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**FOUNDATION INVESTIGATION
AND DESIGN REPORT
W-N/S RAMP HIGH FILL EMBANKMENT
HIGHWAY 401-COUNTY ROAD 30 INTERCHANGE
RAMP AND GRADE IMPROVEMENTS
G.W.P. 256-98-00**

Submitted to:

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PART A

**FOUNDATION INVESTIGATION REPORT
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Giffels Associates Limited (Giffels) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for culvert extensions and new culverts along Proctor's Creek, and for embankments 4.5 m or more in height within a section of the realigned W-N/S Ramp, at the Highway 401-County Road 30 interchange near Brighton, Ontario.

This report addresses the subsurface investigation for the high fill embankment for the proposed realignment of the W-N/S Ramp.

The terms of reference and scope of work for the foundation investigation are outlined in MTO's Request for Proposal, dated May 2006, and in Section 6.8 of Giffels' Technical Proposal for this assignment.

2.0 SITE DESCRIPTION

The new high fill embankment site is located in the southwest quadrant of the Highway 401-County Road 30 interchange, south of the existing W-N/S Ramp, near Brighton, Ontario.

The high fill embankment portion of the new W-N/S Ramp will extend from approximately Station 10+220 to 10+500. The new W-N/S Ramp will be constructed partially over the existing access/service road embankment, which is between 2 m and 2.5 m in height, between approximately Stations 10+310 and 10+460, and it will cross over Proctor's Creek at approximately Station 10+420.

The natural ground surface along the new W-N/S Ramp alignment in the immediate vicinity of Proctor's Creek is at about Elevation 188.5 m to 189, and the creek bed is at about Elevation 188.5 m to 188 m. To the west and east of the creek and its flood plain, the natural ground surface rises to approximately Elevation 202 m.

The terrain at the site is generally grass-covered, with scattered trees and shrubs located along the toes of the existing access/service road and along the banks of Proctor's Creek.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out between May 7 and 11, 2007. Nine boreholes (Boreholes 07-1 to 07-3, 07-5 to 07-9 and 07-11) were advanced using a CME-55 track-mounted drill rig and portable drilling equipment, supplied and operated by Marathon Drilling Company Ltd. of Ottawa, Ontario. The borehole locations are shown on Drawing 1, and noted on the borehole logs.

All of the boreholes were located within the footprint of the proposed alignment of the new W-N/S Ramp. The boreholes were drilled to depths of between 3.4 m and 15.5 m below the natural ground surface or access/service road surface. Boreholes 07-1 to 07-3 and 07-5 to 07-9 were advanced using 108 mm inside diameter continuous flight hollow stem augers, or wash boring methods using "NQ" casing, and Borehole 07-11 was advanced using portable drilling equipment. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth, using 50 mm outside diameter split-spoon samplers driven with an automatic hammer in accordance with the Standard Penetration Test (SPT) procedure. In Borehole 07-11, which was advanced using portable drilling equipment, a half-weight (i.e., 70 pound) hammer was used to drive the split-spoon sampler; as noted on the borehole records appended to this report, the SPT "N" values have been converted to an equivalent value for a full-weight hammer.

The groundwater conditions in the open boreholes were observed throughout the drilling operations, and a standpipe piezometer was installed in each of Boreholes 07-3 and 07-7 to permit monitoring of the groundwater level(s) at these locations. The piezometers consisted of 50 mm diameter PVC pipe, with a 1.5 m long slotted screen sealed within a filter sand pack within the overburden soils, and a bentonite seal above the sand pack; the piezometer installation details are shown on the borehole records appended to this report. Because groundwater was observed to be flowing from the top of the standpipe piezometer installed in Borehole 07-3, this piezometer was decommissioned prior to demobilization from the site in May 2007, and the entire borehole was sealed with bentonite. The remaining boreholes were also sealed up to the ground surface using bentonite, as per Ontario Regulation 128 (amendment to Ontario Regulation 903).

The field work was supervised throughout by a member of Golder's staff, who located the boreholes in the field, directed the drilling, sampling, and in situ testing operations, and logged the boreholes. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and laboratory testing. Index and classification tests consisting of water contents, Atterberg limits and grain size distributions were carried out on selected soil samples. All of the laboratory tests were carried out to MTO and/or ASTM standards as applicable.

The borehole locations were measured in the field relative to the existing culvert and access roadway, and the ground surface elevation at the borehole locations was confirmed using the digital terrain mapping (DTM) for this project. The borehole locations (northing and easting coordinates referenced to MTM NAD83 coordinate system) and ground surface elevations (referenced to geodetic datum) are presented on the borehole logs and on Drawing 1, and are summarized below.

<i>Borehole Number</i>	<i>Northing (m)</i>	<i>Easting (m)</i>	<i>Ground Surface Elevation (m)</i>
07-1	4,882,198.0	203,025.3	190.4
07-2	4,882,182.2	202,973.8	190.9
07-3	4,882,149.2	202,936.9	192.7
07-5	4,882,110.9	202,904.6	193.4
07-6	4,882,070.0	202,875.6	195.3
07-7	4,882,217.9	203,071.4	193.2
07-8	4,882,233.4	203,118.9	196.4
07-9	4,882,190.1	203,023.8	189.2
07-11	4,882,213.5	203,017.2	190.0

4.0 SITE GEOLOGY AND STRATIGRAPHY

4.1 Regional Geological Conditions

The Highway 401-County Road 30 interchange lies within the Iroquois Plain physiographic region, as delineated in *The Physiography of Southern Ontario*¹; the Iroquois Plain extends around the western and northern shores of Lake Ontario. The soils within this physiographic region represent the flat to undulating lake bed and beaches of the former glacial Lake Iroquois, which occupied the Lake Ontario basin during the last glacial recession.

The soils in the Iroquois Plain are typically comprised of glaciolacustrine clays and silts, though deposits of sand and gravel are also known to be present. The overburden soils are underlain by limestone bedrock of the Trenton Group.

4.2 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of the in situ and laboratory testing are given on the Record of Borehole sheets; the laboratory test results are also shown on Figures 1 to 5 following the text of this report. The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic section on Drawing 1 are inferred from non-continuous sampling and observations of drilling progress and cuttings and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In summary, the native subsoil conditions encountered along the proposed W-N/S Ramp alignment consist of existing fill (underlain, in places, by peat), generally underlain by a deposit of loose to very dense silty sand to silt. In the deeper boreholes advanced at and west of Proctor's Creek, the silty sand to silt deposit was underlain by compact to very dense silty sand to sand and silt till, hard clayey silt till, and/or compact to very dense sand and gravel.

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

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

4.2.1 Fill

Fill, associated with the existing access/service road embankment, was encountered immediately below the ground surface in all of the boreholes except Borehole 07-9. The fill ranged from 0.6 m to 2.4 m in thickness, with the base of the fill encountered between Elevations 194.9 m and 188.0 m, consistent with the broad creek valley in the area.

The fill encountered in the boreholes generally consists of silty sand to sand and silt, containing trace to some gravel, trace clay, and trace quantities of organic matter. A 0.9 m thick layer of clayey silt, containing trace sand, was encountered at the base of the fill layer in Borehole 07-1, and a 0.9 m thick layer of sand and gravel, containing trace to some silt, was encountered at the base of the fill layer in Borehole 07-8. The results of grain size distribution tests conducted on four selected samples of the fill are shown on Figure 1, and the results of Atterberg limits testing carried out on two selected samples of the fill are shown on Figure 2; these test results confirm that the tested fill samples typically consist of non-plastic silty sand to sandy and silt.

The measured Standard Penetration Test (SPT) "N" values within the silty sand to sand and silt fill range from 2 to 8 blows per 0.3 m of penetration, indicative of a very loose to loose relative density. The measured SPT "N" value within the clayey silt fill layer in Borehole 07-1 was 5 blows per 0.3 m of penetration, indicative of a firm consistency at this location, while the measured SPT "N" value within the sand and gravel fill layer in Borehole 07-8 was 31 blows per 0.3 m of penetration, indicative of a dense relative density at this location.

4.2.2 Topsoil / Peat

A 200 mm thick layer of topsoil was encountered immediately below the ground surface, on top of the existing fill, in Borehole 07-1.

In Boreholes 07-1, 07-3, 07-5 and 07-11, a 100 mm to 600 mm thick layer of black fibrous peat was encountered below the existing fill, with the peat surface encountered between approximately Elevation 188.0 m and 192.7 m. In Borehole 07-9, which was advanced adjacent to Proctor's Creek south of the existing access/service road embankment, a 750 mm thick layer of peat was encountered immediately below the ground surface, with its surface at Elevation 189.2 m.

4.2.3 Silty Sand to Silt

A deposit ranging in composition from silty sand to silt was encountered below the fill and peat (where present) in all of the boreholes except Borehole 07-3. The surface of the silty sand to silt deposit was encountered between Elevations 187.8 m and 188.8 m in Boreholes 07-1, 07-2, 07-9 and 07-11 near Proctor's Creek; the deposit was fully penetrated in these boreholes, where it was found to

range in thickness from 5.5 m to 10.8 m. The surface of the silty sand to silt deposit was encountered between Elevations 192.7 m and 193.0 m in Boreholes 07-5 and 07-6 to the west of Proctor's Creek, near the west limit of the proposed high fill embankment; the deposit was also fully penetrated in these boreholes, where it was found to be about 1.5 m thick. East of Proctor's Creek in Boreholes 07-7 and 07-8, the surface of the silty sand to silt deposit was encountered at Elevations 190.9 m and 194.9 m, respectively; the deposit was not fully penetrated in these boreholes, but it is at least 5.2 m to 5.9 m thick at these locations.

The deposit typically varies in composition from silt containing trace to some sand, to sandy silt, to sand and silt, to silty sand, containing trace gravel and clay. The results of grain size distribution tests conducted on eleven selected samples of this deposit are shown on Figures 3A and 3B. An Atterberg limits test conducted on one selected sample of silt (Borehole 07-9, Sample 9) confirmed that this deposit is non-plastic.

The measured SPT "N" values within the silty sand to silt deposit range from 0 blows (weight of hammer) to 24 blows per 0.3 m of penetration; however, as noted on the borehole records, the lower SPT "N" values of typically 0 to 8 blows per 0.3 m of penetration are attributed to sample disturbance as a result of groundwater inflow to the borehole during sampling. Therefore, the silty sand to silt deposit is considered to have a loose to compact, but typically compact, relative density.

4.2.4 Silty Sand to Sand and Silt Till

A deposit of silty sand to sand and silt till was encountered at approximately Elevation 179.8 m to 182.4 m, below the silty sand to silt deposit in Boreholes 07-1 and 07-11 near Proctor's Creek. To the west of Proctor's Creek, silty sand to sand and silt till was encountered at Elevation 190.4 m (immediately below the fill and peat) in Borehole 07-3, and at Elevation 191.1 m (below the silty sand to silt deposit) in Borehole 07-5. This deposit was fully penetrated in Boreholes 07-1 and 07-3, where it was found to have a thickness of 4.3 m and 3.5 m, respectively.

