessment of the variability of any existing fill, organic material and surficial soils to confirm the founding elevations within the culvert area and the excavation requirements, particularly for a box culvert.
- Assessment of the consolidation characteristics of the clayey deposit, if higher resistance values are required.
- Assessment of settlement impacts to any settlement-sensitive utilities.



7.0 CLOSURE

This preliminary design report was prepared by Ms. Kim Lesage, P.Eng. and reviewed by Mr. Fintan Heffernan, P.Eng., the designated MTO contact for this project.

GOLDER ASSOCIATES LTD.

Kim Lesage, P.Eng.
Geotechnical Engineer

Fintan Heffernan, P.Eng.
MTO Designated Contact

KSL/FJH/ob

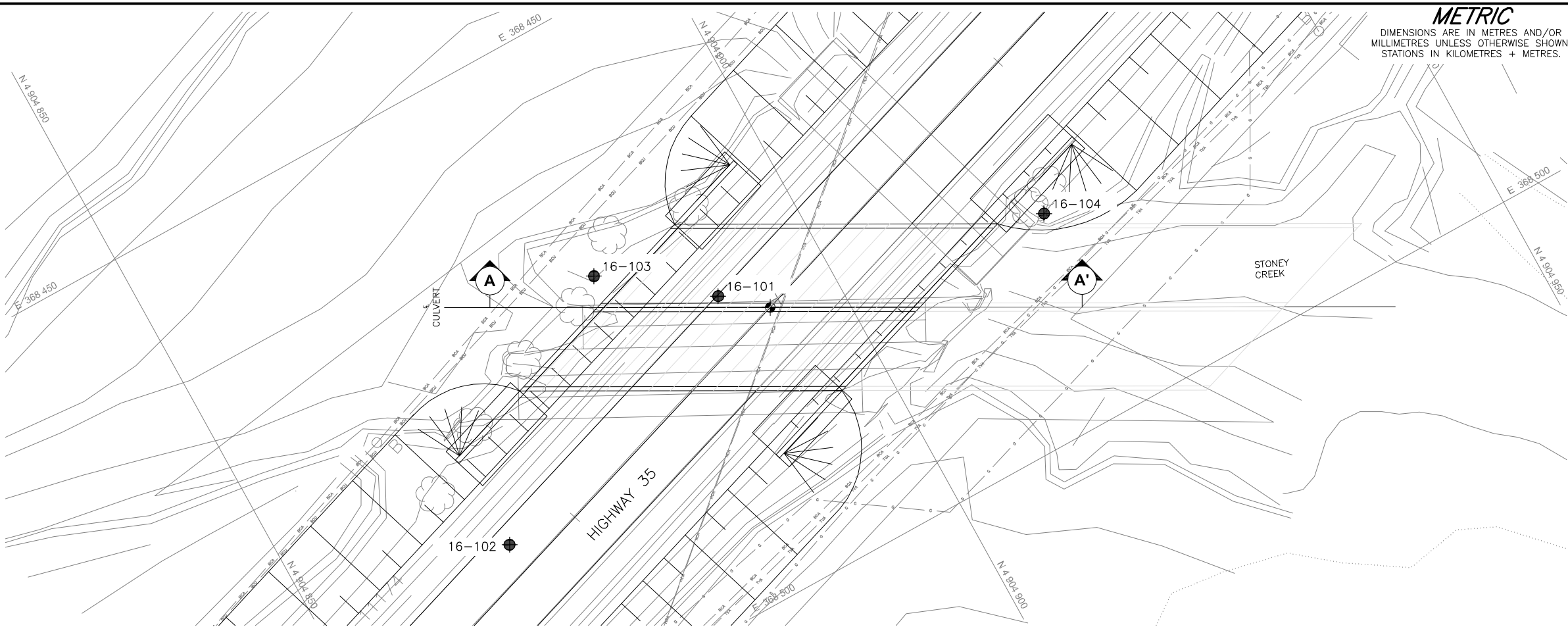
n:\active\2012\1121 - geotechnical\12-1121-0193 dillon mega 3 eastern region\foundations\5 - reports\contract e - stoney creek site 32-110c and 32-141c\12-1121-0193-1220 site 32-110c & 32-141c stoney creek draft february 2017.docx



