DRAFT REPORT

April 17, 2017

FOUNDATION INVESTIGATION AND DESIGN REPORT

HIGHWAY 400/4TH LINE UNDERPASS REPLACEMENT
MTO STRUCTURE SITE NO. 30-212
DB 2016-2021

Submitted to:
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Distribution:

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FOUNDATION INVESTIGATION REPORT
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Hatch Corporation (Hatch) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services in support of the design-build for the replacement of the 4th Line (Churchill Sideroad) underpass in the Town of Innisfil, in the County of Simcoe, Ontario.

The terms of reference and scope of work for the foundation engineering services are outlined in Section 2.4.9 of MTO's Request for Proposal, dated July 2016. Golder's scope of work for foundation engineering services associated with the 4th Line underpass replacement and the associated high fill embankments along 4th Line is contained in Section 2.4.9 of the *Technical Proposal* for this assignment. The work has been carried out in accordance with Golder's Supplementary Specialty Quality Control Plan for foundation engineering services.

2.0 SITE DESCRIPTION

The 4th Line underpass is located approximately 4.2 km north of the Highway 89 interchange and approximately 5.4 km south of the Innisfil Beach Road (Simcoe Road 21) interchange in the Town of Innisfil, in the County of Simcoe. The existing 4th Line underpass is a single-span structure supported on spread footings.

The overall surface topography in the vicinity of the site is relatively flat and consists predominantly of rural farmland. The natural ground surface at the site is at approximately Elevation 284 m to 285 m. Highway 400 has been constructed near the original ground surface, with its grade at approximately Elevation 286 m beneath the 4th Line underpass, while 4th Line has been constructed on embankments up to about 8 m and 7.5 m high on the west and east sides of Highway 400, respectively, with the existing grade along 4th Line at approximately Elevation 292 m near the west and east abutments.

3.0 INVESTIGATION PROCEDURES

3.1 Previous Borehole Investigations (2000 and 2015)

Two boreholes were advanced at this site as part of a 2000 preliminary foundation investigation by Golder for the replacement of the existing 4th Line underpass. Borehole B2-1 was advanced on the east side of Highway 400 to a depth of about 11 m, and Borehole B2-2 was advanced on the west side of Highway 400 to a depth of about 9.5 m, at the locations shown on Drawing 1. The water level in the open boreholes was observed during and following the drilling operations and a piezometer was installed in Borehole B2-1 to allow monitoring of the groundwater level at the site. These boreholes were advanced using solid stem augers, and soil samples were obtained at approximately 0.75 m and 1.5 m intervals of depth, using a 50 mm outer diameter split-spoon sampler driven by a manual hammer in accordance with the Standard Penetration Test (SPT) procedure.[1]

Four boreholes were advanced near the proposed abutment and pier locations as part of an updated preliminary foundation investigation completed by Golder in June 2015, at the locations shown on Drawing 1. These boreholes were advanced at least 3 m below "refusal", defined as a material for which the SPT 'N'-values exceed 100 blows per 0.3 m of penetration. Boreholes BH1/BH1B were advanced on the west side of Highway 400 near the proposed west abutment to a maximum depth of 18.9 m (Borehole BH1 encountered auger refusal on a probable boulder at a depth of 11.6 m, and was abandoned, then Borehole BH1B was redrilled adjacent to Borehole BH1).

[1] ASTM D1586 – Standard Test Method for Standard Penetration Test and Split Barrel Sampling of Soils.

Borehole BH2 was drilled on the west side of Highway 400, behind the existing west abutment and near the proposed centre pier, to a depth of 20.4 m. Borehole BH3 was drilled near the proposed east abutment to a depth of 18.7 m. These boreholes were advanced using hollow stem augers and soil samples were obtained at approximately 0.75 m and 1.5 m intervals of depth, using a 50 mm outer diameter split-spoon sampler driven by an automatic hammer in accordance with the SPT procedure.

The borehole records from the 2015 investigation are contained in Appendix A, along with the current investigation data. The borehole records from the 2000 investigation are contained in Appendix C.

3.2 2017 Borehole Investigation

Seven additional boreholes were drilled at the 4th Line site in January 2017. Boreholes 17-F1 to 17-F3 were drilled along the toes of the existing 4th Line embankment west of Highway 400, and Boreholes 17-F5 to 17-F7 were drilled along the toes of the existing 4th Line embankment east of Highway 400, to provide information for the embankment grade raise and associated widening. Borehole 17-F4 was drilled at the proposed centre pier, on the existing west shoulder of Highway 400. The locations of these boreholes are shown in plan on Drawing 1, and the records of these boreholes are contained in Appendix A.

The boreholes were drilled using a CME-55 track-mounted drill rig supplied and operated by Tri-Phase Environmental Inc. of Mississauga, Ontario. The boreholes were advanced through the overburden using 110 mm outside diameter hollow stem augers. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth, using a 50 mm outside diameter split-spoon sampler driven by an automatic hammer in accordance with the SPT procedure.

The groundwater conditions and water level in the open boreholes were observed during and immediately following the completion of drilling operations. A piezometer was installed in Borehole 17-F4, to allow monitoring of the groundwater level at the centre pier. The piezometer consists of a 19 mm diameter PVC pipe, with a slotted screen sealed within the sandy silt to silty sand till deposit. The borehole and annulus surrounding the piezometer pipe above the screen and sand pack were backfilled with bentonite pellets to near the ground surface and the road pavement was reinstated using concrete and cold asphalt patch. The piezometer installation details and water level readings are shown on the record for Borehole 17-F4 in Appendix A. All other boreholes were backfilled upon completion of drilling in accordance with Ontario Regulation 903 (as amended).

The field work was observed by a member of Golder's engineering staff who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, and logged the boreholes. The soil samples were identified in the field, placed in appropriate containers, labelled and transported to Golder's Mississauga geotechnical laboratory where the samples underwent further visual examination. Classification testing (water content, grain size distribution and Atterberg limits) was carried out on selected soil samples; all of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. The results of the geotechnical laboratory testing are included in Appendix B.

The as-drilled borehole locations were measured relative to the existing on-site features shown on the Digital Terrain Model (DTM) for the site, and the ground surface elevations were determined from the DTM. The borehole locations provided on the borehole records and shown on Drawing 1 are given using MTM NAD83 northing and easting coordinates, and the ground surface elevations are referenced to geodetic datum. The borehole locations, ground surface elevations and drilled depths are summarized below:

Borehole Number	Location (MTM NAD83)[1]		Ground Surface Elevation (m)[2]	Borehole Depth (m)
	Northing (m)	Easting (m)		
17-F1	4899629.1	291316.2	285.1	4.9
17-F2	4899614.3	291375.2	283.8	5.0
17-F3	4899672.1	291409.5	284.4	9.5
17-F4	4899671.0	291464.1	285.9	7.9
17-F5	4899656.6	291519.8	285.7	9.4
17-F6	4899709.9	291554.9	285.7	5.0
17-F7	4899719.3	291604.3	286.7	6.6

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

As delineated in *The Physiography of Southern Ontario*[2], this section of Highway 400 is located within the Peterborough Drumlin Field. The surficial soils in the Peterborough Drumlin Field consist of sand to sand and gravel deposits, and silt/sand till deposits. Deposits of silt, clay or peat may be found in the lower-lying areas between drumlins.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes advanced as part of the 2015 preliminary investigation and 2017 detailed design investigation, together with the results of in situ and geotechnical laboratory testing, are presented on the borehole records and laboratory test summary figures in Appendices A and B, respectively. The borehole records and geotechnical laboratory testing results from the 2000 investigation are presented in Appendix C. The SPT "N" values presented on the borehole records and in Section 4.2 are uncorrected. Per the Canadian Foundation Engineering Manual (*CFEM*, 2006), the energy delivered to the drill rod varies with the hammer release system, hammer type, anvil and operator characteristics. It should be noted that different hammer release systems were used during the 2000 investigation (manual hammer) and the 2015 and 2017 investigations (automatic hammer) and as such SPT "N" values measured during the 2000 investigation may be higher than the SPT "N" values measured during the 2015 and 2017 investigations within the same deposit.

The interpreted stratigraphic profile and cross-sections are shown on Drawings 1 and 2. The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic profile and cross-sections are inferred from observations of drilling progress and 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.

The subsurface conditions at the site consist of the following:

- A layer of asphalt and fill material was encountered immediately below ground surface in those boreholes drilled through the existing Highway 400 or 4th Line embankments.

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

- A thin layer of topsoil was encountered in the boreholes drilled along the embankment toes; the topsoil overlies a thin layer of fill material associated with the 4th Line embankment toe in many of the boreholes. In addition, a layer of organic sandy silt was encountered in some of the boreholes on the east side of Highway 400.
- The fill and topsoil are generally underlain by a layer of clayey silt to silty clay that has been interpreted as a till in some locations; this surficial cohesive deposit was not encountered in some boreholes.
- The clayey silt to silty clay deposit is underlain by a non-cohesive till deposit that varies from sandy silt to silty sand; a sand layer was encountered within this till deposit in the boreholes in the vicinity of the 4th Line underpass. The sandy silt to silty sand till grades to a clayey silt to silty clay till in some locations, such as in the vicinity of Boreholes 17-F2 and 17-F6.

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

4.2.1 Asphalt

An approximately 265 mm thick layer of asphalt was encountered in Borehole 17-F4, located on the existing west shoulder of Highway 400 near the proposed centre pier. In Boreholes BH1, BH2 and BH3 drilled through the 4th Line pavement, 100 mm to 200 mm of asphalt was encountered.

4.2.2 Fill

Approximately 2.1 m of fill material was encountered below the asphalt in Borehole 17-F4, drilled through the Highway 400 shoulder, and about 7.6 m to 7.9 m of fill was encountered below the asphalt in Boreholes BH1/1B, BH2 and BH3 drilled through the 4th Line pavements. Fill material was also encountered below the topsoil in Boreholes 17-F1 to 17-F3 and 17-F5, which were advanced near the toes of the 4th Line embankment; in these boreholes, the encountered fill is approximately 0.4 m to 1.1 m thick. The base of the fill was encountered between Elevation 283.0 m and 285.0 m in the boreholes.

The majority of the fill material is described as non-cohesive, varying in composition from silt and sand to silty sand containing trace to some gravel and trace to some clay, sand containing some gravel and silt, and sand and gravel. In Boreholes 17-F1 and 17-F3 near the toe of the 4th Line embankment west of Highway 400, the fill consists of clayey silt containing some sand and trace gravel. The grain size distributions test results for six samples of fill material obtained during the 2015 and 2017 investigations are shown on Figure B1 in Appendix B. In addition, some of the recovered fill samples were observed to contain asphalt fragments, organics and clay pockets/clayey silt lenses, as noted on the borehole records. A cobble, inferred from auger grinding at a depth of about 7.6 m below existing ground surface, was encountered within the embankment fill in Borehole BH2.

Atterberg limits tests were completed on four samples of the fill material, including two samples of clayey silt fill, and two samples from zones/lenses within the non-cohesive fill. These tests measured plastic limits of about 10 to 14 per cent, liquid limits of about 16 to 23 per cent, and plasticity indices of about 4 to 12 per cent. These results which are plotted on a plasticity chart on Figure B2 in Appendix B, confirm that the fill material in Boreholes 17-F1 and 17-F3 is clayey silt of low plasticity, and that the fines portion of lenses or layers within the predominantly non-cohesive fill in Boreholes BH2 and BH3 consists of clayey silt of low plasticity, or silt of slight plasticity. The natural water content measured on soil samples from the 2015 and 2017 investigations range from about 4 to 14 per cent, except for the cohesive fill samples in Boreholes 17-F1 and 17-F3 where natural water contents of about 20 to 22 per cent were measured.

The SPT "N" values measured within the fill generally range from 0 blows (i.e. weight of hammer) to 29 blows per 0.3 m of penetration, indicating a variable, very loose to compact relative density. Higher SPT "N" values were measured in the silty sand to sand fill below the asphalt in Borehole 17-F4 (58 blows per 0.3 m of penetration), and near the bottom of the fill in Boreholes BH2 and BH3 (49 and 59 blows per 0.3 m of penetration), indicating that some portions of the non-cohesive fill have a dense to very dense relative density. The thin cohesive fill layers in Boreholes 17-F1 and 17-F3 have a firm to stiff consistency, based on SPT "N" values of 4 to 10 blows per 0.3 m of penetration.

4.2.3 Topsoil / Organic Sandy Silt

An approximately 100 mm to 500 mm thick layer of topsoil was encountered immediately below ground surface in Boreholes 17-F1 to 17-F3 and 17-F5 to 17-F7, which were drilled at the toes of the 4th Line embankment.

A layer of black organic sandy silt was encountered below the topsoil or fill in Boreholes BH3, 17-F5 to 17-F7, and B2-1, all located east of Highway 400; a thin layer of organic silt was also encountered below the 4th Line embankment fill in Boreholes BH1 and BH2 near the proposed west abutment and pier, respectively. This layer is approximately 0.1 m to 1.8 m in thickness, with its base encountered between Elevation 283.9 m and 284.8 m. The organic content measured on four selected samples of this organic layer range from 7 to 10 per cent. Grain size distribution tests were completed on two selected samples, and the results are shown on Figure B3 in Appendix B. The measured SPT "N" values within the organic deposit range from 4 to 16 blows per 0.3 m of penetration, indicating a loose to compact relative density.

4.2.4 Upper Clayey Silt to Silty Clay (Till)

An upper cohesive deposit was encountered below the topsoil, fill and organic sandy silt (where present) in Boreholes BH1, BH2, 17-F2 to 17-F4, and 17-F5 and 17-F7. This upper cohesive deposit was not encountered in the vicinity of the proposed east abutment (Borehole BH3), and at select locations along the west and east approach embankments (Boreholes 17-F1 and 17-F6). Where encountered, the deposit is between 0.7 m and 3.3 m in thickness, with its base between Elevation 279.8 m and 283.8 m at the borehole locations.

The deposit consists of clayey silt to silty clay, containing trace to some sand and trace to some gravel; portions of the deposit are described as sandy clayey silt (i.e., containing a higher proportion of sand). As a result of the proportion of sand and gravel, this deposit was interpreted to be a till in some locations in the 2000 and 2015 investigations, although the results of limited grain size distribution tests (see Figure B4 in Appendix B, and Figure 1 in Appendix C) show that portions of this stratum do not exhibit a typical till-like distribution.

Atterberg limits testing was completed on four samples of the clayey silt to silty clay from the 2015 and 2017 investigations, and measured plastic limits of 11 to 19 per cent, liquid limits of 19 to 41 per cent, and plasticity indices of 8 to 24 per cent. These results, which are plotted on a plasticity chart on Figure B5 in Appendix B, confirm that the deposit varies in composition from clayey silt of low plasticity to silty clay of medium plasticity. The natural water content measured on samples of this upper clayey silt to silty clay deposit range from about 24 to 30 per cent.

The SPT "N" values measured within the upper clayey silt to silty clay deposit range from 10 blows to 25 blows per 0.3 m of penetration, suggesting a stiff to very stiff consistency.

4.2.5 Sandy Silt to Silty Sand Till (including Lower Silty Clay Till)

The above-noted fill and native soil deposits are underlain by a generally non-cohesive deposit that has been classified and interpreted as a till in the 2015 and 2017 investigations. The surface of this deposit was encountered between Elevation 279.8 m and 284.8 m in the 2015 and 2017 boreholes, and the boreholes generally terminate in this deposit, which extends to about Elevation 272 m in the deepest boreholes at the site. It is noted that this deposit contains a sand interlayer, which is discussed in greater detail in Section 4.2.6.

The deposit varies in composition from sandy silt, to silt and sand, to silty sand, containing trace to some clay and trace to some gravel; in Boreholes 17-F2 and 17-F6, the till deposit grades to clayey silt containing trace to some sand and trace gravel. The results of grain size distribution tests on eleven samples of the non-cohesive till are shown on Figures B6A and B6B in Appendix B. Auger grinding was noted during drilling at a depth of about 13.1 m (Elevation 279.0 m) in Borehole BH2, and auger refusal was encountered at a depth of 11.6 m (Elevation 280.2 m) in Borehole BH1, suggesting the presence of cobbles and boulders within this till deposit.

Atterberg limits testing was completed on five samples of the till from the 2015 and 2017 investigation, with the results plotted on a plasticity chart on Figure B7 in Appendix B. For four of the tested samples, the plastic limits range from 9 to 12 per cent, the liquid limits from 11 to 15 per cent, and the plasticity indices from less than 1 per cent to 4 per cent; these test results, together with the grain size distribution data, are the basis for classification of the majority of this till deposit as non-cohesive, or as having fines with slight plasticity. The limits test on one sample of the till deposit measured a plastic limit of 13 per cent, a liquid limit of 29 per cent, and a plasticity index of 16 per cent; this test result confirms that the tested portion of the deposit grades to a clayey silt of low plasticity. The natural water content measured on samples of the non-cohesive portions of the till deposit ranges from about 6 to 17 per cent, while the natural water content measured on two sample of the cohesive till are about 24 and 28 per cent.

The SPT "N" values measured within the non-cohesive portions of this till deposit range from 4 to greater than 100 blows per 0.3 m of penetration, indicating a variable, loose to very dense relative density; however, the SPT "N" values are generally greater than 20 blows per 0.3 m of penetration, and become denser with depth. The SPT "N" values measured within the cohesive portion of the till deposit range from 22 to 54 blows per 0.3 m of penetration, suggesting a very stiff to hard consistency.

4.2.6 Sand Layers within Till Deposit

A layer of sand is present within the predominantly sandy silt to silty sand till deposit. This layer was encountered in Boreholes BH1B, BH2 and BH3, with its surface between approximately Elevation 277.3 m and 284.0 m, generally rising from west to east as shown on the profile on Drawing 1; the layer is between 1.5 m and 3.7 m thick in these boreholes. A sand layer was also encountered in Borehole 17-F7 near the east limit of the investigation, with its surface at approximately Elevation 281.2 m; the borehole was terminated within this layer after penetrating it for 1.1 m.

These layers/interlayers consist of sand containing trace to some silt and trace gravel. The results of grain size distribution tests on two samples are shown on Figure B8 in Appendix B. The natural water content measured on samples from this layer ranges from about 13 to 17 per cent.

The SPT "N" values measured within the sand layers range from 23 to 64 blows per 0.3 m of penetration, indicating a compact to very dense relative density.

4.3 Groundwater Conditions

The water level encountered during drilling is recorded on the borehole records in Appendix A; however, these water levels do not necessarily represent the long-term, stabilized groundwater level at the site.