The results of grain size distribution tests completed on two samples of the cohesionless till deposit are shown on Figure 4. These results, together with one Atterberg limit test (on Borehole 07-3, Sample 6) which showed the material to be non-plastic, confirm that this till is a non-plastic silty sand to sand and silt, containing trace to some gravel and trace clay.

The measured SPT "N" values within the silty sand to sand and silt till range from 3 blows (though typically greater than 17 blows) to greater than 100 blows per 0.3 m of penetration, indicating that the deposit generally has a compact to very dense relative density.

4.2.5 Clayey Silt Till

A deposit of clayey silt till was encountered at Elevation 191.5 m, below the silty sand to silt deposit, in Borehole 07-6 near the western limit of the proposed high fill embankment. The borehole was terminated within the clayey silt till, which was penetrated for a thickness of about 2.9 m.

A grain size distribution test was conducted on one selected sample of this deposit; the result, which is plotted with the other till gradation results on Figure 4, indicates that the deposit consists of clayey silt with sand, some gravel, and that it is finer in gradation than the silty sand to sand and silt till encountered elsewhere at the site.

The measured SPT "N" values within the clayey silt till range from 45 to 71 blows per 0.3 m of penetration, indicating that the deposit has a hard consistency.

4.2.6 Sand and Gravel

A sand and gravel deposit was encountered below the silty sand to silt deposit, or the silty sand to sand and silt till deposit, in Boreholes 07-1, 07-2, 07-3 and 07-9. The surface of the sand and gravel deposit was encountered between about Elevations 186.9m and 175.5 m in these boreholes. The sand and gravel ranged in thickness between 0.6 m and 3.6 m; however, none of the boreholes fully penetrated the deposit.

The deposit varies in composition from sand and gravel, some silt to silty sand and gravel; the results of grain size distribution tests conducted on two selected samples of this material are shown on Figure 5.

The measured SPT "N" values within the sand and gravel deposit ranged from 18 blows per 0.3 m of penetration to 109 blows for 0.1 m of penetration, indicating that the deposit has a compact to very dense relative density.

4.3 Groundwater Conditions

The water levels were observed in the boreholes following completion of drilling, and these observations are noted on the borehole records following the text of this report. Artesian groundwater conditions were observed in Boreholes 07-3, 07-9 and 07-11 immediately following completion of the drilling and prior to withdrawal of the hollow stem augers. In Boreholes 07-9 and 07-11, the artesian groundwater pressures subsided immediately following withdrawal of the hollow stem augers, and these boreholes were sealed up to the ground surface (above any caved soils as noted on the borehole records) using bentonite.

A standpipe piezometer was installed to measure the artesian condition in Borehole 07-3; a standpipe piezometer was also installed in Borehole 07-7, to monitor the water level at this location. Details of the piezometer installations are shown on the borehole records appended to this report. The water levels measured in the piezometers are summarized as follows:

<i>Borehole Number</i>	<i>Depth to Water Level</i>	<i>Water Level Elevation</i>	<i>Date</i>
07-3	3.0 m+ Artesian	195.7 m+	May 11, 2007*
07-7	0.0 m	193.2 m	May 11, 2007

* Piezometer was subsequently removed and the borehole was sealed with bentonite

Following installation of the standpipe piezometer in Borehole 07-3, groundwater was observed to be flowing from the top of the standpipe piezometer at 3.0 m above ground surface. This standpipe piezometer was decommissioned and the borehole sealed with bentonite prior to demobilizing from the site on May 11, 2007.

Based on the moisture conditions and water levels observed during drilling and in the piezometers, the groundwater level associated with the near-surface soils varies from about Elevation 188 m to 189 m near Proctor's Creek, to about Elevation 189 m to 192 m (at or just below the original ground surface) to the west of Proctor's Creek, and to about Elevation 191 m to 194.5 m (again, at or just below the original ground surface) to the east of Proctor's Creek. However, higher water levels, associated with the groundwater pressures in the deeper silty sand and sand and gravel deposits, have been encountered in some of the boreholes, as follows:

- approximately Elevation 189.5 m to 190 m near Proctor's Creek; and
- up to about Elevation 195.7 m as encountered in Borehole 07-3 to the west of Proctor's Creek.

The groundwater level at the site should be expected to fluctuate as a result of seasonal variations in precipitation and the Proctor's Creek water levels.

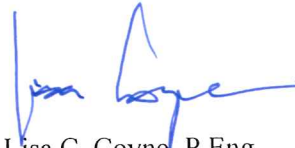
5.0 CLOSURE

This Foundation Investigation Report was prepared by Mr. Matthew Kelly, and reviewed by Ms. Lisa Coyne, P.Eng., an Associate and geotechnical engineer with Golder. Mr. Jorge Costa, P.Eng., a Principal of and Designated MTO Contact for Golder, conducted an independent review of the report.

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PART B

**FOUNDATION DESIGN REPORT
W-N/S RAMP HIGH FILL EMBANKMENT
HIGHWAY 401-COUNTY ROAD 30 INTERCHANGE
RAMP AND GRADE IMPROVEMENTS
G.W.P. 256-98-00**

6.0 ENGINEERING RECOMMENDATIONS

6.1 General

The following sections of this report provide geotechnical/foundation design recommendations for the high fill embankment portion of the realigned W-N/S Ramp, as part of the Highway 401-County Road 30 interchange improvement works. The high fill embankment portion of the realigned W-N/S Ramp will extend from approximately Station 10+220 to 10+500, and will range in height from about 4.5 m to a maximum of approximately 7.5 m near Proctor's Creek at approximately Station 10+420. Although earth or granular fill will be used for most of the new high fill embankment, consideration is being given to the use of rock fill for construction of a portion of the new high fill embankment, between approximately Stations 10+320 and 10+440, to minimize encroachment into the Proctor's Creek floodplain in this area.

The recommendations provided in the following sections are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation at this site. The interpretation and recommendations are intended to provide the designers with sufficient information to design the proposed high fill embankment. Where comments are made on construction, they are provided in order to highlight those aspects which could affect the design of the project, and for which special provisions or operational constraints may be required in the Contract Documents. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, scheduling and the like.

6.2 Subgrade Preparation and Embankment Construction

6.2.1 Subgrade Preparation

The embankment fill for the existing access/service road, over which the new W-N/S Ramp will be constructed, has a very loose to loose relative density (based on measured Standard Penetration Test "N" values of 2 to 8 blows per 0.3 m of penetration). Further, in several of the boreholes, this existing fill was found to be underlain by between 100 mm and 600 mm of very soft fibrous peat.

In order to minimize settlement and stability issues and improve the long-term performance of the high fill embankment and pavement structure, it is recommended that all existing embankment fill and peat within the footprint of the realigned W-N/S Ramp be removed prior to construction of the new high fill embankment. This will require subexcavation adjacent to and, in places, below the south toe of the existing W-N/S Ramp embankment, particularly in the vicinity of Proctor's Creek.

If the existing W-N/S Ramp will remain open during subexcavation works under the south toe of the existing ramp embankment, special excavation procedures will be required to maintain stability of the existing ramp embankment, as follows:

- Removal of the existing embankment fill and peat below the south toe of the existing W-N/S Ramp embankment should be carried out in short sections perpendicular to the existing embankment, with the base of the excavation not wider than 3 m at any time. Excavation and backfilling operations should be carried out simultaneously in such a manner that the excavation is not left open for more than 3 m in length at any time.
- The sub-excavation should be carried out such that the base of the excavation is maintained outside a zone defined by a line drawn downward at 1 horizontal to 1 vertical (1H:1V) from the crest of the existing W-N/S Ramp embankment to the base of the excavation.

6.2.2 Embankment Construction

The new W-N/S Ramp embankment fill should be placed and compacted in accordance with MTO's Special Provision 105S10. The new embankment fill could consist of clean earth fill or granular fill. Alternatively, between approximately Stations 10+320 and 10+440 where steeper embankment side slopes may be desirable to minimize impacts on the Proctor's Creek floodplain, consideration could be given to the use of rock fill for the embankment construction; rock fill material would be acceptable provided that the silty sand to silt subgrade is covered with a sand and gravel blanket (OPSS 1010 Granular "B" Type II or similar), and provided that the surface of the rock fill is properly chinked or a separation layer is placed before placing any granular fill for the pavement structure.

To reduce surface water erosion on the new W-N/S Ramp embankment side slopes, placement of topsoil and seeding or pegged sod is recommended. Ditching alongside the new ramp embankment may extend below the groundwater level at the site, particularly during wet periods of the year. The ditch cuts should be inspected after completion to check for evidence of water seepage that could affect the surficial stability. It is recommended that remedial measures, such as a granular blanket, be placed on the ditch slopes where seepage is present.

6.3 Static Embankment Stability

The following sections outline the methods and parameters used to assess the static global stability of the proposed high fill embankment section, and the results of the static stability analyses.

6.3.1 Analysis Methods

Static slope stability analyses were performed using the commercially available program SLOPE/W, produced by Geo-Slope International Ltd., employing the Morgenstern-Price method of analysis. For all analyses, the factor of safety of numerous potential failure surfaces was computed in order to establish the minimum factor of safety. A target factor of safety of 1.3 against deep-seated, global failure that would affect ramp operation is normally used for the design of embankment slopes under static conditions. This factor of safety is considered adequate for the W-N/S Ramp embankment at this site, considering the design requirements and the available field data.

For cohesionless soils, effective stress parameters were employed in the analyses assuming drained conditions. The effective stress parameters (effective friction angle and cohesion) for these soils were estimated from empirical correlations using the results of in situ Standard Penetration Tests (SPT), in conjunction with engineering judgement considering experience in similar soil conditions.

The static stability analyses were performed for the critical section of the proposed high fill embankment; for the W-N/S Ramp, the critical section was assumed to correspond to the highest embankment height of about 7.5 m, which occurs at approximately Station 10+420 near Proctor's Creek. The soil parameters that have been used in the stability analyses are summarized below.

<i>Soil Type</i>	<i>Bulk Unit Weight</i>	<i>Effective Angle of Friction</i>	<i>Effective Cohesion</i>
Earth or granular fill for new W-N/S Ramp embankment	21 kN/m ³	32°	0 kPa
Rock fill for new ramp W-N/S Ramp embankment	19 kN/m ³	38°	0 kPa
Compact silty sand to silt	18 kN/m ³	30°	0 kPa
Compact to very dense silty sand to sand and silt till	21 kN/m ³	32° to 35°	0 kPa
Very dense sand and gravel	21 kN/m ³	35°	0 kPa

The static stability analyses were carried out with the groundwater level at the existing ground surface, as this is the expected worst case scenario during periods of high water levels.

