



May 2016

REPORT ON

**Foundation Investigation and Design
Retaining Wall Rehabilitation
March Road Underpass
Site No. 3-357
Highway 417
Ottawa, Ontario
W.P. 4104-13-01**

Submitted to:
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REPORT



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PART A

FOUNDATION INVESTIGATION REPORT
RETAINING WALL REHABILITATION
MARCH ROAD UNDERPASS
SITE 3-357
HIGHWAY 417
OTTAWA, ONTARIO
W.P. 4104-13-01



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by MMM Group Ltd. (MMM) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out a foundation investigation for the rehabilitation of the retaining walls at the March Road underpass, Site No. 3-357 (W.P. 4104-13-01) located on Highway 417 approximately 8 km west of Highway 7 in Ottawa, Ontario as part of the MEGA 6 project.

As part of the current assignment, previously collected subsurface information pertinent to the site was reviewed and compiled. This existing subsurface information was contained in the following:

- Report prepared by Geocon Inc. for the MTO titled “*Subsurface Geotechnical Investigation, Proposed Highway 17 and 44, Underpass, Ottawa, Ontario, WP 34-81-02, Site 3-357*”, dated November 1990 (GEOCREC No. 31F-110).

The purpose of this current investigation was to assess the subsurface conditions at the site of the proposed retaining wall rehabilitation by borehole drilling and carrying out in-situ and laboratory testing on selected samples.

The terms of reference and scope of work for the foundation engineering services are outlined in MTO’s Request for Proposal (RFP) for Assignment No. 4014-E-0015 dated October 2014 and in Golder’s proposal for this project dated December 11, 2014.



2.0 SITE DESCRIPTION

The March Road underpass (structure Site No. 3-357) is located at about Station 18+507 on Highway 417 about 8 km west of Highway 7 in Ottawa, Ontario. Through this area, Highway 417 is a four lane divided highway with a rural cross-section. The existing structure is aligned approximately northeast-southwest and crosses the highway at a skew of approximately 55 degrees. However, for this report, the bridge alignment will be referred to as north-south. The bridge was constructed in about 1992 and consists of a two-span structure, approximately 90 m in length and 15.5 m in width (i.e., is two lanes wide). The abutments are perched within the embankments, and along with the pier, are supported on end bearing steel H-piles.

The existing approach embankments are about 8 to 9 m high relative to the surrounding ground surface and have approximately 2.5 horizontal to 1 vertical (i.e., 2.5H:1V) side slopes. No signs of embankment instability were observed. Retained Soil System (RSS) walls currently retain the embankment fill at the abutments and at the wing walls. The wing walls are aligned parallel to March Road and are about 9 m in length along the southeast and northwest sides of the embankments and about 16 m in length along the southwest and northeast sides of the embankments. There is evidence that the embankments have experienced settlement as there are visible gaps between the RSS wall panels at the face of the abutments and along the wing walls.



3.0 INVESTIGATION PROCEDURES

The subsurface investigation for the retaining wall rehabilitation was carried out between November 30 and December 8, 2015, at which time four boreholes (numbered 15-1 to 15-4, inclusive) and two test pits (numbered 15-101 and 15-103) were advanced at the locations shown on Drawings 1 and 2. The boreholes were advanced as follows:

- Boreholes 15-1, 15-3 and 15-4 were advanced near the toes of the existing north and south approach embankments, using 200 mm inside diameter continuous-flight hollow-stem augers on a track-mounted drill rig, supplied and operated by CCC Geotechnical & Environmental Drilling Ltd. of Ottawa, Ontario. The boreholes were advanced to depths of about 11.8 to 12.2 m (Elevations 105.2 and 107.0 m) metres below the existing ground surface while carrying out soil sampling and in situ testing. Below these depths, the boreholes were advanced without sampling, using a dynamic cone penetration test (DCPT), to depths between about 21.8 and 25.1 m (Elevations 93.7 and 96.3 m) below the existing ground surface.
- Borehole 15-2 was advanced near the west toe of the existing south approach embankment using portable drilling equipment supplied and operated by CCC Geotechnical & Environmental Drilling Ltd. of Ottawa, Ontario. The borehole was advanced using near-continuous sampling procedures to a depth of about 12.5 m below the existing ground surface, at about Elevation 105.9 m.
- Test pits 15-101 and 15-103 were advanced through the approach embankments, adjacent to one end of both the south and north abutments, respectively, using a backhoe supplied by Glenn Wright Excavating of Ottawa, Ontario. The test pits were advanced to depths of up to about 4 m below the existing ground surface. It should be noted that proposed test pits 15-102 and 15-104 could not be excavated due to limited site access at the proposed locations.

Soil samples in the boreholes were obtained at vertical intervals of about 0.60 to 1.52 m, using a 50 mm outer diameter split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures to depths between about 11.8 and 12.5 m (Elevations 105.2 and 107.0 m) in Boreholes 15-1, 15-3, and 15-4.

Where appropriate, the SPT sampling was supplemented with in-situ shear vane testing. An MTO “N”-size vane was used to measure the undrained shear strength of the cohesive soils encountered at Boreholes 15-1, 15-3 and 15-4. In addition, six relatively undisturbed 73 millimetre diameter thin walled Shelby tube samples of the silty clay were obtained from these boreholes using a fixed piston sampler.

A standpipe piezometer was installed in Borehole 15-4 to monitor the groundwater level at the site. The standpipe consists of a 19 mm diameter rigid PVC pipe with a 1.5 m long slotted screen section, installed within silica sand backfill and sealed by a section of bentonite pellet backfill. The water level in the standpipe piezometer was measured on December 21, 2015.

Soil samples of embankment fill were obtained from the test pits and the groundwater seepage conditions in the test pits were observed during the short time they remained open.

The boreholes were backfilled with bentonite pellets, mixed with native soils in the overburden. The test pits were loosely backfilled upon completion of excavating and sampling. The site conditions were restored following completion of work.



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The field work was supervised by members of Golder's technical staff, who located the boreholes and test pits, supervised the drilling/excavating, sampling and in situ testing operations, logged the boreholes and test pits, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled, and transported to Golder's laboratories in Ottawa for further examination. Index and classification tests consisting of grain size distribution, Atterberg limits, and water content testing were carried out on selected soil samples at Golder's Mississauga and Ottawa laboratories. Consolidation testing was carried out on one sample obtained from Borehole 15-1 at Golder's Mississauga laboratory. All of the laboratory tests were carried out to MTO and/or ASTM standards as appropriate.

Prior to drilling, the borehole and test pit locations were staked and surveyed by Golder personnel using a Trimble R8 GPS unit. The borehole and test pit locations, including MTM NAD83 northing and easting coordinates and ground surface elevations referenced to Geodetic datum, are summarized in the following table and are shown on Drawings 1 and 2.

Test Hole Number	Type	Test Hole Location	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)
15-1	Borehole	South Embankment Toe (East)	5019276.6	339535.1	118.1
15-2	Borehole	South Embankment Toe (West)	5019307.6	339494.9	118.4
15-3	Borehole	North Embankment Toe (East)	5019341.3	339605.9	118.8
15-4	Borehole	North Embankment Toe (West)	5019375.9	339566.1	117.0
15-101	Test Pit	South Abutment (East)	5019288.3	339521.6	122.4
15-103	Test Pit	North Abutment (West)	5019356.9	339574.3	120.5

Notes: 1) Northing and Easting coordinates shown are relative to the MTM NAD83 (Zone 9) coordinate system.
2) Ground surface elevations shown are relative to Geodetic Datum.



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Five boreholes had been advanced at the proposed abutment locations as part of the original investigation at this site in 1989/1990. The elevations of the ground surface at the borehole locations were surveyed relative to Geodetic datum at the time of the investigation. The borehole locations in plan were established by comparing the site plans prepared at the time of original design with the current site survey data received from MMM. As such, the MTM NAD83 northing and easting coordinates summarized in the following table and shown on Drawings 1 and 2 should be considered approximate only.

Borehole Number	Borehole Location	Northing (m)	Easting (m)	Former Ground Surface Elevation (m)
2	South Abutment	5019299.1	339510.7	116.6
3	South Abutment	5019295.1	339526.2	116.8
5	North Abutment	5019353.0	339573.5	117.5
6	North Abutment	5019348.4	339589.8	117.2
8	North Abutment	5019356.8	339577.8	117.2

Notes: 1) Northing and Easting coordinates shown are relative to the MTM NAD83 (Zone 9) coordinate system and are approximate only.
2) Ground surface elevations shown are relative to Geodetic Datum.



4.0 SITE GEOLOGY AND STRATIGRAPHY

4.1 Regional Geological Conditions

The study area for this assignment lies within the minor physiographic region known as the Ottawa Valley Clay Plain, as delineated in *The Physiography of Southern Ontario*¹ that lies within the major physiographic region of the Ottawa-St. Lawrence Lowland.

The Ottawa Valley Clay Plain region is characterized by relatively thick deposits of sensitive marine clay, silt and silty clay that were deposited within the Champlain Sea basin. These deposits, known as the Champlain Sea clay or Leda clay, overlie relatively thin, commonly reworked glacial till and glaciofluvial deposits, that in turn overlie bedrock.² This region is underlain by a series of sedimentary rocks, consisting of sandstones, dolostones, limestones and shales that are, in turn, underlain by igneous and metamorphic bedrock of the Precambrian Shield.

4.2 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes and test pits put down as part of the current investigation and the results of related in situ and laboratory testing are given on the Record of Borehole and Test Pit sheets contained in Appendix A. The relevant borehole logs from the previous investigation, carried out in 1990 (prior to construction of the bridge), are included in Appendix B. The results of geotechnical laboratory testing carried out as part of the current investigation are also included in Appendix C. The results of consolidation test results from the previous 1990 investigation are included in Appendix D.

The interpreted stratigraphic conditions along the centreline of the south and north abutments are shown on Drawings 1 and 2. The stratigraphic boundaries shown on the Record of Borehole and Test Pit sheets and on the interpreted stratigraphic sections included on Drawings 1 and 2 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole and test pit locations.

In general, the subsurface conditions at the site consist of embankment fill overlying surficial silty sand and sandy silt, which is underlain by a thick deposit of sensitive silty clay to clayey silt followed by glacial till. A more detailed description of the subsurface conditions encountered in the boreholes and test pits is provided in the following sections, with a focus on the results from the current investigation, in addition to the consolidation test results from the 1990 investigation.

4.2.1 Embankment Fill

The embankment fill was proven to depths of about 4.0 and 3.2 m (Elevations 118.4 and 117.3 m) at Test Pits 15-101 and 15-103, respectively, and was fully penetrated at all of the current borehole locations to depths of between about 1.5 and 2.3 m (Elevations 115.3 and 116.6 m). Approximately 80 to 150 mm of topsoil fill was encountered at the ground surface at the Boreholes 15-1 to 15-4, inclusive. The underlying embankment fill generally consists of varying amounts of sand, gravel and silt. Organic matter, wood and cobbles were also encountered within the embankment fill at some locations.

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.

² Belanger, J.R. "Urban Geology of Canada's National Capital Area", in *Urban Geology of Canadian Cities*, Geological Association of Canada Special Paper 42, Ed. P.F. Karrow and O.L. White, 1998.



Between about 1.2 and 2.1 m (i.e., Elevations 115.0 to 115.7 m) of surficial sand fill was encountered at ground surface at all of the previous borehole locations.

Standard Penetration Test (SPT) “N” values measured within the fill range from 5 to 37 blows per 0.3 m of penetration, indicating a loose to dense state of packing.

The results of grain size distribution testing carried out on samples of the embankment fill are provided on Figure C1 in Appendix C. The measured water content of selected samples of the embankment fill ranges from approximately 4 to 22 percent.

4.2.2 Silty Sand

About 1.1 to 2.3 m of silty sand were encountered below the embankment fill at the borehole locations with the exception of previous Boreholes 5, 6 and 8. The silty sand was fully penetrated to elevations of about 113.2 to 115.0 m.

The SPT “N” values measured within this material range from 4 to 38 blows per 0.3 m of penetration indicating a very loose to dense state of packing.

The results of grain size distribution testing carried out on samples of the silty sand are provided on Figure C2 in Appendix C. The results of Atterberg limits testing carried out on three samples of the silty sand indicate that the this material is non-plastic. The measured natural water content of selected samples of the silty sand ranges from about 18 to 22 percent.

4.2.3 Sandy Silt to Silt

An approximately 1.5 to 3.1 m thick layer of sandy silt to silt exists below the embankment fill at previous Boreholes 5, 6 and 8 and below the silty sand at Boreholes 15-1, 15-2 and 15-3. Where encountered, the material was fully penetrated to elevations of about 111.2 to 113.6 m.

The SPT “N” values measured within this material range from 1 to 20 blows per 0.3 m of penetration indicating a very loose to compact state of packing.

The results of grain size distribution testing carried out on samples of the sandy silt are provided on Figure C3 in Appendix C. The results of Atterberg limit testing carried out on samples of the sandy silt indicate plasticity index values between about 2 and 4 percent and liquid limit value between about 18 and 19 percent, as shown on Figure C4, indicating that the tested samples consist of silt of low plasticity. The measured natural water content of selected samples of the sandy silt ranges from about 20 to 29 percent.

4.2.4 Silty Clay to Clayey Silt

The silty sand and/or sandy silt are underlain by a deposit of grey silty clay to clayey silt. The silty clay to clayey silt was fully penetrated in the previous boreholes to elevations between about 96.4 to 103.4 m with thicknesses between 10.4 and 17.1 m. The deposit was proven to depths between about 11.8 and 12.5 m (Elevations 105.2 and 107.0 m) at the current borehole locations, then inferred to depths of between about 16.8 and 20.7 m (Elevations 96.3 and 101.4 m) from the results of the DCPT.