A standpipe piezometer was installed in Borehole B2-2 from the 2000 investigation, Boreholes BH1B and BH3 near the proposed west and east abutments during the 2015 investigation, and Borehole 17-F4 near the centre pier during the 2017 investigation. The groundwater level measured in the piezometers is shown on the borehole records and summarized below:

Borehole No.	Depth to Water Level (m)	Groundwater Elevation (m)	Date of Measurement
B2-2	6.0	279.9	October 26, 2000
	1.9	284.0	January 19, 2001
	1.1	284.8	March 15, 2001
BH1B	6.3	285.5	July 6, 2015
BH3	7.2	284.8	June 11, 2015
	7.2	284.8	July 6, 2015
17-F4	1.5	284.4	January 18, 2017

The water level at the site is expected to fluctuate seasonally in response to changes in precipitation and snow melt, and is expected to be higher during the spring and periods of precipitation.

5.0 CLOSURE

This Foundation Investigation Report was prepared by Andrea Begin, EIT, and reviewed by Kevin Bentley, P.Eng., a geotechnical engineer and Associate with Golder. Lisa Coyne, P.Eng., a Principal and Designated MTO Foundations Contact for Golder, conducted an independent technical and quality review of this report.

GOLDER ASSOCIATES LTD.

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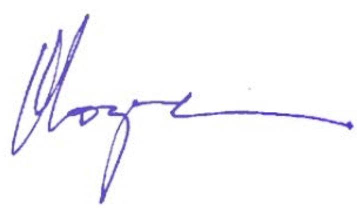

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PART B

FOUNDATION DESIGN REPORT
HIGHWAY 400/4th LINE UNDERPASS REPLACEMENT
MTO STRUCTURE SITE NO. 30-212
DB 2016-2021

April 17, 2017
Report No. 1663130

6.0 DISCUSSION AND FOUNDATION ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides foundation recommendations for the design-build for the proposed replacement of the Highway 400-4th Line underpass (MTO Structure Site No. 30-212) and associated wingwalls and retaining walls. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the 2015 and 2017 investigations at this site, with the earlier preliminary foundation recommendations re-evaluated in the context of the Canadian Highway Bridge Design Code CSA S6-14. The interpretation and recommendations contained in this report are intended to provide the designers with sufficient information to carry out the detail design of the underpass and associated wingwall/retaining wall foundations.

Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project, and for which special provisions may be required during construction. The design-build contractor should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods and scheduling.

6.2 Selection of Preferred Foundation Alternatives

According to the available information, the existing single-span structure is supported on spread footings that are founded at approximately Elevation 284.5 m; the existing structure is understood to have performed satisfactorily, with no visual evidence of undue settlement or distortion. The existing underpass will be removed and replaced with a two-span structure along the same alignment, under a full closure/detour on 4th Line. In the future ultimate configuration, Highway 400 will be widened by approximately 35 m to the west with the existing centreline re-aligned to the west of the existing highway, and with its grade maintained at approximately Elevation 286 m to 286.5 m at the structure site. In the interim condition, the Highway 400 northbound and southbound lanes will be maintained between the new centre pier and east abutment. The 4th Line grade will be raised by about 1.5 m and 2 m at the east and west abutments, respectively, to accommodate the longer-span structure.

Shallow and deep foundation design alternatives have been considered for support of the new two-span structure as part of the design-build process. The subsurface conditions are suitable for driven pile foundations at the abutment and pier locations, with the piles driven into “100-blow” till which was encountered below approximately Elevation 275.5 m to 276.5 m; therefore the minimum required pile length of 5 m for integral abutments will be achievable. Pile driving shoes are recommended to protect the pile tips from damage during driving into the very dense till, which contains cobbles and boulders. An integral abutment structure has been selected with the pile caps perched above the Highway 400 grade, with an interim false abutment configuration at the east abutment, and an open configuration (i.e., abutment foreslope) in front of the west abutment. Some subexcavation of the near-surface organic layer will be required for the new retained soil system (RSS) wall in front of the east abutment for the interim configuration.

The detail design stage of investigation focused on additional investigation at the centre pier to assess the feasibility of a shallow foundation for support of this element, as an alternative to a more expensive deep foundation system. Borehole 17-F4 was advanced at the north end of the proposed pier, and encountered very dense to compact sand to silt and sand fill extending to Elevation 283.5 m, a depth of approximately 2.4 m below the Highway 400 grade. This fill is underlain by a 1.6 m thick deposit of stiff to very stiff clayey silt to silty clay, and then compact to very dense sandy silt to silty sand till. Shallow groundwater is present at a depth of approximately 1.5 m (Elevation 284.4 m, although this level may be higher during wet periods of the year), perched on top of the clayey silt to silty clay deposit, such that the lower portion of the fill is water-bearing. Based on the detailed design assessment, the cohesive deposit and underlying competent till deposit (within the zone of influence for shallow foundations) are considered suitable for support of a strip footing at the centre pier location, and this foundation type has been selected as the preferred alternative for support of the pier. The founding level for this footing has been selected based on penetrating through the water-bearing fill material to bear directly on native soil; this additional embedment has the added advantage of increasing the geotechnical resistance values for this foundation element.

6.3 Consequence and Site Understanding Classification

In accordance with Section 6.5 of CSA S6-14 and its Commentary, this Highway 400 structure site may be classified as having large traffic volumes and its performance as having potential impacts on other transportation corridors. Therefore, a “typical” consequence classification (Table 6.1, CSA S6-14) has been adopted in the development of the factored geotechnical resistances. Based on the level of site investigation completed as part of the 2015 and 2017 investigations, the degree of site and prediction model understanding has been assessed as “typical” (Table 6.2, CSA S6-14). The appropriate ULS and SLS consequence factor, Ψ, and geotechnical resistance factors, ϕ_{gu} and ϕ_{gs}, have been used in the development of the factored ultimate and serviceability geotechnical resistances, global stability and settlements presented in this report.

6.4 Shallow Foundations for Centre Pier

The 2015 Preliminary Foundation Report recommended that a strip footing for the centre pier be founded at Elevation 280 m, about 6 m below the Highway 400 grade, and consequently driven piles were adopted for support of the pier at the preliminary design stage. However, based on the additional borehole advanced within the pier footprint in the 2017 investigation, the centre pier can be founded on a strip footing, although some subexcavation and a founding level deeper than that required strictly for frost protection are recommended. Protection systems will be required for the pier footing construction, and dewatering will be required for any foundation removal or excavations that extend to or below approximately Elevation 285.5 m.

6.4.1 Founding Elevation and Geotechnical Axial Resistances

The centre pier footing should be provided with a minimum 1.5 m of soil cover for frost protection as per OPSD 3090.101 *(Frost Penetration Depths for Southern Ontario),* as measured vertically and perpendicular from the face of the abutment slope to the edge of the underside of the footing. If adequate soil cover cannot be provided for the footing, rigid styrofoam insulation could be installed to compensate for the lack of soil cover and provide protection from frost penetration.

If the centre pier footing is founded at a depth of 1.5 m for frost protection (i.e., approximately Elevation 284.5 m), it will be near or below the groundwater level; this represents water that is “perched” in a shallow aquifer atop the clayey silt to silty clay deposit. It can be difficult to maintain a dry and stable subgrade in the silt/sand materials underlain at shallow depth by lower permeability soils, and in addition the soils at this elevation consist of fill material. Therefore, it is recommended that the centre pier footing be extended deeper, to Elevation 283.5 m, to bear directly on the clayey silt to silty clay deposit; this additional embedment depth will also increase the geotechnical resistance for the centre pier foundation. Alternatively, the footing may be founded higher, at Elevation 284.5 m, following subexcavation of the saturated silt/sand fill materials and replacement with compacted granular fill.

The following table summarizes the factored ultimate and serviceability geotechnical resistances for various footing widths, for foundations at Elevation 284.5 m (following subexcavation to Elevation 283.5 m and backfill with compacted granular fill) and 283.5 m.

Footing Width (m)	Approximate Foundation Elevation (m)	Factored Ultimate Geotechnical Resistance (kPa) [1]	Factored Serviceability Geotechnical Resistance (kPa) [1,2]
3.0	284.5 [3]	350	350
3.0	283.5	400	375
3.5	284.5 [3]	375	350
3.5	283.5	450	375
4.0	284.5 [3]	400	300
4.0	283.5	475	325

NOTES:

1. Factored geotechnical resistances have been provided in accordance with the 2014 Canadian Highway Bridge Design Code (CSA S6-14).
2. Factored serviceability geotechnical resistances have been provided for 25 mm of settlement.
3. Subexcavation required to Elevation 283.5 m to remove silt/sand fill, followed by replaced with compacted granular fill.

The factored geotechnical resistances provided above are given for loads that will be applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the footing, inclination of the load should be taken into account in accordance with Section 6.10.4 of the *CHBDC* (CSA S6-14).

The cohesive soils that will be exposed within the centre pier footing excavation will be susceptible to disturbance from construction traffic, precipitation and ponded water. To limit the effects of this disturbance, it is recommended that a concrete working slab be placed on the subgrade within four hours after preparation, inspection and approval of the subgrade. The minimum thickness of the concrete working slab should be 100 mm and the concrete should have a minimum 28-day compressive strength of 20 MPa.

6.4.2 Resistance to Lateral Loads

Resistance to lateral forces/sliding resistance between a cast-in-place concrete footing and the subsoils should be calculated in accordance with Section 6.10.5 of CSA S6-14. The coefficient of friction, tan φ', for the interface between a cast-in-place concrete footing and the stiff to very stiff clayey silt to silty clay deposit may be taken as 0.53. In accordance with Table 6.2, CSA S6-14, a factor of ϕ_{gu}= 0.8 should be applied for assessment of the sliding resistance.

6.5 Driven Steel H-Pile Foundations

6.5.1 Pile Tip Elevations and Geotechnical Axial Resistances

The abutments and associated wingwalls for the replacement structure may be supported on steel H-piles driven to found within the very dense ("100-blow") sandy silt to silty sand till deposit. Driven pile foundations may also be used to support the centre pier, and foundation recommendations have been included herein although shallow foundations are recommended for support of the pier.

The pile caps should be founded at a minimum depth of 1.5 m for frost protection per OPSD 3090.101 *(Frost Penetration Depths for Southern Ontario),* as measured vertically and/or perpendicular from the face of the abutment slope to the edge of the underside of the pile cap. If adequate soil cover cannot be provided for the pile cap, rigid styrofoam insulation could be installed to compensate for the lack of soil cover and provide protection from frost penetration.

The design pile tip elevation and factored ultimate geotechnical axial resistance (f-ULS) and the factored serviceability geotechnical resistance (f-SLS, for 25 mm of settlement) for driven HP310x110 piles is summarized below, assuming the use of perched integral abutments:

Foundation Element	Approx. Surface Elevation of “100-Blow” Soil (m)	Estimated Design Tip Elevation* (m)	Approximate Pile Length (m)	f-ULS (kN)	f-SLS (kN)
West Abutment	276.5	274.5*	13.5*	1,400	N/A **
Centre Pier	275.5	273.5*	11*	1,300	N/A **
East Abutment	278.0	276.0*	12*	1,400	N/A **

* There is potential that the piles will have to be driven deeper into the 100-blow till deposit to achieve these design resistances.
** f-SLS for 25 mm of settlement will be greater than f-ULS and as such, the SLS condition does not apply.

Based on the soil density and potential for cobbles/boulders in the till deposit at this site, the piles should be reinforced at the tip with driving shoes in accordance with OPSD 3000.100 (Steel H-Pile Driving Shoe), to reduce the potential for damage to the piles during driving.

Pile installation should be in accordance with OPSS 903 (Deep Foundations). The pile termination or set criteria will be dependent on the pile driving hammer type and helmet; the criteria must therefore be established at the time of construction after the piling equipment is known. The pile capacity should be verified in the field by the use of the Hiley method (MTO’s Standard Drawing SS103-11, Pile Driving Control) during the final stages of driving to verify that the required ultimate capacity has been achieved; retapping of piles should be completed in accordance with OPSS 903. The following note should be shown on the Foundation Layout drawing for the abutments:

Piles shall be driven in accordance with OPSS 903 and SS103-11 using an ultimate geotechnical resistance of 2,800 kN per pile.

6.5.2 Resistance to Lateral Loads

The design of piles subjected to lateral loads should take into account the batter of the pile (where applicable), the relative rigidity of the pile to the surrounding soil, the fixity condition at the head of the pile, the structural capacity of the pile to withstand bending moments, the soil resistance that can be mobilized, the tolerable lateral deflections at the head of the pile, and pile group effects. For a longer, more flexible pile, the maximum yield moment of the pile may be reached prior to mobilization of the lateral geotechnical resistance. For design purposes, both the structural and geotechnical resistances should be evaluated to establish the governing case.

The resistance to lateral loading in front of a single pile may be calculated using subgrade reaction theory where the coefficient of horizontal subgrade reaction, k_h (kPa/m), is based on the following equations (*CFEM*, 1992 as referenced in the *CHBDC CSA S6-06 Commentary*):

For cohesionless soils:

$$k_h = \frac{n_h z}{B}$$

where: n_h = coefficient related to soil density (kPa/m)
z = depth (m)
B = pile diameter or width (m)

For cohesive soils:

$$k_h = \frac{67 s_u}{B}$$

where: s_u = undrained shear strength of the soil (kPa)
B = pile diameter or width (m)

The values of n_h (Terzaghi, 1955 and Reese, 1975) and s_u to be incorporated into the calculations of the coefficient of horizontal subgrade reaction (k_h) to be used for the structural analysis of the piles are summarized below, based on the soil strata shown on Drawing 1. Where integral abutment design includes the installation of CSP liners (with the annular space between the pile and liner filled with uniform-grained, uncompacted sand), the upper portion of the H-piles installed inside the CSP will be free to flex and move laterally. With this design, the passive lateral resistance over the length of the CSP liner should be neglected. Accordingly, the values given in the table below are provided for soils below the base of the CSP liners at the abutment locations, and below the pile cap underside at the centre pier location.

Soil Unit	**Elevation (m)**			**n_h (kPa/m)**	**s_u (kPa)**
	West Abut	Centre Pier	East Abut		
Stiff to very stiff upper clayey silt to silty clay	Above 281.5	Above 281.0	N/A	-	150
Compact to very dense upper silt/sand till	281.5-278.5	281.0-277.0	N/A	15,000	-
Compact sand	N/A	277.0-276.0	Above 280.5	7,500	-
Dense to very dense sand	278.5-277.0	N/A	N/A	20,000	-
Dense to very dense silt/sand till	Below 277.0	Below 276.0	Below 280.5	33,000	-

Group action for lateral loading should also be considered when the pile spacing in the direction of the loading is less than six to eight pile diameters. Group action can be evaluated by reducing the coefficient of horizontal subgrade reaction (NAVFAC, 1982) in the direction of loading by a reduction factor, R, as follows:

Pile Spacing in Direction of Loading (d = pile diameter)	**Subgrade Reaction Reduction Factor, R**
8d	1.00
6d	0.70
4d	0.40
3d	0.25

The subgrade reaction reduction factor should be interpolated for pile spacings in between those provided in the above table.

6.6 Lateral Earth Pressures for Design

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

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

- Select, free draining granular fill meeting the specifications of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II should be used as backfill behind the walls. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (Compacting).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the wall stem. Other surcharge loadings should be accounted for in the design as required.
- For restrained walls, granular fill should be placed in a zone with the width equal to at least 1.5 m behind the back of the wall (in accordance with Figure C6.20(a) of the *Commentary* to the *CHBDC (CSA S6-2014*). For unrestrained walls, fill should be placed within the wedge-shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (in accordance with Figure C6.20(b) of the *Commentary* to the *CHBDC (2014*). The following parameters (unfactored) may be used:

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

Where the wall support does not allow lateral yielding, at-rest earth pressures should be assumed for the geotechnical design. Where the wall support allows lateral yielding of the stem, active earth pressures should be used in the geotechnical design of the wall structure(s). The movement required to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.12.1 and Table C6.6 of the *Commentary* to the *CHBDC (CSA S6-14)*.

6.7 Retained Soil System (RSS) Walls

Relatively short retaining walls are required adjacent to the abutments and wingwalls at this site. These walls will be constructed parallel to 4th Line, with the base of the wall "stepped up" into the approach embankment slope as the retaining wall extends away from the abutment. Retained soil system (RSS) walls are considered to be a geotechnically suitable option for this application, as an alternative to concrete retaining walls.

An RSS wall is also required in front of the east abutment, parallel to Highway 400, for the “false abutment” configuration during the interim condition.

6.7.1 Founding Elevations

The front facing panels and the reinforced soil mass of the RSS wall should be founded below any existing topsoil and/or unsuitable fill soils. Typically, the front facing panels should be embedded a minimum of 500 mm below the lowest surrounding grade, and supported on a levelling pad. The levelling pad should consist of a minimum thickness of 300 mm of compacted OPSS.PROV 1010 Granular A material, which should extend at least 0.5 m beyond the outside edges of the facing footing, then outward/downward at a slope of 1H:1V.

For the RSS wall that is proposed in front of the east abutment at this site, it is recommended to subexcavate the organic sandy silt layer from below the footprint of the facing panels and reinforced soil mass. Based on the results from Borehole BH3 near the new east abutment, and Borehole B2-1 drilled as part of the 2000 investigation near the north end of the proposed wall, there is potential for topsoil/organic soils to be present below the proposed RSS wall alignment. This topsoil/organic soil extends from about Elevation 284.3 m to 284 m in Borehole BH3 near the abutment, and from about Elevation 284.7 m to 283.9 m in the borehole near the north end of the wall. This 0.3 m to 0.8 m thick layer of organic soil would undergo settlement, particularly in the wall areas that extend north and south of the limits of the existing 4th Line embankment. The settlement could vary along the length of the wall, owing in part to the varying height of the wall, and the potential variability associated with the organic deposit.

The subexcavation for the RSS wall in front of the east abutment should extend to Elevation 284 m, which will extend below the groundwater table at the site. To limit groundwater control requirements associated with this operation, it is recommended that the subexcavation be completed in strips limited to 5 m in maximum dimension, with immediate backfilling of the subexcavated area with OPSS.PROV 1010 Granular B Type II material. This granular material will minimize segregation during placement in wet conditions, will behave as an appropriate “filter” relative to the native soils at the site, and will form an acceptable base for construction of an RSS wall of this height. A non-standard Special Provision has been developed to address this procedure, and is included in Appendix D.