6.3.2 Results of Static Global Stability Analyses

Where granular or earth fill is used for the new W-N/S Ramp embankment, the new side slopes should be constructed no steeper than 2 horizontal to 1 vertical (2H:1V). If rock fill is adopted for the new W-N/S Ramp embankment between Stations 10+320 and 10+440, the embankment side slopes should be constructed no steeper than 1.25H:1V.

The results of the static slope stability analyses using the parameters and the embankment side slope configurations given above indicate that the W-N/S Ramp embankment will have a factor of safety of greater than 1.3 against deep-seated slope instability, for 2H:1V side slope configurations for earth/granular fill, and for 1.25H:1V side slope configurations for rock fill. Sample results of the static global stability analyses for earth/granular fill and rock fill embankments are shown on Figures 6 and 7, respectively.

6.4 Liquefaction Potential and Embankment Stability Under Seismic Loading

The following sections outline the methods and parameters used to assess the liquefaction potential and embankment stability under seismic loading, and the results of these seismic analyses.

6.4.1 Analysis Methods

The liquefaction potential of granular soils under seismic loading has been considered using the empirical method outlined in Section C.4.6.2 of the *Commentary to the Canadian Highway Bridge Code (CHBDC)*, which compares the cyclic resistance ratio (CRR) of the soils to the cyclic stress ratio (CSR) caused by the earthquake. The CRR is determined based on correlations with the normalized penetration resistance and fines content of the soil, and corrected for earthquake magnitude and overburden stress effects. The CSR at a given depth is related to the peak ground acceleration, the ratio of the total to effective overburden stress at that depth, and soil flexibility. A factor of 0.65 is used to convert the maximum CSR to an equivalent CSR of uniform cycles. In general, geologically young, loose, saturated deposits of sand, silty sands, and non-plastic silt can be susceptible to liquefaction.

Where liquefaction of the subsoils under the embankment loading is not anticipated, the stability of the embankment slopes is assessed using conventional pseudo-static methods of slope stability analysis under the earthquake-induced peak ground acceleration. A calculated factor of safety of 1.0 is considered appropriate; however, a factor of safety less than 1.0 does not indicate full-scale failure of the embankment slope due to the application of the peak ground acceleration in one direction for a short period of time. In this case, other methods, such as the Newmark sliding block method, can be used to assess the magnitude of the ground movement.

6.4.2 Results of Seismic Analyses

The liquefaction susceptibility of the granular soil deposits underlying the site of the new W-N/S Ramp embankment at Highway 401-County Road 30 and the consequent stability of the embankment under seismic loading conditions has been assessed as described above, using a peak zonal acceleration of 0.07 g. This is based on the zonal acceleration for the Brighton area of 0.05 g, multiplied by an amplification factor of 1.33 for the soil types found at the site. Using the methods outlined above, the soils at this site have a low risk of liquefaction under the characteristic earthquake loading (magnitude 7.5).

A factor of safety of greater than 1.0 is obtained against instability of earth/granular fill (2H:1V side slope configuration) embankments under seismic loading, using a peak zonal acceleration of 0.07 g as described above.

6.5 Settlement Under High Fill Embankment Loading

The following sections outline the methods and parameters used to conduct the settlement analyses, the results of the settlement analyses, and discussions regarding potential settlement mitigation measures.

6.5.1 Methods of Analysis and Geotechnical Engineering Parameters

Settlement analyses have been carried out to estimate the total magnitude of settlement that will occur under the new W-N/S Ramp high fill embankment, between approximately Stations 10+220 and Station 10+500. The settlement analyses were carried out using the commercially-available program UNISETTLE (Version 3.0).

The compression of the compact silty sand to silt, compact to very dense silty sand to sand and silt till, hard clayey silt till, and compact to very dense sand and gravel deposits were modelled by estimating an elastic modulus of deformation based on the SPT "N" values and correlations proposed by Bowles (1984)² and Kulhawy and Mayne (1990)³. The parameters used in the settlement analyses are presented below:

² Bowles, J.E. 1984. *Physical and Geotechnical Properties of Soils*, 2nd Edition, Ed. McGraw-Hill Book Company.

³ Kulhawy, F.H. and P.W. Mayne. 1990. *Manual on Estimating Soil Properties for Foundation Design*. Final Report 1493-6, EL-6800, Electric Power Research Institute, Palo Alto, California.

<i>Soil Unit</i>	<i>Bulk Unit Weight</i>	<i>Elastic Modulus</i>
Existing embankment fill (removed prior to construction of new W-N/S Ramp embankment)	20 kN/m ³	–
Earth/granular fill for new high fill embankment	20 kN/m ³	–
Rock fill for new high fill embankment	19 kN/m ³	–
Compact silty sand to silt	18 kN/m ³	15 MPa
Compact to very dense silty sand to sand and silt till / Hard clayey silt till	21 kN/m ³	40 MPa
Hard clayey silt till	21 kN/m ³	90 MPa
Very dense sand and gravel	21 kN/m ³	90 MPa

6.5.2 Predicted Magnitude of Settlement

The following sources of settlement have been considered:

- self-weight compression of the new W-N/S Ramp embankment fill materials; and
- relatively rapid elastic compression of the generally compact silty sand to silt, compact to very dense silty sand to sand and silt till or hard clayey silt till, and generally very dense sand and gravel deposits that underlie the site.

Settlement of Embankment Fill

Where earth fill or granular fill is used for construction of the new W-N/S Ramp high fill embankment, the settlement of the new fill is expected to be between approximately 15 mm and 20 mm, based on placement of 4.5 m to 7.5 m of earth/granular fill. The majority of this settlement will occur during construction of the new high fill embankment.

If rock fill is adopted for the construction of the new high fill embankment between approximately Stations 10+320 and 10+440, settlement of the rock fill itself will depend on the type of rock, and on the method and sequence of placement and compaction of the rock fill; for this project, it is assumed that limestone rock fill would likely be used. Post-construction settlement may occur as a result of rearrangement of rock particles under load and breakage of rock particles (i.e. local crushing and degradation). Assuming that the rock fill is not end-dumped into its final position and that it is placed in accordance with the requirements outlined in the Special Provision Amendment to OPSS 206, the settlement of rock fill in embankments up to 7 m in height is estimated to be about 0.4 per cent of the rock fill height (per “Rockfill in the Foundation Design of Highway Structures”, prepared by the MTO Research and Development Branch, dated 1982). For the construction of the approximately 7 m to 7.5 m high W-N/S Ramp embankment between Stations 10+320 and 10+440, the potential settlement of rock fill would be between 20 mm and 30 mm. The majority of this settlement will occur during the first year following construction.

Settlement of Founding Soils

Based on the methods of settlement analysis and parameters identified above and the subsurface conditions as encountered in the boreholes, and assuming that the existing embankment fill (approximately 2 m to 2.5 m in thickness) is removed from within the footprint of the new W-N/S Ramp embankment, the following magnitudes of settlement of the founding soils are predicted:

- **West of Station 10+350:** It is estimated that a total of about 20 mm to 25 mm of elastic compression of the founding soils will occur under this section of the high fill embankment, which will be approximately 5 m to 7 m in height relative to the natural ground surface. Of this, approximately 15 mm to 20 mm of compression is predicted to occur in the compact silty sand to silt deposit, and the remainder (less than 5 mm) is predicted to occur in the compact to very dense/hard till and very dense sand and gravel deposits.
- **Between Stations 10+350 and 10+450:** It is estimated that a total of about 60 mm of elastic compression of the founding soils will occur under this section of the high fill embankment, which will be approximately 7 m to 8 m in height relative to the natural ground surface. If rock fill is adopted instead of earth/granular fill for the new embankment construction in this area, it is estimated that a total of about 50 mm to 55 mm of elastic compression of the founding soils will occur under this section of the high fill embankment. The majority of the compression settlement is predicted to occur in the compact silty sand to silt deposit, and less than about 5 mm of compression settlement is predicted to occur in the generally very dense silty sand till and sand and gravel deposit.
- **East of Station 10+450:** It is estimated that approximately 50 mm of elastic compression of the founding soils will occur under this section of the high fill embankment, which will be about 6 m to 7 m in height relative to the natural ground surface.

The magnitudes of settlement as summarized above are those that will be experienced under the ramp pavement, based on the net additional loading (i.e., new high fill embankment loading following removal of the existing embankment fill).

The elastic settlement of the founding soils as predicted above will occur relatively rapidly during and immediately following (within approximately one month) completion of the new high fill embankment.

6.5.3 Settlement Mitigation

Since the settlement of the founding soils will occur relatively rapidly during and immediately following completion of the new high fill embankment, it is recommended that construction of the new W-N/S Ramp embankment be completed one month in advance of the ramp paving.

Ultra-lightweight slag fill could also be used for the new embankment construction between approximately Stations 10+350 and 10+500, to reduce the magnitude of new loading imposed on the founding soils, thereby reducing the magnitude of elastic compression of the founding soils. The use of ultra-lightweight slag fill in this area would reduce the predicted magnitude of elastic compression to approximately 25 mm to 30 mm. However, the use of ultra-lightweight slag fill is not considered to be practical for construction of the new embankment due to the relatively high cost for supply of the slag fill, the relatively small magnitude and short duration of predicted settlement, and the availability of sufficient time (one month) for "preloading" prior to paving.

6.6 Construction Considerations

6.6.1 Excavation and Temporary Roadway Protection

Prior to construction of the new W-N/S Ramp high fill, excavation of the existing access/service road embankment fill and a portion of the south side slope of the existing W-N/S Ramp embankment (in the vicinity of Proctor's Creek) will be required. As discussed in Section 6.2, controlled excavation, carried out perpendicular to the existing W-N/S Ramp embankment, will be required to maintain traffic on the existing W-N/S Ramp during the subexcavation work. A sample operational constraint to address these special excavation procedures is provided in Appendix A.

Alternatively, depending on the construction staging sequence and schedule, temporary roadway protection could be provided along the existing W-N/S Ramp in the vicinity of Proctor's Creek to facilitate the subexcavation of the existing embankment fill and removal of the underlying peat. The temporary excavation support system should be designed and constructed in accordance with MTO's Special Provision 105S19. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in SP105S19, provided that any utilities that may remain present adjacent to the excavation can tolerate this level of deformation.

6.6.2 Preloading

As discussed in Section 6.5.3, it is recommended that construction of the new W-N/S Ramp embankment be completed one month in advance of the ramp paving. A sample operational constraint to address this one-month "preloading" period is provided in Appendix A.

