

**Golder Associates Ltd.**

2390 Argentia Road  
Mississauga, Ontario, Canada L5N 5Z7  
Telephone: (905) 567-4444  
Fax: (905) 567-6561



**FOUNDATION INVESTIGATION REPORT  
THIRD STREET OVERPASS  
QEW WIDENING FROM HIGHWAY 406  
TO GARDEN CITY SKYWAY  
ST. CATHARINES, ONTARIO  
G.W.P. 607-00-00**

Submitted to:

Morrison Hershfield Limited  
235 Yorkland Boulevard, Suite 600  
Toronto, Ontario  
M2J 1T1

**DISTRIBUTION:**

- 1 Copy - Morrison Hershfield, Toronto, Ontario
- 1 Copy - Ministry of Transportation Ontario, Downsview, Ontario

January 2007

04-1111-002-1



## TABLE OF CONTENTS

<b><u>SECTION</u></b>	<b><u>PAGE</u></b>
1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION .....	2
3.0 INVESTIGATION PROCEDURES .....	3
4.0 SITE GEOLOGY AND STRATIGRAPHY .....	5
4.1 Regional Geological Conditions .....	5
4.2 Subsurface Conditions at Third Street Overpass.....	5
4.2.1 Asphalt / Fill.....	6
4.2.2 Surficial Silty Sand.....	6
4.2.3 Clayey Silt Till to Silty Sand Till.....	7
4.2.4 Lower Silty Sand to Sand.....	8
4.2.5 Lower Till/Residual Soil .....	8
4.2.6 Bedrock .....	9
4.2.7 Groundwater Conditions .....	10
5.0 CLOSURE .....	11

In Order  
Following  
Page 11

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Records of Boreholes/Drillholes 101 to 106

Figures 1 to 5

### LIST OF FIGURES

Figure 1	Grain Size Distribution Test Results – Clayey Silt Till
Figure 2	Plasticity Chart – Clayey Silt Till to Silty Sand Till
Figures 3A to 3D	Consolidation Test Results – Clayey Silt Till
Figure 4	Grain Size Distribution Test Results – Lower Silty Sand to Sand
Figure 5	Plasticity Chart – Lower Till/Residual Soil

## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield (MH) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services associated with the widening of the Queen Elizabeth Way (QEW) between Highway 406 and the Garden City Skyway in the City of St. Catharines, in the Region of Niagara. Foundation engineering services are required for the widening or replacement of five structures (Third Street overpass, Martindale Road underpass, Lake Street underpass, Geneva Street overpass, and Welland Avenue overpass), new retaining walls and noise barrier walls, culvert extensions, and high mast light poles.

This report addresses the foundation investigation carried out for the Third Street overpass structure (MTO Structure Site No. 18-246).

The terms of reference and scope of work for the foundation investigation are outlined in MTO's Request for Proposal for Agreement No. 2005-A-000564, issued in July 2002, and in Section 6.8 of MH's *Technical Proposal* for G.W.P. 607-00-00.

## **2.0 SITE DESCRIPTION**

The QEW-Third Street overpass is located approximately 200 m west of the QEW-Highway 406 interchange in St. Catharines, Ontario. The existing overpass is a single-span structure, with the abutments supported on steel H-piles.

Third Street is constructed in a cut below the QEW, with the deepest portion of the cut (immediately below the overpass) at approximately Elevation 86 m to 86.5 m; this is approximately 6.5 m to 7 m below the QEW grade which is at about Elevation 93 m at the structure location, and 5.5 m to 7 m below the surrounding terrain, which is at about Elevation 92 m to 93 m. To the northwest of the structure site, an approximately 6 m high stockpile of earth fill is present, and to the southeast, the ground surface declines toward Richardson Creek, where the creek banks are at about Elevation 80 m to 81 m.

Further to the east at the Highway 406 interchange, the QEW grade is at about Elevation 89 m to 89.5 m in a shallow cut, and Highway 406 has been constructed on embankment fill with its grade at approximately 96 m to 97 m.

### 3.0 INVESTIGATION PROCEDURES

A subsurface investigation was carried out at the QEW-Third Street overpass site in November and December 2004, at which time six boreholes (Boreholes 101 to 106) were advanced using both track-mounted and truck-mounted drill rigs, supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. The borehole locations are shown on the Borehole Location and Soil Strata drawings contained in the Contract Documents.

The boreholes were advanced to depths ranging from 9.8 m to 22.6 m, through the overburden and into the shale bedrock, using hollow stem and solid stem augers. Soil samples were obtained at 0.76 m and 1.5 m intervals of depth, using 50 mm outer diameter split-spoon samplers driven by an automatic hammer in accordance with the Standard Penetration Test (SPT) procedure. Approximately 2.7 m and 3.1 m of bedrock coring was carried out in Boreholes 102 (NQ-size) and 104 (HQ-size, in order to install a piezometer within the bedrock), respectively.