6.7.2 Geotechnical Resistance/Reaction

For the RSS facing panels founded on a 0.6 m wide footing constructed on a compacted granular pad as described above, the wall design may be completed based on a factored ultimate geotechnical resistance of 150 kPa, and a factored serviceability geotechnical resistance (for 25 mm of settlement) of 100 kPa.

Assuming that an RSS wall acts as a unit and use the full width of the reinforced soil mass, a factored ultimate geotechnical resistance of 350 kPa may be used for design. The factored serviceability geotechnical resistance, for 25 mm of settlement, may be taken as 200 kPa. The minimum reinforcing length for the reinforced soil mass is provided in Section 6.7.4, based on global stability requirements.

6.7.3 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces/sliding resistance between the compacted fill of the RSS wall and the subgrade should be calculated in accordance with Section 6.10.5 of CSA S6-14. The coefficient of friction, tan φ’, for the interface between the compacted granular fill of the RSS wall and the properly prepared subgrade may be taken as 0.57. In accordance with Table 6.2, CSA S6-14, a factor of ϕ_{gu}= 0.8 should be applied for assessment of the sliding resistance.

6.7.4 Global Stability of RSS Walls

Limit equilibrium stability analyses for the RSS wall in front of the east abutment, as well as the RSS walls adjacent to the wingwalls, were carried out using the commercially available program Slide (Version 6.0), developed by Rocscience Inc., employing the Morgenstern-Price method of analysis. For all analyses, the factors of safety of numerous potential failure surfaces were computed to establish the minimum factor of safety (i.e., the ratio of the forces tending to resist failure to the driving forces tending to cause failure). For the purpose of the stability analyses for the RSS walls, the factor of safety is equal to the inverse of the product of the consequence factor, Ψ, and the geotechnical resistance factor, ϕ_{gu}. (i.e. $FoS = 1/(\Psi \cdot \phi_{gu})$). Accordingly, a target minimum factor of safety of 1.5 has been used for the design of the RSS walls against deep-seated global failures in the long-term/permanent condition, as per Table 6.2 of CHBDC (2014).

The native overburden at this site is generally comprised of stiff to very stiff cohesive deposits or compact to very dense non-cohesive materials. Based on global stability analyses, the factor of safety against global instability of the RSS walls at this site is greater than 1.5 in long-term, effective stress conditions. Figure 1 shows the results of the analysis for one selected wall configuration, representing the maximum RSS wall height in front of the east abutment.

Based on the RSS wall stability analyses and the proposed embankment geometry above and/or below the RSS walls, the following minimum reinforcement lengths are required to obtain a minimum factor of safety of 1.54 against global instability:

Wall Location	RSS Wall Height (m)	Ratio of Minimum Reinforced Mass Width to Wall Height
Adjacent to wingwalls (perched in approach embankments)	Up to approximately 2 m*	1.0
East abutment RSS wall	4.6	1.0
	3.4	1.0
	2.3	1.25

* **NOTE**: The completed, exposed height of the RSS walls adjacent to the abutments (and parallel to 4th Line) will be significantly shorter than the height of the facing panel, based on the proposed finished grading for the embankment slope in front of the wall.

The internal stability of the RSS walls is to be assessed by the proprietary product designer as part of the design of their reinforcement.

6.7.5 Settlement of RSS Walls

Based on the subsurface conditions encountered in the boreholes, and given the grade raise of approximately 1.5 m to 2 m above the current 4th Line grade, the settlement of the RSS walls adjacent to the wingwalls is estimated to be less than 25 mm. For the new RSS wall in front of the east abutment, following subexcavation of the organic deposit and simultaneous backfilling of the subexcavation with Granular B Type II, the settlement is estimated to be less than 25 mm. This settlement is expected to be completed essentially during or upon completion of construction. Therefore, it is anticipated that the settlement performance for RSS walls and their facing panels will be acceptable.

6.8 Approach/High Fill Embankments

Based on observations at the time of Golder's 2015 field investigation, the existing 4th Line embankment side slopes have performed satisfactorily, with no visual evidence of instability or settlement. The existing 4th Line embankment will be raised by approximately 1.5 m to 2 m immediately behind the new east and west abutments, respectively.

6.8.1 Subgrade Preparation and Embankment Construction

The raised/widened 4th Line embankment side slopes should be formed no steeper than 2 horizontal to 1 vertical (2H:1V). Benching the existing embankment side slopes is recommended to "key in" the new fill on the side slopes, in accordance with OPSD 208.010 (Benching of Earth Slopes). Where the grade raise to the 4th Line embankments results in an overall earth embankment height of 8 m or greater, a 2 m wide mid-height bench should be incorporated into the side slope as per OPSD 202.010 (Slope Flattening), to minimize potential erosion on the slope face. To further reduce erosion of the embankment side slopes due to surface water runoff, placement of topsoil and seeding (per OPSS.PROV 804 (Seed and Cover)) should be carried out as soon as practicable after construction of the embankments.

It is recommended that the existing topsoil layer be stripped from within the footprint of the widening, beyond the existing 4th Line embankment toes. The thickness of topsoil encountered in Boreholes 17-F1 to 17-F3 and 17-F5 to 17-F7 varies from 100 mm to 450 mm.

A layer of loose to compact organic sandy silt is present below the topsoil, and in some cases below a thin layer of fill, in Boreholes 17-F5, 17-F6 and 17-F7, which were drilled at the toes of the 4th Line embankment east of Highway 400. This layer is approximately 0.5 m to 2 m thick, and it extends to a depth of 1.2 m, 0.9 m and 2.1 m below the existing ground surface at the borehole locations, respectively. This layer is classified as an organic soil, based on organic contents of about 7 to 10 per cent. Because of its organic content, this material may continue to decompose/compress under the new fill placed on the embankment side slope and at the toe. Therefore, while removal of this material is not strictly required from a global stability perspective (as discussed in Section 6.8.2), it is recommended that partial removal of the organic layer be implemented to improve the settlement performance of the widened embankment side slopes/toes. The following partial removal operation is recommended:

- Strip the topsoil within the footprint of the 4th Line embankment widening.
- Inspect the subgrade below the topsoil; where black, organic soil is present, remove this material to a depth of 1.0 m.
- Backfill the subexcavated area with earth fill, select subgrade material or granular fill, such as OPSS.PROV 1010 Granular B Type II.

6.8.2 Approach/High Fill Embankment Stability

The global stability for the widened/raised approach embankments and high fill embankments to the west and east of the bridge (between approximately Station 9+800 and 10+150) has been assessed relative to CHBDC 2014 (CSA S6-14), based on the results of the boreholes advanced during the 2015 and 2017 investigations. As for the RSS walls, limit equilibrium stability analyses for the 4th Line embankments were carried out using the commercially available program Slide (Version 6.0), developed by Rocscience Inc., employing the Morgenstern-Price method of analysis. Target minimum factors of safety of 1.3 and 1.5 have been used for the design of the 4th Line embankment slopes for temporary and permanent conditions against deep-seated global failures, respectively, as per Table 6.2 of CHBDC (2014).

The results of the global stability analyses for the 4th Line embankments under the proposed grade raise (up to approximately 1.5 m and 2 m immediately behind the east and west abutments, respectively) demonstrate that factors of safety of greater than 1.3 and 1.5 are achieved in short-term and long-term conditions, respectively, assuming that the embankment side slopes are formed no steeper than 2H:1V. An example of the long-term global stability analysis is shown on Figure 2 for a section of 4th Line east of Highway 400, including the presence of an approximately 2 m thick layer of organic sandy silt (similar to that encountered in Borehole 17-F7, and assuming this material extends under the existing 4th Line embankment). This analysis demonstrates that removal or partial removal of the organic layer is not necessary from a global stability perspective; however, it has been recommended to improve the settlement performance of the embankment side slopes and to minimize the potential for slumping at the toes of the 4th Line embankment.

6.8.3 Approach/High Fill Embankment Settlement

The settlement under the approximately 1.5 m to 2 m grade raise/widening on the 4th Line embankment is estimated to be 25 mm or less, based on the subsurface conditions encountered in the boreholes (i.e., limited thicknesses of loose or stiff to very stiff near-surface soils, overlying compact to very dense non-cohesive soils), and correlations with compressibility/modulus based on CFEM (2006) and Bowles (1984). Given the predominantly granular nature of the underlying soils, the majority of the settlement will occur during or immediately following placement and compaction of the fill for the grade raise.

6.9 Construction Considerations

6.9.1 Open-Cut Excavation and Temporary Protection Systems

All excavations must be carried out in accordance with Ontario Regulation 213 (Ontario Occupational Health and Safety Act (OHSA) for Construction Projects). The removal of the existing abutment footings and construction of the new centre pier footing will require excavation to a depth of about 1.5 m to 2.5 m below the existing Highway 400 grade; this excavation will be made through the existing Highway 400/4th Line embankment fill and into native sand/silt soils, and will extend below the groundwater table near a depth of 1.5 m. The new abutment pile caps will be "perched" within the approach embankment fills at about 288 m, and will require excavation to about 4 m to 4.5 m below the existing 4th Line grade. The existing fill material and native stiff to very stiff cohesive deposits, and compact to dense sand/silt deposits, are classified as Type 3 soils above the groundwater table, according to the OHSA. As such, temporary open-cut excavations above the groundwater level should be made with side slopes no steeper than 1H:1V. Where excavations extend below the groundwater table, groundwater control and/or shallower side slopes will be required.

As discussed in Section 6.7.1 for the RSS wall in front of the east abutment, some subexcavation of organic soils will be required within the footprint of this RSS wall, and excavation and backfilling for this area has been addressed via a non-standard special provision.

Temporary protection systems may be required along the existing Highway 400 northbound and southbound lanes to maintain traffic while facilitating the removal of the existing bridge foundations and construction of the new east abutment and centre pier. Temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection System), and the lateral movement should meet Performance Level 2. The selection and design of protection systems adjacent to the existing/proposed footings will be the responsibility of the Design-Build Contractor.

6.9.2 Control of Groundwater

The abutment pile caps will be "perched" at approximately Elevation 288 m, and both the pile caps and augered CSP (corrugated steel pipe) liners will be maintained above the groundwater level at the site.

The excavations for the centre pier and for removal of the existing abutment footings will extend to about Elevation 283.5 m and 284.5 m, respectively, which is approximately 2.5 m and 1.5 m below the Highway 400 grade. These excavations will extend through or into water-bearing silt and sand to silty sand fill, native sand, and native cohesive soils, with the groundwater level anticipated to be at about Elevation 284.5 m, potentially increasing to near Elevation 285 m during wet periods of the year.

Based on the subsurface conditions and proposed founding elevation for the centre pier, and for the footing removals, it is anticipated that groundwater flows can be managed by pumping from properly filtered sumps within the excavation. An assessment of dewatering requirements was completed for the centre pier footing excavation and existing footing removal excavations, using estimated hydraulic conductivities based on correlations with grain size distribution data; the highest correlated permeability, at approximately $2x10^{-5}$ m/s, has been used in the assessment. An estimate of the volume of groundwater that will flow into the open excavations was made using the analytical equation for steady-state flow from an unconfined (water table) aquifer to a theoretical circular well with an area equivalent to that of the excavation (Powers, 2007). Based on these considerations, it is estimated that the groundwater inflow rate into the open excavation at the new centre pier/existing west abutment will be approximately 14,000 L/day; lower groundwater inflow rates are estimated for the shallower excavation for the east abutment footing removal. This estimate is for the groundwater component of flow only, and does not include precipitation or surface water runoff; however, given the size of the excavation, the volume input from precipitation is expected to be relatively insignificant.

Based on the foregoing, it is anticipated that the groundwater pumping requirements for construction associated with the 4th Line underpass replacement will not exceed 50,000 L/day, and therefore a Permit to Take Water (PTTW) or Environmental Activity and Sector Registry (EASR) registration for this portion of the work is not expected to be required. However, these estimates are approximate, are based on limited data, and do not include pumping of precipitation from large storm events; further, they do not include other water control needs as may be required on this project, such as for culvert construction. As the Draft Permit to Take Water can be valid for a period of 30 days until December 2017, it is recommended that the Design-Builder consider obtaining the finalized permit to facilitate the proposed construction, in the event of significant precipitation events or dewatering from multiple excavation areas at one time.

The zone of influence for groundwater control works will be localized at the structure site. Assuming the system is properly constructed and operated such that there is no loss of fine soil particles, the dewatering operations are not expected to cause settlement in the fill and native soils at this site.

6.9.3 Cobbles and Boulders (Obstructions)

Cobbles and boulders are inferred to be present within the soils at this site, based on instances of difficult drilling, grinding augers and/or refusal, as noted on the borehole records. Cobbles and boulders (obstructions) may be encountered during excavation, installation of temporary protection systems and driving of pile foundations. Based on these conditions, it is recommended that driven steel piles be equipped with pile driving shoes (see Section 6.5.1) to minimize the potential for damage to the pile during driving.

6.9.4 Subgrade Protection

The subgrade soils exposed at the centre pier will be susceptible to disturbance from construction traffic, precipitation and ponded water. To limit the effects of this disturbance, a concrete working slab should be placed on the subgrade within four hours after preparation, inspection and approval of the subgrade. The minimum thickness of the concrete working slab should be 100 mm and the concrete should have a minimum 28-day compressive strength of 20 MPa.

6.9.5 Monitoring During and Post-Construction

Based on the estimated magnitude of settlement along the 4th Line embankments under the grade raise behind the new abutments, and given that this settlement is anticipated to occur relatively quickly during and immediately following construction, settlement monitoring is not proposed during the construction period.

In accordance with Section 2.4.9.11 of the RFP, the Design-Build Contractor will complete measurements of differential settlements between the abutments and abutment approaches at Months 3, 6, 12, 18 and 24 of the General Warranty period. Following paving, the elevation shall be measured at the centreline of each lane on 4th Line, at the bridge abutments and at distances of 20 m, 50 m, 75 m and 100 m behind the abutments. These same locations shall be surveyed at Months 3, 6, 12, 18 and 24, with the survey measurements provided to MTO.

7.0 CLOSURE

This Foundation Design Report was prepared and reviewed by Kevin Bentley, P.Eng., a geotechnical engineer and Associate with Golder, and Lisa Coyne, P.Eng., a Principal and Designated MTO Foundations Contact for Golder.

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

Ministry of Transportation Ontario:

Drawing SS103-11 Pile Driving Control

Ontario Occupational Health and Safety Act:

Ontario Regulation 213 Ontario Occupational Health and Safety Act, Construction Projects (as amended)

Ontario Provincial Standard Specifications (OPSS)

OPSS.PROV 501 Construction Specification for Compacting

OPSS.PROV 539 Construction Specification for Temporary Protection Systems

OPSS 903 Construction Specification for Deep Foundations

OPSS.PROV 1010 Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material

Ontario Provincial Standard Drawings (OPSD)

OPSD 202.010	Slope Flattening Using Surplus Excavated Material on Earth or Rock Embankment
OPSD 208.010	Benching of Earth Slopes
OPSD 3000.100	Foundation, Piles, Steel H-Pile, Driving Shoe
OPSD 3090.101	Foundation, Frost Penetration Depths for Southern Ontario
OPSD 3121.150	Walls, Retaining, Backfill, Minimum Granular Requirement

Ontario Water Resources Act:

Ontario Regulation 903	Wells (as amended)

MINISTRY OF TRANSPORTATION, ONTARIO

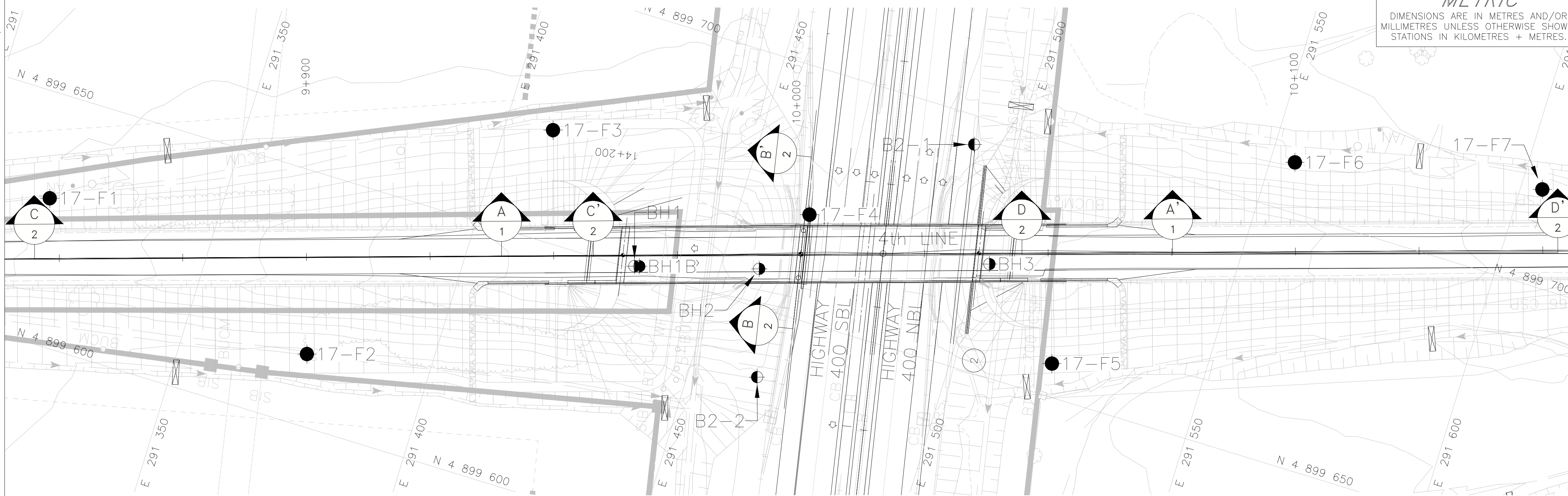
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. DB 2016-2021
WP NO. 2186-10-00

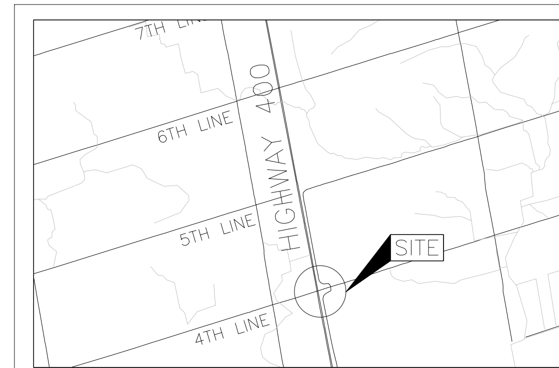
4TH LINE UNDERPASS
HIGHWAY 400 WIDENING
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET S02