In situ vane testing carried out within the deposit measured undrained shear strengths ranging from 36 to 110 kPa, but more typically in the range of 42 to 60 kPa indicating a firm to stiff consistency.



The results of grain size distribution testing carried out on one sample of the silty clay to clayey silt are provided on Figure C5. The results of Atterberg limit testing carried out on several samples of the silty clay to clayey silt indicate plasticity index value between about 6 and 19 percent and liquid limit value between about 19 and 37 percent, as shown on Figure C6, indicating that the tested samples consist of silty clay to clayey silt of low to intermediate plasticity (but generally low). The measured natural water content of selected samples of the deposit ranges from 31 to 52 percent. These natural water contents are all above the measured liquid limits.

Oedometer consolidation testing was carried out on one relatively undisturbed sample of the grey silty clay to clayey silt deposit from Borehole 15-1, the results of which are provided on Figure C7. Consolidation testing was also carried out on two samples of the silty clay from Borehole 6 from the 1990 investigation the results of which are provided in Appendix D. The results of these consolidation tests are summarized in the table below.

Borehole/Sample Number	Sample Depth/Elevation (m)	Unit Weight (kN/m ³)	σ_P' (kP)	σ_{vo}' (kP)	$\sigma_P' - \sigma_{vo}'$ (kPa)	Cc	Cr	e _o	OCR
15-1 / 11	7.6 – 8.1 / 110.0 – 110.5	18.6	265	90	170	0.51	0.013	0.95	2.9
6 / 8	7.9 / 109.3	-	259	77	182	0.31	0.013	0.98	3.4
6 / 11	12.5 / 104.7	-	383	112	271	1.06	0.040	1.44	3.4

Notes:

σ_P'	-	Apparent preconsolidation pressure	Cr	-	Recompression index
σ_{vo}'	-	Computed existing vertical effective stress	e _o	-	Initial void ratio
Cc	-	Compression index	OCR	-	Overconsolidation ratio

4.2.5 Till

Glacial till was encountered/inferred below the silty clay to clayey silt deposit. The till was fully penetrated at previous Boreholes 2 and 8 to about Elevations 97.3 and 93.8 m, respectively, and proven to about Elevations 102.6, 95.7 and 93.5 m at previous Boreholes 3, 5 and 6, respectively. The glacial till was interpreted from the results of the DCPT to elevations of about 96.3, 93.7 and 94.7 m at Boreholes 15-1, 15-3 and 15-4, respectively.

The glacial till is considered to generally consist of a heterogeneous mixture of gravel, cobbles and boulders in a matrix of sand and silt containing a trace to some clay.

The measured SPT “N” values within the till deposit range from 3 to 38 blows per 0.3 m of penetration, indicating a very loose to dense state of packing.

4.2.6 Refusal and Bedrock

Dynamic cone penetration refusal was encountered in Boreholes 15-1, 15-3 and 15-4; this refusal has been inferred to likely represent the bedrock surface. Bedrock was encountered beneath the till at previous Boreholes 2 and 8 where it was cored for depths of about 1.5 and 3.3 m, respectively.

The following table summarizes the bedrock surface depths and elevations encountered at the borehole locations during the current and previous investigations.



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Borehole Number	Existing Ground Surface Elevation (m)	Depth to Bedrock (m)	Bedrock Surface Elevation (m)
15-1	118.1	21.8	96.3*
15-3	118.8	25.1	93.7*
15-4	117.0	22.3	94.7*
2	116.6	19.3	97.3
8	117.2	23.4	93.8

Note: * Depth and elevation to bedrock inferred from DCPT refusal.

The bedrock encountered in the cored boreholes of the previous investigation typically consists of fresh grey limestone bedrock. The Rock Quality Designation (RQD) values measured on the recovered bedrock core samples typically ranged from about 54 to 80 percent, indicating fair to good quality rock.

4.2.7 Groundwater Conditions

The groundwater level measured in the standpipe piezometer in Borehole 15-4 is presented in the table below:

Borehole	Ground Surface Elevation (m)	Water Level Depth (m)	Water Level Elevation (m)	Date
15-4	117.0	0.5	116.5	December 21, 2015

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



5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Susan Trickey, P.Eng., and reviewed by Mr. Mike Cunningham, P.Eng., a Principal and geotechnical engineer with Golder. Mr. Fin Heffernan, P.Eng., Golder's Designated MTO Foundations Contact for this project, conducted an independent quality review of the report.

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PART B

FOUNDATION DESIGN REPORT
RETAINING WALL REHABILITATION
MARCH ROAD UNDERPASS
SITE 3-357
HIGHWAY 417
OTTAWA, ONTARIO
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6.0 DISCUSSION

6.1 General

This section of the report provides a discussion of the foundation design considerations for the rehabilitation options of retaining walls at the March Road underpass, on Highway 417 at MTO Structure Site No. 3-357, approximately 8 km west of Highway 7 in Ottawa, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation as well as those included in the original 1990 foundation investigation report for the underpass structure (by Geocon Inc.). The discussion presented is intended to provide the designers with an overview of the proposed design options from a foundations engineering perspective. Detailed recommendations are not provided, as the preferred rehabilitation option for the retaining walls was selected prior to the completion of this report and does not require detailed foundation design.

The existing approach embankments are about 8 to 9 m high relative to the surrounding ground surface and have approximately 2.5 horizontal to 1 vertical (i.e., 2.5H:1V) side slopes. Retained Soil System (RSS) walls currently retain the embankment fill beneath the north and south abutments and at the wing walls. The wing walls are aligned parallel to March Road and are about 9 m in length along the southeast and northwest sides of the embankments and about 16 m in length along the southwest and northeast sides of the embankments. There are indications of previous movement of the RSS wing walls relative to the abutments and the overlying barrier walls, as well as some damage to the panels (i.e., visible gaps, which are now patched) where they were not free to move. Construction maintenance records for the RSS walls indicate that these gaps were filled with concrete in 2000. These records also indicate that in 2014 steel plates were placed over several deteriorated panels and that voids in the backfill behind the panels were grouted.

6.2 Rehabilitation Options

It is understood that the Request For Proposal (RFP) for this site was prepared with the intention that the existing RSS walls would be replaced. The replacement was considered necessary due to the belief that the existing RSS walls were failing. Therefore, the current foundation investigation was also carried out based on this assumption. However, upon review of the consolidation test results from both the current and previous investigations it appears that the weight of the existing embankment fill has raised the stress level in the underlying silty clay deposit to its preconsolidation pressure (i.e., yield stress). Therefore, the distress that has been experienced by the existing RSS wing walls can, at least in part, be attributed to settlement of the embankments. In addition, MMM has indicated that the embankment fills appear to have settled up to about 145 mm relative to the pile-supported abutments based on a gap survey that was carried out in 2000 and provided to them by MTO. MMM has also indicated that, based on a comparison of the condition of the patches in photos taken in 2000 and 2015, it appears that the majority of the embankment settlement likely took place prior to 2000, with very little settlement thereafter. These observations would tend to indicate that most of the settlement occurred within the 5 to 10 years following construction of the bridge, due to primary consolidation, and that the longer term secondary compression settlements have been quite limited. Therefore, it is considered that the bulk of the expected settlements of the embankments under the existing conditions at this site have already occurred.



It is understood that MMM has considered several rehabilitation options for the retaining walls as outlined in their memo titled "W.P. 4104-13-01, Site No. 3-357 – Highway 417/March Road Underpass, RSS Wall Rehabilitation" dated February 19, 2016. A summary of the advantages and disadvantages associated with each of the proposed rehabilitation options from a foundation engineering perspective are provided in the following sections, and a comparison of the alternative rehabilitation options based on advantages, disadvantages, risks and relative costs is provided in Table 1 following the text of this report.

6.2.1 Option 1 - Preservation Management of the Existing RSS Walls

This option would consist of replacing the existing deteriorated RSS panels (which are currently covered by steel plates) with new concrete panels. Furthermore, any voids observed behind the panels would be grouted. In addition, the existing approach slabs would be removed and any voids beneath them backfilled with granular material, prior to replacement. As indicated above, it appears that the bulk of the expected settlements at this site have already occurred, therefore this rehabilitation option is considered feasible as it is essentially maintaining the existing site conditions (i.e., with a negligible stress increase on the underlying silty clay deposit). Therefore further excessive post-construction settlements are not expected. Nevertheless, there is potential for some minimal future settlement at this site, given that the rate of ongoing settlement of the silty clay is unknown. However, this option is the preferred option from a foundation engineering perspective.

6.2.2 Option 2 - RSS Walls Perpendicular to the Existing RSS Walls

This option would consist of constructing new RSS walls parallel to Highway 417 adjacent to the north and south abutments to retain the embankments such that the existing wing walls are not required to perform as earth retaining structures (and would be buried within the new embankment fill). The new walls would be constructed adjacent to the east and west ends of the abutments and extend for lengths between about 11 and 21 m. The height of the walls would vary between about 2 and 5 m. This option was originally developed at the preliminary design stage due to the assumption that the existing RSS wing walls needed to be replaced. However, following the foundations investigation and further understanding of the cause of the distress to the existing RSS walls, this option is no longer preferred, as the construction of new RSS walls would involve up to about 4 m of filling on the existing embankment slopes. This additional filling would increase the stress level in the underlying silty clay deposit which would result in new/additional settlement. As a preliminary estimate, it is expected that this settlement could be in the order of 25 to 50 mm in magnitude if granular backfill materials are used. Furthermore, additional settlement of the existing RSS panels at the east and west ends of the abutment retaining walls would also likely occur, resulting in further wall distress and potential backfill soil loss. Light weight fill behind the new RSS walls could be considered (such as polystyrene blocks or cellular concrete) to mitigate some of the potential settlement for this option, however it would be more costly than typical construction materials and more difficult to design and construct. This option, although considered feasible from a foundation engineered perspective, would not be preferred given the expected resulting settlements and/or the need for light weight fill materials.

6.2.3 Option 3a - RSS Walls Parallel to the Existing RSS Walls

This option would consist of constructing new RSS walls approximately 750 mm in front of the existing RSS wing walls. The new walls would act as a more aesthetically pleasing facing to the existing walls while preventing further loss of backfill material through any gaps that may develop in the existing RSS walls. This option would result in some limited additional loading on the existing embankment slopes (i.e., where backfill will be placed between the new and existing RSS walls), and therefore some additional limited settlement (e.g. less than 25 mm)



of the underlying silty clay deposit could be expected. This option is also considered feasible from a foundation engineering perspective, however, consideration should be given to designing the new panel arrangements to allow for some flexibility, since the rate of ongoing settlement of the silty clay is unknown, but likely minimal.

6.2.4 Option 3b - Cast-In-Place Concrete Retaining Walls on Piled Foundations

This option would consist of constructing cast-in-place concrete retaining walls supported on piles driven to the bedrock adjacent to the existing RSS wing walls, similar to Option 3a. The new walls would improve the aesthetics as well as prevent further loss of material through any gaps in the existing RSS wing walls. As with Option 3a, there would be some additional loading on the existing embankment slopes (i.e., where backfill will be placed between the new and existing walls), and therefore some additional limited settlement of the underlying silty clay deposit could be expected. However, the walls would be supported on piles driven to the bedrock, therefore, settlement of the retaining walls themselves would not occur. This option is not considered preferred or economical, given that the deep foundations required to support the retaining walls would need to extend to at least 20 m or more below foundation level to reach the bedrock surface, which would result in long and expensive piles.

6.2.5 Selection of Preferred Option

A summary of the advantages, disadvantages, risks and relative costs of the rehabilitation options is provided in Table 1 following the text of this report. Based on the above considerations, Option 1, preservation management of the existing RSS walls, is the preferred rehabilitation option from a foundation design perspective, as it is both cost efficient and would result in negligible settlement. This assessment supports the decision made by MTO following their review of MMM's is February 19, 2016, "RSS Wall Rehabilitation Options" memo. It should be noted that the no detailed design or analysis was carried out for the rehabilitation options, as the preferred option had already been selected prior to the preparation of this report and that option does not require foundations engineering input. However, detailed design recommendations for the various options can be provided if the selected rehabilitation option is changed.

6.2.6 Further Considerations

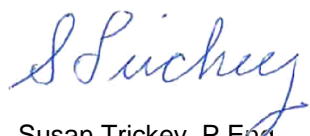
If an evaluation of the on-going settlement of the existing RSS walls is of interest, consideration could be given to carrying out settlement monitoring or at least to establishing baseline elevations which might be useful if some new distress is observed in the future. This could be undertaken by establishing survey pins on the existing RSS panels (e.g., 3 survey pins at each sidewall location) and carrying out baseline survey readings at the time of the retaining wall rehabilitation (or shortly thereafter). Observation and comparison of the gaps between the panels could subsequently be carried out at the time of the next structural bridge inspection (i.e., in 2 years' time) and if any additional movement is observed, consideration could then be given to surveying the pre-established monitoring points for comparison with the baseline survey elevations.



7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Susan Trickey, P.Eng. and reviewed by Mr. Mike Cunningham, P.Eng., a Principal and geotechnical engineer with Golder. Mr. Fin Heffernan, P.Eng., Golder's Designated MTO Foundations Contact for this project, conducted an independent quality review of the report.

GOLDER ASSOCIATES LTD.