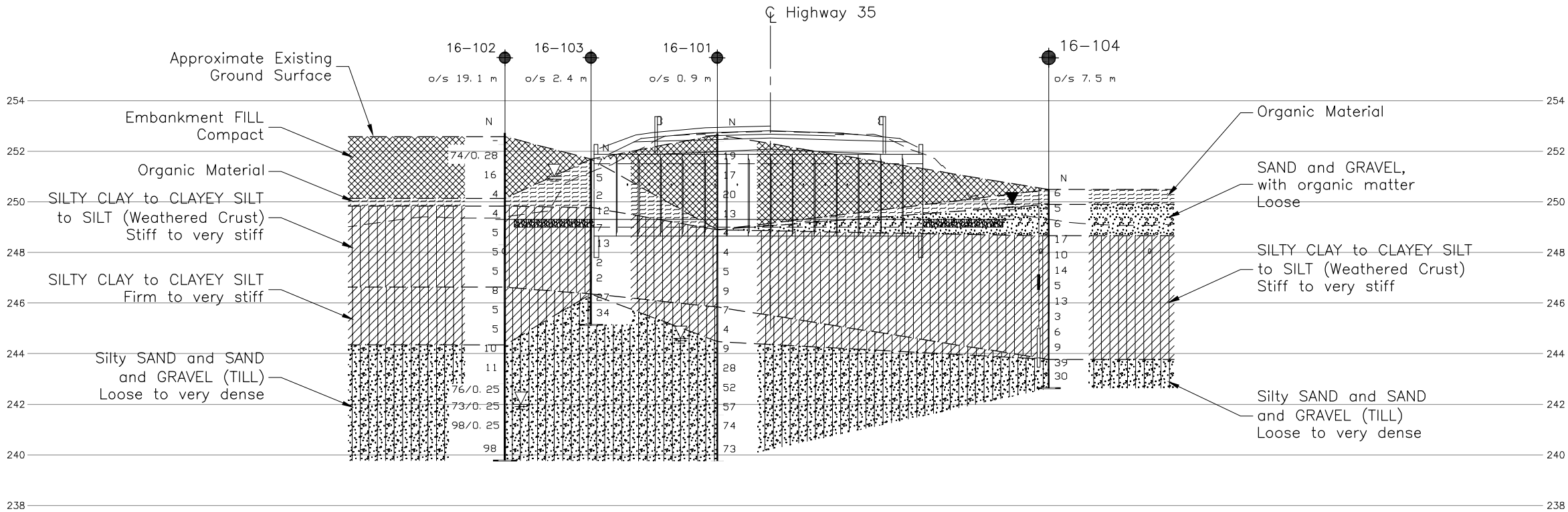
**DRAFT PRELIMINARY FOUNDATION REPORT
HIGHWAY 35 CULVERT REPLACEMENT - SITE NO. 32-110C & 32-141C**

**Table 1
Comparison of Foundation Alternatives
W.P. 4106-00-01**

Foundation Option	Feasibility	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Box Culvert founded on the layered stiff clay and silt	<ul style="list-style-type: none">■ Feasible, preferred option	<ul style="list-style-type: none">■ Potentially shallower excavation depths■ Foundation loads distributed over a larger area, therefore reducing settlement magnitudes■ Precast sections would be quicker and easier to install (i.e., less disruption to traffic)	<ul style="list-style-type: none">■ Relatively low geotechnical resistances on the native soils■ Groundwater control and a temporary protection system are required	<ul style="list-style-type: none">■ Moderate cost	<ul style="list-style-type: none">■ Low risk option
Rigid Frame Open Footing Culvert founded on the layered stiff clay and silt	<ul style="list-style-type: none">■ Feasible	<ul style="list-style-type: none">■ No need for substrate for fisheries	<ul style="list-style-type: none">■ Deeper excavation depth■ Groundwater control and a temporary protection system are required	<ul style="list-style-type: none">■ Moderate cost, higher than box culvert option	<ul style="list-style-type: none">■ Low risk option



PLAN
SCALE
0 4 8 m



SECTION A-A'
HORIZ. SCALE
0 4 8 m
VERT. SCALE
0 2 4 m

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

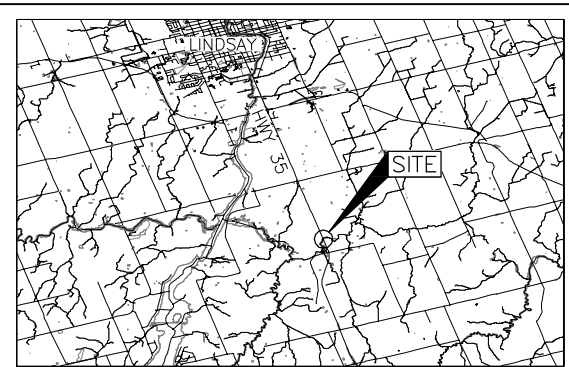
CONT No.
WP No.4106-00-01

PROPOSED CULVERT REPLACEMENT
STONEY CREEK AT HIGHWAY 35
BOREHOLE LOCATIONS
AND SOIL STRATA

SHEET



Golder Associates Ltd.
OTTAWA ONTARIO, CANADA



KEY PLAN



SCALE
0 3 6 KM

LEGEND

- Borehole - Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow)
- WL in piezometer, measured on Dec. 7, 2016
- WL upon completion of drilling
- Seal
- Piezometer

DRAFT

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
16-101	252.7	4904891.0	368476.0
16-102	252.7	4904866.7	368485.4
16-103	251.7	4904883.1	368469.8
16-104	250.5	4904917.2	368482.9

NOTES

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

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

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

REFERENCE

Base plan provided in digital format by Dillon, drawing file no. 4084-GENERAL ARRANGEMENT.DWG, December 23, 2016.