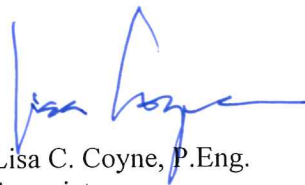
7.0 CLOSURE

This Foundation Design Report was prepared by Mr. Matthew Kelly, and reviewed by Ms. Lisa Coyne, P. Eng., an Associate and geotechnical engineer with Golder. Mr. Jorge Costa, P.Eng., a Principal of and Designated MTO Contact for Golder, conducted an independent review of the report.

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Principal, Designated MTO Contact

MWK/LCC/JMAC/mwk/lcc

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LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

III. SOIL DESCRIPTION

(a) Cohesionless Soils

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

(b) Cohesive Soils

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

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

IV. SOIL TESTS

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

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

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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
$\log_{10} x$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation
*	Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density \times acceleration due to gravity)

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

- Notes: 1 $\tau = c' + \sigma' \tan \phi'$
2 Shear strength = (Compressive strength)/2

PROJECT 06-1111-057		RECORD OF BOREHOLE No 07-1		1 OF 2 METRIC	
W.P. 256-98-00		LOCATION N 4882198.0 ; E 203025.3		ORIGINATED BY SB	
DIST HWY 401		BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers		COMPILED BY MWK	
DATUM Geodetic		DATE May 7, 2007		CHECKED BY LCC/JMAC	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)			
190.4	GROUND SURFACE						20	40	60	80	100							
0.0	TOPSOIL																	
0.2	Sand and silt, trace to some gravel, trace clay, containing rootlets (FILL) Loose Brown Moist		1	SS	7													
			2	SS	8										12 43 40 5			
188.8																		
1.6	Clayey silt, trace sand (FILL) Firm Brown Moist		3	SS	5						o				0 2 84 14			
188.0																		
2.6	PEAT		4	SS	4													
	SILT, trace to some sand, trace clay Compact Brown to grey Moist to wet		5	SS	16						o							
			6	SS	21						o				0 10 80 10			
			7	SS	13													
			8	SS	3*													
			9	SS	WH*						o				0 7 89 4			
			10	SS	19													
179.8																		
10.6	Silty SAND, some gravel, trace clay (TILL) Compact to very dense Grey Moist		11	SS	22													
			12	SS	47										23 49 25 3			
			13	SS	92						o							
175.5																		

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Continued Next Page

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



RECORD OF BOREHOLE No 07-1

2 OF 2 METRIC

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882198.0 ; E 203025.3

ORIGINATED BY SB

DIST HWY 401

BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers

COMPILED BY MWK

DATUM Geodetic

DATE May 7, 2007

CHECKED BY LCC/JMAC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L		
14.9	SAND and GRAVEL		14	SS	91/15		175										
174.9	Very dense																
15.5	Grey Wet																
Notes: 1. * Low SPT "N" values (WH and 3 blows/0.3 m of penetration) are the result of sample disturbance due to groundwater inflow to the borehole. 2. Water level in open borehole at a depth of 2.1 m (Elev. 188.3 m) on completion of drilling.																	

+³, X³: Numbers refer to Sensitivity O³% STRAIN AT FAILURE

RECORD OF BOREHOLE No 07-2

1 OF 1 **METRIC**

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882182.2 :E 202973.8

ORIGINATED BY SB

DIST HWY 401

BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers

COMPILED BY MWK

DATUM Geodetic

DATE May 8, 2007

CHECKED BY LCC/JMAC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)		
								20 40 60 80 100							10 20 30		
190.9	GROUND SURFACE																
0.0	Silty sand, trace gravel, containing rootlets (FILL) Loose Brown to grey Moist		1	SS	5												
			2	SS	5												
			3	SS	6												
188.8																	
2.1	SAND and SILT, trace gravel Compact Grey-brown, becoming grey at a depth of 3.8 m Wet		4	SS	16									3 40 55 2			
			5	SS	17												
			6	SS	21												
			7	SS	20												
			8	SS	18												
183.3			9	SS	18									22 66 10 2			
7.6	SAND and GRAVEL to gravelly SAND, some silt Compact to very dense Grey Wet		10	SS	100/1												
180.0			11	SS	109/1												
10.9	END OF BOREHOLE																
	Notes: 1. Water level in open borehole at a depth of 1.0 m (Elev. 189.9 m) on completion of drilling.																

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RECORD OF BOREHOLE No 07-3

1 OF 1 **METRIC**

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882149.2 ; E 202936.9

ORIGINATED BY SB

DIST HWY 401

BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers

COMPILED BY MWK

DATUM Geodetic

DATE May 8, 2007

CHECKED BY LCC/JMAC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
192.7	GROUND SURFACE													
0.0	Silty sand, trace gravel, containing rootlets (FILL) Very loose to loose Grey-brown to grey Moist		1	SS	2		192							
			2	SS	6									
190.9			3	SS	3		191							
1.8	PEAT													
190.4														
2.3	SAND and SILT, trace gravel and clay (TILL) Very loose to compact Grey Moist to wet		4	SS	3		190							
			5	SS	22									
			6	SS	22		189							
			7	SS	17		188							
186.9														
5.8	SAND and GRAVEL, some silt Very dense Grey Moist		8	SS	63/15		187							
							186							
			9	SS	78/15		185							
							184							
183.3			10	SS	92/15									
9.4	END OF BOREHOLE													
	Notes: 1. Water level in piezometer flowing (artesian conditions) at 3.0 m above ground surface (i.e. at Elev. 195.7 m) upon completion of installation. 2. Piezometer removed and borehole sealed with bentonite.													

MIS-MTO 001 061111057MTO.GPJ GAL-MISS.GDT 11/15/07 JFC

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

RECORD OF BOREHOLE No 07-5

1 OF 1 **METRIC**

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882110.9 ; E 202904.6

ORIGINATED BY SB

DIST HWY 401

BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers

COMPILED BY MWK

DATUM Geodetic

DATE May 10, 2007

CHECKED BY LCC/JMAC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL						
193.4	GROUND SURFACE						20	40	60	80	100					
0.0	Silty sand (FILL) Very loose Brown Moist		1	SS	2	▽	193									
192.7	PEAT						192									
0.8	SAND and SILT, some gravel, trace to some clay Compact Grey - brown Moist		2	SS	10											
			3	SS	11											
191.1	Silty SAND, some gravel, trace clay, containing cobbles and boulders (TILL) Dense to very dense Grey Moist		4	SS	36		191									
2.3			5	SS	100/1											
190.0	END OF BOREHOLE						190									
3.4	Notes: 1. Borehole terminated at 3.4 m depth due to auger refusal/grinding on probable boulder. 2. Water level in open borehole at a depth of 2.7 m (Elev. 190.7 m) on completion of drilling.															

RECORD OF BOREHOLE No 07-6

1 OF 1 **METRIC**

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882070.0 ; E 202875.6

ORIGINATED BY SB

DIST HWY 401


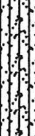

BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers

COMPILED BY MWK

DATUM Geodetic

DATE May 9, 2007

CHECKED BY LCC/JMAC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								20 40 60 80 100										10 20 30		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED												
195.3	GROUND SURFACE																			
0.0	Sand and silt, containing organics and rootlets (FILL) Very loose to loose Brown Moist		1	SS	3															
			2	SS	4															
			3	SS	7															
193.0	Sandy SILT, some clay, trace to some gravel Compact Grey-brown Moist to wet		4	SS	19															
2.3			5	SS	24															
191.5	CLAYEY SILT with sand, trace gravel (TILL) Hard Grey Moist		6	SS	57															
3.8			7	SS	71															
188.6	END OF BOREHOLE		8	SS	45															
6.7	Notes: 1. Borehole dry on completion of drilling.																			

RECORD OF BOREHOLE No 07-7

1 OF 1 **METRIC**

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882217.9 ; E 203071.4

ORIGINATED BY SB

DIST HWY 401



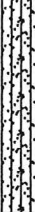
BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers

COMPILED BY MWK

DATUM Geodetic

DATE May 10, 2007

CHECKED BY LCC/JMAC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED										W _p W W _L		
193.2	GROUND SURFACE						20	40	60	80	100	10	20	30						
0.0	Sand and silt, trace gravel, containing rootlets and organics (FILL) Loose Brown Moist		1	SS	5															
			2	SS	6															
			3	SS	4															
190.9																				
2.3	Sandy SILT, trace gravel Compact Brown Wet		4	SS	18															
			5	SS	15															
			6	SS	12															
			7	SS	17															
187.1																				
6.1	Silty SAND, trace gravel Loose to compact Brown Wet		8	SS	9															
			9	SS	11															
185.0																				
8.2	END OF BOREHOLE																			
	Notes: 1. Water level in piezometer at a depth of 1.5 m (Elev. 191.7 m) on completion of installation. 2. Water level measured at a depth of 0.0 m (Elev. 193.2 m) on May 11, 2007.																			

MIS-MTO 001 061111057MTO.GPJ GAL-MISS.GDT 11/15/07 JFC

RECORD OF BOREHOLE No 07-8

1 OF 1 **METRIC**

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882233.4, E 203118.9

ORIGINATED BY SB

DIST HWY 401

BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers

COMPILED BY MWK

DATUM Geodetic

DATE May 10, 2007

CHECKED BY LCC/JMAC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								20 40 60 80 100										10 20 30		

196.4	GROUND SURFACE																
0.0	Silty sand, trace gravel, containing rootlets (FILL)		1	SS	7		196										
195.8	Loose Brown Moist																
0.6	Sand, and gravel, trace to some silt (FILL)		2	SS	31												
194.9	Dense Brown Moist to wet	3	SS	6													
1.5	SAND and SILT to SILT, trace sand, trace clay and gravel	4	SS	12													
	Loose to dense	5	SS	20													
	Brown to grey	6	SS	32													
	Moist to wet	7	SS	29													

RECORD OF BOREHOLE No 07-9

1 OF 2 **METRIC**

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882190.1 ; E 203023.8

ORIGINATED BY SB

DIST HWY 401

BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers

COMPILED BY MWK

DATUM Geodetic

DATE May 11, 2007

CHECKED BY LCC/JMAC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)			
								20 40 60 80 100							PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED											
189.2 0.0	GROUND SURFACE PEAT		1	SS	2	iV	189											
188.4 0.8	SILT, trace to some sand, trace clay Compact Brown to grey Moist to wet		2	SS	16		188											
			3	SS	11													
			4	SS	11		187											
			5	SS	13		186											
			6	SS	8*		185											
			7	SS	13		184											
								183										
			8	SS	5*		182											
								181										
			9	SS	16		180											
								179										
	10	SS	7*	178														
	11	SS	16															
177.6 11.6	SAND and GRAVEL Very dense Grey Wet		12	SS	116		177											
176.6 12.6	END OF BOREHOLE																	