Susan Trickey, P.Eng.
Geotechnical Engineer



Mike Cunningham, P.Eng.
Principal, Geotechnical Engineer



Fin Heffernan, P.Eng.
Designated MTO Contact



SAT/MIC/FJH/ob

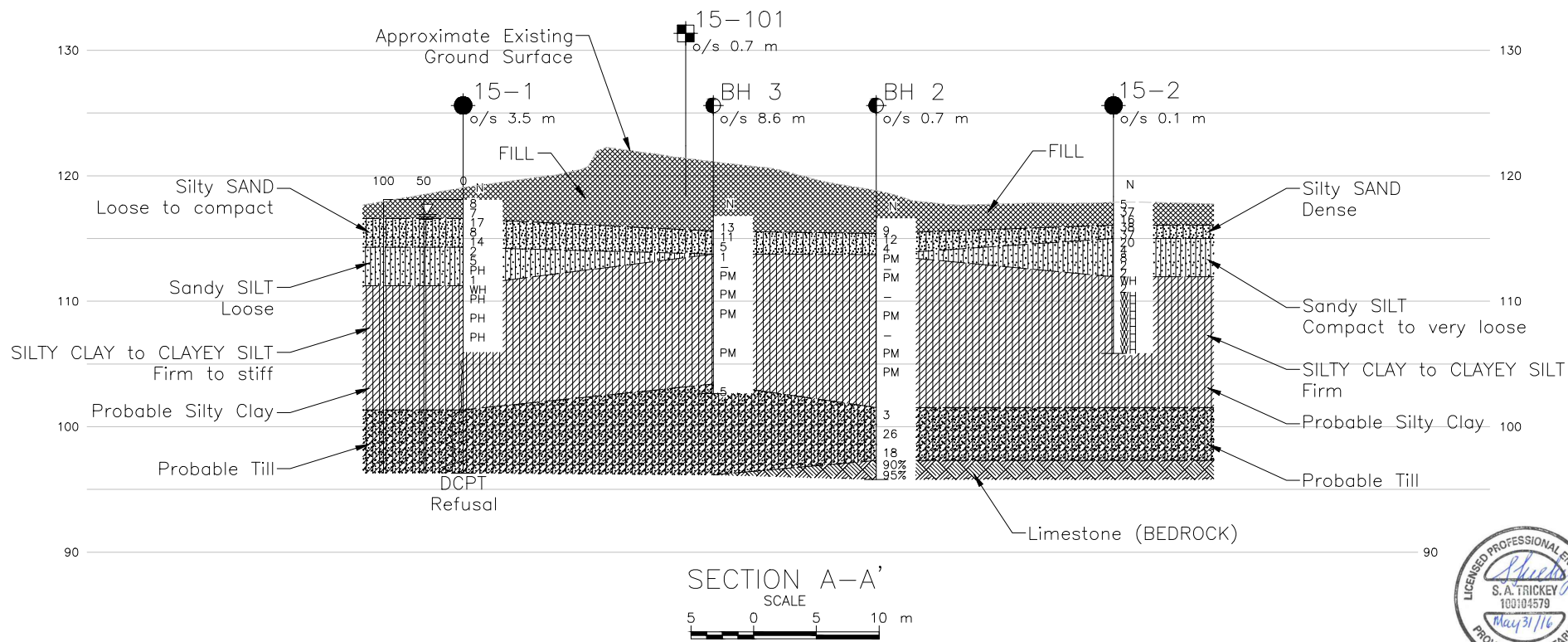
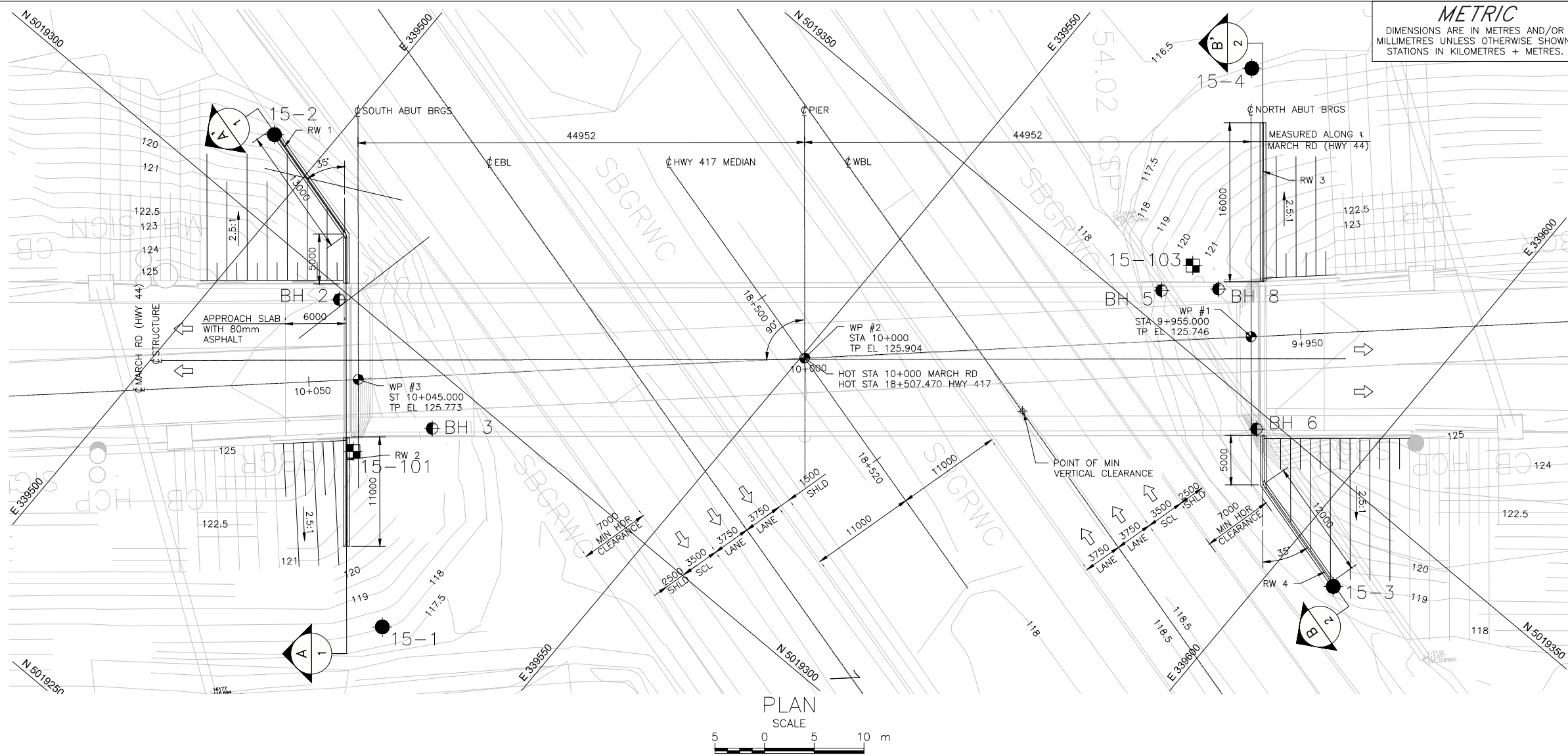
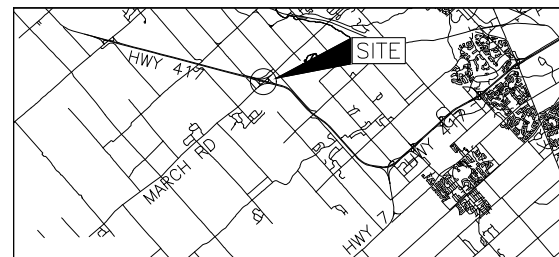
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**FOUNDATION REPORT - RETAINING WALL REHABILITATION
MARCH ROAD UNDERPASS - HIGHWAY 417**

Table 1 – Comparison of Foundation Alternatives

Foundation Option	Feasibility	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Option 1 Preservation Management of Existing RSS Wall	<ul style="list-style-type: none"> Feasible, preferred option 	<ul style="list-style-type: none"> Negligible additional settlement 	<ul style="list-style-type: none"> Does not completely improve the aesthetics of the existing walls 	<ul style="list-style-type: none"> Low cost 	<ul style="list-style-type: none"> Low risk option
Option 2 RSS Walls Perpendicular to Existing RSS Walls	<ul style="list-style-type: none"> Feasible 	<ul style="list-style-type: none"> Would improve the aesthetics of the bridge, since existing RSS walls would be buried 	<ul style="list-style-type: none"> Significant additional load to the underlying clay that would induce settlement Could cause additional settlement of the RSS walls at the abutments Likely need to use light weight fill 	<ul style="list-style-type: none"> Moderate cost 	<ul style="list-style-type: none"> Higher risk option in terms of settlement
Option 3a RSS Walls Parallel to Existing RSS Walls	<ul style="list-style-type: none"> Feasible 	<ul style="list-style-type: none"> Limited additional settlement Would improve the aesthetics of the existing walls 	<ul style="list-style-type: none"> More complex design required in terms of anchorages for new walls and to accommodate some limited future settlement 	<ul style="list-style-type: none"> Moderate cost 	<ul style="list-style-type: none"> Low risk option
Option 3b Cast-in-Place Concrete Retaining Wall on Piles	<ul style="list-style-type: none"> Feasible but not required or economical 	<ul style="list-style-type: none"> Minimal additional settlement Would improve the aesthetics of the existing walls 	<ul style="list-style-type: none"> Would require long expensive piles 	<ul style="list-style-type: none"> High cost 	<ul style="list-style-type: none"> Low risk option

CONT No. 2016-4032
WP No. 4104-13-01RETAINING WALL REHABILITATION
MARCH ROAD UNDERPASS
HIGHWAY 417
BOREHOLE LOCATIONS AND SOIL STRATAKEY PLAN
SCALE 1:6000

LEGEND

- Borehole - Current Investigation
- Test Pit - Current Investigation
- Borehole - Previous Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Total Core Recovery (REC)
- WL in piezometer, measured on Dec. 21, 2015
- WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
15-1	118.1	5019276.6	339535.1
15-2	118.4	5019307.6	339494.9
15-3	118.8	5019341.3	339605.9
15-4	117.0	5019375.9	339566.1
15-101	122.4	5019288.3	339521.6
15-103	120.5	5019356.9	339574.3
BH 2	116.6	5019299.1	339510.7
BH 3	116.8	5019295.1	339526.2
BH 5	117.5	5019353.0	339573.5
BH 6	117.2	5019348.4	339589.8
BH 8	117.2	5019356.8	339577.8

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 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