The water level in the open boreholes was observed throughout the drilling operations, and a piezometer was installed in Boreholes 102 and 104, sealed within the till and bedrock respectively, to permit monitoring of the groundwater level(s) at the site. The piezometers consist of 50 mm diameter PVC pipe with a 1.5 m long slotted screen installed within a sand filter pack; the installation details can be found on the borehole records. Upon completion, all boreholes were backfilled to ground surface using bentonite pellets.

The field work was supervised on a full-time basis 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 and bedrock samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and testing. Index and classification tests consisting of water content determinations, Atterberg limits testing and grain size distribution analyses were carried out on selected soil samples. Oedometer testing was carried out on one soil sample, and point load index testing was carried out on selected samples of the bedrock core obtained in Boreholes 102 and 104.

The northings, eastings and elevations of the as-drilled borehole locations were measured in the field by a member of Golder's technical staff, relative to the locations staked by Morrison Hershfield. The borehole 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 the Borehole Location and Soil Strata drawings contained in the Contract Documents.

---

<i><b>Borehole Number</b></i>	<i><b>MTM NAD83 Northing (m)</b></i>	<i><b>MTM NAD83 Easting (m)</b></i>	<i><b>Ground Surface Elevation (m)</b></i>
101	4,782,028.0	322,026.0	93.1
102	4,782,029.4	322,050.6	86.0
103	4,781,995.6	322,053.0	85.8
104	4,781,993.6	322,070.0	86.2
105	4,782,027.2	322,069.1	86.4
106	4,782,020.0	322,090.2	92.5

## 4.0 SITE GEOLOGY AND STRATIGRAPHY

### 4.1 Regional Geological Conditions

This area of the QEW lies within the Iroquois Plain physiographic region, as delineated in *The Physiography of Southern Ontario*<sup>1</sup> and *Urban Geology of Canadian Cities*<sup>2</sup>.

The Iroquois Plain extends around the western shores of Lake Ontario; on the south side of the lake, in the St. Catharines area, the Plain is located between the present Lake Ontario shorebluffs and the foot of the Niagara Escarpment. The Plain is comprised of the flat to undulating lake bed and beaches of the former glacial Lake Iroquois, which occupied this area during the last glacial recession.

The surficial soils in the Iroquois Plain are typically comprised of glaciolacustrine clays and silts. However, in the St. Catharines area, surficial deposits of beach sand and gravel are present. The surficial sands, silts and clays are underlain by an extensive till deposit; portions of the till are considered to be “water-lain” (that is, formed by sediment rain-out either from a floating ice margin or from iceberg dumping), resulting in a predominantly massive, matrix-supported structure, as well as relatively thin sand to silt stringers or interlayers. This extensive till deposit may be underlain by or interlayered with a lower glaciolacustrine clay deposit, although this glaciolacustrine layer is absent in some portions of the Iroquois Plain in the St. Catharines area. Finally, the till and/or glaciolacustrine layer may be underlain by a lower till unit, that typically has increasing gravel content with proximity to the underlying bedrock (Menzies and Taylor, 1998).

The overburden soils are underlain by red shale bedrock of the Queenston Formation. This shale formation contains limestone and siltstone interlayers as well as “occasional patches of gypsum” (Menzies and Taylor, 1998).

### 4.2 Subsurface Conditions at Third Street Overpass

Six boreholes (Boreholes 101 to 106) were advanced at this site at the locations shown on the Borehole Location and Soil Strata drawings contained in the Contract Documents. Four boreholes (Boreholes 102 to 105) were drilled in the vicinity of the abutments at the Third Street grade level, and the other two boreholes (Boreholes 101 and 106) were drilled on the northern shoulder of the QEW. The detailed subsurface soil and groundwater conditions encountered in

---

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

<sup>2</sup> Menzies, J. and Taylor, E.M. “Urban Geology of St. Catharines-Niagara Falls, Region Niagara”. In *Urban Geology of Canadian Cities*, Geological Association of Canada Special Paper 42, Ed. Karrow, P.F. and White, O.L., 1998.

the boreholes and the results of in situ and laboratory testing are summarized on the Record of Borehole sheets and on Figures 1 to 5. The stratigraphic boundaries shown on the borehole records 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 location.

The subsurface conditions encountered at the site consist of sand and gravel fill (associated with the Third Street and QEW pavement structures) overlying a thin surficial deposit of loose to dense silty sand, which is underlain by an extensive stiff to hard clayey silt till deposit. The clayey silt till is underlain at depth by a dense to very dense lower silty sand to sand deposit and a hard or very dense lower till/residual soil deposit. Shale bedrock of the Queenston Formation was encountered at Elevation 67.1 m to 68.1 m (about 18.3 m to 18.9 m below the Third Street grade).