MIS-MTO 001 061111057MTO.GPJ GAL-MISS.GDT 11/15/07 JFC

Continued Next Page

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



RECORD OF BOREHOLE No 07-9

2 OF 2 **METRIC**

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882190.1 ; E 203023.8

ORIGINATED BY SB

DIST HWY 401

BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers

COMPILED BY MWK

DATUM Geodetic

DATE May 11, 2007

CHECKED BY LCC/JMAC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40						60	80	100	20
<p>Notes:</p> <p>1. * Low SPT "N" values (5, 7 and 8 blows/0.3 m of penetration) are the result of sample disturbance due to groundwater inflow to the borehole.</p> <p>2. Slight artesian groundwater pressures encountered at a depth of 12.2 m. Artesian pressures subsided as augers withdrawn and soils caved into borehole below a depth of 6.1 m. Borehole sealed with bentonite from ground surface to depth of 6.1 m.</p> <p>3. Water level in open borehole at a depth of 0.7 m (Elev. 188.5 m) on completion of drilling.</p>																		

MIS-MTO 001 061111057MTO.GPJ GAL-MISS.GDT 11/15/07 JFC

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



RECORD OF BOREHOLE No 07-11

1 OF 1 METRIC

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882213.5 ; E 203017.2

ORIGINATED BY SB

DIST HWY 401

BOREHOLE TYPE Portable Drilling Equipment, NQ Casing

COMPILED BY MWK

DATUM Geodetic

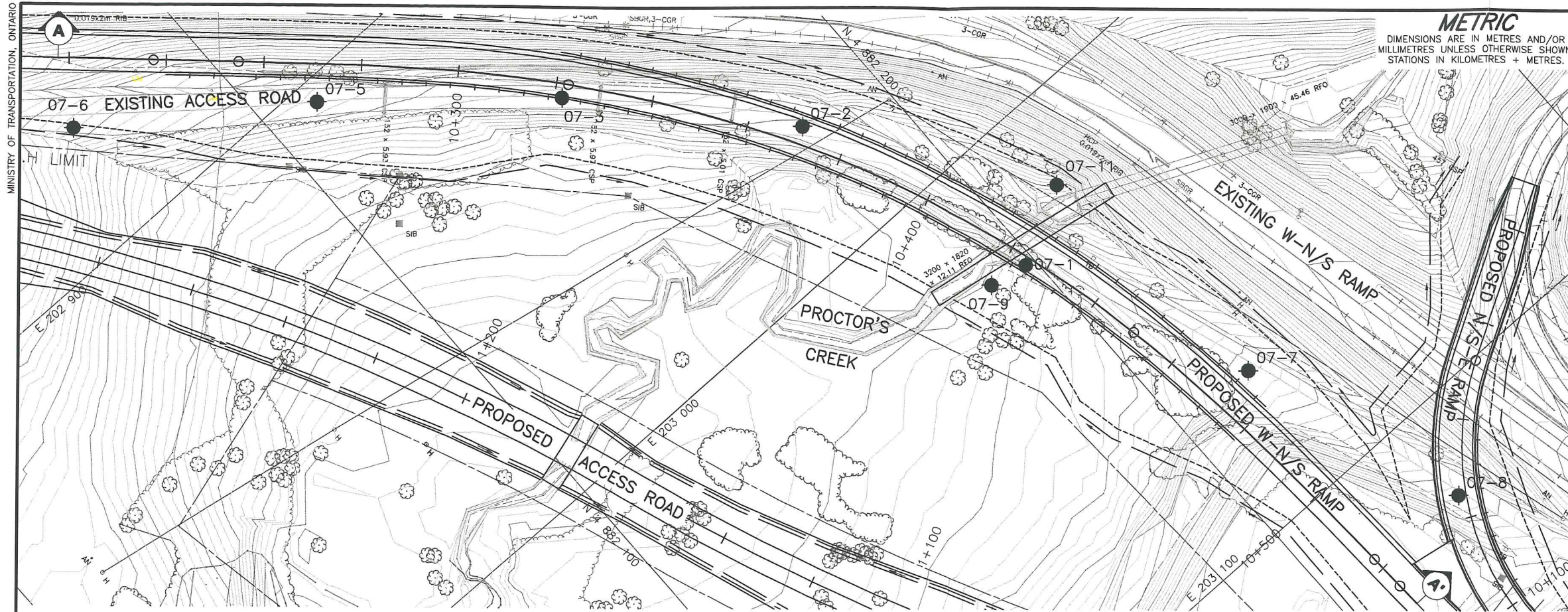
DATE May 14, 2007

CHECKED BY LCC/JMAC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
190.0	GROUND SURFACE													
0.0	Sand and silt, some gravel, trace clay, containing rootlets (FILL) Very loose Brown to grey Moist		1	SS	2									
188.8			2	SS	2		189							
1.2	PEAT, containing silty sand seams Very soft Wet		3	SS	2									
188.2														
1.8	SILT, trace to some sand, trace gravel, trace clay Compact Grey Wet		4	SS	10		188							7 13 74 6
							187							
			5	SS	12		186							
			6	SS	21		185							
							184							
			7	SS	6*									0 6 86 8
							183							
182.4														
7.6	Silty SAND, some gravel, trace clay (TILL) Very dense Grey Wet		8	SS	25/1		182							
180.9							181							
9.1	END OF BOREHOLE		9	SS	26/1									
	Notes: 1. * Low SPT "N" value (6 blows/0.3 m of penetration) is the result of sample disturbance due to groundwater inflow to the borehole. 2. Borehole advanced using portable drilling equipment with a half-weight hammer. SPT "N" values shown on this log have been adjusted to reflect "N" values that would be obtained using a standard - weight hammer. 3. Water flowing (artesian conditions) from borehole on completion of drilling. 4. Borehole sealed with bentonite.													

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

MIS-MTO 001 061111057MTO.GPJ GAL-MISS.GDT 11/15/07 JFC

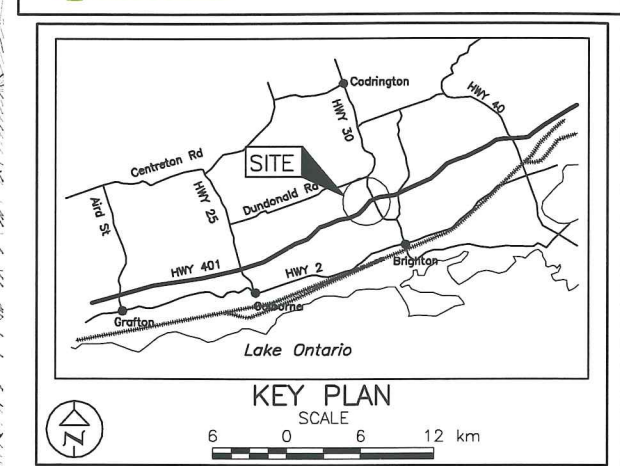


CONT No.
WP No. 256-98-00

HIGHWAY 401 - COUNTY ROAD 30
W-N/S RAMP EMBANKMENT
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

SHEET



LEGEND

- Borehole - Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow); * indicates SPT "N" value affected by groundwater inflow to borehole
- WL in piezometer
- WL upon completion of drilling

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
07-1	190.4	4882198.0	203025.3
07-2	190.9	4882182.2	202973.8
07-3	192.7	4882149.2	202936.9
07-5	193.4	4882110.9	202904.6
07-6	195.3	4882070.0	202875.6
07-7	193.2	4882217.9	203071.4
07-8	196.4	4882233.4	203118.9
07-9	189.2	4882190.1	203023.8
07-11	190.0	4882213.5	203017.2

NOTES

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

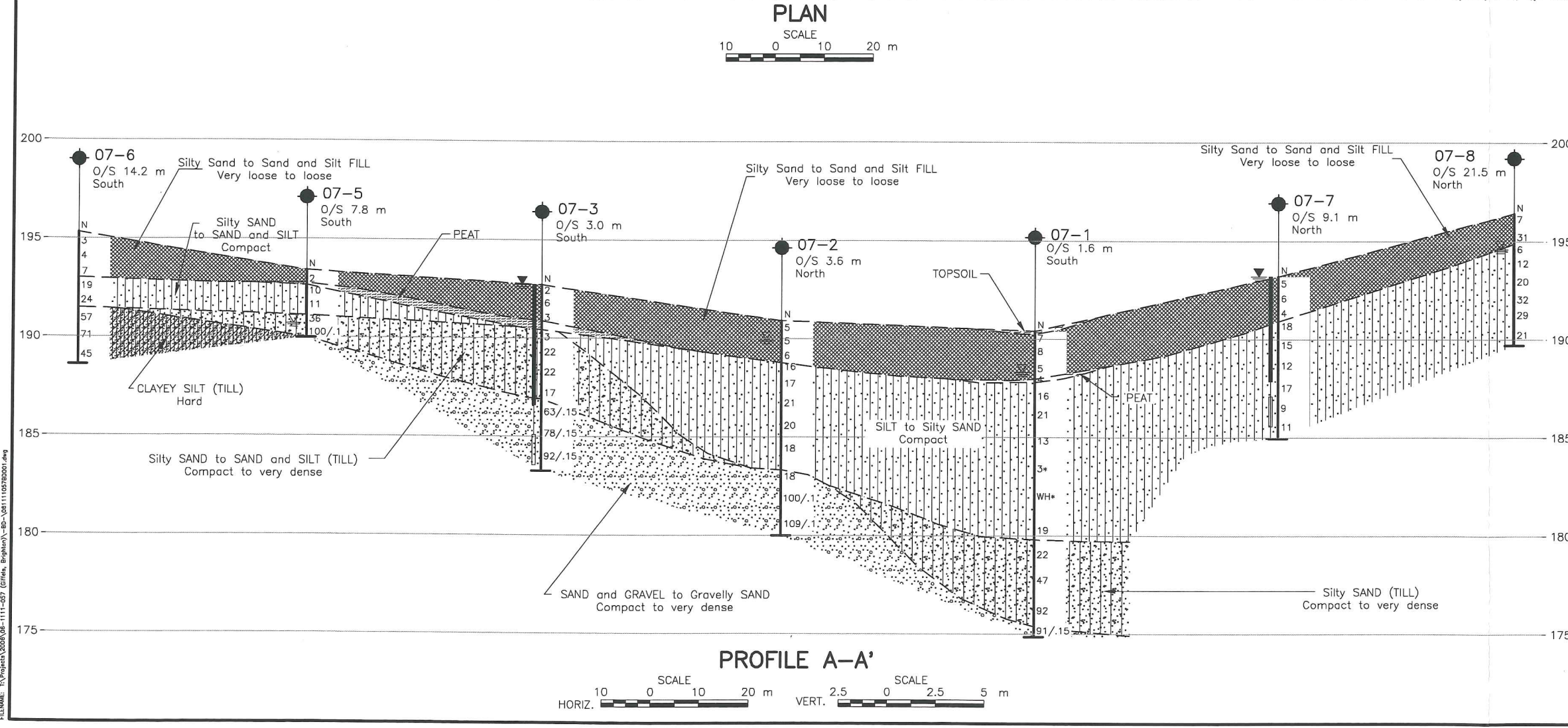
The boundaries between soil strata have been established only at borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

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

REFERENCE

Base plan provided in digital format by Giffels (drawing file name "401_30NEWC.dwg", received May 23, 2007).