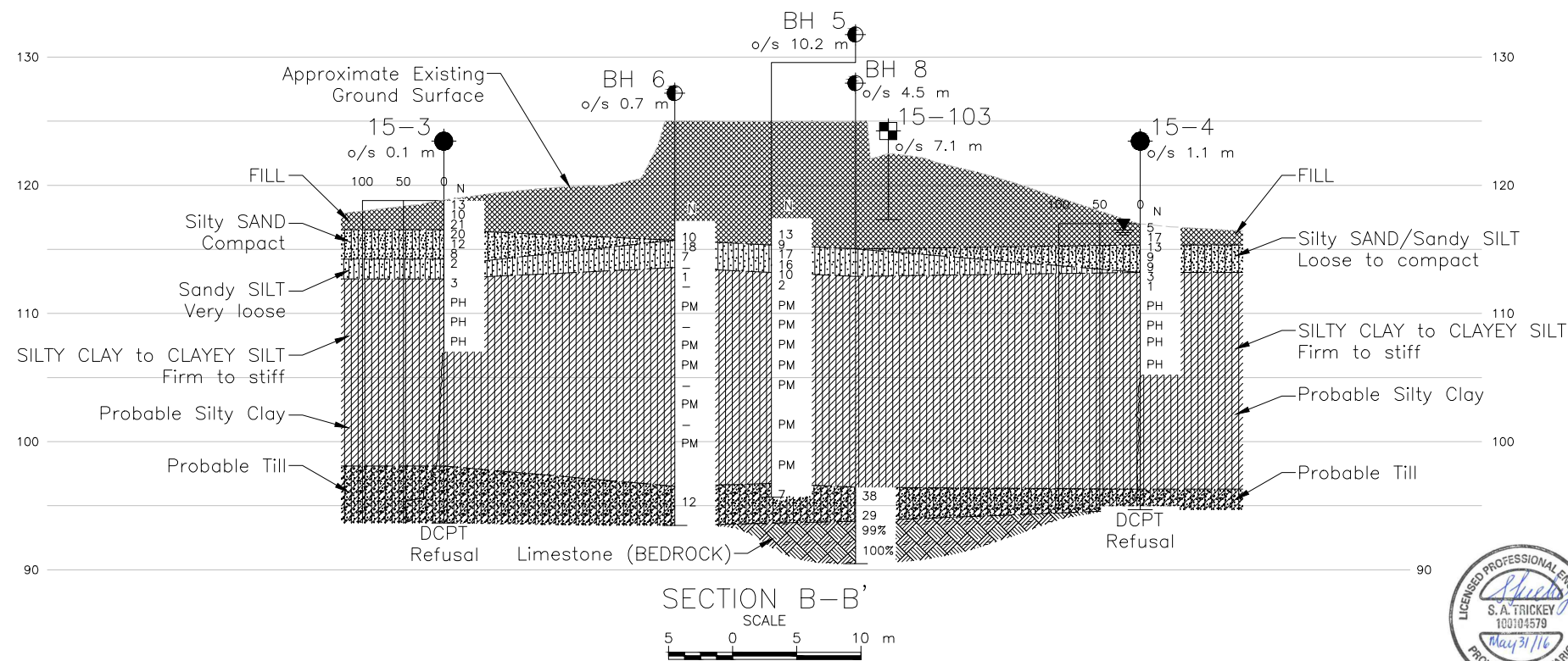
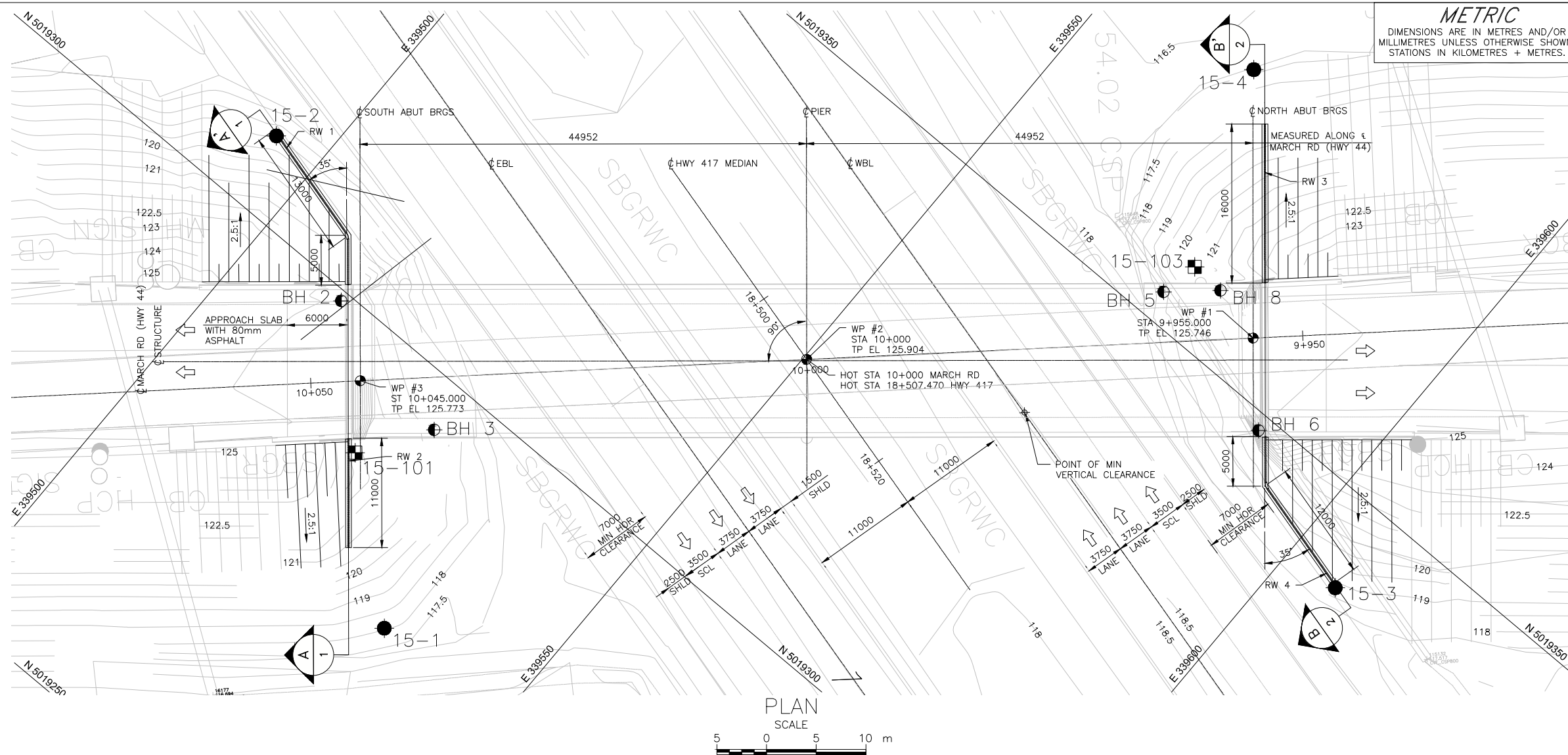
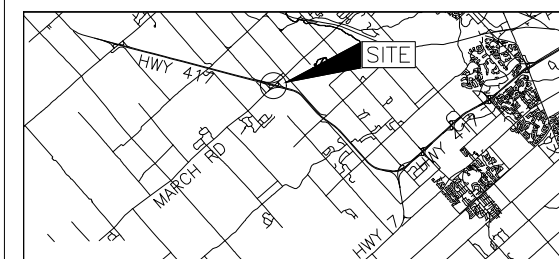
Base plans provided in digital format by MMM Group, drawing file no. March Road UP Plan.dwg, received Nov 6, 2015.

NO.	DATE	BY	REVISION
1	03/24/2016	FJH	1

Geocres No. 31F-192

HWY. 417	PROJECT NO. 1417217	DIST. EASTERN
SUBM'D. SAT	CHKD. SAT	DATE: 03/24/2016
DRAWN: JM	CHKD. MIC	APPD. FJH



CONT No. 2016-4032
WP No. 4104-13-01RETAINING WALL REHABILITATION
MARCH ROAD UNDERPASS
HIGHWAY 417
BOREHOLE LOCATIONS AND SOIL STRATAKEY PLAN
SCALE
0 4 6 km

LEGEND

- Borehole - Current Investigation
- Test Pit - Current Investigation
- Borehole - Previous Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Total Core Recovery (REC)
- ≡ WL in piezometer, measured on Dec. 21, 2015
- ≡ WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
15-1	118.1	5019276.6	339535.1
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15-3	118.8	5019341.3	339605.9
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15-101	122.4	5019288.3	339521.6
15-103	120.5	5019356.9	339574.3
BH 2	116.6	5019299.1	339510.7
BH 3	116.8	5019295.1	339526.2
BH 5	117.5	5019353.0	339573.5
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REFERENCE

Base plans provided in digital format by MMM Group, drawing file no. March Road UP Plan.dwg, received Nov 6, 2015.

NO.	DATE	BY	REVISION

Geocres No. 31F-192

HWY. 417	PROJECT NO. 1417217	DIST. EASTERN
SUBM'D. SAT	CHKD. SAT	DATE: 03/24/2016
DRAWN: JM	CHKD. MIC	APPD. FJH
		SITE: 3-357
		DWG. 2





APPENDIX A

List of Abbreviations and Symbols Borehole Records

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		III. SOIL DESCRIPTION		
AS	Auger sample	(a) Cohesionless Soils		
BS	Block sample	Density Index (Relative Density)	N	
CS	Chunk sample		Blows/300 mm	
DO or DP	Seamless open-ended, driven or pushed tube samplers		Or Blows/ft.	
DS	Denison type sample		0 to 4	
FS	Foil sample		4 to 10	
RC	Rock core		10 to 30	
SC	Soil core		30 to 50	
SS	Split spoon sampler		over 50	
ST	Slotted tube	(b) Cohesive Soils C _u or S _u		
TO	Thin-walled, open			
TP	Thin-walled, piston			
WS	Wash sample			
DT	Dual tube sample			
DD	Diamond drilling			
II. PENETRATION RESISTANCE				
Standard Penetration Resistance (SPT), N:				
The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split spoon sampler for a distance of 300 mm (12 in.).				
Dynamic Cone Penetration Resistance (DCPT); N _d :				
The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive an uncased 50 mm (2 in.) diameter, 60 ⁰ cone attached to “A” size drill rods for a distance of 300 mm (12 in.).				
PH:	Sampler advanced by hydraulic pressure	IV. SOIL TESTS		
PM:	Sampler advanced by manual pressure			
WH:	Sampler advanced by static weight of hammer			
WR:	Sampler advanced by weight of sampler and rod			
Cone Penetration Test (CPT):				
An electronic cone penetrometer with a 60 ⁰ conical tip and a projected 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 (u) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.				
			w	Water content
			w _p or PL	Plastic limited
			w _l or LL	Liquid limit
			C	Consolidaiton (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
		DS	Direct shear test	
		G _s	Specific gravity	
		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 test (LV-laboratory vane test)	
		γ	Unit weight	

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

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
$\ln x$	natural logarithm of x
$\log_{10} x$ or $\log x$	logarithm of x to base 10
g	acceleration due to gravity
t	time
FOS	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 vertical effective overburden stress
$\sigma_1 \sigma_2 \sigma_3$	principal stresses (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 (overconsolidated range)
C_s	swelling index
C_α	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	overconsolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

τ_p or 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 or 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:

$$^1 \tau = c' + \sigma' \tan \phi'$$

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



SHEET 1 OF 3

METRIC

CHECKED BY SAT

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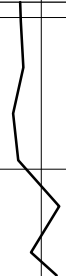
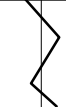
+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT 1417217				RECORD OF BOREHOLE No 15-1				SHEET 2 OF 3				METRIC					
G.W.P. 4104-13-01				LOCATION N 5019276.6;E 339535.1				ORIGINATED BY DWM									
DIST Eastern HWY 417				BOREHOLE TYPE Power Auger 200 mm Diam. (Hollow Stem), DCPT				COMPILED BY JM									
DATUM Geodetic				DATE December 3-4, 2015				CHECKED BY SAT									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)				
	--- CONTINUED FROM PREVIOUS PAGE ---						20 40 60 80 100	○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					W _p — W — W _L 25 50 75				
105.9 12.2	SILTY CLAY to CLAYEY SILT Firm to stiff Grey Wet ----- Probable Silty Clay		13	TP	PH		108	×		+							
								107									
								×		+							
								×		+							
							106										
							105										
							104										
							103										
							102										
							101										
101.3 16.8	Probable Till						100										
							99										

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

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PROJECT <u>1417217</u>		RECORD OF BOREHOLE No 15-1				SHEET 3 OF 3		METRIC								
G.W.P. <u>4104-13-01</u>		LOCATION <u>N 5019276.6 ; E 339535.1</u>				ORIGINATED BY <u>DWM</u>										
DIST <u>Eastern</u> HWY <u>417</u>		BOREHOLE TYPE <u>Power Auger 200 mm Diam. (Hollow Stem), DCPT</u>				COMPILED BY <u>JM</u>										
DATUM <u>Geodetic</u>		DATE <u>December 3-4, 2015</u>				CHECKED BY <u>SAT</u>										
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								
	--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED				WATER CONTENT (%)				
	Probable Till						98									
	96.3 21.8						97									
	END OF BOREHOLE DCPT REFUSAL															
	NOTES: 1. Water level in open borehole at a depth of 1.2 m below ground surface (Elev. 116.9 m), measured during drilling.															

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PROJECT 1417217		RECORD OF BOREHOLE No 15-2		SHEET 1 OF 2		METRIC						
G.W.P. 4104-13-01		LOCATION N 5019307.6 ; E 339494.9		ORIGINATED BY DWM								
DIST Eastern HWY 417		BOREHOLE TYPE Portable		COMPILED BY JM								
DATUM Geodetic		DATE December 1-2, 2015		CHECKED BY SAT								
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID UNIT WEIGHT REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	20 40 60 80 100	W _p W W _L	γ	GR SA SI CL
118.4	GROUND SURFACE											
0.0	Sandy silt to silty sand (TOPSOIL/FILL)											
118.2	Brown											
0.2	Silty sand, trace gravel, clay and organic matter, occasional cobble (FILL)		1	SS	5		118					
117.5	Loose Dark brown to black											
0.9	Moist											
116.9	Silty sand, some gravel (FILL)		2	SS	37		117					
1.5	Dense Grey-brown											
	Moist											
116.1	Sand and gravel, trace silt (FILL)		3	SS	16							
	Compact Grey-brown											
	Wet											
2.3	Silty SAND, some gravel, contains non-plastic fines		4	SS	38		116			o		1 74 18 7
	Dense Grey-brown											
	Wet											
115.1			5	SS	37							
3.4	Sandy SILT											
	Compact to very loose											
	Grey											
	Wet											
112.0			6	SS	20		115					
6.4	SILTY CLAY to CLAYEY SILT, contains sandy silt seams											
	Firm											
	Grey											
	Wet											
			7	SS	4		114					
			8	SS	8					o		0 15 71 14
			9	SS	2		113			H o		
			10	SS	2							
			11	SS	WH		112			H o		
			12	SS	2		111					
			13	SS	WH							
			14	SS	WH		110					
			15	SS	WH							
			16	SS	WH		109					

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

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PROJECT <u>1417217</u>			RECORD OF BOREHOLE No 15-2			SHEET 2 OF 2			METRIC								
G.W.P. <u>4104-13-01</u>			LOCATION <u>N 5019307.6 ; E 339494.9</u>			ORIGINATED BY <u>DWM</u>											
DIST <u>Eastern</u> HWY <u>417</u>			BOREHOLE TYPE <u>Portable</u>			COMPILED BY <u>JM</u>											
DATUM <u>Geodetic</u>			DATE <u>December 1-2, 2015</u>			CHECKED BY <u>SAT</u>											
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									
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%)				
								20	40	60	80	100	25	50	75		
105.9	SILTY CLAY to CLAYEY SILT, contains sandy silt seams Firm Grey Wet		17	SS	WH		108										
			18	SS	WH												
			19	SS	WH		107										
			20	SS	WH		106										
12.5	END OF BOREHOLE																

GTA-MTO 001 N:\ACTIVE\SPATIAL\IMMM\GROUP\MEGA6_VARIOUSSTRUCTURES02_DATA\GINT1417217.GPJ GAL-GTA.GDT 05/31/16 JM

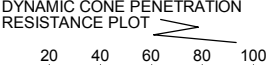


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+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

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

PROJECT 1417217		RECORD OF BOREHOLE No 15-3				SHEET 3 OF 3		METRIC			
G.W.P. 4104-13-01		LOCATION N 5019341.3 ; E 339605.9				ORIGINATED BY DWM					
DIST Eastern HWY 417		BOREHOLE TYPE Power Auger 200 mm Diam. (Hollow Stem), DCPT				COMPILED BY JM					
DATUM Geodetic		DATE December 4-7, 2015				CHECKED BY SAT					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%)	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
98.1	Probable Silty Clay										
20.7	Probable Till										
93.7	END OF BOREHOLE DCPT REFUSAL										
25.1											