NO.	DATE	BY	REVISION
Geocres No.			
HWY. 35	PROJECT NO. 12-1121-0193		DIST. EASTERN
SUBM'D. KSL	CHKD. KSL	DATE: 2/1/2017	SITE:
DRAWN: JM	CHKD. FJH	APPD. FJH	DWG. 1



APPENDIX A

**List of Abbreviations and Symbols
Record of Borehole and Drillhole Sheets**



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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

Notes: 1
2

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

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



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 (Cohesionless) Soils

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

(b) Cohesive Soils Consistency

	C_u, S_u	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

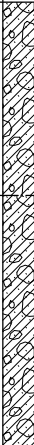
w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

PROJECT		12-1121-0193-1220		RECORD OF BOREHOLE No 16-101		SHEET 1 OF 2		METRIC																
W.P.		4106-00-01		LOCATION		N 4904891.0 ; E 368476.0		ORIGINATED BY																
DIST		Eastern HWY 35		BOREHOLE TYPE		Power Auger 200 mm Diam. (Hollow Stem)		COMPILED BY																
DATUM		Geodetic		DATE		November 29, 2016		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			20	40	60						80	100	20	40	60	80	100	25	50
252.7	GROUND SURFACE																							
0.0	ASPHALTIC CONCRETE																							
252.4	Sand (FILL)		1	GRAB	-																			
0.3	Brown Moist																							
	Sand and gravel, some silt, trace clay (FILL)																							
	Compact Brown to grey																							
	Moist to wet																							
			2	SS	19																			
			3	SS	17																			
			4	SS	20																			
			5	SS	13																			
248.9	CLAYEY SILT to SILT, some sand, trace gravel and organic matter (rootlets)		6	SS	4																			
3.8	Grey-brown Wet																							
			7	SS	4																			
247.4	SILTY CLAY, trace sand lenses (Weathered Crust)		8	SS	5																			
5.3	Stiff to very stiff Grey-brown Wet																							
			9	SS	9																			
245.8	SILTY CLAY to CLAYEY SILT, trace sand lenses		10	SS	7																			
6.9	Stiff Grey Wet																							
			11	SS	4																			
244.5	Silty SAND, some gravel, trace clay (TILL)		12	SS	9																			
8.2	Loose to very dense Grey Wet																							
			13	SS	28																			

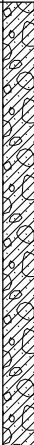
PROJECT 12-1121-0193-1220			RECORD OF BOREHOLE No 16-101			SHEET 2 OF 2			METRIC																	
W.P. 4106-00-01			LOCATION N 4904891.0 ; E 368476.0			ORIGINATED BY DG																				
DIST Eastern HWY 35			BOREHOLE TYPE Power Auger 200 mm Diam. (Hollow Stem)			COMPILED BY JM																				
DATUM Geodetic			DATE November 29, 2016			CHECKED BY																				
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			ELEVATION SCALE			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES																					
--- CONTINUED FROM PREVIOUS PAGE ---																										
241.4 11.3	Silty SAND, some gravel, trace clay (TILL) Loose to very dense Grey Wet		14	SS	52																					
			15	SS	57																					
			16	SS	74																					
			17	SS	73																					
239.8 13.0	END OF BOREHOLE																									
NOTES: 1. Water level in open borehole at a depth of 8.1 m below ground surface (Elev. 244.6 m), measured during drilling.																										

GTA-MTO 001 N:\ACTIVE\2012\1121 - GEOTECHNICAL\12-1121-0193 DILLON MEGA 3 EASTERN REGION\SPATIAL_IM\GINT\PHASE 1220\1211210193-1220.GPJ GAL-GTA.GDT 02/01/17 JM



GTA-MTO 001 N:ACTIVE2012\121 - GEOTECHNICAL\12-1121-0193 DILLON MEGA 3 EASTERN REGION\SPATIAL_IMG\INT\PHASE_1220\1211210193-1220.GPJ GAL-GTA.GDT 02/01/17 JM

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

PROJECT 12-1121-0193-1220			RECORD OF BOREHOLE No 16-102			SHEET 2 OF 2			METRIC																
W.P. 4106-00-01			LOCATION N 4904866.7 ; E 368485.4			ORIGINATED BY DG																			
DIST Eastern HWY 35			BOREHOLE TYPE Power Auger 200 mm Diam. (Hollow Stem)			COMPILED BY JM																			
DATUM Geodetic			DATE November 28, 2016			CHECKED BY																			
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			ELEVATION SCALE			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES																				
--- CONTINUED FROM PREVIOUS PAGE ---																									
9.9	Silty SAND, some gravel, trace clay (TILL) Very dense Grey Wet		14	SS	76/0.25																				
			15	SS	73/0.25																				
			16	SS	98/0.25																				
			17	SS	98																				
239.8 13.0	END OF BOREHOLE																								
NOTES: 1. Water level in open borehole at a depth of 9.7 m below ground surface (Elev. 243.0 m), measured during drilling.																									