Golder Associates

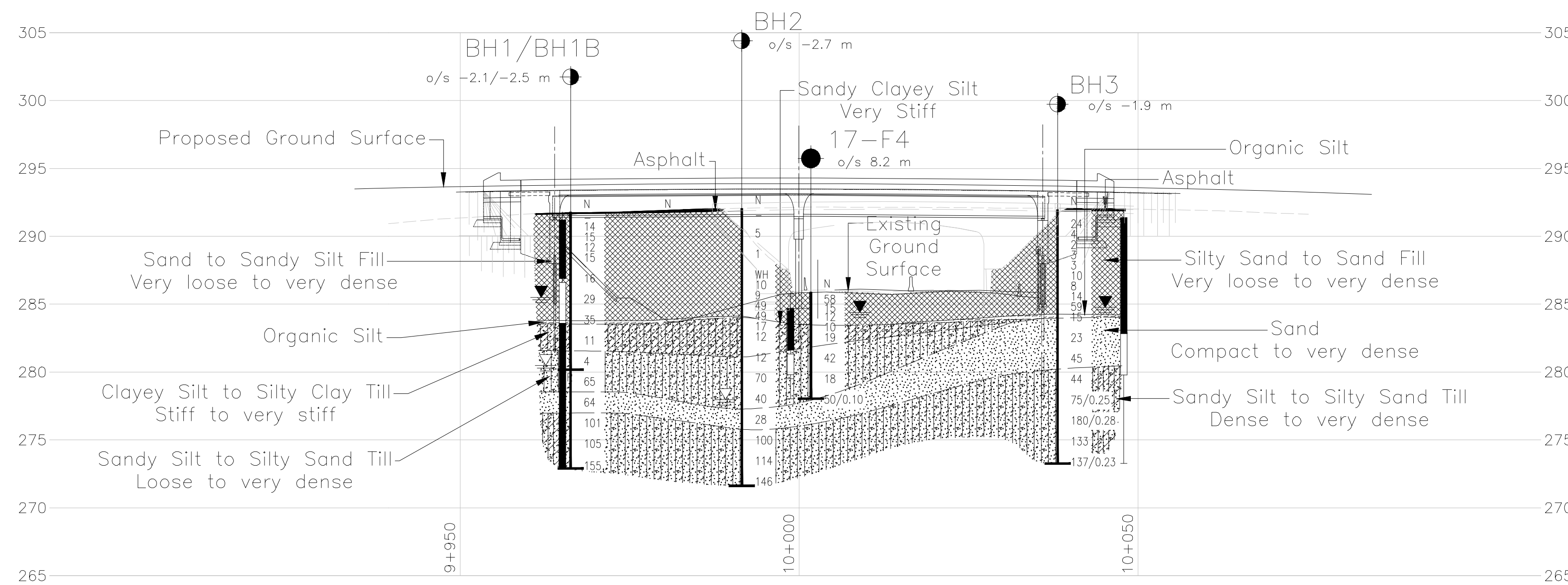


PLAN
SCALE
10 0 10 20 m



LEGEND

●	Borehole – 2017 Investigation
	Borehole – 2015 Investigation
	Borehole – 2000 Investigation
	Seal
	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
	WL upon completion of drilling
	WL in piezometer



A-A' 1 4th LINE CENTRELINE PROFILE

HORIZONTAL SCALE
10 0 10 20 m

VERTICAL SCALE
5 0 5 10 m

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
17-F1	285.1	4899629.1	291316.2
17-F2	283.8	4899614.3	291375.2
17-F3	284.4	4899672.1	291409.5
17-F4	285.9	4899671.0	291464.1
17-F5	285.7	4899656.6	291519.8
17-F6	285.7	4899709.9	291554.9
17-F7	286.7	4899719.3	291604.3
B2-1	286.2	4899694.3	291491.8
B2-2	285.9	4899636.5	291463.6
BH1	291.8	4899650.6	291433.3
BH1B	291.8	4899650.9	291434.3
BH2	292.1	4899657.5	291457.6
BH3	292.0	4899672.1	291501.8

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 design configuration as shown elsewhere in the design drawings.

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

REFERENCE

Existing ground surface data provided in digital format by AECOM, drawing file no. X-Surfaces.dwg, received April 14, 2015.
Design plans and profile provided in digital format by Hatch, drawing file nos. H352242-03-260-SEG0-0001.dwg and H352242-20-260-REF0-0019.dwg, modified Apr. 17, 2017, and H352242-20-260-REF0-0020.dwg, modified Apr. 13, 2017, all received Apr. 17, 2017.

LICENSED PROFESSIONAL ENGINEER L.C. COYNE Apr. 13, 2017 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER K. J. BENTLEY Apr. 13, 2017 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION
0	17/04/13	LCC	ISSUED FOR CONSTRUCTION

Geocres No.

HWY. 400	PROJECT NO. 1663130	DIST. CENTRAL
SUBM'D. LCC	CHKD. LCC	DATE: Apr. 2017	SITE: 30-212
DRAWN: MR/SMD	CHKD. KJB	APPD. LCC	DWG. 1

PLOT DATE: April 17, 2017
FILENAME: \\golder.gds\gal\Mississauga\SIM\Clients\MTO\Hwy_400_Barrie\99_PROJ\1663130_Hatch_HWY_400_Widening\40_PROD\0001_4th_Line Underpass\1663130-0001-BG-0001.dwg

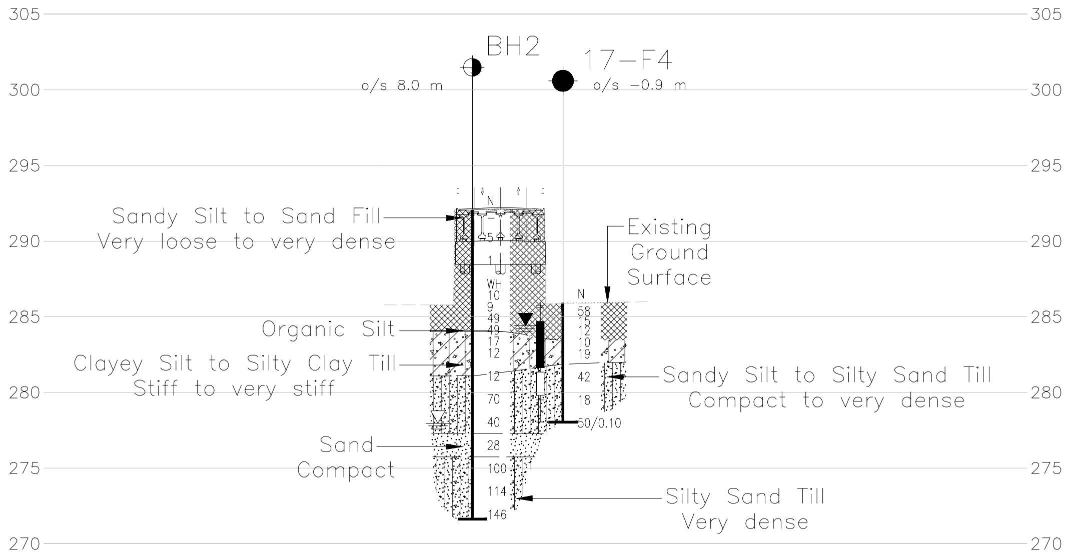
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. DB 2016-2021
WP NO. 2186-10-00

4TH LINE UNDERPASS
HIGHWAY 400 WIDENING
SOIL STRATA

SHEET S03

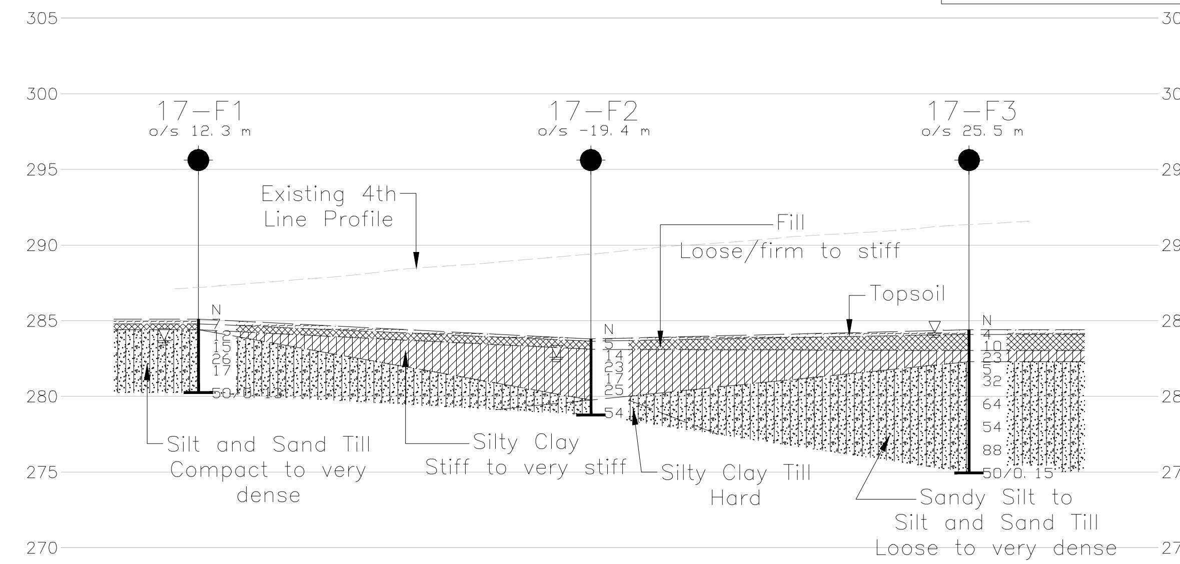
Golder Associates



CROSS-SECTION B-B'
CENTER PIER

B-B' 1

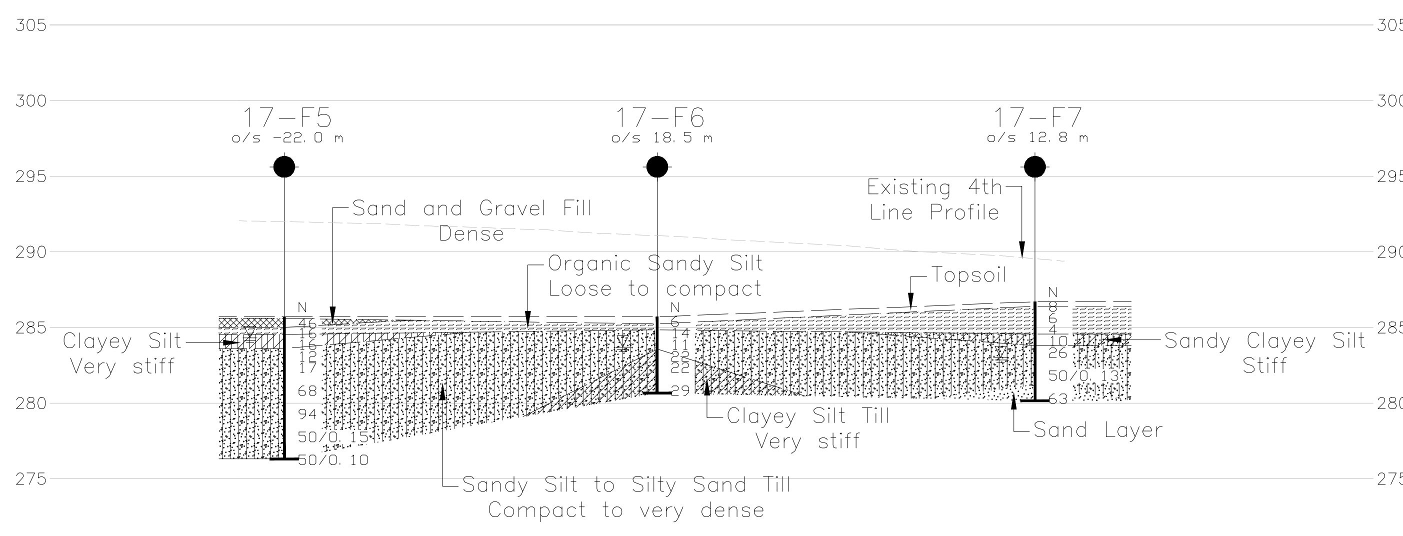
HORIZONTAL SCALE 10 0 10 20 m
VERTICAL SCALE 5 0 5 10 m



CROSS-SECTION C-C'
WEST APPROACH/HIGH FILL EMBANKMENT

C-C' 1

HORIZONTAL SCALE 10 0 10 20 m
VERTICAL SCALE 5 0 5 10 m



CROSS-SECTION D-D'
EAST APPROACH/HIGH FILL EMBANKMENT

D-D' 1

HORIZONTAL SCALE 10 0 10 20 m
VERTICAL SCALE 5 0 5 10 m

KEY PLAN
SCALE
1 0 1 2 km

LEGEND

- Borehole - 2017 Investigation
- Borehole - 2015 Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling
- WL in piezometer

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
17-F1	285.1	4899629.1	291316.2
17-F2	283.8	4899614.3	291375.2
17-F3	284.4	4899672.1	291409.5
17-F4	285.9	4899671.0	291464.1
17-F5	285.7	4899656.6	291519.8
17-F6	285.7	4899709.9	291554.9
17-F7	286.7	4899719.3	291604.3
BH2	292.1	4899657.5	291457.6

NOTES

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REFERENCE

Existing ground surface data provided in digital format by AECOM, drawing file no. X-Surfaces.dwg, received April 14, 2015.
Design plans and profile provided in digital format by Hatch, drawing file nos. H352242-03-260-SEG0-0001.dwg and H352242-20-260-REF0-0019.dwg, modified Apr. 17, 2017, and H352242-20-260-REF0-0020.dwg, modified Apr. 13, 2017, all received Apr. 17, 2017.

LICENSED PROFESSIONAL ENGINEER L.C. COYNE Apr. 13, 2017 PROVINCE OF ONTARIO

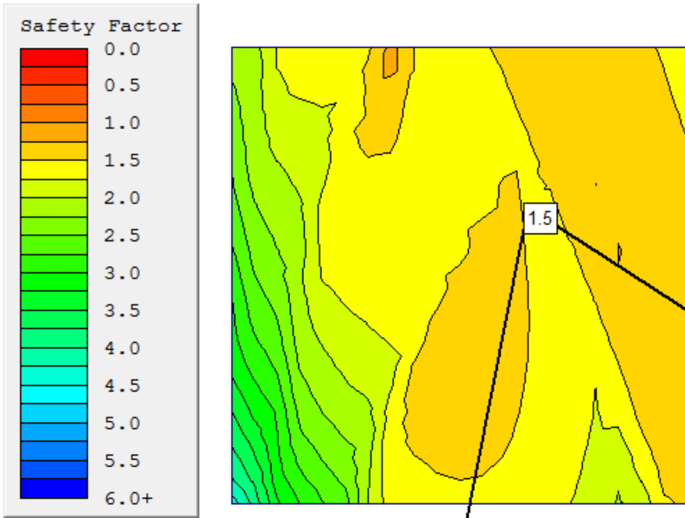
LICENSED PROFESSIONAL ENGINEER K. J. BENTLEY Apr. 13, 2017 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION
0	17/04/13	LCC	ISSUED FOR CONSTRUCTION

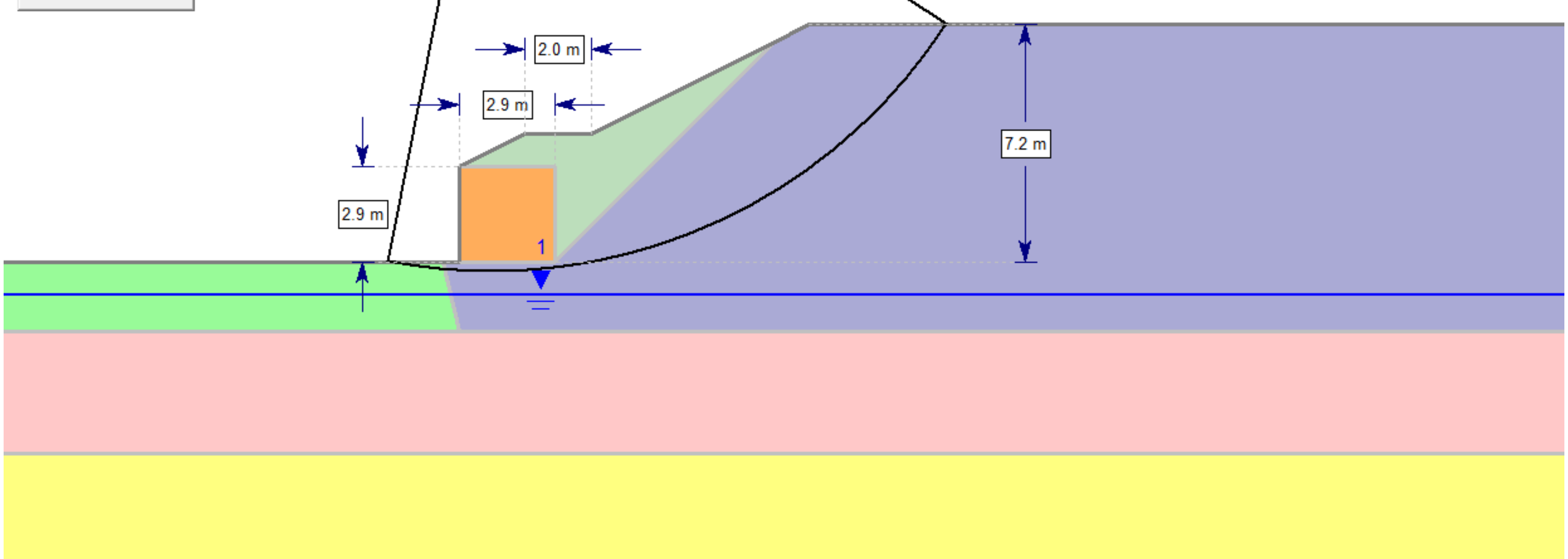
Geocres No.