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMM\MM\GROUP\WEGA6_VARIOUSSTRUCTURES02_DATA\GINT1417217.GPJ GAL-GTA.GDT 05/31/16 JM

PROJECT 1417217		RECORD OF BOREHOLE No 15-4		SHEET 1 OF 3		METRIC	
G.W.P. 4104-13-01		LOCATION N 5019375.9 ; E 339566.1		ORIGINATED BY DWM			
DIST Eastern HWY 417		BOREHOLE TYPE Power Auger 200 mm Diam. (Hollow Stem), DCPT		COMPILED BY JM			
DATUM Geodetic		DATE December 7-8, 2015		CHECKED BY SAT			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT			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 (%)				
117.0	GROUND SURFACE						20	40	60	80	100	W _p	W	W _L			
0.0	TOPSOIL/FILL																
0.2	Silty sand, trace organic matter (FILL) Loose Grey-brown Wet		1	SS	5												
116.2	Silty sand (FILL) Compact Brown Wet		2	SS	17												
0.8																	
115.3																	
1.7	Silty SAND/Sandy SILT, contains non-plastic fines and shells Loose to compact Grey Wet		3	SS	13											0 55 34 11	
			4	SS	9												
			5	SS	9											0 37 55 8	
113.2	SILTY CLAY to CLAYEY SILT, contains sand seams and shells Firm to stiff Grey Wet		6	SS	3												
3.8			7	SS	1												
			8	TP	PH												
			9	SS	PH												
			10	TP	PH												

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

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMM\MM\GROUP\WEGA6_VARIOUS\STRUCTURES02_DATA\GINT1417217.GPJ GAL-GTA.GDT 05/31/16 JM

PROJECT <u>1417217</u>		RECORD OF BOREHOLE No 15-4		SHEET 2 OF 3		METRIC											
G.W.P. <u>4104-13-01</u>		LOCATION <u>N 5019375.9; E 339566.1</u>		ORIGINATED BY <u>DWM</u>													
DIST <u>Eastern</u> HWY <u>417</u>		BOREHOLE TYPE <u>Power Auger 200 mm Diam. (Hollow Stem), DCPT</u>		COMPILED BY <u>JM</u>													
DATUM <u>Geodetic</u>		DATE <u>December 7-8, 2015</u>		CHECKED BY <u>SAT</u>													
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE		"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa					W _p W W _L				
	--- CONTINUED FROM PREVIOUS PAGE ---																
	SILTY CLAY to CLAYEY SILT, contains sand seams and shells Firm to stiff Grey Wet																
			11	SS	PH		106										
105.2																	
11.8	Probable Silty Clay						105										
							104										
							103										
							102										
							101										
							100										
							99										
							98										

Continued Next Page

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

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMMM_GROUP\MEGA6_VARIOUSSTRUCTURES02_DATA\GINT1417217.GPJ GAL-GTA.GDT 05/31/16 JM

PROJECT 1417217		RECORD OF BOREHOLE No 15-4				SHEET 3 OF 3		METRIC											
G.W.P. 4104-13-01		LOCATION N 5019375.9;E 339566.1				ORIGINATED BY DWM													
DIST Eastern HWY 417		BOREHOLE TYPE Power Auger 200 mm Diam. (Hollow Stem), DCPT				COMPILED BY JM													
DATUM Geodetic		DATE December 7-8, 2015				CHECKED BY SAT													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa			WATER CONTENT (%)			γ			GR SA SI CL		
	--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100	○ UNCONFINED + FIELD VANE	W _p	W	W _L							
	Probable Silty Clay							20 40 60 80 100	● QUICK TRIAXIAL × REMOULDED	25 50 75									
96.3	Probable Till						96												
20.7							95												
94.7	END OF BOREHOLE DCPT REFUSAL																		
22.3	NOTES: 1. Water level in piezometer at a depth of 0.5 m below ground surface (Elev. 116.5 m), measured Dec. 21, 2015.																		

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMM\MM\GROUP\WEGA6_VARIOUS\STRUCTURES02_DATA\GINT1417217.GPJ GAL-GTA.GDT 05/31/16 JM

PROJECT 1417217				RECORD OF TEST PIT No 15-101				SHEET 1 OF 1				METRIC					
G.W.P. 4104-13-01				LOCATION N 5019288.3 ; E 339521.6				ORIGINATED BY DWM									
DIST Eastern HWY 417				BOREHOLE TYPE Excavator				COMPILED BY JM									
DATUM Geodetic				DATE November 30, 2015				CHECKED BY SAT									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
122.4	GROUND SURFACE						20	40	60	80	100						
0.0	Silty sand (TOPSOIL/FILL)																
0.1	Brown																
	Sandy gravel/gravelly sand, some silt, trace clay (FILL)		1	GRAB	-											50	35 11 4
	Grey-brown		2	GRAB	-												
	Moist		3	GRAB	-											27	43 21 9
119.4	Sandy silt, trace gravel and rootlets (FILL)		4	GRAB	-												
119.0	Dark brown		5	GRAB	-												
119.0	Moist		6	GRAB	-												
118.4	Silty sand (FILL)																
118.4	Grey-brown																
4.0	Moist																
	END OF TEST PIT																
	NOTES:																
	1. Test pit dry upon completion of drilling.																

PROJECT 1417217		RECORD OF TEST PIT No 15-103				SHEET 1 OF 1		METRIC									
G.W.P. 4104-13-01		LOCATION N 5019356.9 ; E 339574.3				ORIGINATED BY DWM											
DIST Eastern HWY 417		BOREHOLE TYPE Excavator				COMPILED BY JM											
DATUM Geodetic		DATE November 30, 2015				CHECKED BY SAT											
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									
120.5	GROUND SURFACE																
0.0	Sandy silt to silty sand (TOPSOIL/FILL)																
0.1	Brown Sandy gravel/gravelly sand, some silt, trace clay (FILL) Grey-brown Moist		1	GRAB	-												
			2	GRAB	-												
			3	GRAB	-												
			4	GRAB	-												
117.6	Sand, some silt to silty sand (FILL)		5	GRAB	-												
2.9	Brown		6	GRAB	-												
117.3																	
3.2	END OF TEST PIT																
NOTES:																	
1. Test pit dry upon completion of drilling.																	



APPENDIX B

Borehole Records, Previous Investigation (1990)

RECORD OF BOREHOLE No 2

METRIC

W P 34-81-02 LOCATION CH 10 + 045.9 - 8.7 RT (Hwy. 44) ORIGINATED BY R.K.
 DIST 9 HWY 44 BOREHOLE TYPE Hollow Stem Auger, Rotary Coring (BQ) @ 15.09 m. COMPILED BY I.C.
 DATUM Geodetic DATE December 11, 1989 CHECKED BY

OFFICE REPORT ON SOIL EXPLORATION

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZ DISTRIBUTIO (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			20	40	60	80	100					
116.62	Ground Level															
0.00	Loose, brown sand.															
115.40	Some silt. Fill		1	SS	9											
1.22	Compact to loose silty fine sand. Tr clay.		2	SS	12											
113.72	Silt and clay. Contents increase with depth.		3	SS	4											
2.90			4	SS	PM*											
	Stiff, grey silty clay with 3 mm thick clayey silt varves at 25-30 mm spacings.		5	ST	-											
			6	SS	PM*											
			7	ST	-											
			8	SS	PM											
			9	ST	-											
			10	SS	PM											
			11	SS	PM											
101.53																
15.09	Loose to compact, grey silty sand. Tr clay, some gravel. Occ boulder. Till		12	SS	3											
	Fresh, grey, medium grained limestone bed- rock with dark grey, closely spaced, dark grey partings (below 10mm) of shale 50mm fractured zone at 20.2 m.		13	SS	26											
97.31			14	SS	18											
19.31			15	BQ												
95.79			16	BQ												
20.83	End of Borehole															
<p>Notes</p> <p>Water level in standpipe Piezometer at elevation 115.78 m on 22/12/89.</p> <p>PM* - Sample taken from disturbed ground.</p>																

RECORD OF BOREHOLE No 3

METRIC

W P 34-81-02 LOCATION CH 10 + 037.2 - 5.2 LT (Hwy. 44) ORIGINATED BY R.K.
DIST 9 HWY 44 BOREHOLE TYPE Hollow Stem Auger & Penetration Test COMPILED BY I.C.
DATUM Geodetic DATE December 13-14, 1989 CHECKED BY

OFFICE REPORT ON SOIL EXPLORATION

SOIL PROFILE		STRAT. PLOT	SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION		NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
116.81	Ground Level																
0.00	Compact, brown sand Fill																
115.59			1	SS	13		116										
1.22	Compact to loose sandy Silt. Tr Clay. Silt and clay contents increase with depth.		2	SS	11												
113.76			3	SS	5												
3.05	Stiff grey silty clay with 3 mm thick clayey silt varves at 25-30 mm spacings.		4	SS	1/50		114										
			5	ST	-												
			6	SS	PM		112										
			7	SS	PM		110										
			8	SS	PM		108										
			9	SS	PM		106										
103.40							104										
13.41	Loose, grey silty sand																
102.64	Some gravel, Till.		10	SS	5		102										
14.17	End of Borehole						100										
96.16							98										
20.63	End of penetration test																
	Notes Water level in stand-pipe at elevation 113.81 m on 24/01/90																

Redrive values after pulling back 0.9 m

+3, x5: Numbers refer to Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 5

METRIC

W P 34-81-02 LOCATION CH 9 + 962.8 - 5.0 RT (Hwy. 44) ORIGINATED BY R.K.
 DIST 9 HWY 44 BOREHOLE TYPE Hollow Stem Auger COMPILED BY I.C.
 DATUM Geodetic DATE December 4, 1989 CHECKED BY

OFFICE REPORT ON SOIL EXPLORATION

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI C				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE									
117.46	Ground Level						20	40	60	80	100						
0.00	Compact to loose brown sand. Occ organics.		1	SS	13												
115.33	Fill.		2	SS	9												
2.13	Compact, grey silt. Tr. sand and clay. Occ. shells		3	SS	17												
113.19			4	SS	16												
4.27			5	SS	10												
	Stiff to firm, grey silty clay with 3 mm thick clayey silt varves at 25-30 mm spacings.		6	SS	2												
			7	SS	PM*												
			8	SS	PM												
			9	SS	PM												
			10	SS	PM												
			11	SS	PM												
			12	SS	PM												
			13	SS	PM												
96.74	Loose, grey silty sand		14	SS	7												
20.72	Some gravel. Till																
21.79	End of Borehole																
<p><u>Note</u></p> <p>Piezometer installed a short distance away from Borehole 5.</p> <p>Water level in stand-pipe at elevation 116.06 m on 22/12/89.</p> <p>PM* - Sample taken from disturbed ground.</p>																	

+3, x5: Numbers refer to Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 6

METRIC

W P 34-81-02 LOCATION CH 9 + 954.1 - 9.0 LT (Hwy. 44) ORIGINATED BY R.K.
DIST 9 HWY 44 BOREHOLE TYPE Hollow Stem Auger COMPILED BY I.C.
DATUM Geodetic DATE December 5, 6, 1989 CHECKED BY

OFFICE REPORT ON SOIL EXPLORATION

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
117.23	Ground Level																
0.00	Loose, brown sand. Tr Silt Fill		1	SS	10		116										
115.71			2	SS	18												
1.52	Compact to loose, grey sandy silt. Tr. clay. Occ. shells		3	SS	7												
113.57			4	ST	-		114										
3.66	Stiff, grey silty clay with 3 mm thick clayey silt varves at 25-30mm spacings.		5	SS	1/50 cm												
			6	SS			112										
			7	SS	PM												
			8	ST	-		110										
			9	SS	PM		108										
			10	SS	PM		106										
			11	ST	-		104										
			12	SS	PM		102										
			13	ST	-		100										
			14	SS	PM		98										
96.51																	
20.72	Compact, grey silty sand and gravel. Tr clay. Occ boulder.		15	SS	12		96										
93.46	Till.						94										
23.77	End of Borehole Auger refusal																

+3, +5: Numbers refer to 20
Sensitivity 15 - 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 8

METRIC

W P 34-81-02

LOCATION CH 9 + 957 - 5.0 Rt (Hwy 44)

ORIGINATED BY MK

DIST 9 HWY 44

BOREHOLE TYPE Hollow Stem Auger, Rotary Coring (BQ) @ 23.37 m

COMPILED BY IC

DATUM Geodetic

DATE January 22, 23 and 24, 1990

CHECKED BY _____

[illegible]