NO.	DATE	BY	REVISION
Geocres No.			
HWY: HIGHWAY 401		PROJECT NO: 06-1111-057	DIST.
SUBM'D. MWK	CHKD. LCC	DATE: 12/4/07	SITE:
DRAWN: JFC/RJ	CHKD. MWK/LCC	APPD. LCC/JMAC	DWG. 1

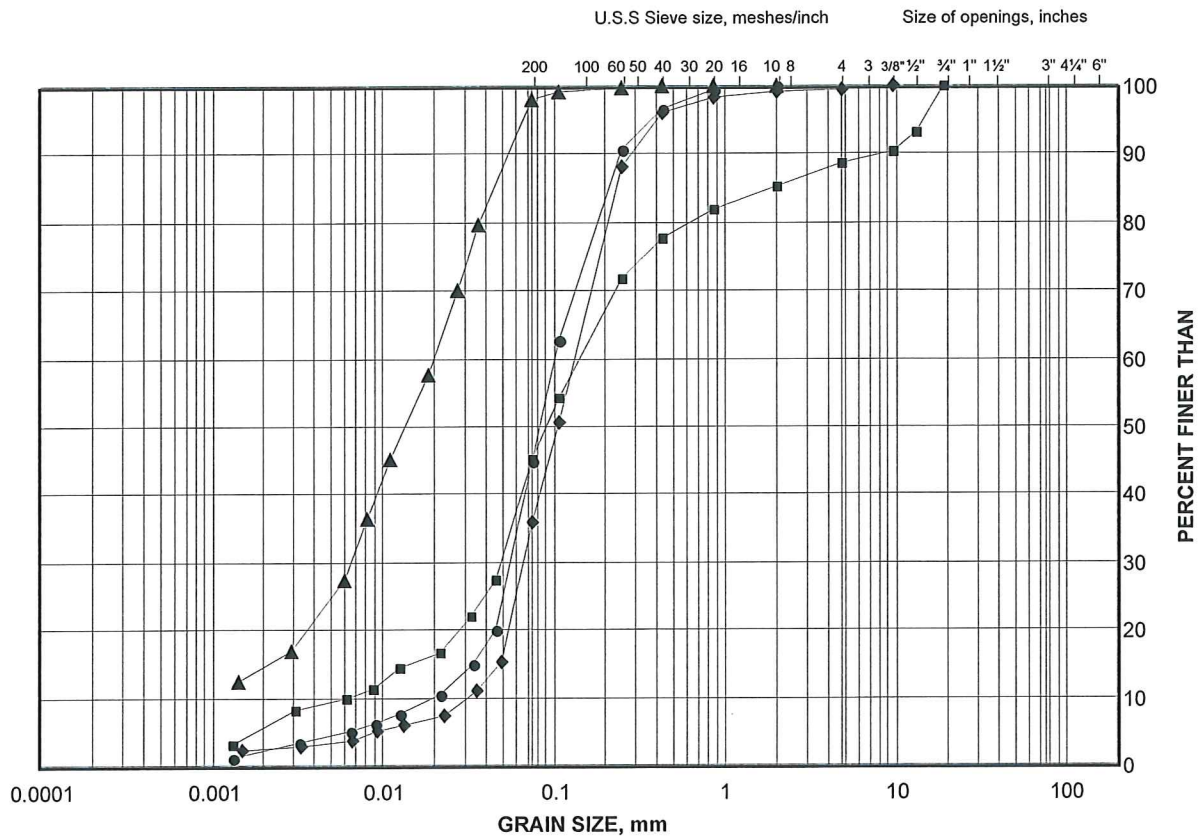


PLOT DATE: December 4, 2007
DRAWN: JFC/RJ
CHECKED: JFC/RJ
APP'D: JFC/RJ
DATE: 12/4/07
PROJECT NO: 06-1111-057
SHEET: 1 OF 1

GRAIN SIZE DISTRIBUTION TEST RESULTS

Silt to Silty Sand Fill

FIGURE 1



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-6	2	194.2
■	07-1	2	189.4
◆	07-7	2	192.1
▲	07-1	3	188.6

Project Number: 06-1111-057-2

Checked By: *Woye*

Golder Associates

Date: 29-Nov-07

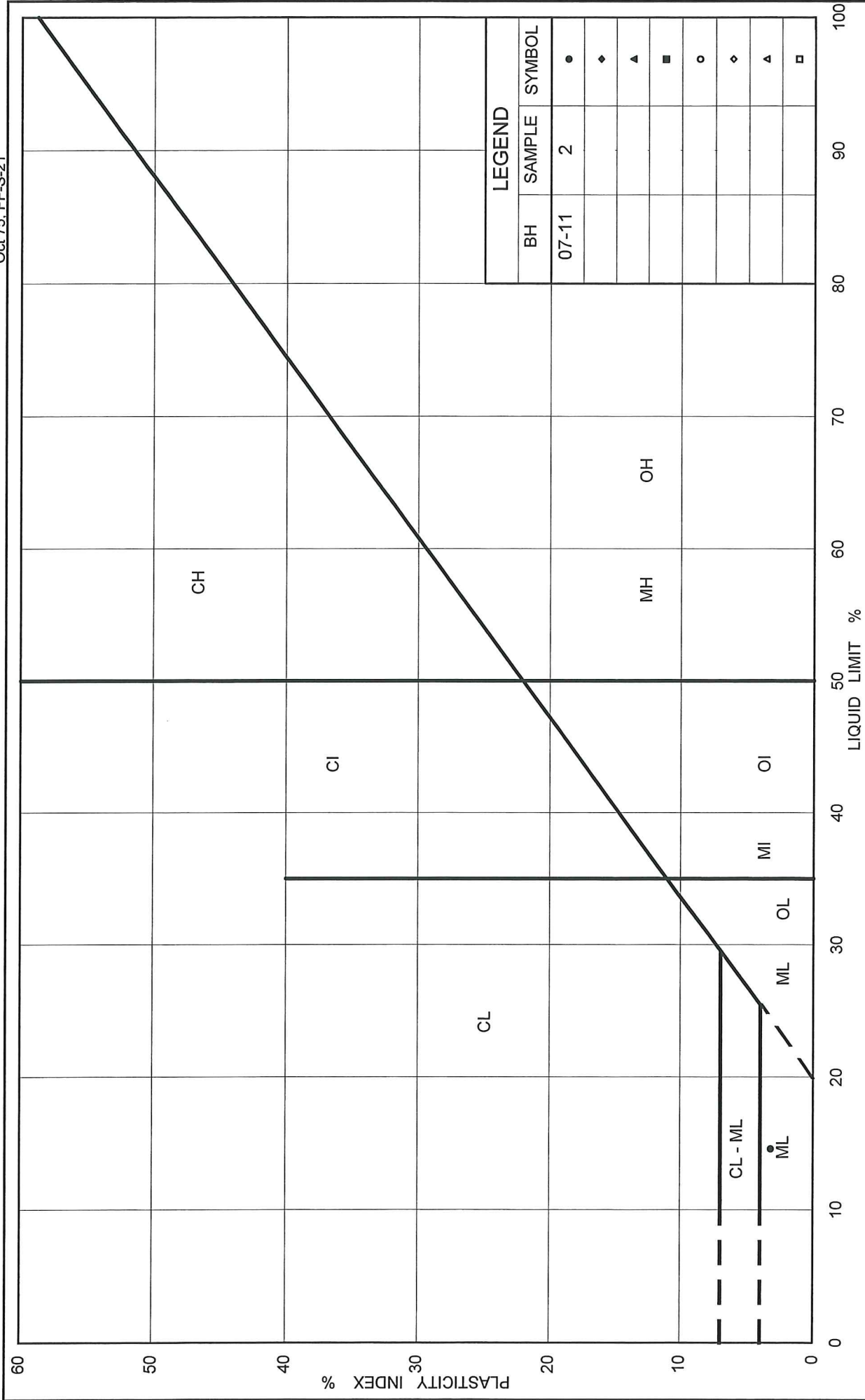


Figure 2

PLASTICITY CHART Silt Fill

Ministry of Transportation



Ontario

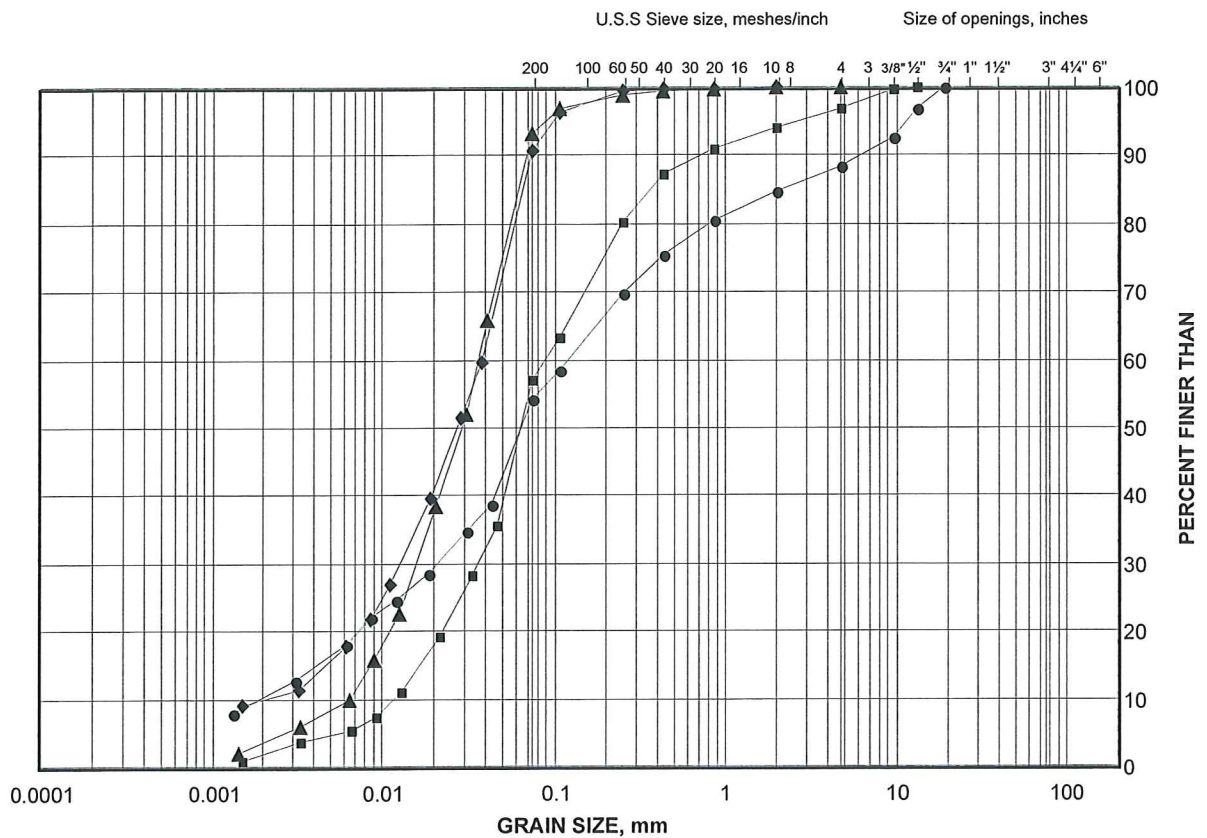
Project No. 06-1111-057-2

Checked By: *Woyce*

GRAIN SIZE DISTRIBUTION TEST RESULTS

Silty Sand to Silt

FIGURE 3A



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-5	3	191.6
■	07-2	4	188.4
◆	07-1	6	186.3
▲	07-1	9	182.4