GTA-MTO 001 N:\ACTIVE\2012\1121 - GEOTECHNICAL\12-1121-0193 DILLON MEGA 3 EASTERN REGION\SPATIAL_IM\GINT\PHASE 1220\1211210193-1220.GPJ GAL-GTA.GDT 02/01/17 JM

PROJECT 12-1121-0193-1220			RECORD OF BOREHOLE No 16-103			SHEET 1 OF 1			METRIC								
W.P. 4106-00-01			LOCATION N 4904883.1 ; E 368469.8			ORIGINATED BY DG											
DIST Eastern HWY 35			BOREHOLE TYPE Portable Drill/N Casing			COMPILED BY JM											
DATUM Geodetic			DATE November 29 - December 1, 2016			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									
251.7	GROUND SURFACE							20	40	60	80	100					
0.0	Fibrous organic SILT, some sand, trace gravel Loose Grey-brown Moist		1	SS	7												
			2	SS	5												
250.5	Silty SAND, with organic matter (wood fibres) Very loose Grey-brown Wet		3	SS	2												
249.8	SILTY CLAY, trace sand (Weathered Crust) Stiff to very stiff Grey-brown Wet		4	SS	12												
			5	SS	7												
			6	SS	13												
247.9	SILTY CLAY, trace sand Stiff to firm Grey-brown Wet		7	SS	2												
3.8			8	SS	2												
246.4	Silty SAND, some gravel, trace clay (TILL) Compact to dense Grey Wet		9	SS	27												
			10	SS	34												
245.2	END OF BOREHOLE																
6.6	NOTES: 1. Water level in open borehole at a depth of 0.7 m below ground surface (Elev. 251.0 m), measured during drilling.																

PROJECT		12-1121-0193-1220		RECORD OF BOREHOLE No 16-104		SHEET 1 OF 1		METRIC														
W.P.		4106-00-01		LOCATION		N 4904917.2 ; E 368482.9		ORIGINATED BY														
DIST		Eastern HWY 35		BOREHOLE TYPE		Portable Drill/N Casing		COMPILED BY														
DATUM		Geodetic		DATE		December 1-2, 2016		CHECKED BY														
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV	DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ					
250.5	0.0	GROUND SURFACE							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					25 50 75 W _p W W _L			kN/m ³			GR SA SI CL		
249.9	0.1	TOPSOIL		1	SS	6		250														
	0.6	Fibrous PEAT, some gravelly silty sand Dark brown Moist		2	SS	5		249														
		SAND and GRAVEL, contains organic matter (wood fibres) Loose Grey-brown Wet		3	SS	6		249														
248.7	1.8	SILTY CLAY, trace sand lenses (Weathered Crust) Stiff to very stiff Grey-brown Wet		4	SS	17		248														
				5	SS	10		248														
				6	SS	14		247														
				7	SS	5		247														
				8	SS	13		246														
245.6	4.9	SILTY CLAY to CLAY Stiff to firm Grey-brown Wet		9	SS	3		245														
				10	SS	6		245														
				11	SS	9		244														
243.8	6.7	Silty SAND, some gravel, trace clay (TILL) Dense Grey Wet		12	SS	39		243														
				13	SS	30		243														
242.7	7.9	END OF BOREHOLE																				
		NOTES: 1. Water level in piezometer at a depth of 1.1 m below ground surface (Elev. 249.4m), measured on Dec. 7, 2016.																				