OFFICE REPORT ON SOIL EXPLORATION

+3, x5 : Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

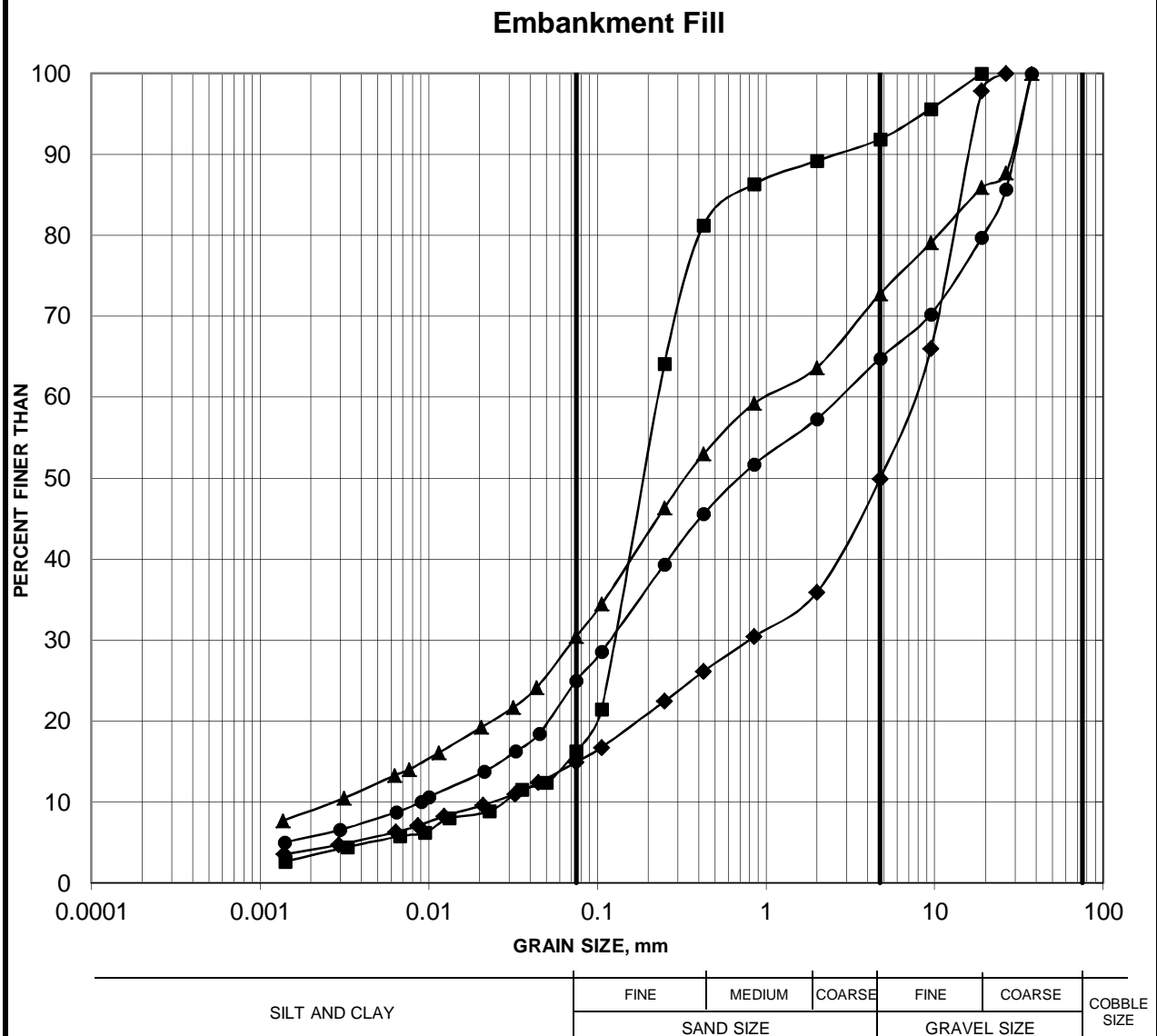


APPENDIX C

Laboratory Test Results, Current Investigation

GRAIN SIZE DISTRIBUTION

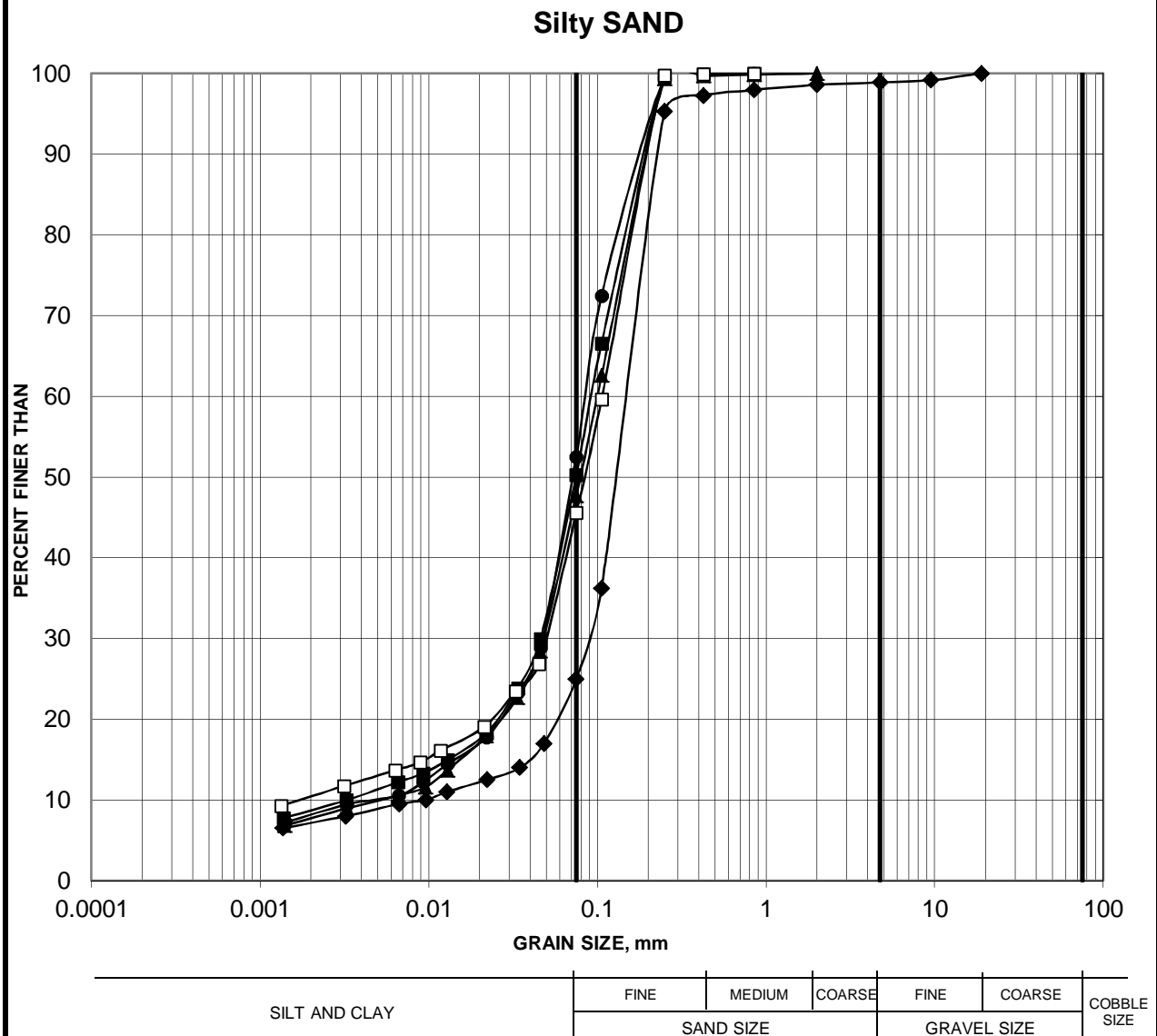
FIGURE C1



Borehole	Sample	Depth (m)
■ 15-3	2	0.76-1.37
◆ 15-101	1	0.13-0.90
▲ 15-101	3	1.20-1.60
● 15-103	4	1.40-1.70

GRAIN SIZE DISTRIBUTION

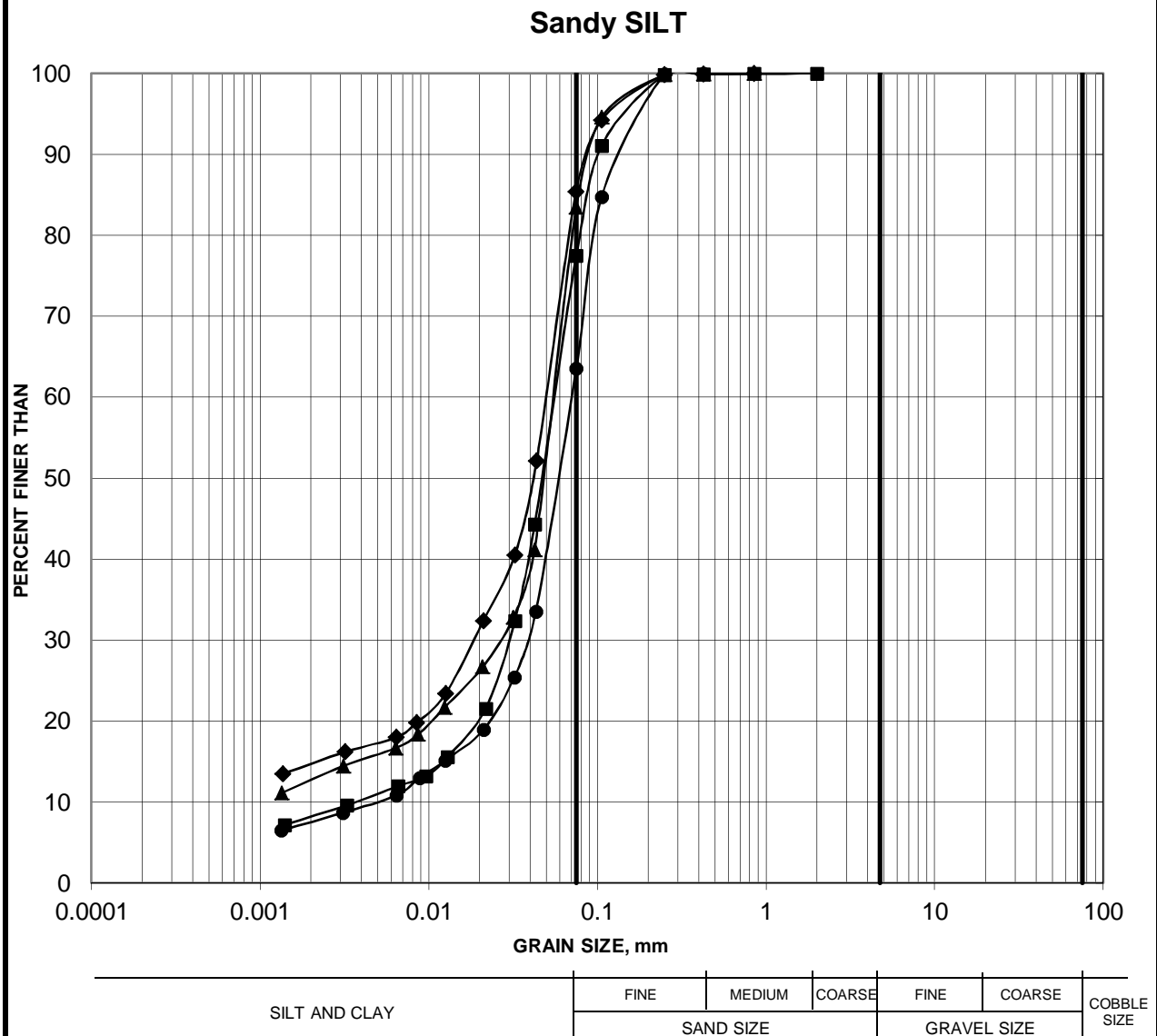
FIGURE C2



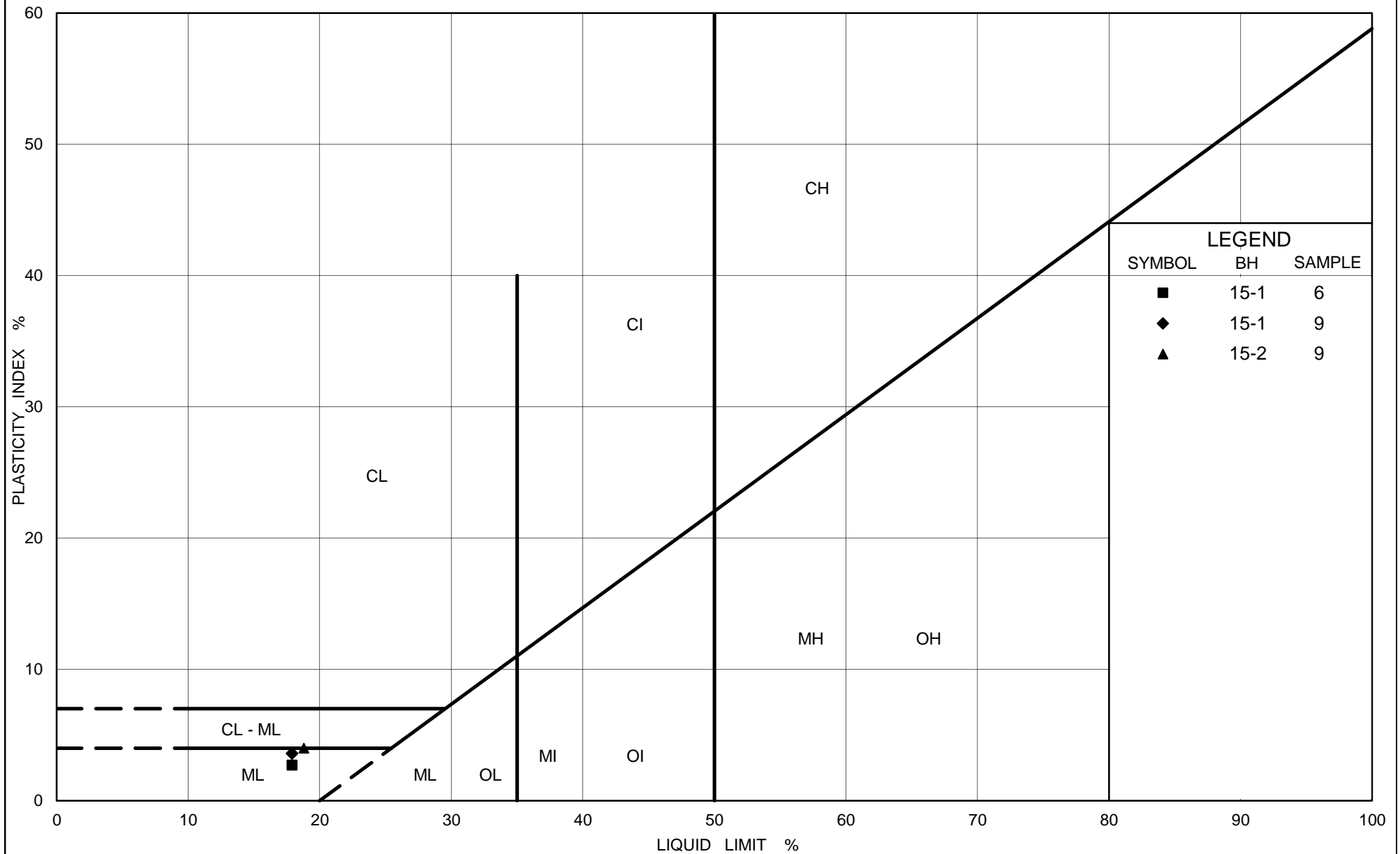
Borehole	Sample	Depth (m)
■ 15-1	4	2.28-2.89
◆ 15-2	4	2.13-2.74
▲ 15-3	5	3.05-3.66
● 15-3	6	3.81-4.42
□ 15-4	3	1.52-2.13