Project Number: 06-1111-057-2

Checked By: *Uhoyle*

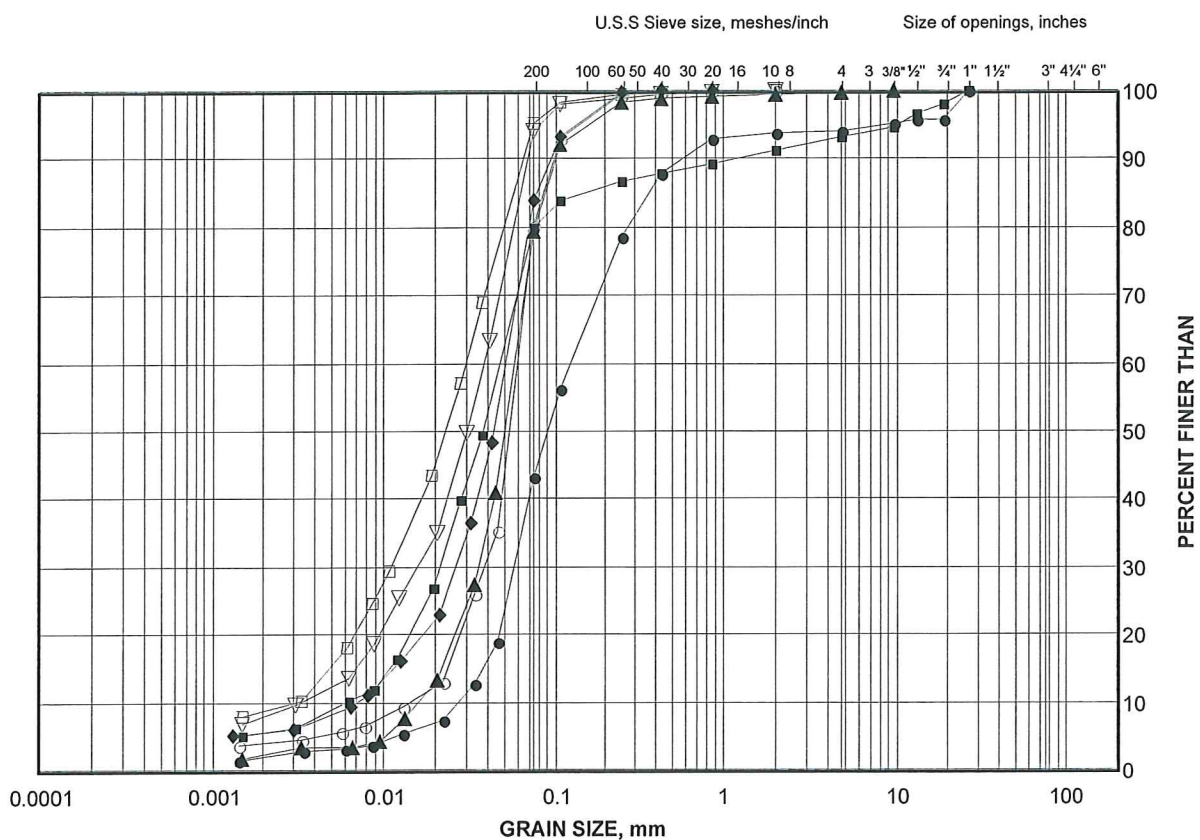
Golder Associates

Date: 29-Nov-07

GRAIN SIZE DISTRIBUTION TEST RESULTS

Silty Sand to Silt

FIGURE 3B



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-8	4	193.8
■	07-11	4	187.8
◆	07-9	5	185.8
▲	07-7	5	189.8
▽	07-11	7	183.6
○	07-8	8	190.0
□	07-9	8	182.8

Project Number: 06-1111-057-2

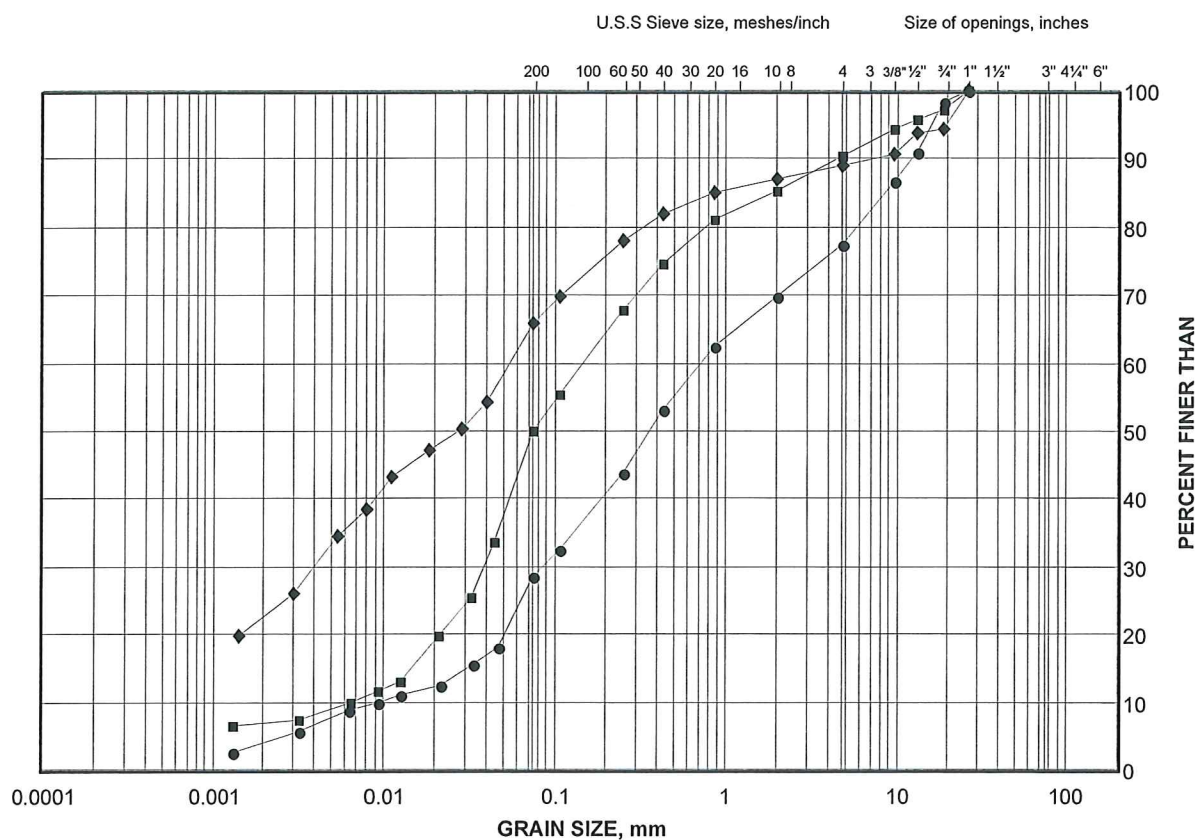
Checked By: *[Signature]*

Golder Associates

Date: 29-Nov-07

Silty Sand Till to Clayey Silt Till

FIGURE 4



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

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-1	12	177.9
■	07-3	5	189.4
◆	07-6	8	188.9

Checked By: Moye

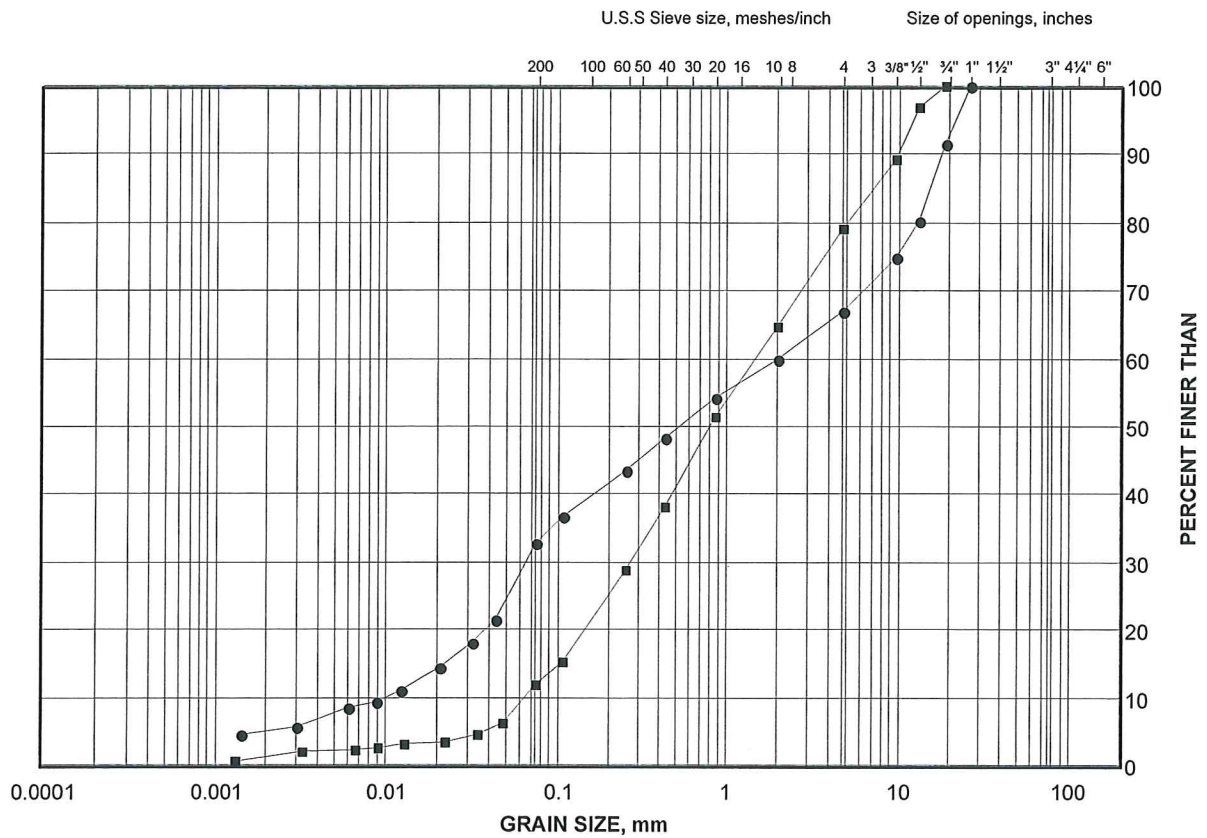
Golder Associates

Date: 29-Nov-07

GRAIN SIZE DISTRIBUTION TEST RESULTS

Silty Sand and Gravel to Gravelly Sand

FIGURE 5



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-3	8	186.3
■	07-2	9	183.0

Project Number: 06-1111-057-2

Checked By: *[Signature]*

Golder Associates

Date: 29-Nov-07

DRAFT

November 2007

06-1111-057-2

APPENDIX A

OPERATIONAL CONSTRAINTS

OPERATIONAL CONSTRAINT

Special Provision

Preload Requirement – W-N/S Ramp Embankment

Following completion of the W-N/S Ramp embankment construction between Stations 10+220 and 10+550, the fill shall remain in place for a minimum of four (4) weeks before paving of the W-N/S Ramp embankment.