APPENDIX B

Laboratory Test Results

Table B1 – Organic Content

Figure B1 – Grain Size Distribution – Fill

Figure B2 – Grain Size Distribution – Clayey Silt to Silt

Figure B3 – Grain Size Distribution – Silty Clay to Clayey Silt

Figure B4 – Plasticity Chart – Silty Clay to Clayey Silt

Figure B5 – Grain Size Distribution – Till

TABLE B1

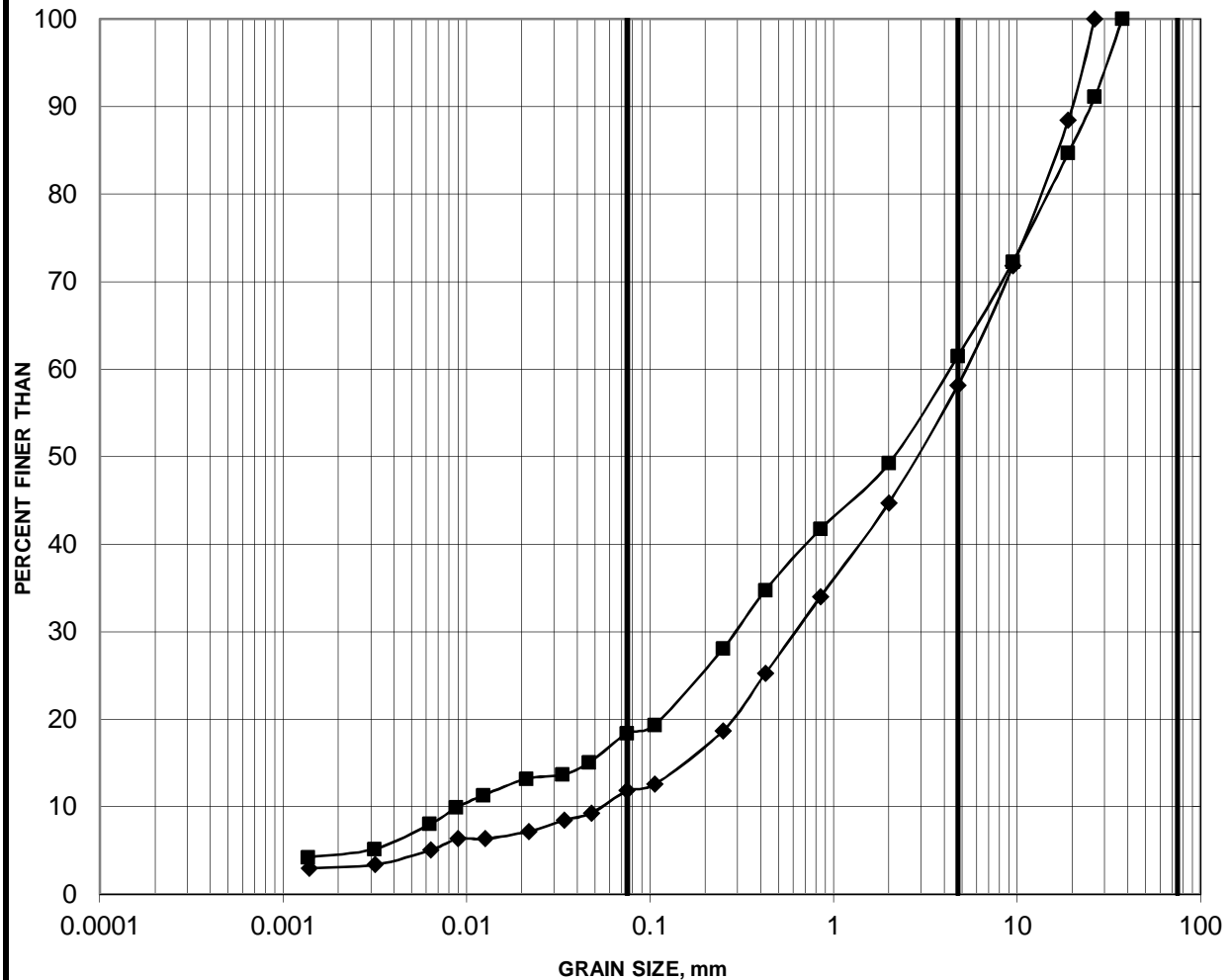
SUMMARY OF ORGANIC CONTENT BY PERCENTAGE

PROJECT NUMBER : 12-1121-0193 /1220				
PROJECT NAME : Dillon - Mega 3 Eastern Region - Stoney Creek				
DATE TESTED : 5-Jan-17				
Borehole No.	Sample No.	Depth (m)	Water Content (%)	Organic Content (%)
16-101	7	4.57-5.18	19.9%	0.9%
16-102	4B	2.59-2.90	47.7%	9.1%
16-103	2	0.61-1.22	35.2%	5.3%
16-103	3A	1.30-1.45	29.3%	3.8%

GRAIN SIZE DISTRIBUTION

FIGURE B1

Sand and gravel (FILL)