GRAIN SIZE DISTRIBUTION

FIGURE C3



Borehole	Sample	Depth (m)
15-1	7	4.57-5.18
15-2	8	4.57-5.18
15-3	7	4.57-5.18
15-4	5	3.05-3.66



Ontario

Ministry of Transportation

PLASTICITY CHART

Sandy SILT

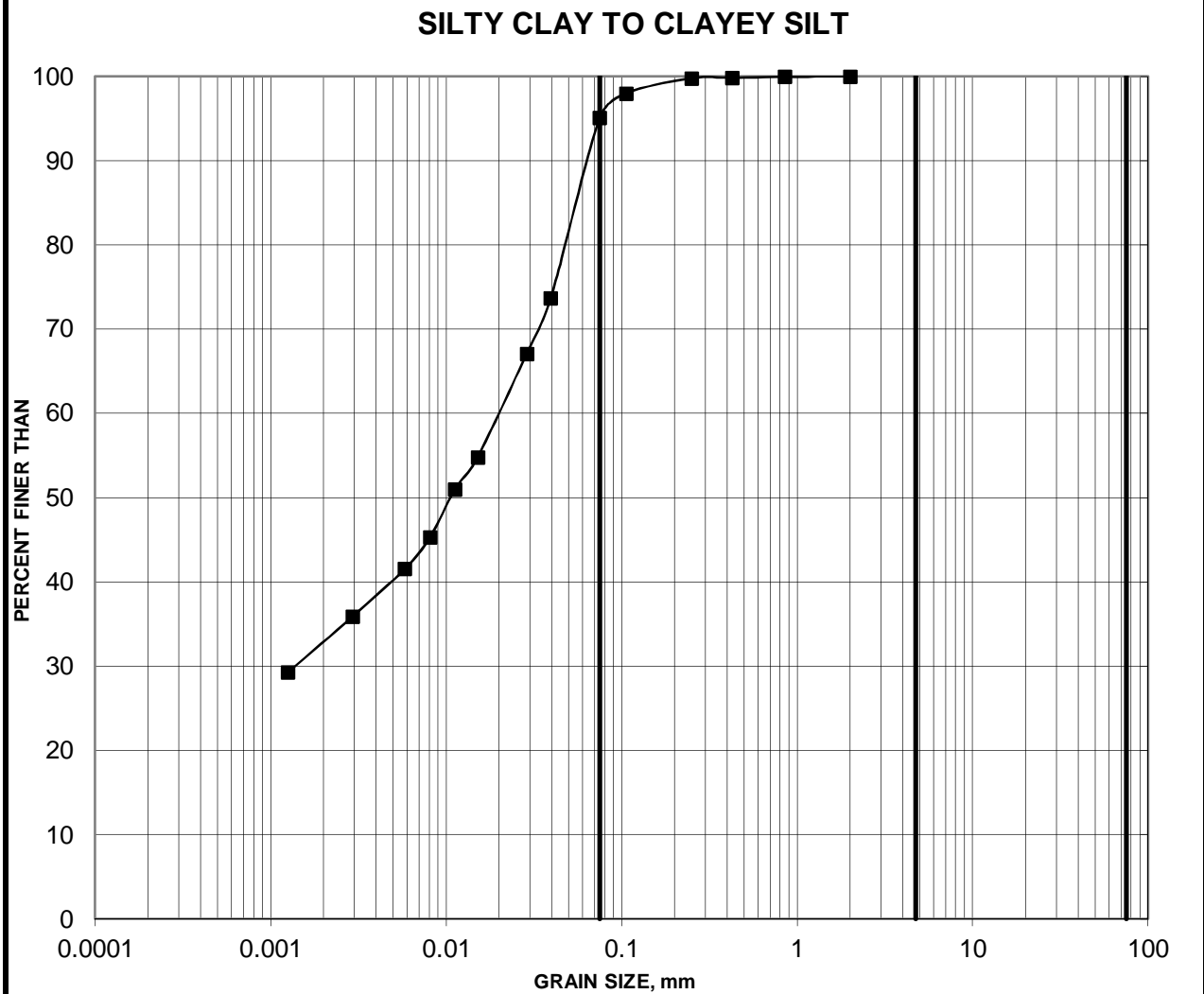
FIG No. C4

Project No. 1417217

Compiled By : MI Checked By : CNM

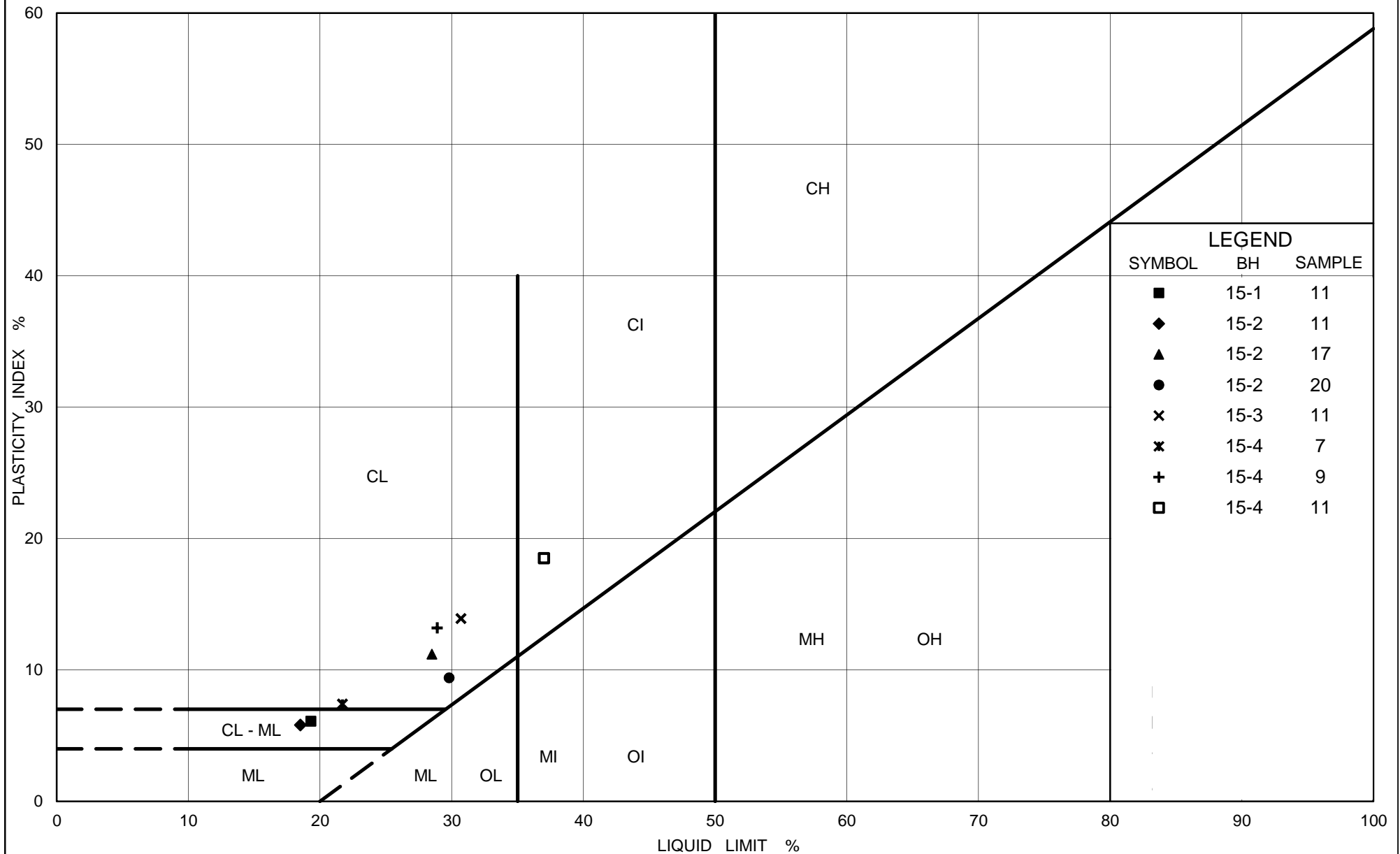
GRAIN SIZE DISTRIBUTION

FIGURE C5



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

Borehole	Sample	Depth (m)
—■— 15-2	14	8.23-8.84



Ontario

Ministry of Transportation

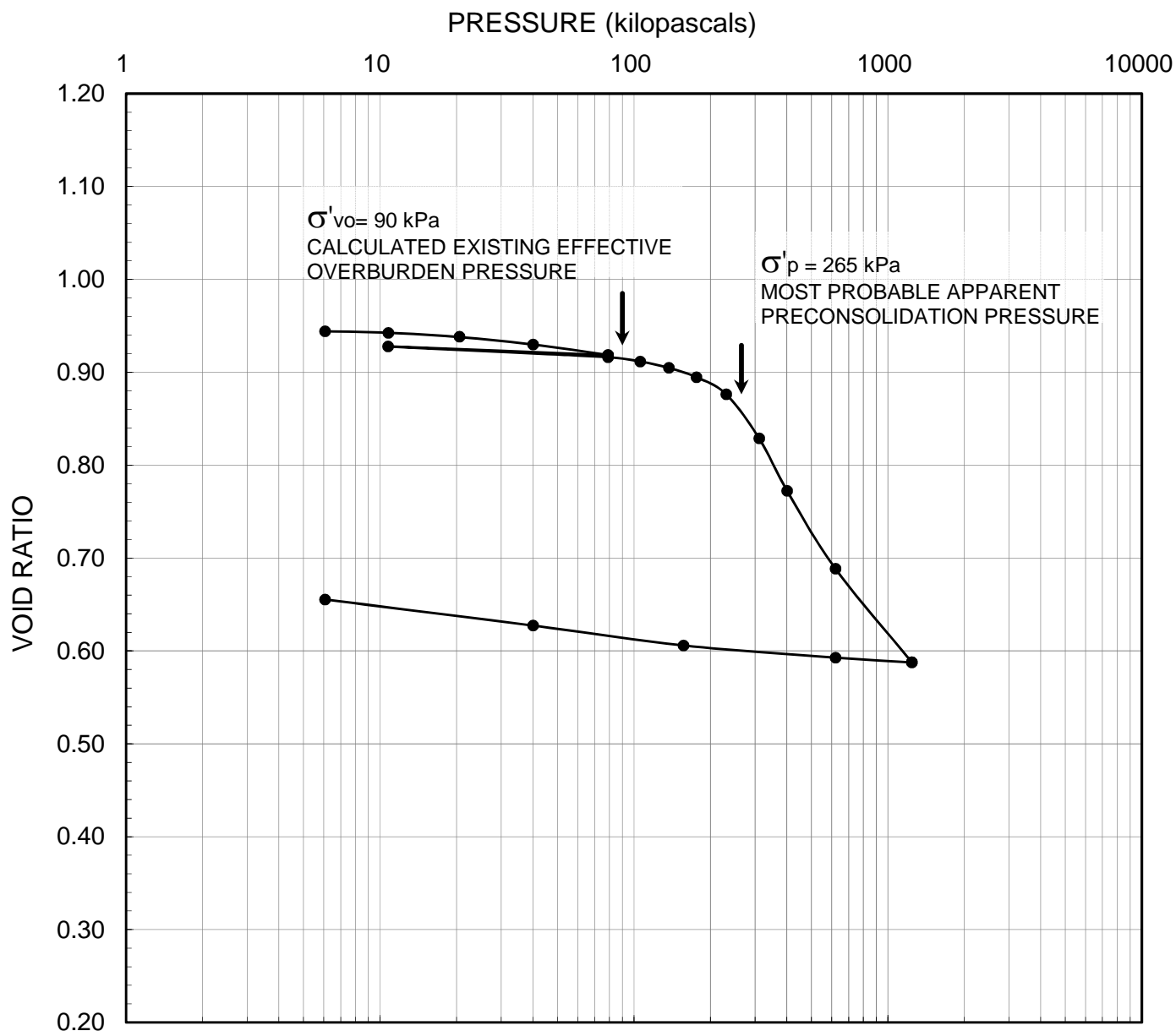
PLASTICITY CHART SILTY CLAY TO CLAYEY SILT