OPERATIONAL CONSTRAINT

Special Provision

Subexcavation of Peat/Organic Soils Adjacent to Existing W-N/S Ramp

This special provision outlines the procedure to be used for subexcavation of the peat/organic soils adjacent to the existing W-N/S Ramp embankment, within the footprint of the new ramp embankment.

Removal of the peat/organic soils shall be in accordance with OPSD 203.020 except as noted herein.

The subexcavation should be carried out such that the base of the excavation is maintained outside a zone defined by a line drawn downward at 1 horizontal to 1 vertical (1H:1V) from the crest of the existing W-N/S Ramp embankment to the base of the excavation.

Removal of the peat/organic soils shall be carried out in short sections perpendicular to the existing W-N/S Ramp alignment, with the base of the excavation/trench not wider than 3 m at any time. Excavation and backfilling operations shall be carried out simultaneously in a manner that the excavation is not left open for more than 3 m in length at any time.

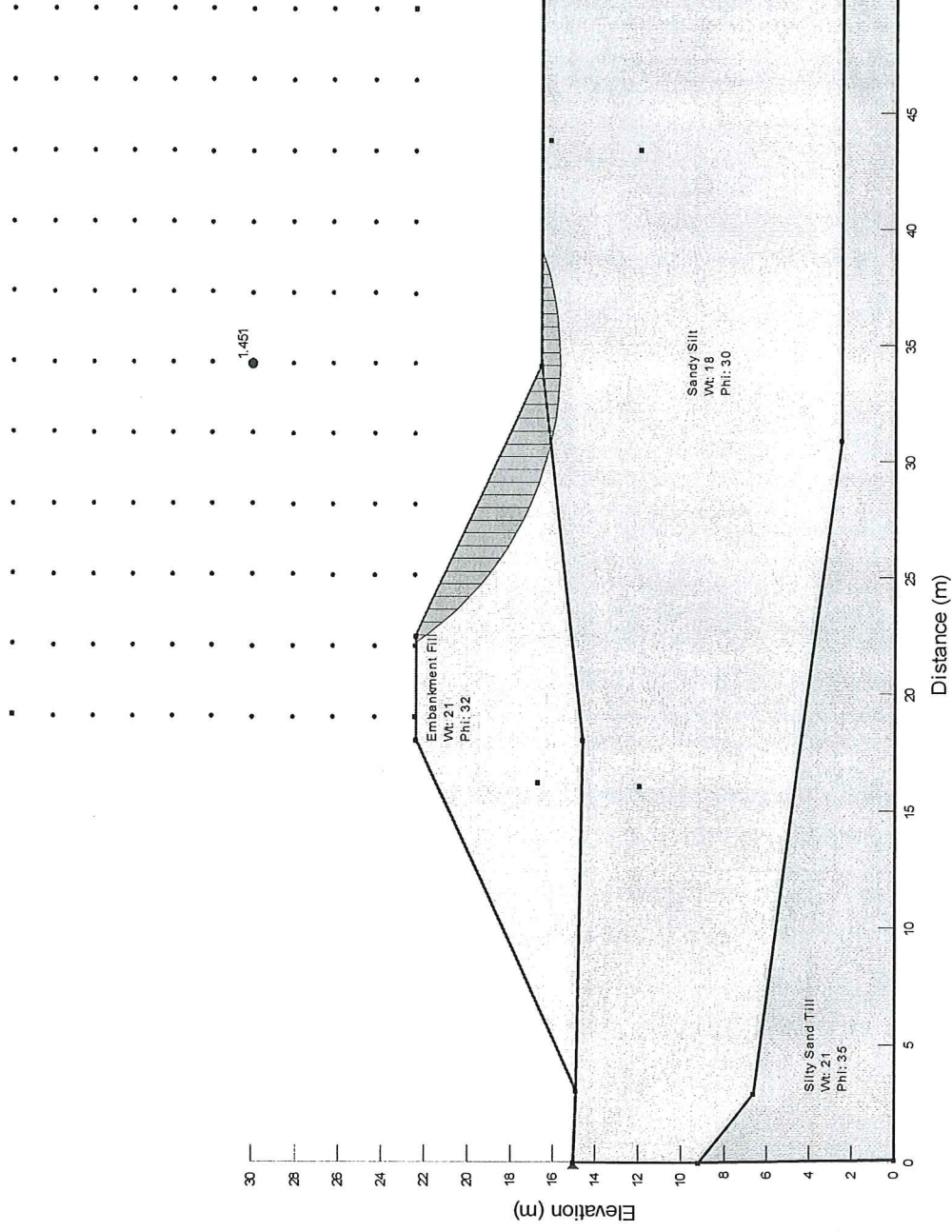
The Contractor shall maintain the operation of the existing W-N/S Ramp during excavation and backfilling operations.

Basis of Payment

Payment for the Contractor to provide the above requirements, including all equipment, labour and materials shall be deemed to be included in the contract bid price for the various tender items.

STATIC EMBANKMENT STABILITY - EARTH/GRANULAR FILL (2H:1V SIDE SLOPES)

FIGURE 6



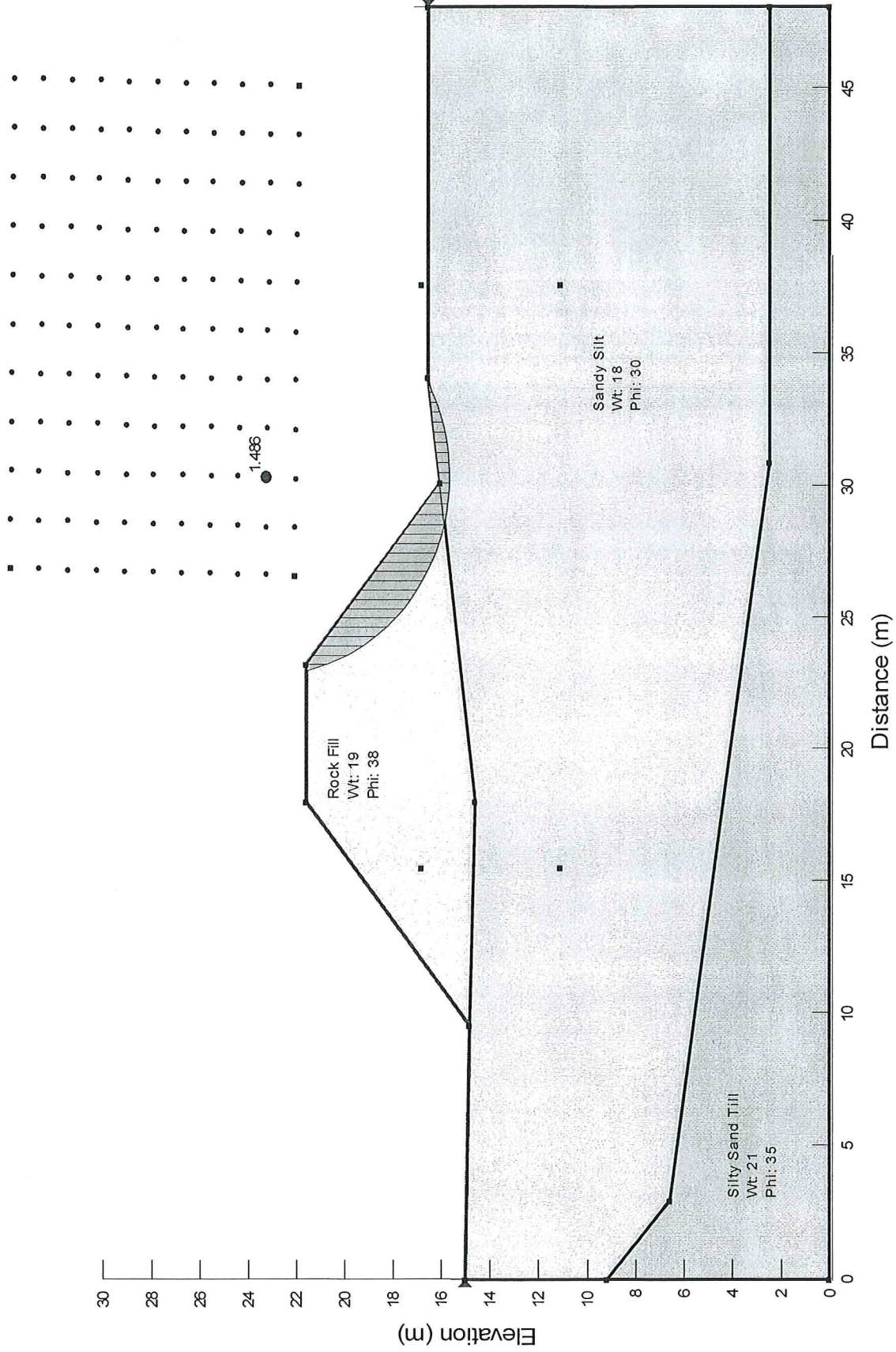
Date: December 2007
Project: 06-1111-057-2

Golder Associates

Drawn: VO
Checked: LCC

STATIC EMBANKMENT STABILITY - ROCK FILL (1.25H:1V SIDE SLOPES)

FIGURE 7



Date: December 2007
 Project: 06-1111-057-2

Golder Associates

Drawn: VO
 Checked: LCC