HWY. 400		PROJECT NO. 1663130	DIST.
SUBM'D. LCC	CHKD. LCC	DATE: Apr. 2017	SITE: 30-212
DRAWN: MR/SMD	CHKD. KJB	APPD. LCC	DWG. 2

PLOT DATE: April 17, 2017



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface
RSS Mass		22	Mohr-Coulomb	0	85	Piezometric Line 1
New Emb. Fill		21	Mohr-Coulomb	0	30	Piezometric Line 1
Existing Emb. Fill		20	Mohr-Coulomb	0	28	Piezometric Line 1
Sand		21	Mohr-Coulomb	0	37	Piezometric Line 1
Silty Sand Till		21	Mohr-Coulomb	0	40	Piezometric Line 1
Backfill Substitute		21	Mohr-Coulomb	0	30	Piezometric Line 1



CLIENT
HATCH

PROJECT
Highway 400/4th Line Underpass Replacement

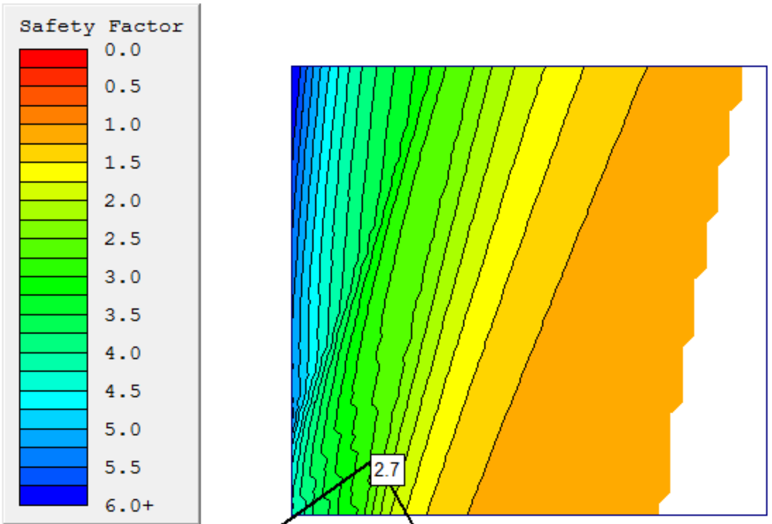
CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-30
PREPARED	AB
DESIGN	AB
REVIEW	KJB
APPROVED	LCC

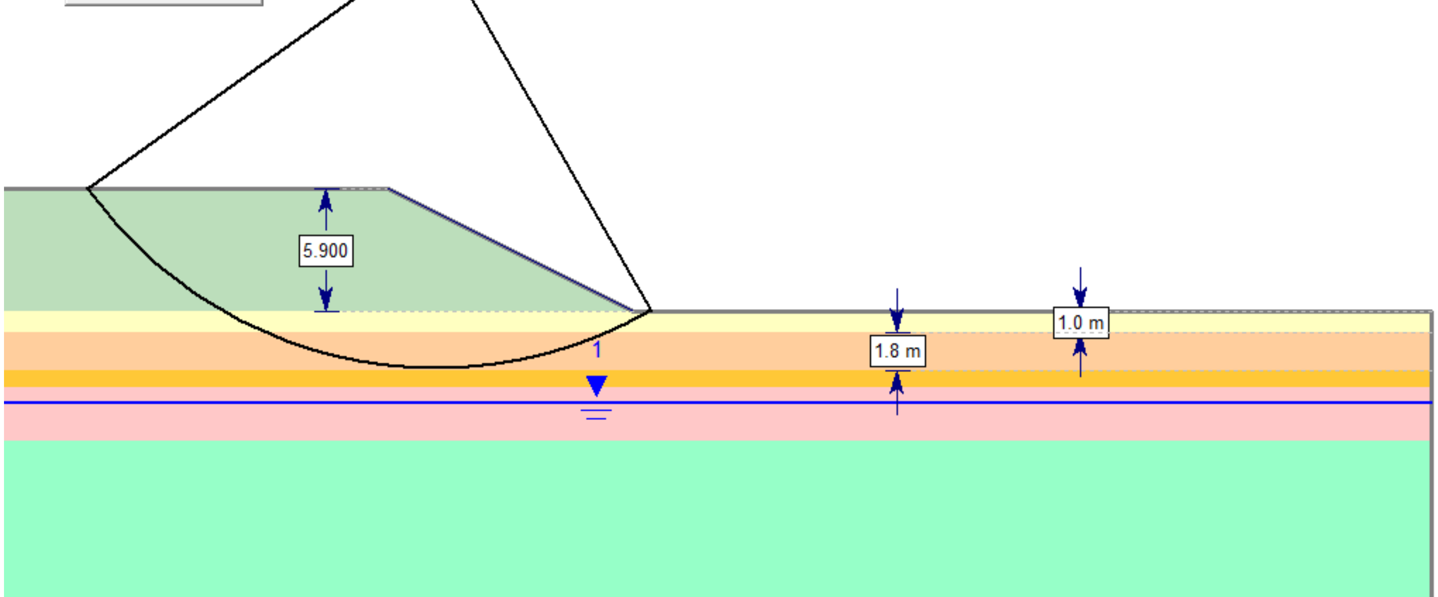
TITLE
STATIC GLOBAL STABILITY ANALYSIS
RSS WALL IN FRONT OF EAST ABUTMENT

PROJECT No.
1663130

FIGURE No.
1



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface
Granular		21	Mohr-Coulomb	0	32	Piezometric Line 1
New Emb. Fill		21	Mohr-Coulomb	0	30	Piezometric Line 1
Organics		18	Mohr-Coulomb	0	23	Piezometric Line 1
Sandy Clayey Silt		19	Mohr-Coulomb	0	31	Piezometric Line 1
Silty Sand		21	Mohr-Coulomb	0	40	Piezometric Line 1
Sand		21	Mohr-Coulomb	0	40	Piezometric Line 1



CLIENT
HATCH

PROJECT
Highway 400/4th Line Underpass Replacement

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-30
PREPARED	AB
DESIGN	AB
REVIEW	KJB
APPROVED	LCC

TITLE
STATIC GLOBAL STABILITY ANALYSIS
HIGH FILL EMBANKMENT ON 4TH LINE EAST OF HIGHWAY 400

PROJECT No.
1663130

FIGURE No.
2

APPENDIX A

Borehole Records – Golder 2015 and 2017 Investigations

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
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d:

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

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (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

(b) Cohesive Soils
Consistency

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

IV. SOIL TESTS

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

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

V. MINOR SOIL CONSTITUENTS

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

RECORD OF BOREHOLE No BH1

SHEET 1 OF 2 **METRIC**

PROJECT 14-1111-0002
W.O. 06-20016
DIST Central HWY 400
DATUM Geodetic

LOCATION N 4899650.6 ; E 291433.3
BOREHOLE TYPE 210 mm O.D.Continous Flight Hollow Stem Augers
DATE June 4, 2015

ORIGINATED BY JIL
COMPILED BY ZR/JFC
CHECKED BY JIL/CN

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
291.8	GROUND SURFACE						
0.0	ASPHALT (100 mm)						
0.1	Silt and sand, trace to some gravel, trace to some clay, some clayey silt lenses (FILL) Compact to dense Brown to grey Dry to moist	1	AS	-			
		2	SS	14			2 50 36 12
		3	SS	15			
		4	SS	12			
		5	SS	15			
		6	SS	16			
		7	SS	29			
283.8	ORGANIC SILT, trace sand, trace rootlets Black Moist	8A / 8B	SS	35			
8.2	SILTY CLAY, some sand (TILL) Stiff Grey Moist to wet	9	SS	11		40	
281.6 / 10.2	Silty SAND, some clay, trace gravel (TILL) Loose Grey Moist to wet	10	SS	4	▽		
280.2 / 11.6	END OF BOREHOLE AUGER REFUSAL (Inferred Boulder)						

NOTES:

1. Water level in open borehole measured at a depth of 11.3 m below ground surface (Elev. 280.5 m) upon completion of drilling.

2. An additional borehole was advanced 2.0 m east of BH1 to obtain split spoon samples; see Record of Borehole BH1B for details.

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; ELEVATION SCALE (291, 290, 289, 288, 287, 286, 285, 284, 283, 282, 281); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³

Continued Next Page

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

Golder Associates

PROJECT 14-1111-0002	RECORD OF BOREHOLE No BH1	SHEET 2 OF 2	METRIC
W.O. 06-20016	LOCATION N 4899650.6 ; E 291433.3	ORIGINATED BY JIL	
DIST Central HWY 400	BOREHOLE TYPE 210 mm O.D.Continous Flight Hollow Stem Augers	COMPILED BY ZR/JFC	
DATUM Geodetic	DATE June 4, 2015	CHECKED BY JIL/CN	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
	3. An additional borehole advanced 2.6 m east of Borehole BH1 encountered auger refusal at a depth of 1.8 m.										

$+^3, \times^3$: Numbers refer to Sensitivity

$\bigcirc^{3\%}$ STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No BH1B

SHEET 1 OF 2 **METRIC**

PROJECT 14-1111-0002			
W.O. 06-20016	LOCATION N 4899650.9 ; E 291434.3	ORIGINATED BY JIL	
DIST Central HWY 400	BOREHOLE TYPE 210 mm O.D.Continous Flight Hollow Stem Augers	COMPILED BY ZR/JFC	
DATUM Geodetic	DATE June 4, 2015	CHECKED BY JIL/CN	

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%) (w)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
291.8	GROUND SURFACE													
0.0	See Record of Borehole BH1 for subsurface conditions between elevation 291.8 m and 280.2 m.													
279.6 / 12.2	Silty SAND, some gravel, trace to some clay (TILL) Very dense Brown Moist		1	SS	65				~9					
278.5 / 13.3	SAND, some silt, trace gravel, trace clay Very dense Brown to grey Moist to wet		2	SS	64				~12		1	81	15	3
277.0 / 14.8														

Elevation scale: 291, 290, 289, 288, 287, 286, 285, 284, 283, 282, 281, 280, 279, 278, 277

Legend: DCPT scale 20 40 60 80 100; Shear strength: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20 40 60 80 100. PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30. REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL.

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No BH1B

METRIC

PROJECT	14-1111-0002		
W.O.	06-20016	LOCATION	N 4899650.9 ; E 291434.3
ORIGINATED BY	JIL		
DIST	Central	HWY	400
BOREHOLE TYPE	210 mm O.D.Continous Flight Hollow Stem Augers	COMPILED BY	ZR/JFC
DATUM	Geodetic	DATE	June 4, 2015
CHECKED BY	JIL/CN		

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty SAND, trace gravel to gravelly, some clay (TILL) Very dense Grey Moist	3	SS	101	276		
		4	SS	105	275		
					274		
272.9		5	SS	155	273		9 54 25 12
18.9	END OF BOREHOLE						

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

NOTES:

1. Water level measurements in piezometer:

Date	Depth (m)	Elev. (m)
07/06/15	6.3	285.5

2. Water level meter passed through an approximately 0.5 m thick clayey slurry before reaching the bottom of the standpipe piezometer at a depth of 6.8 m below ground surface (Elev. 285.0 m) on July 6, 2015.

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

RECORD OF BOREHOLE No BH2

SHEET 1 OF 2 **METRIC**

PROJECT 14-1111-0002
W.O. 06-20016
LOCATION N 4899657.5; E 291457.6
ORIGINATED BY JIL
DIST Central HWY 400
BOREHOLE TYPE 210 mm O.D.Continous Flight Hollow Stem Augers
COMPILED BY ZR/JFC
DATUM Geodetic
DATE June 3 and 4, 2015
CHECKED BY JIL/CN

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
292.1	GROUND SURFACE							
0.0	ASPHALT (200 mm)							
0.2	Silty sand, trace to some gravel, trace to some clay (FILL) Very loose to dense Brown to grey Moist to wet	1	AS	-				
						291		
		2	SS	5		290	○	
		3	SS	1		289		
						288		
		4	SS	WH		287		
		5	SS	10		286		
		6	SS	9			○	
		7	SS	49		285	○ (wP–wL range)	6 56 27 11
284.1	Auger grinding at a depth of about 7.6 m on inferred cobble.	8A	SS	49				
8.0	ORGANIC SILT, trace rootlets Black Moist	8B				284		
	Sandy CLAYEY SILT, some gravel Very stiff Grey Moist	9	SS	17				
283.0 9.1	SILTY CLAY, trace gravel, trace sand, some sand lenses (TILL) Stiff Grey to brown Moist	10	SS	12		283	○	
						282		
281.1		11A	SS	12				
11.0	Silty SAND, trace to some gravel, trace to some clay (TILL) Compact to very dense Brown to grey Moist	11B				281		
						280		
		12	SS	70			○	
	Auger grinding at a depth of about 13.1 m on inferred cobble.					279		
		13	SS	40	∇	278		
277.3 14.8								

Continued Next Page

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED; 20 40 60 80 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m^3

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

Golder Associates

RECORD OF BOREHOLE No BH2

SHEET 2 OF 2 **METRIC**

PROJECT 14-1111-0002
W.O. 06-20016
DIST Central HWY 400
DATUM Geodetic
LOCATION N 4899657.5; E 291457.6
BOREHOLE TYPE 210 mm O.D.Continous Flight Hollow Stem Augers
DATE June 3 and 4, 2015
ORIGINATED BY JIL
COMPILED BY ZR/JFC
CHECKED BY JIL/CN

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	SAND, some silt, trace gravel Compact Grey Wet	14	SS	28						
					276					
275.8 16.3	Silty SAND, trace to some gravel, trace to some clay (TILL) Very dense Brown to grey Moist									
		15	SS	100	275					
					274					
		16	SS	114		~8	2	59	28	11
					273					
		17	SS	146	272					
271.7 20.4	END OF BOREHOLE NOTE: 1. Water level in open borehole measured at a depth of 14.1 m below ground surface (Elev. 278.0 m) upon completion of drilling.									

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

RECORD OF BOREHOLE No BH3

SHEET 1 OF 2

METRIC

PROJECT 14-1111-0002
W.O. 06-20016
LOCATION N 4899672.1 ;E 291501.8
ORIGINATED BY QC
DIST Central HWY 400
BOREHOLE TYPE 210 mm O.D.Continous Flight Hollow Stem Augers
COMPILED BY ZR/JFC
DATUM Geodetic
DATE June 11, 2015
CHECKED BY JIL/CN

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
292.0	GROUND SURFACE									
0.0	ASPHALT (130 mm)									
0.1	Sand, some gravel to gravelly, some silt to silty, some asphalt fragments (FILL) Loose to compact Brown Moist	1	AS							
		2	SS	24	291					
		3	SS	4	290					
289.9 / 2.1	Silty sand, trace to some gravel, trace to some clay, trace organics, some asphalt fragments (FILL) Very loose to very dense Brown to grey Moist	4	SS	2						
		5	SS	3	289					
		6	SS	3	288					
		7	SS	10	287					
		8	SS	8			12	48	28	12
		9	SS	14	286					
	Trace organics at a depth of 6.9 m.	10	SS	59	285					
284.3	ORGANIC SILT, trace sand Black Moist	11A	SS	15						
284.0 / 8.0	SAND, some silt, trace gravel, trace clay, some silty clay pockets Compact to dense Brown to grey Wet	11B			284					
					283					
		12	SS	23	282		2	77	18	3
		13	SS	45	281					
280.3 / 11.7	Silty SAND, trace to some gravel, trace to some clay (TILL) Dense to very dense Grey Moist				280					
		14	SS	44	279					
		15	SS	75/0.25	278					

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

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

Golder Associates

Foundation Design

RECORD OF BOREHOLE No BH3

SHEET 2 OF 2

METRIC

PROJECT 14-1111-0002			
W.O. 06-20016	LOCATION N 4899672.1 ;E 291501.8	ORIGINATED BY QC	
DIST Central HWY 400	BOREHOLE TYPE 210 mm O.D.Continous Flight Hollow Stem Augers	COMPILED BY ZR/JFC	
DATUM Geodetic	DATE June 11, 2015	CHECKED BY JIL/CN	

SOIL PROFILE | SAMPLES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) | SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20 40 60 80 100) | PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10 20 30) | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%)

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	GR	SA	SI	CL
	Silty SAND, trace to some gravel, trace to some clay (TILL) Dense to very dense Grey Moist		16	SS	180/0.28					
						276				
			17	SS	133	275	7	58	24	11
						274				
273.3			18	SS	137/0.23					
18.7	END OF BOREHOLE									

NOTE:

1. Water level measurements in piezometer:

Date	Depth (m)	Elev. (m)
06/11/15	7.2	284.8
07/06/15	7.2	284.8

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

Golder Associates

RECORD OF BOREHOLE No 17-F1

SHEET 1 OF 1

METRIC

PROJECT 1663130 (2002)

W.P. DB-2016-2021

LOCATION N 4899629.1; E 291316.2 MTM ZONE 10 (LAT. 44.2365; LONG. -79.6688)

ORIGINATED BY JL

DIST Central HWY 400

BOREHOLE TYPE CME 55 Track Mount, 110 mm O.D. Continuous Flight Solid Stem Augers

COMPILED BY ACK

DATUM Geodetic

DATE January 18, 2017

CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
285.1	GROUND SURFACE					285						
0.0	TOPSOIL											
284.8	Clayey silt, some sand, containing rootlets (FILL) Firm Brown Moist	1	SS	7								
284.4 / 0.7	SILT and SAND, trace clay, trace gravel (TILL) Compact to very dense Brown Moist to wet	2	SS	12	∇	284						
		3	SS	15		283			4	41	47	8
		4	SS	26		282						
		5	SS	17		281						
280.3 / 4.9	END OF BOREHOLE	6	SS	50/0.13								

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10, 20, 30; REMARKS & GRAIN SIZE DISTRIBUTION (%)

NOTES:

1. Water level in open borehole measured at a depth of 1.4 m below ground surface (Elev. 283.7 m) upon completion of drilling.

DRAFT

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

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Golder Associates

Foundation Design

RECORD OF BOREHOLE No 17-F2

SHEET 1 OF 1 **METRIC**

PROJECT 1663130 (2002)
W.P. DB-2016-2021 LOCATION N 4899614.3; E 291375.2 MTM ZONE 10 (LAT. 44.2364; LONG. -79.6681) ORIGINATED BY JL
DIST Central HWY 400 BOREHOLE TYPE CME 55 Track Mount, 110 mm O.D. Continuous Flight Solid Stem Augers COMPILED BY ACK
DATUM Geodetic DATE January 18, 2017 CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	GR	SA	SI	CL
283.8	GROUND SURFACE								
0.0	TOPSOIL								
0.2	Silty sand, trace gravel, trace clay, trace organics (FILL) Loose Brown Moist	1	SS	5					
283.1 / 0.7	SILTY CLAY, trace to some sand, trace gravel, containing sand seams and zones Stiff to very stiff Brown Moist - Becoming grey below a depth of 2.1 m	2	SS	14		0	10	42	48
		3	SS	23					
		4	SS	17					
		5	SS	25					
279.8 / 4.0	SILTY CLAY, some sand, trace gravel (TILL) Hard Grey Moist	6	SS	54					
278.8 / 5.0	END OF BOREHOLE								

NOTES:

1. Water level in open borehole measured at a depth of 1.2 m below ground surface (Elev. 282.6 m) upon completion of drilling.