FIG No. C6

Project No. 1417217

Compiled By : MI

Checked By : CNM



LEGEND

Borehole: 15-1	$w_i = 34\%$	$S_o = 98\%$	$\gamma = 18.6 \text{ kN/m}^3$
Sample: 11	$w_f = 24\%$	$e_o = 0.95$	$G_s = 2.77$
Depth (m): 7.6-8.1	$w_l = 19\%$	$C_c = 0.51$	
Elevation (m): 110.5-110.0	$w_p = 13\%$	$C_r = 0.013$	



SCALE	AS SHOWN
DATE	03/23/16
CADD	LH
ENTERED	MI

TITLE

CONSOLIDATION TEST RESULTS

FILE No.	Consolidation summary
PROJECT No.	1417217 /1100
REV.	3

CHECK	CNM
REVIEW	SAT

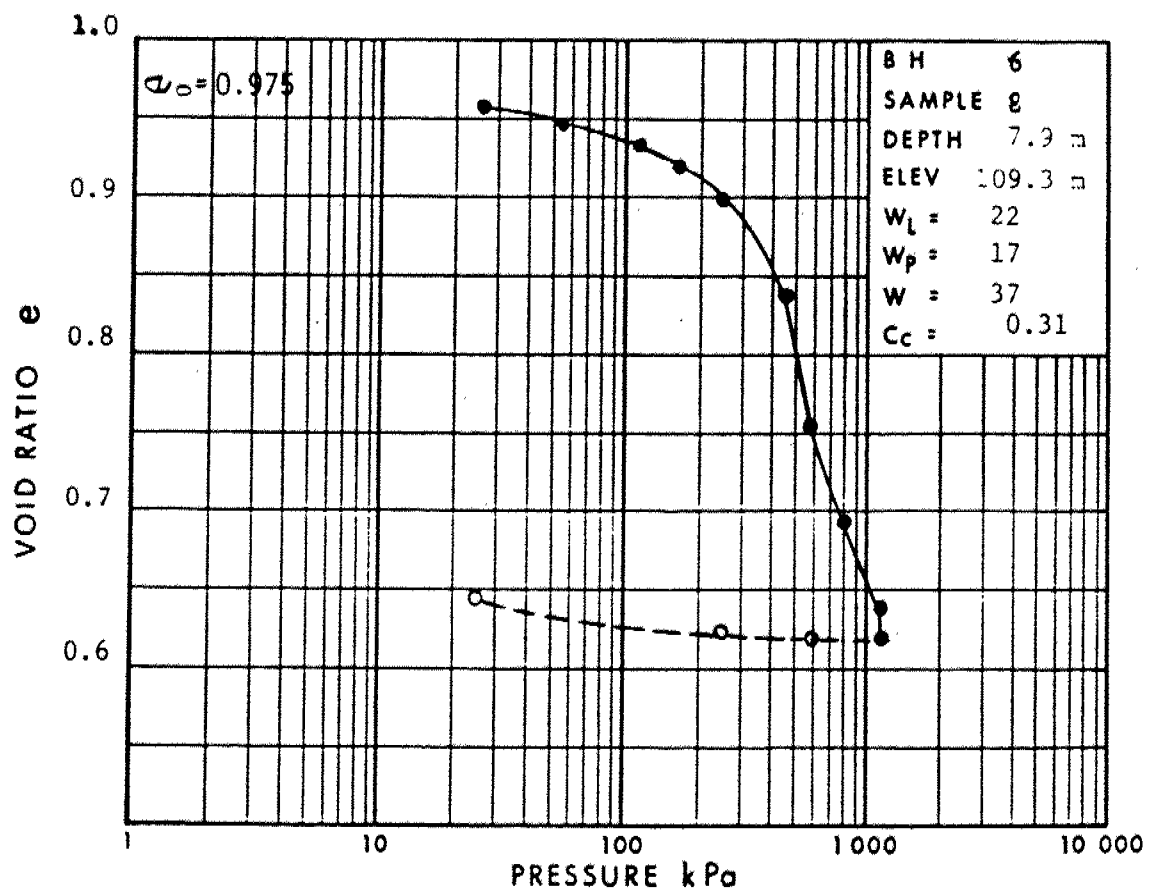
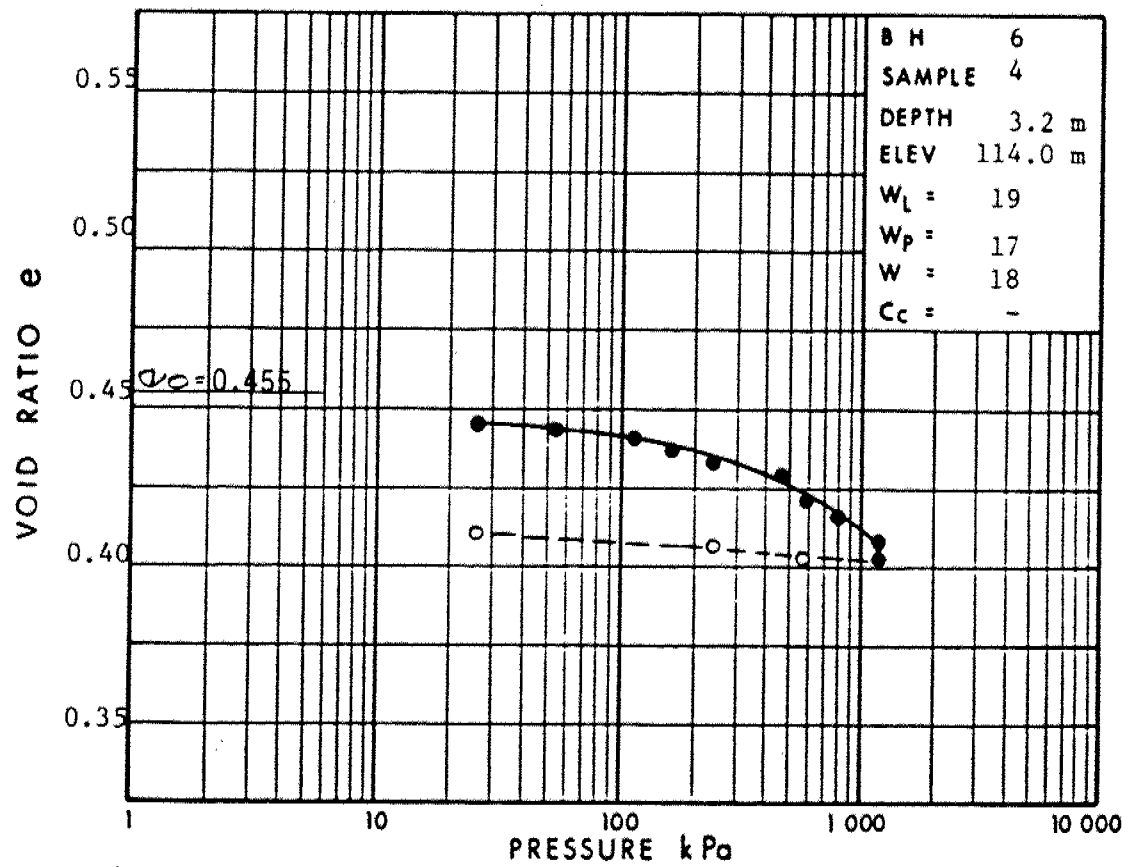
FIGURE

C7



APPENDIX D

Consolidation Test Results, Previous Investigation (1990)



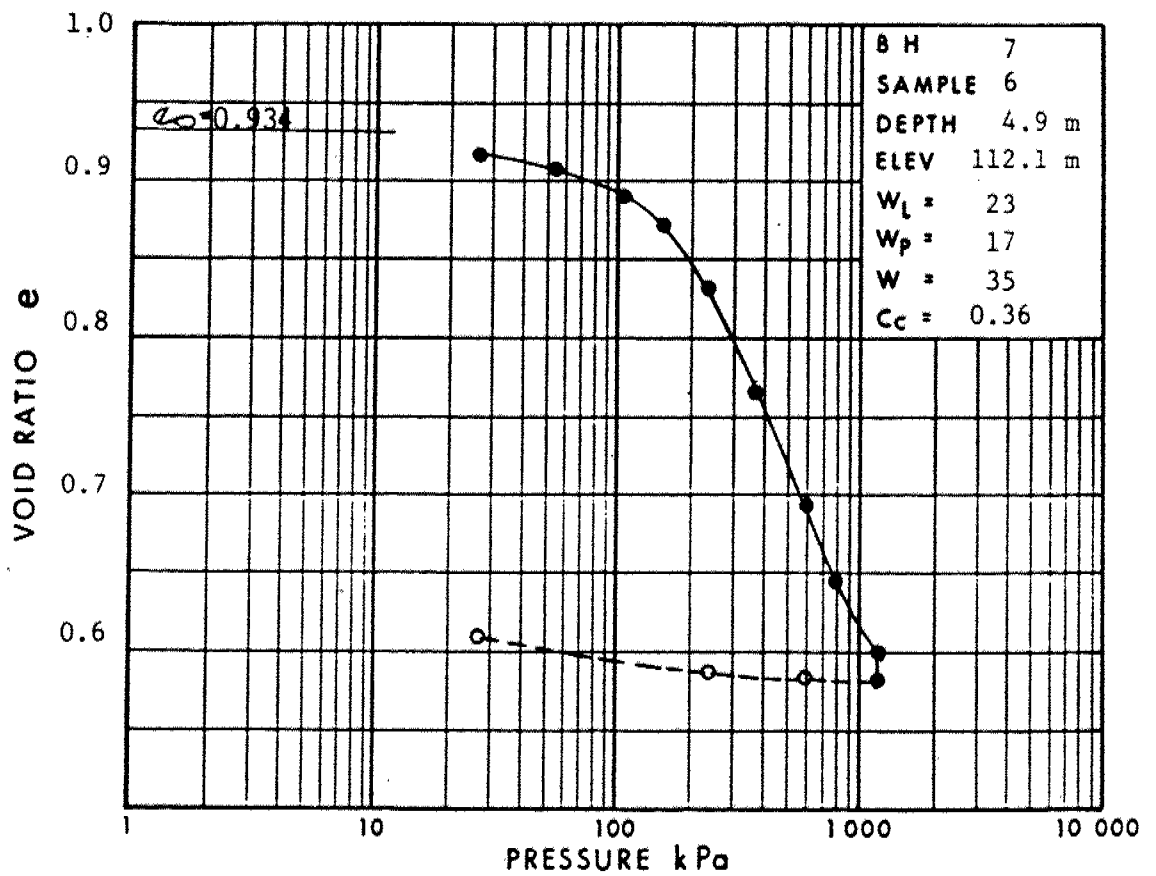
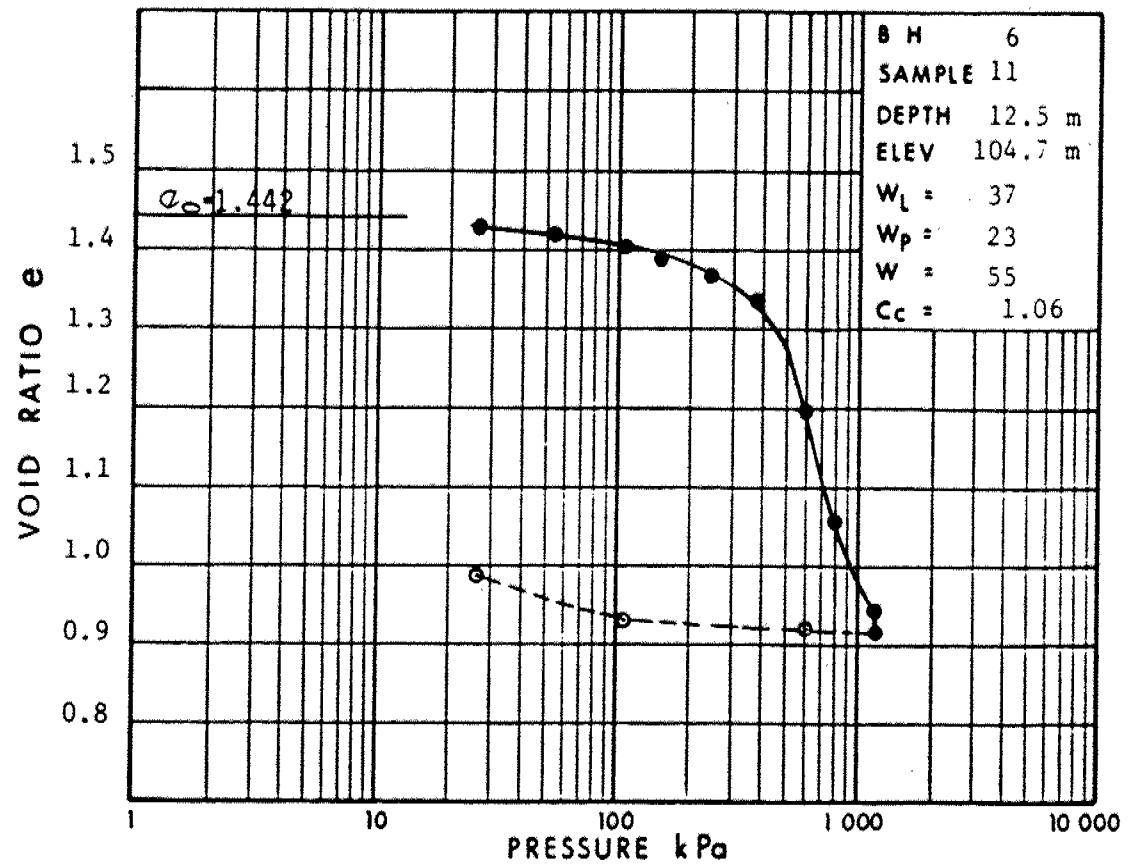


Fig No 5

W P 34-81-02

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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North America	+ 1 800 275 3281
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