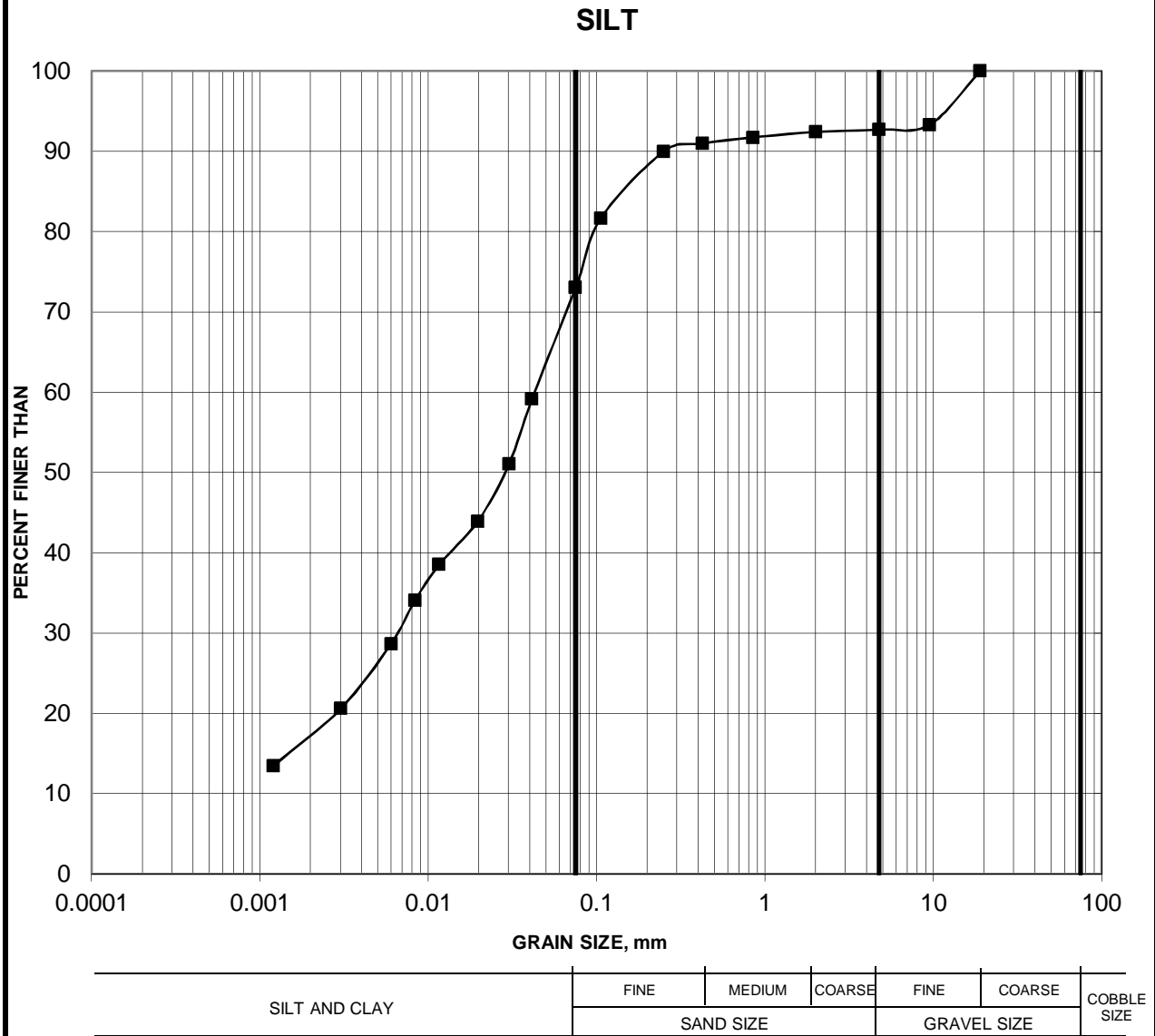


SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
16-101	4	2.29-2.90
16-102	2	0.76-1.19