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (283, 282, 281, 280, 279); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

DRAFT

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

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Golder Associates

RECORD OF BOREHOLE No 17-F3

SHEET 1 OF 1 **METRIC**

PROJECT 1663130 (2002)

W.P. DB-2016-2021 LOCATION N 4899672.1; E 291409.5 MTM ZONE 10 (LAT. 44.2369; LONG. -79.6676) ORIGINATED BY JL

DIST Central HWY 400 BOREHOLE TYPE CME 55 Track Mount, 110 mm O.D. Continuous Flight Solid Stem Augers COMPILED BY ACK

DATUM Geodetic DATE January 18, 2017 CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
284.4	GROUND SURFACE				
284.1 / 0.0	TOPSOIL				
0.3	Clayey silt, some sand, trace gravel, trace organics (FILL) Firm to stiff Brown Moist to wet	1	SS	4	
		2	SS	10	1 17 44 38
283.0 / 1.4	CLAYEY SILT, trace to some gravel, trace sand Very stiff Grey Moist	3	SS	23	
282.3 / 2.1	Sandy SILT to SILT and SAND, trace to some gravel, trace clay (TILL) Loose to very dense Grey Moist	4	SS	5	17 44 35 4
		5	SS	32	
		6	SS	64	
		7	SS	54	
		8	SS	88	
275.0 / 9.5		9	SS	50/0.15	
	END OF BOREHOLE				

NOTES:

1. Water level in open borehole measured at a depth of 0.2 m below ground surface (Elev. 284.2 m) upon completion of drilling.

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (284 to 275); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

DRAFT

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

Golder Associates

RECORD OF BOREHOLE No 17-F4

SHEET 1 OF 1 **METRIC**

PROJECT	1663130 (2002)		
W.P.	DB-2016-2021	LOCATION	N 4899671.0; E 291464.1 MTM ZONE 10 (LAT. 44.2369; LONG. -79.667)
DIST	Central HWY 400	BOREHOLE TYPE	CME 55 Track Mount, 110 mm O.D. Continuous Flight Solid Stem Augers
DATUM	Geodetic	DATE	January 18, 2017
ORIGINATED BY	JL	COMPILED BY	ACK
CHECKED BY	LCC		

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
285.9	GROUND SURFACE
0.0	ASPHALT (265 mm)
285.4 / 0.6	Silty sand, trace to some gravel, trace clay (FILL) Very dense Brown Moist
284.7 / 1.2	Sand, trace clay (FILL) Very dense to compact Brown Moist
283.5 / 2.4	Silt and sand to silty sand, trace clay, trace to some gravel, containing wood fragments (FILL) Compact Grey Moist - Trace organics between 1.2 m and 1.8 m below ground surface
281.9 / 4.0	SILTY CLAY to CLAYEY SILT, trace to some sand, trace gravel Stiff to very stiff Brown Moist to wet
278.0 / 7.9	Sandy SILT to silty SAND, trace to some clay, trace gravel (TILL) Compact to very dense Brown Moist
	END OF BOREHOLE

SAMPLES

NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1A / 1B	SS	58		
2A / 2B	SS	15		14 51 29 8
3	SS	12		3 49 41 7
4	SS	10	41	
5	SS	19		
6	SS	42		3 58 30 9
7	SS	18		
8	SS	50/0.10		

ELEVATION SCALE: 285, 284, 283, 282, 281, 280, 279

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

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

PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L

WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

NOTES:

1. Water level in open borehole measured at a depth of 1.5 m below ground surface (Elev. 284.4 m) upon completion of drilling.

DRAFT

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

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Golder Associates

RECORD OF BOREHOLE No 17-F5

SHEET 1 OF 1 **METRIC**

PROJECT 1663130 (2002)
W.P. DB-2016-2021 LOCATION N 4899656.6; E 291519.8 MTM ZONE 10 (LAT. 44.2368; LONG. -79.6663) ORIGINATED BY JL
DIST Central HWY 400 BOREHOLE TYPE CME 55 Track Mount, 110 mm O.D. Continuous Flight Solid Stem Augers COMPILED BY ACK
DATUM Geodetic DATE January 19, 2017 CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
285.7	GROUND SURFACE											
0.0	TOPSOIL											
0.1	Sand and gravel, trace clay (FILL) Dense Brown Moist	1	SS	46		285						
285.0 / 0.7	Organic sandy SILT, trace to some clay, trace gravel, containing rootlets Compact Black Moist	2A / 2B	SS	16	∇		○	OC=10.4%	1	22	66	11
284.5 / 1.2	CLAYEY SILT, trace sand, trace gravel, containing fine sand seams and wet sand zones Very stiff to stiff Grey Moist to wet	3	SS	16		284						
283.6 / 2.1	Sandy SILT to silty SAND, trace clay, trace gravel (TILL) Compact to very dense Grey with oxidation staining between depths of 4.0 m and 5.6 m Moist to wet	4	SS	12		283	H○					
		5	SS	17		282	○		1	32	52	15
		6	SS	68		281						
		7	SS	94		280, 279	○					
		8	SS	50/0.15		278, 277						
276.3 / 9.4	END OF BOREHOLE	9	SS	50/0.10								

NOTES:

1. Water level in open borehole measured at a depth of 1.4 m below ground surface (Elev. 284.3 m) upon completion of drilling.

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED; 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
REMARKS & GRAIN SIZE DISTRIBUTION (%)

DRAFT

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

Golder Associates

RECORD OF BOREHOLE No 17-F6

SHEET 1 OF 1

METRIC

PROJECT 1663130 (2002)
W.P. DB-2016-2021
LOCATION N 4899709.9; E 291554.9 MTM ZONE 10 (LAT. 44.2373; LONG. -79.6658)
ORIGINATED BY JL
DIST Central HWY 400
BOREHOLE TYPE CME 55 Track Mount, 110 mm O.D. Continuous Flight Solid Stem Augers
COMPILED BY ACK
DATUM Geodetic
DATE January 19, 2017
CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	NATURAL MOISTURE CONTENT w (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
285.7	GROUND SURFACE							
0.0	TOPSOIL	1	SS	6				
285.2	Organic sandy SILT Loose to compact Black Moist to wet	2A 2B 2C	SS	14		285	~15	
284.8 0.9	SILT and SAND to silty SAND, trace clay, trace gravel, trace organics (TILL) Compact Brown Moist to wet	3	SS	11	▽	284	~11	4 52 36 8
283.6 2.1	CLAYEY SILT, trace to some sand, trace gravel (TILL) Very stiff Brown Moist	4	SS	22		283		
		5	SS	22		282		
		6	SS	29		281	~17 (wP ~13, wL ~29)	
280.7 5.0	END OF BOREHOLE							

NOTES:

1. Water level in open borehole measured at a depth of 2.0 m below ground surface (Elev. 283.7 m) upon completion of drilling.

Column headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; STRAT PLOT.

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

DRAFT

Golder Associates

RECORD OF BOREHOLE No 17-F7

SHEET 1 OF 1

METRIC

PROJECT 1663130 (2002)
W.P. DB-2016-2021
DIST Central HWY 400
DATUM Geodetic

LOCATION N 4899719.3; E 291604.3 MTM ZONE 10 (LAT. 44.2374; LONG. -79.6652)
BOREHOLE TYPE CME 55 Track Mount, 110 mm O.D. Continuous Flight Solid Stem Augers
DATE January 19, 2017

ORIGINATED BY JL
COMPILED BY ACK
CHECKED BY LCC

ELEV DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
286.7	GROUND SURFACE										
0.0	TOPSOIL										
286.4 / 0.3	Organic sandy SILT to organic SILT and SAND, trace clay, trace to some gravel, Loose, Black, Moist	1	SS	8			OC=7.7%				
		2	SS	6			OC=7.0%				
		3	SS	4			OC=8.8%	7	43	44	6
284.6 / 2.1	Sandy CLAYEY SILT, trace gravel, Stiff, Brown, Moist to wet	4	SS	10							
283.8 / 2.9	Silty SAND, trace clay, trace to some gravel (TILL), Compact to very dense, Brown, Wet	5	SS	26	▽ (Elev. 283.0)		NP	10	56	28	6
		6	SS	50/0.13							
281.2 / 5.5	SAND, fine to medium, trace clay, Very dense, Brown, Wet	7	SS	63							
280.2 / 6.6	END OF BOREHOLE										

NOTES:

1. Water level in open borehole measured at a depth of 3.7 m below ground surface (Elev. 283.0 m) upon completion of drilling.

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED: 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
ELEVATION SCALE: 286, 285, 284, 283, 282, 281

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

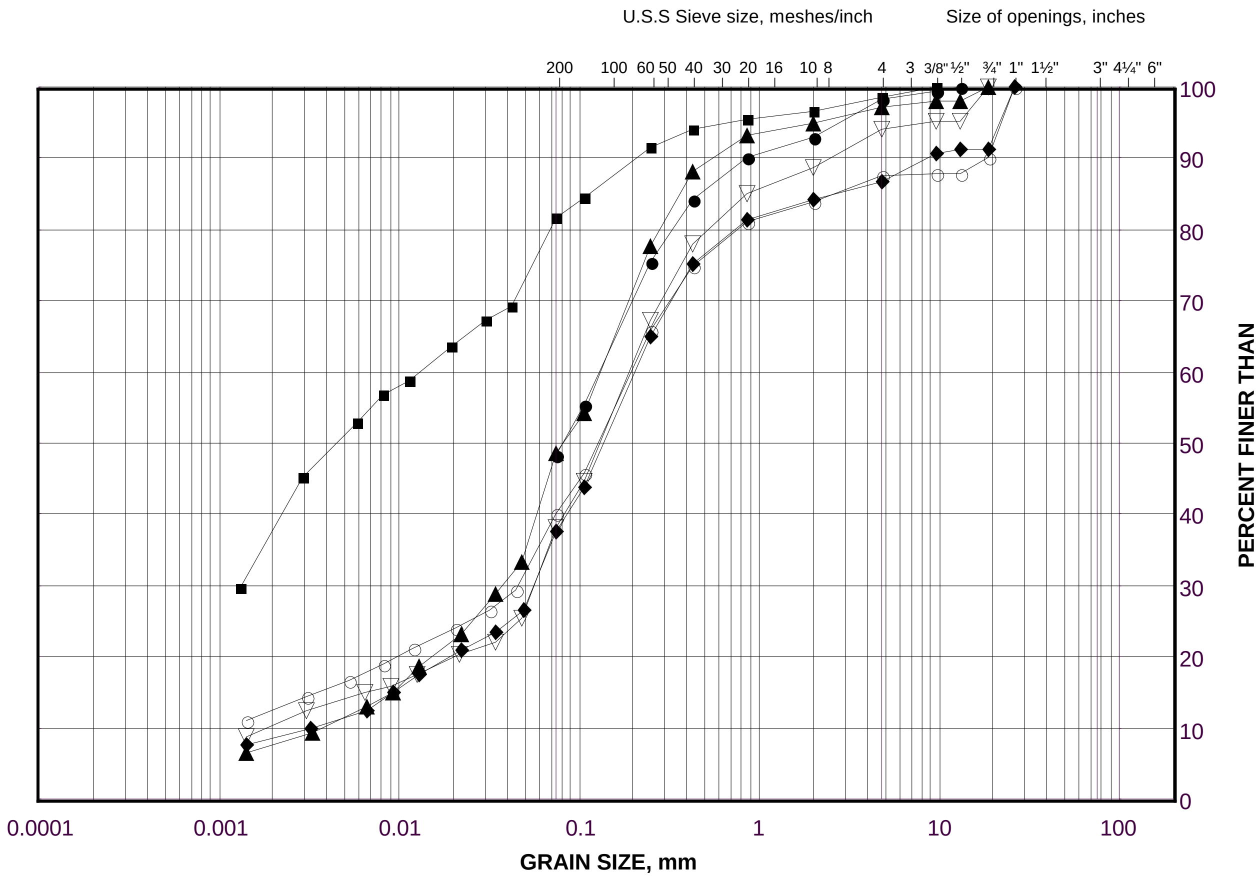
APPENDIX B

Geotechnical Laboratory Test Results – Golder 2015 and 2017 Investigations

GRAIN SIZE DISTRIBUTION

Silt and Sand Fill to Clayey Silt Fill

FIGURE B1



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

LEGEND

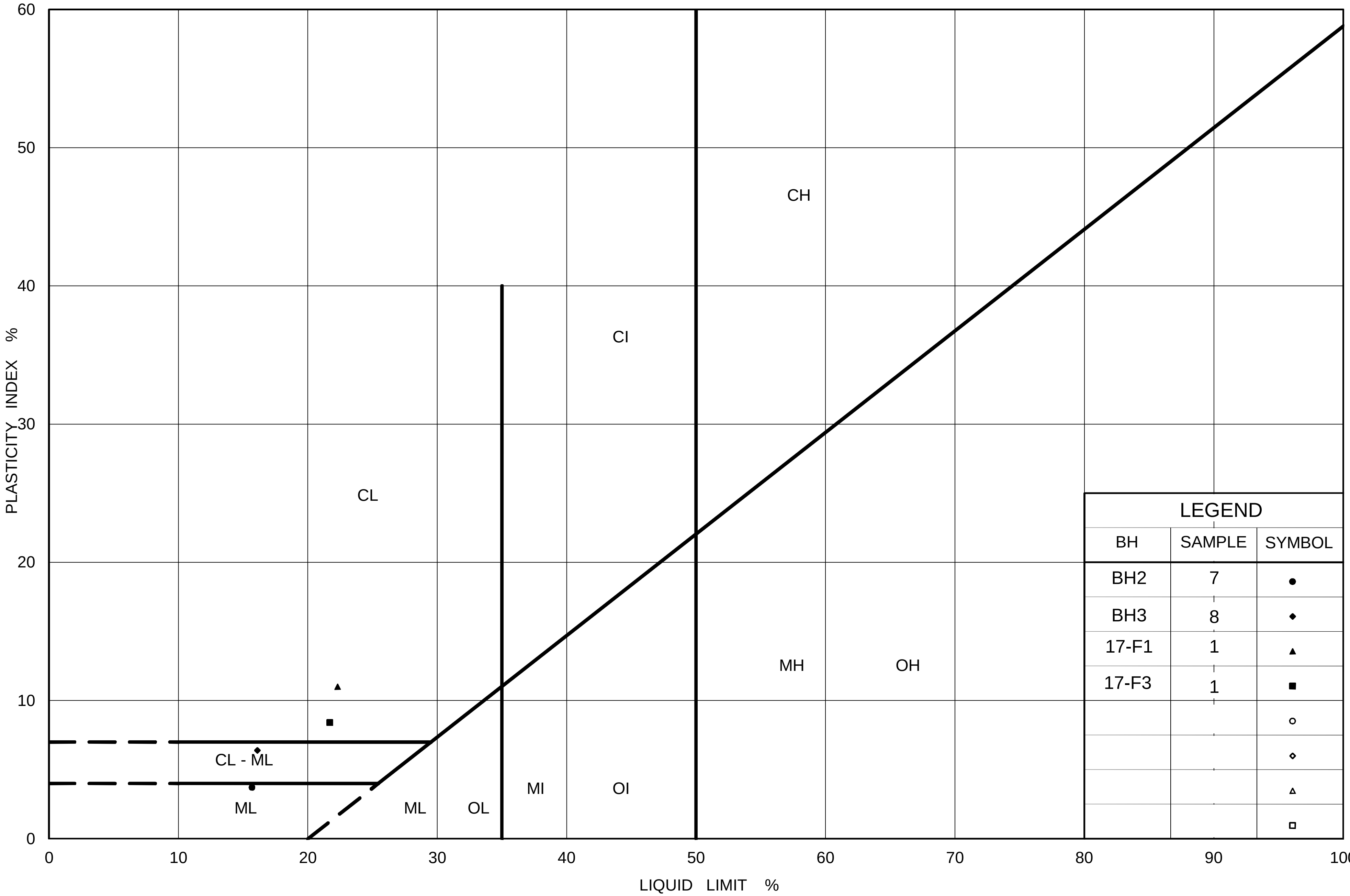
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BH1	2	290.7
■	17-F3	2	283.4
◆	17-F4	2B	284.6
▲	17-F4	3	284.2
▽	BH2	7	284.9
❍	BH3	8	286.3

Project Number: 1663130

Checked By: LCC

Golder Associates

Date: 10-Mar-17



Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt Fill and Cohesive Zones Within Silt and Sand to Silty Sand Fill