GRAIN SIZE DISTRIBUTION

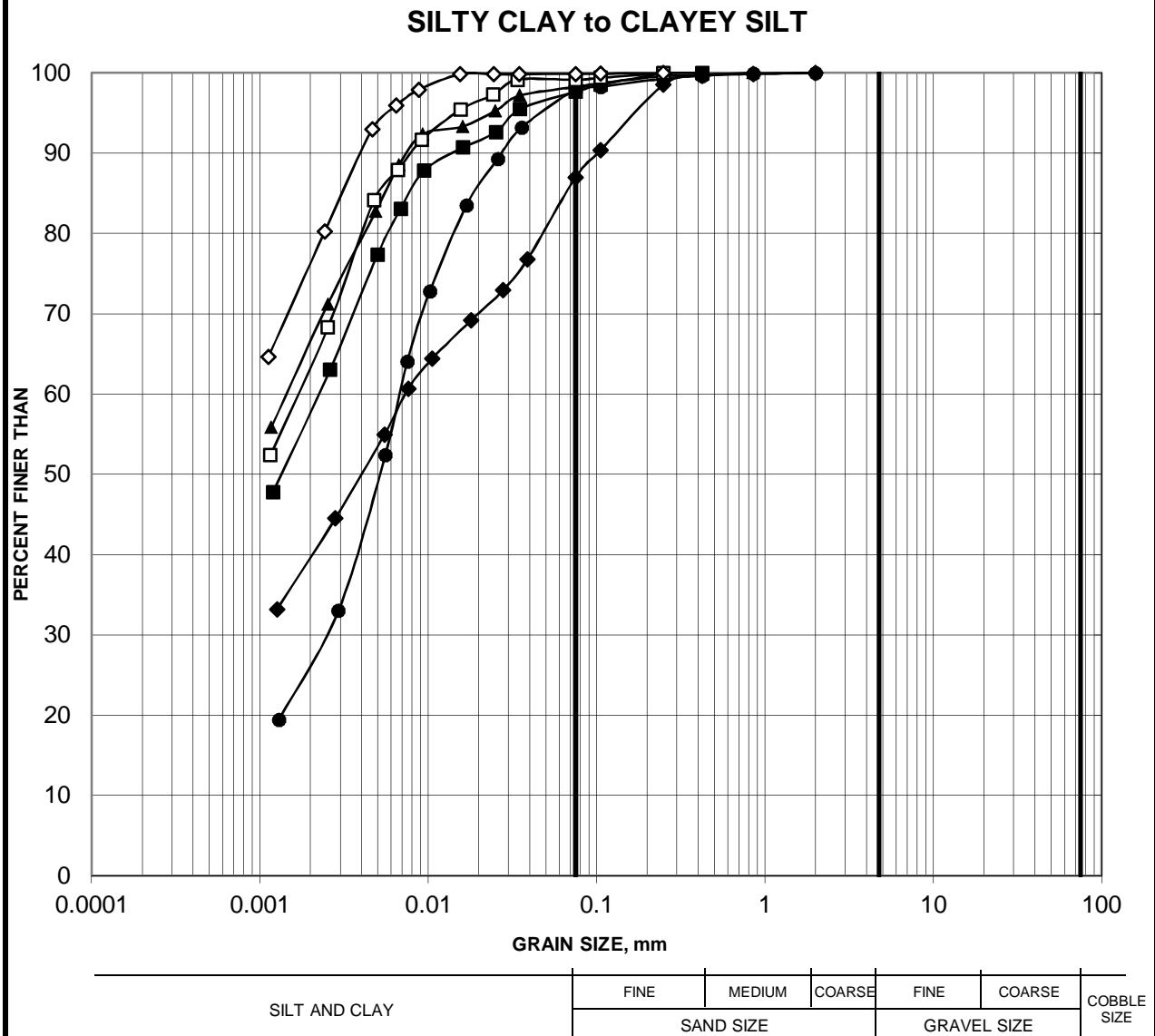
FIGURE B2



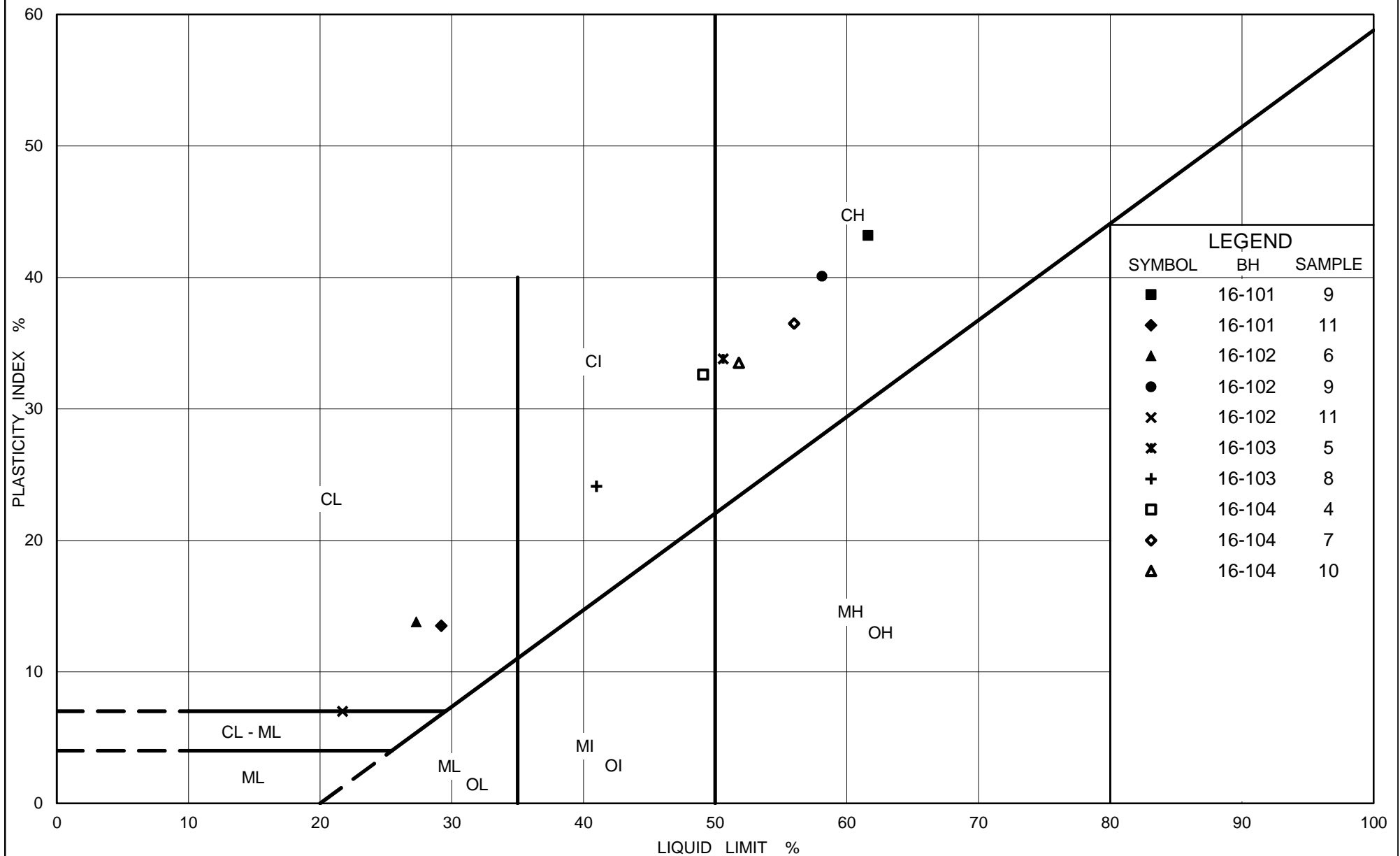
Borehole	Sample	Depth (m)
—■— 16-101	7	4.57-5.18

GRAIN SIZE DISTRIBUTION

FIGURE B3



Borehole	Sample	Depth (m)
16-101	8	5.34-5.95
16-102	6	3.81-4.42
16-102	7	4.57-5.18
16-102	11	7.62-8.23
16-103	6	3.20-3.81
16-104	10	5.49-6.10



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PLASTICITY CHART SILTY CLAY to CLAYEY SILT

FIG No. B4

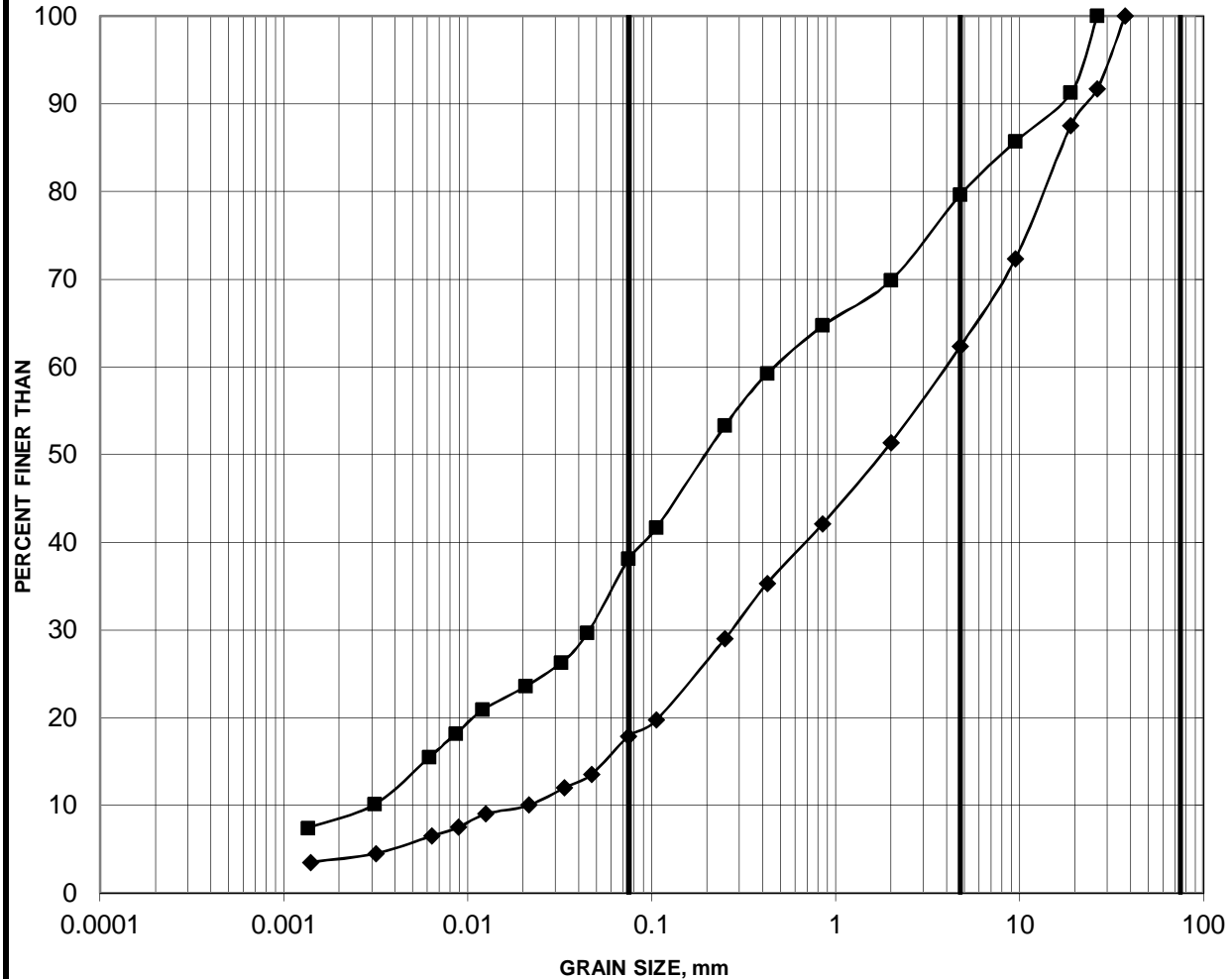
Project No.12-1121-0193 /1220

Compiled By : CW Checked By : CNM

GRAIN SIZE DISTRIBUTION

FIGURE B5

SILTY SAND (TILL) to SAND and GRAVEL



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

Borehole	Sample	Depth (m)
16-101	13	9.15-9.76
16-102	13	9.15-9.76

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