Figure No. B2

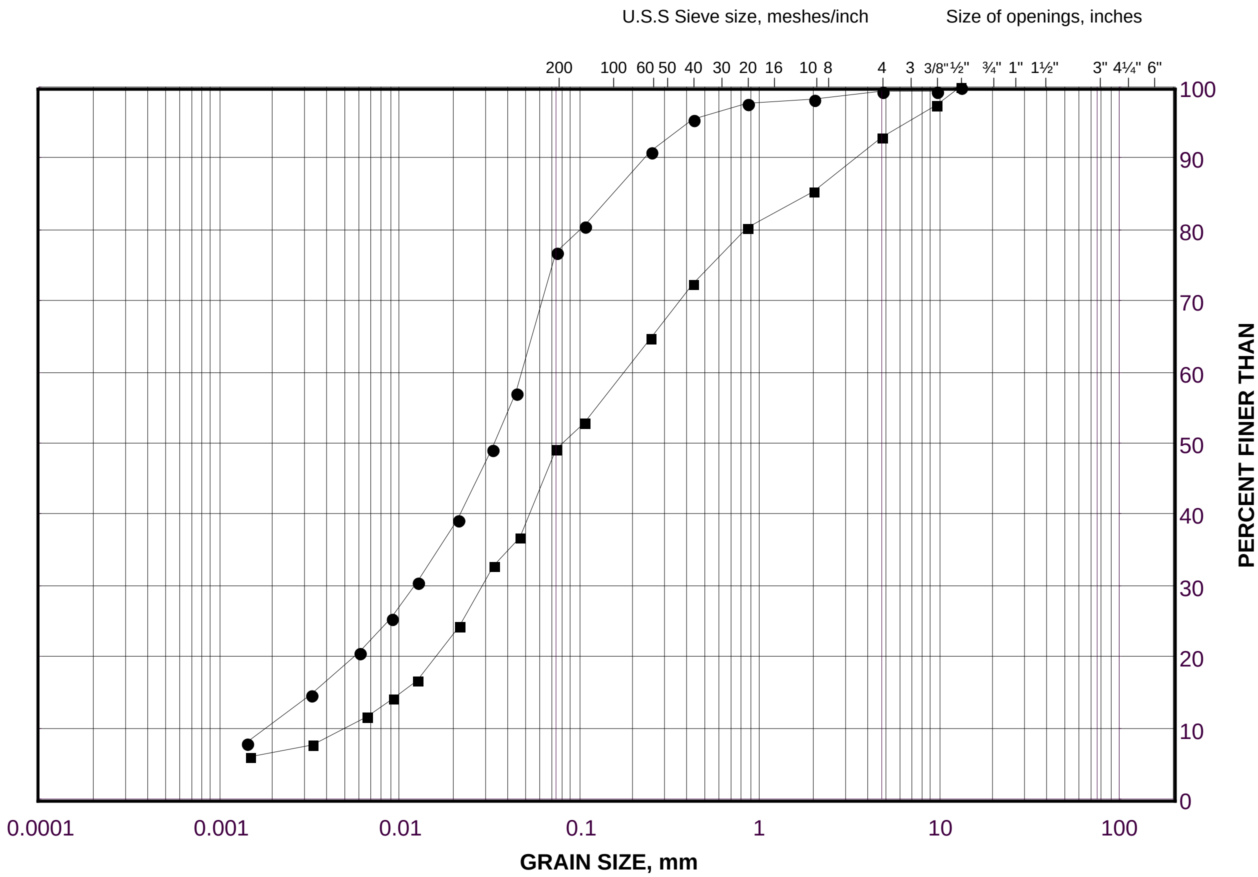
Project No. 1663130

Checked By: LCC

GRAIN SIZE DISTRIBUTION

Organic Sandy Silt to Organic Sand and Silt

FIGURE B3



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	17-F5	2A	284.7
■	17-F7	3	285.0

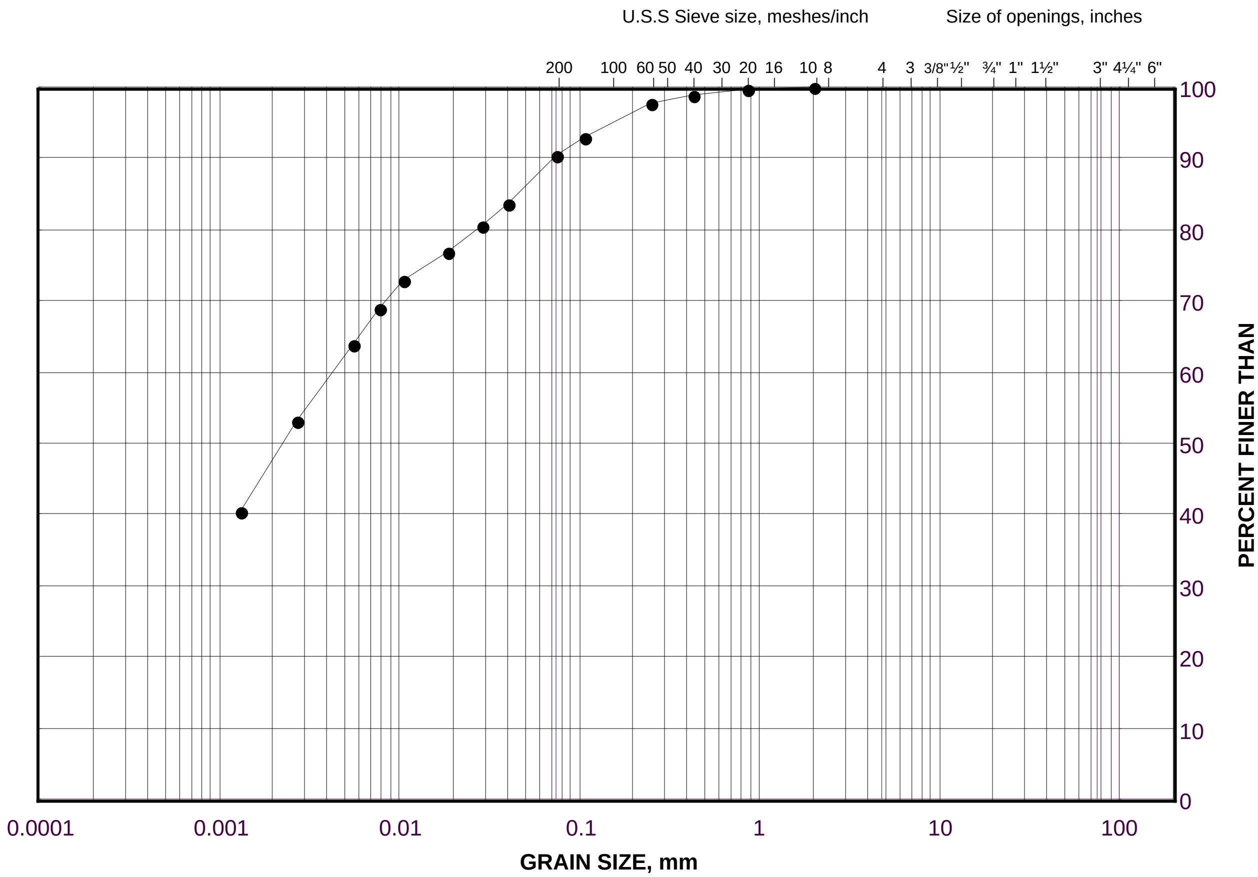
Project Number: 1663130

Checked By: LCC

Golder Associates

Date: 22-Feb-17

GRAIN SIZE DISTRIBUTION Clayey Silt to Silty Clay	FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	17-F2	2	282.8

Project Number: 1663130

Checked By: LCC

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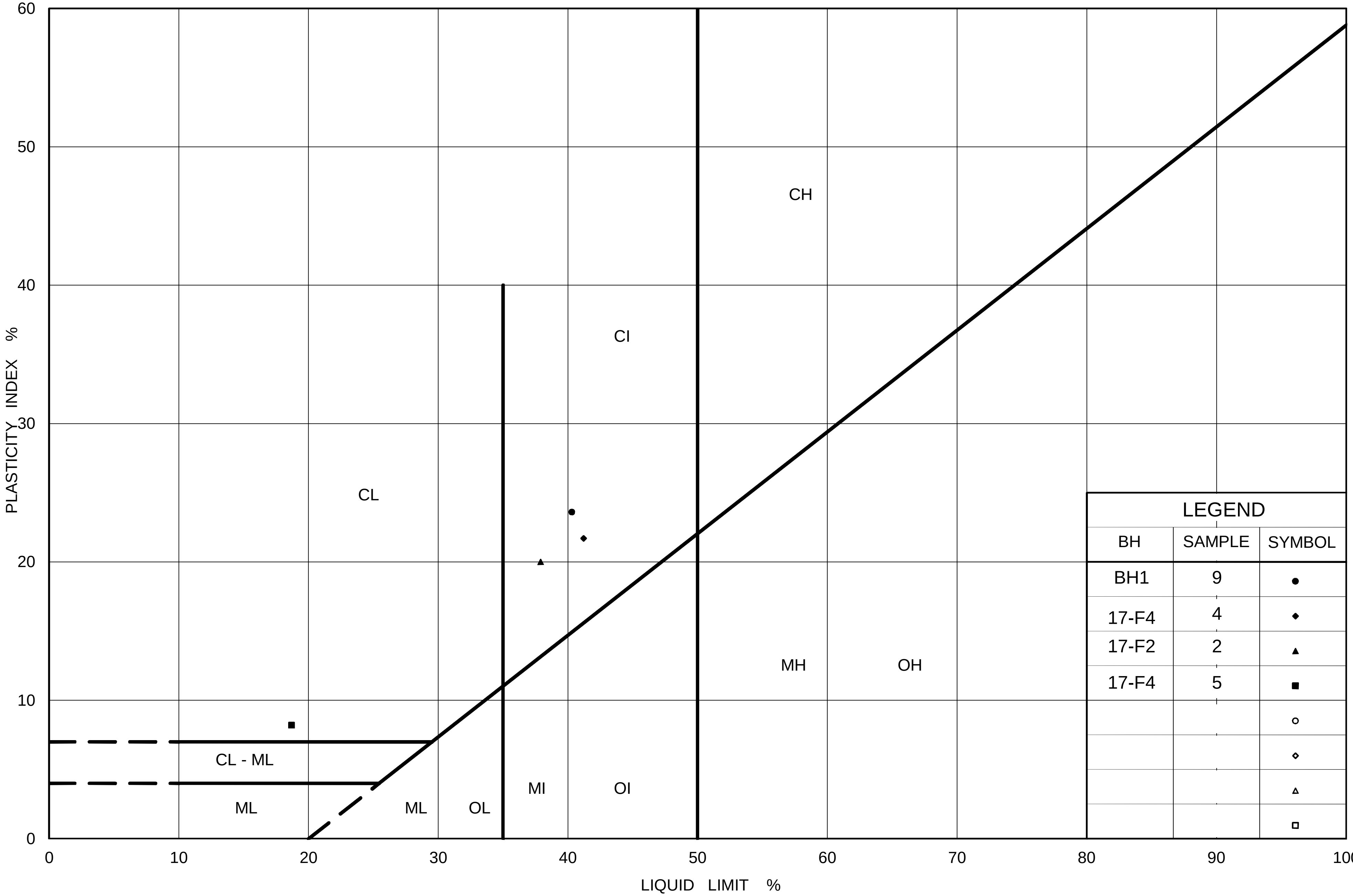
Date: 22-Feb-17



LEGEND

BH	SAMPLE	SYMBOL
BH1	9	●
17-F4	4	◆
17-F2	2	▲
17-F4	5	■
		○
		◇
		△
		□

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PLASTICITY CHART
Clayey Silt to Silty Clay

Figure No. B5

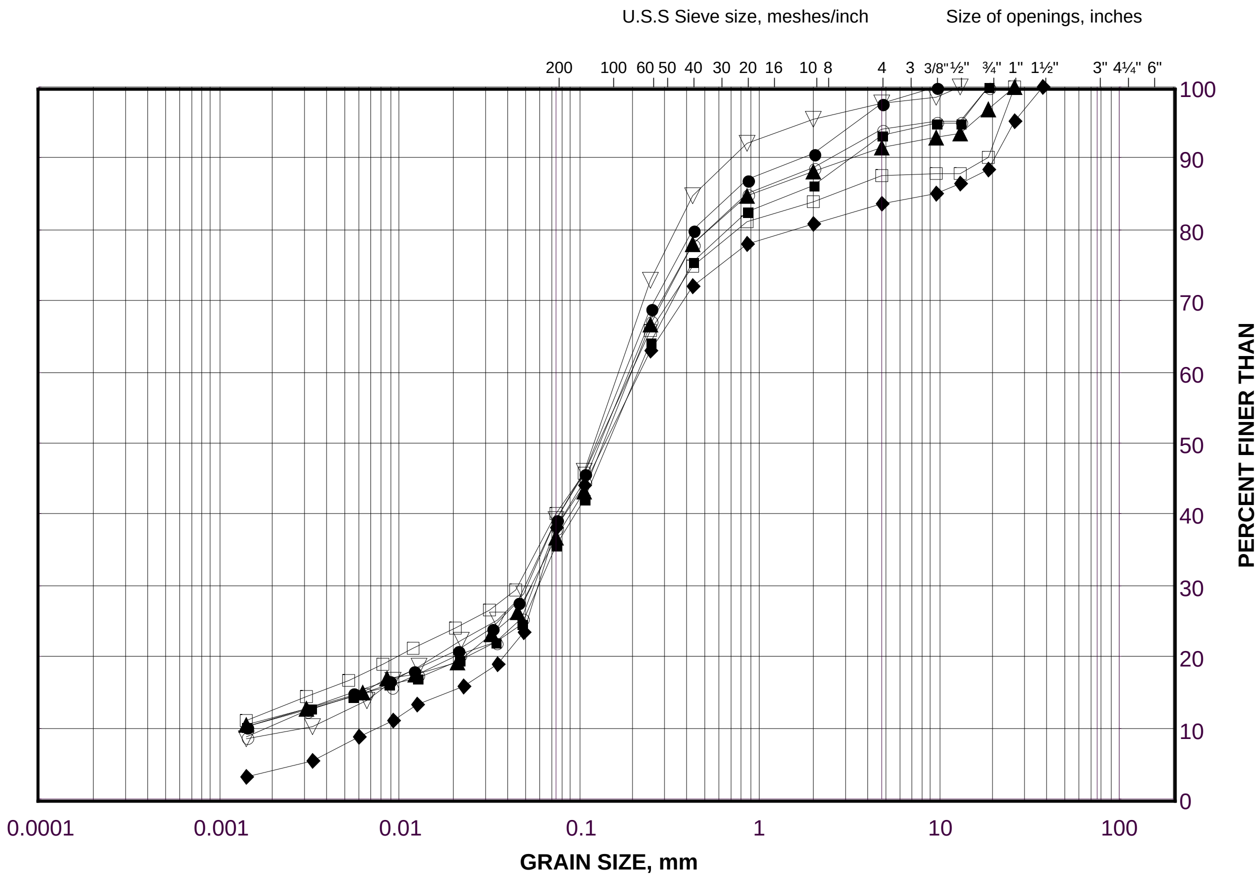
Project No. 1663130

Checked By: LCC

GRAIN SIZE DISTRIBUTION

Sandy Silt to Silty Sand Till

FIGURE B6A



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BH2	16	273.5
■	BH3	17	275.0
◆	17-F3	4	282.8
▲	BH1B	5	273.3
▽	17-F4	6	281.1
❍	BH2	7	284.9
□	BH3	8	286.3

Project Number: 1663130

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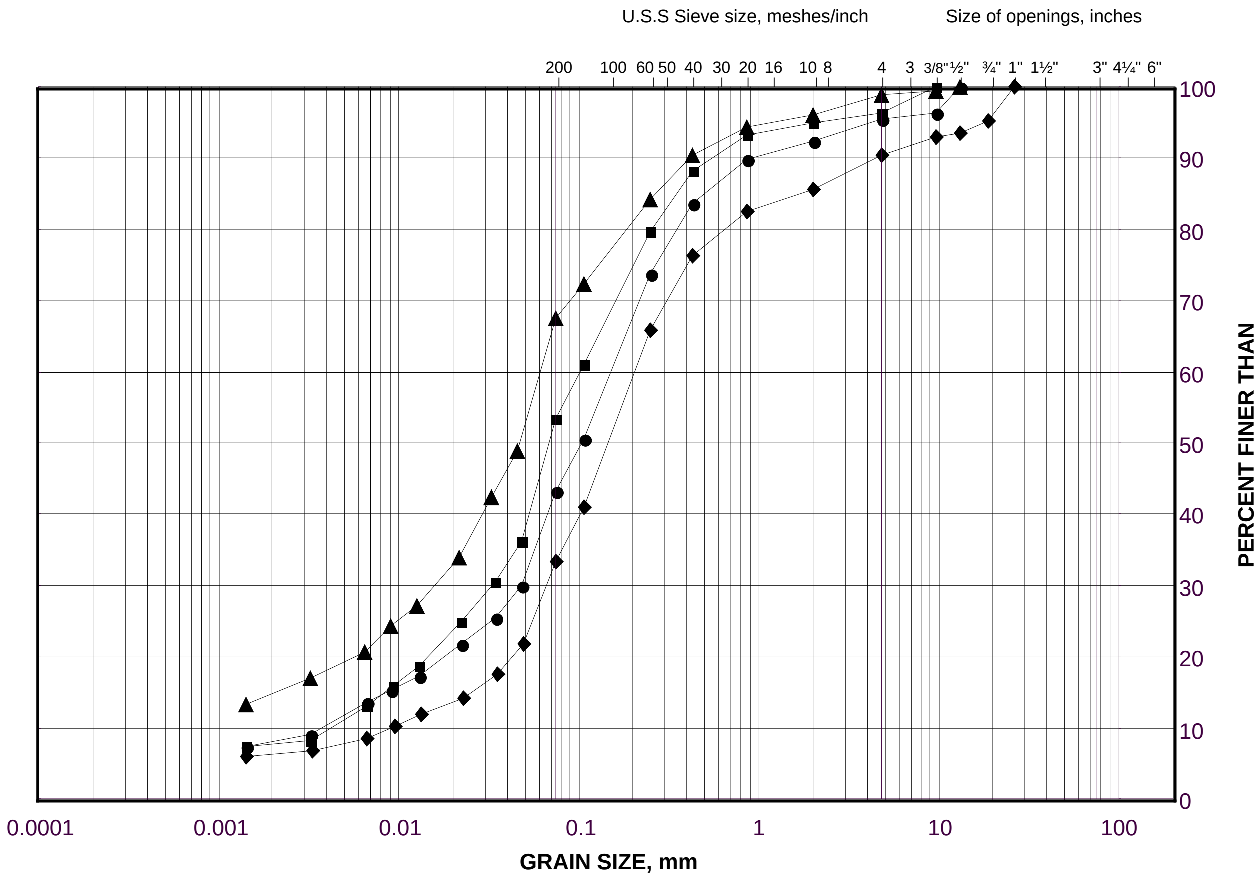
Date: 22-Feb-17

GRAIN SIZE DISTRIBUTION

Sandy Silt to Silty Sand Till

FIGURE B6B



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	17-F6	3	284.0
■	17-F1	3	283.4
◆	17-F7	5	283.2
▲	17-F5	5	282.4

Project Number: 1663130

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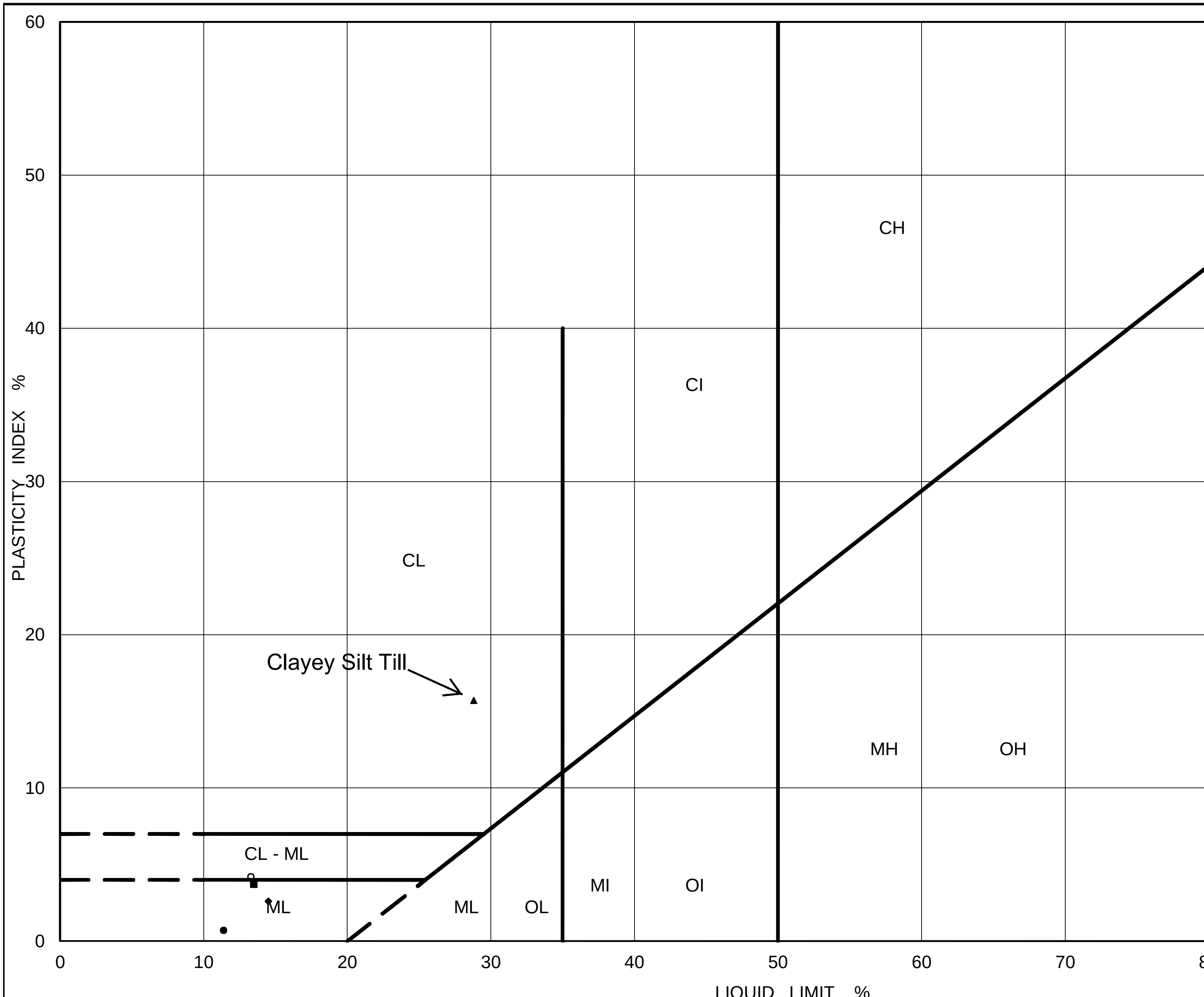
Date: 22-Feb-17



LEGEND		
BH	SAMPLE	SYMBOL
17-F3	4	●
17-F5	4	◆
17-F6	6	▲
BH1B	5	■
BH3	17	○
		◇
		△
		□

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PLASTICITY CHART
Sandy Silt to Silty Sand Till and Clayey Silt Till

Figure No. B7

Project No. 1663130

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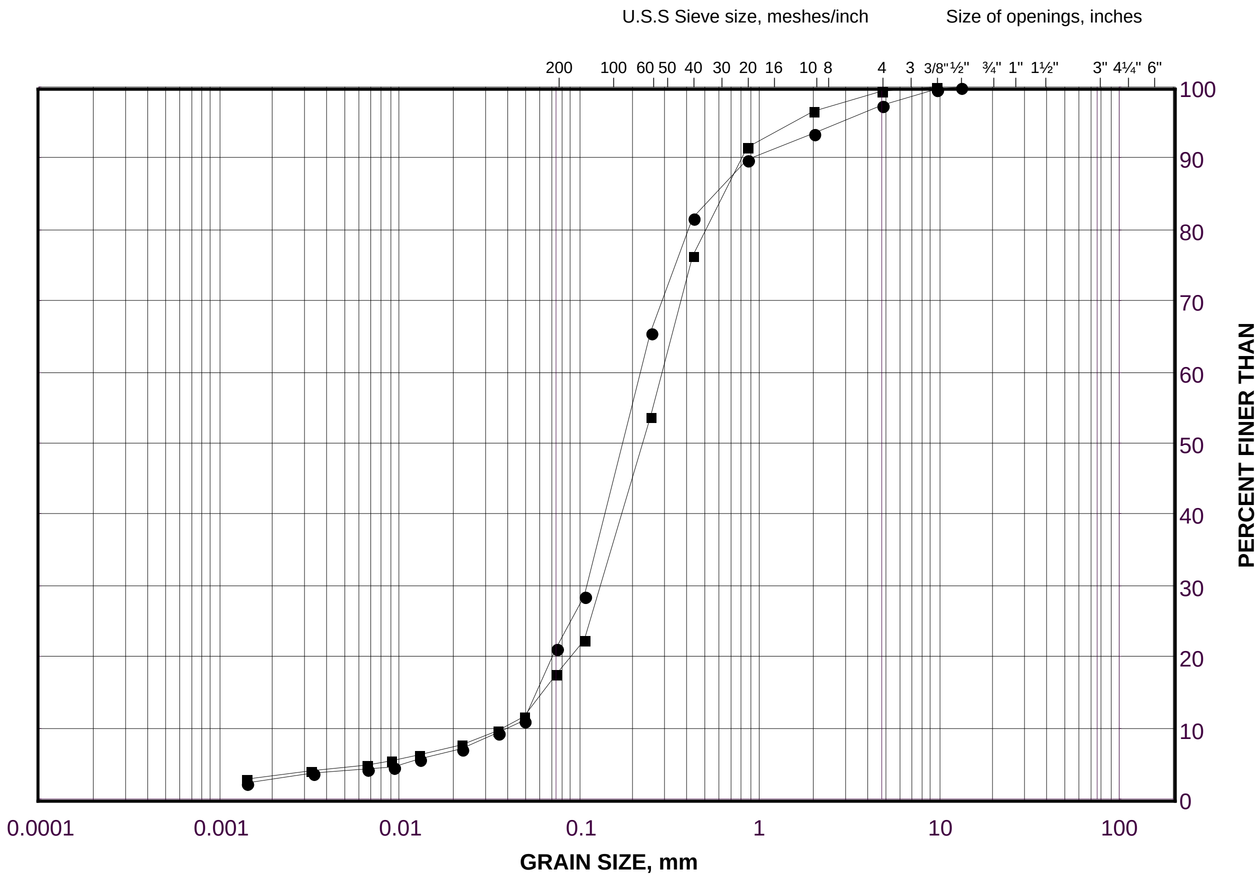
GRAIN SIZE DISTRIBUTION

Sand Layers

FIGURE B8



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BH3	12	282.5
■	BH1B	2	277.8

Project Number: 1663130

Checked By: LCC

Golder Associates

Date: 22-Feb-17

APPENDIX C

Borehole Records and Laboratory Test Results – Golder 2000 Investigation

RECORD OF BOREHOLE No B2-1

METRIC

PROJECT 001-1143F
W.P. 30-95-00
DIST SW HWY 400
DATUM Geodetic
LOCATION N 4899694.3; E 291491.8
BOREHOLE TYPE 108mm DIAMETER SOLID STEM AUGERS
DATE Oct.23/2000
ORIGINATED BY AZ
COMPILED BY LCC
CHECKED BY ASP

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	UNIT WEIGHT / REMARKS	GR	SA	SI	CL
286.2	GROUND SURFACE									
0.0	Silty Sand, some organics, trace clay and gravel (Fill) Compact Moist Brown/black	1	SS	18						
284.7 / 1.5	Topsoil	2	SS	13	~30	OC=7.3%				
283.9 / 2.3	Silty Clay, trace sand and gravel (Till) Very stiff Brown Moist	3	SS	21	w_P ~19, w ~24, w_L ~39					
283.1 / 3.1	Silty Sand to Sand and Silt, trace clay and gravel Loose to very dense Brown Moist to wet	4	SS	9						
		5	SS	51	~14		2	43	50	5
		6	SS	44						
		7	SS	82	~13					
279.6 / 6.6	Clayey Silt, some sand, trace gravel. (Till) Hard Grey Moist	8	SS	108/.15						
		9	SS	100/.08	~7					
		10	SS	100/.15						
275.2 / 11.0	END OF BOREHOLE									

Note:
Water level in open borehole at 2.1m depth (Elev.284.1m) on completion of drilling operations.

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

RECORD OF BOREHOLE No B2-2

METRIC

PROJECT 001-1143F
W.P. 30-95-00
DIST SW HWY 400
DATUM Geodetic
LOCATION N 4899636.5; E 291463.6
BOREHOLE TYPE 108mm DIAMETER SOLID STEM AUGERS
DATE Oct.26/2000
ORIGINATED BY PKS
COMPILED BY LCC
CHECKED BY ASP

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
285.9	GROUND SURFACE				
0.0	Sand and Gravel, trace silt, trace clay pockets and asphalt pieces (Fill) Loose to compact Moist Brown	1	SS	7	
		2	SS	25	
		3	SS	16	
283.8	Topsoil				
283.5 / 2.4	Silty Clay, trace sand and gravel (Till) Stiff to very stiff Moist Grey	4	SS	15	
		5	SS	15	1 24 36 39
		6	SS	23	
		7	SS	15	
279.9 / 6.0	Clayey Silt, trace to some sand and gravel (Till) Hard Moist Grey	8	SS	121	
		9	SS	108	
277.1 / 8.8	Silty Sand, trace clay and gravel (Till) Very dense Moist Grey	10	SS	100/.23	
276.4 / 9.5	END OF BOREHOLE				

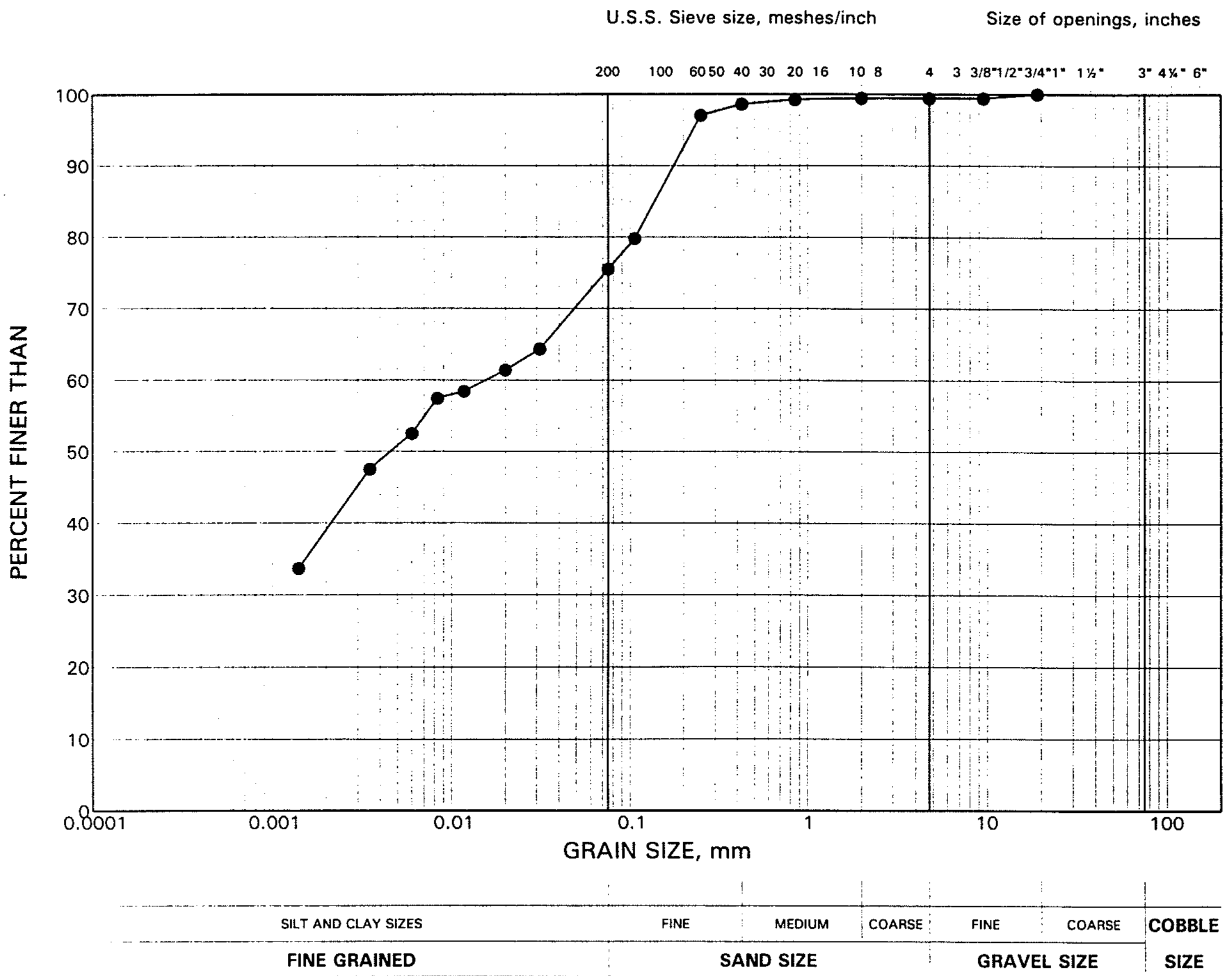
Notes:
1. Water level in open borehole at 6m depth (Elev.279.9m) on completion of drilling operations.
2. Water level in piezometer at 1.9m depth (Elev.284.0m) on January 19, 2001, and at 1.1m depth (Elev.284.8m) on March 15, 2001.

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (285, 284, 283, 282, 281, 280, 279, 278, 277); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X REMOULDED; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³

+³, X³: Numbers refer to Sensitivity   O ³% STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION TEST RESULT
Silty Clay Till

FIGURE 1



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	B2-2	5	282.5

Project 001-1143F

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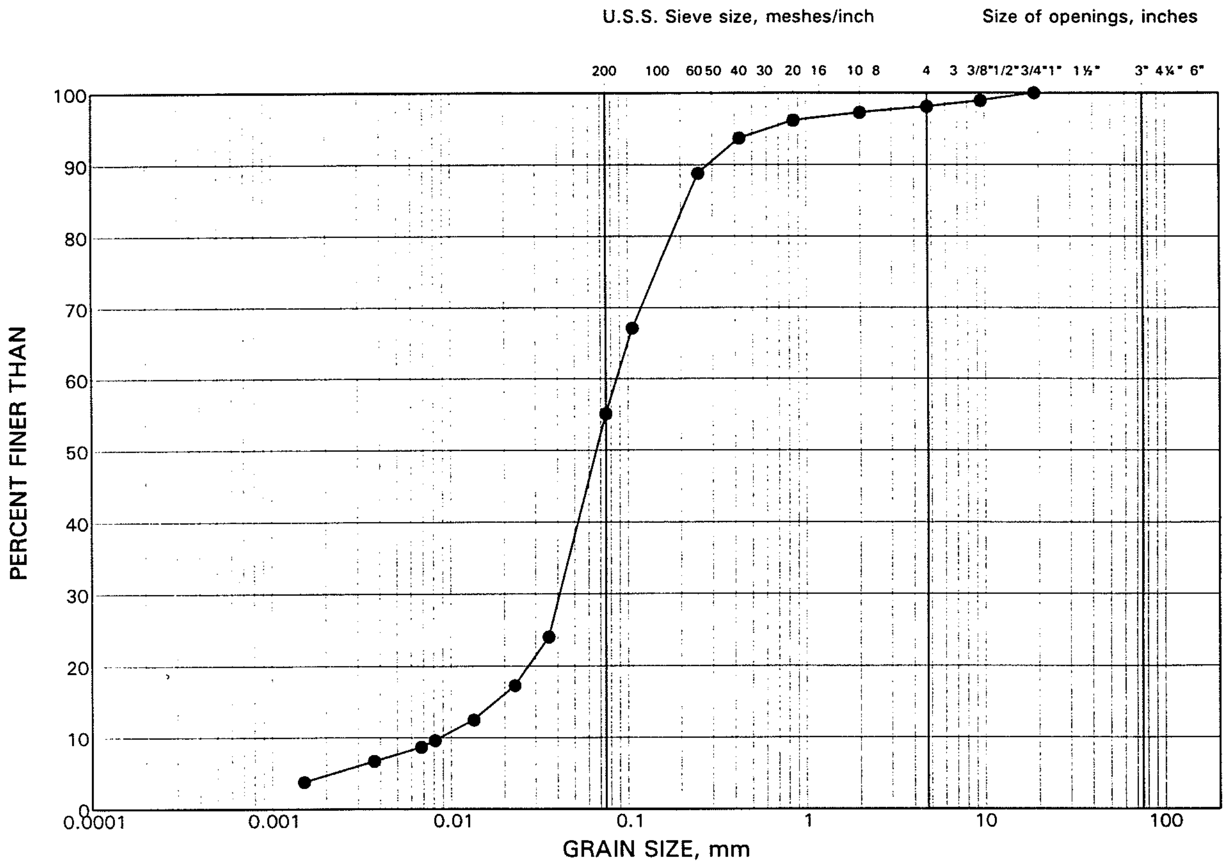
GRAIN SIZE DISTRIBUTION TEST RESULT
Sand and Silt

FIGURE 2



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	B2-1	5	282.1

APPENDIX D

Non-Standard Special Provision

NON-STANDARD SPECIAL PROVISION – Subexcavation for RSS Wall in Front of East Abutment

Special Provision

This special provision outlines the procedure to be used for sub-excavation of the organic layer within the footprint of the retained soil system (RSS) wall in front of the east abutment of the Highway 400-4th Line underpass. The depth of subexcavation and backfilling requirements is noted on the East Abutment Retained Soil System Wall drawing.

Staged excavation in strips of limited width shall be carried out to maintain the stability of the excavation adjacent to Highway 400, and to minimize groundwater control requirements during backfilling. The staged excavation procedures are outlined as follows:

a) Removal of the organic layer and overlying fill materials within the RSS wall footprint shall be carried out in short "strip" sections perpendicular to the Highway 400 alignment, with the base of the excavation (as measured parallel to Highway 400) not wider than 3 m.

b) Excavation and backfilling operations shall be carried out simultaneously in a manner that the excavation is not left open for more than the 3 m "strip" width at any given time.

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