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

#### **4.2.1 Asphalt / Fill**

Approximately 1.3 m of sand and gravel fill was encountered underlying a 200 mm thick asphalt layer in Boreholes 101 and 106, which were drilled on the shoulder of the QEW. In Boreholes 102 to 105, which were drilled on the Third Street shoulders, the thickness of the sand and gravel fill varies between 0.6 m and 0.8 m.

The measured SPT “N” values within the granular fill range from 11 to 57 blows per 0.3 m of penetration, indicating that the granular fill has a compact to very dense relative density.

#### **4.2.2 Surficial Silty Sand**

A surficial deposit consisting of brown silty sand containing trace gravel was encountered below the fill in Boreholes 101 and 106, which were advanced through the QEW shoulder. The top of the surficial silty sand was encountered at Elevations 91.6 m and 91.0 m in these two boreholes, and the deposit was found to be about 1.2 m and 0.8 m in thickness.

The measured SPT “N” values within the surficial silty sand were between 9 and 30 blows per 0.3 m of penetration, indicating that this deposit has a loose to dense (but typically compact) relative density.



### 4.2.3 Clayey Silt Till to Silty Sand Till

An extensive glacial till deposit underlies the fill and, where present, the surficial silty sand. The till extends to between 13.7 m and 15.2 m depth (Elevation 72.1 m to 71.0 m) below the Third Street cut grade where it was fully penetrated in Boreholes 102 to 105; the deposit is 12.9 m to 14.6 m in thickness (relative to the Third Street cut grade) at these locations.

The till typically consists of clayey silt with sand to some sand, containing trace to some gravel and shale fragments, although a small portion of the deposit consists of a silty sand till in Boreholes 104 (where the silty sand till is 0.3 m in thickness) and 105 (where it is 0.9 m in thickness). Silty sand to sandy silt seams were observed within the clayey silt till in some of the recovered samples. The results of grain size distribution tests carried out on six selected samples of the clayey silt till deposit are shown on Figure 1.

Boulders and cobbles were not encountered in this deposit during the borehole investigation. However, these glacially-derived soils may contain boulders and cobbles.

Atterberg limits testing was carried out on fifteen samples of the till deposit and measured plastic limits between 12 and 15 per cent, liquid limits between 16 and 26 per cent, and corresponding plasticity indices between 4 and 11 per cent. These results, which are plotted on a plasticity chart on Figure 2, confirm that the till is predominantly a clayey silt of low plasticity, although one tested sample (Borehole 105, Sample 11) is a non-plastic material. The measured water contents of the selected samples of the till deposit were between 5 and 18 per cent, typically at or below the plastic limit.

The measured SPT “N” values within the till range from 9 to more than 100 blows per 0.3 m of penetration, indicating that the till has a stiff to hard consistency. In Boreholes 102 to 105, the lower SPT “N” values of about 9 to 20 blows per 0.3 m of penetration were generally encountered within the upper 5 m of the till, extending from below the granular fill to about Elevation 80 m. In Boreholes 101 and 106 which were advanced from the QEW grade, the upper portion of the till is generally hard, becoming stiff to very stiff (SPT “N” values of 20 or less) below approximately Elevation 86 m; these two boreholes were terminated within the stiff to very stiff till at about Elevations 83.3 m and 82.7 m, respectively. It is noted that the lowest SPT “N” values of 9 to 10 blows per 0.3 m of penetration were encountered only in the upper 0.5 m to 1 m of the till deposit in Boreholes 102 to 105, immediately below the granular fill.

Oedometer testing was carried out on one sample of the stiff clayey silt till from a thin-walled Shelby tube sample that was obtained from Borehole 102. The following table summarizes the consolidation parameters for this soil as interpreted from the oedometer test results shown on Figures 3A to 3D.

Borehole/ Sample No.	Sample Depth/Elev.	Unit Wt. (kN/m <sup>3</sup> )	$\sigma_{v0}'$ (kPa)	$\sigma_p'$ (kPa)	$\sigma_p' - \sigma_{v0}'$ (kPa)	$C_c$	$C_r$	$e_o$	OCR
102 / 5	3.4 m / 82.6 m	22.0	55	250	195	0.1	0.03	0.393	4.6

**NOTES:**

$\sigma_p'$	Apparent preconsolidation pressure	$\sigma_{v0}'$	Computed existing vertical effective stress
$C_c$	Compression index	$C_r$	Recompression index
$e_o$	Initial void ratio	OCR	Overconsolidation ratio

**4.2.4 Lower Silty Sand to Sand**

In the four deeper boreholes (Boreholes 102 to 105) where the clayey silt till deposit was penetrated, a lower silty sand to sand deposit was encountered at approximately Elevation 72.1 m to 71.2 m, with thickness between 1.6 m and 3.5 m. The results of grain size distribution testing carried out on two selected samples of this deposit are shown on Figure 4.

Boulders and cobbles were not encountered in this deposit during the borehole investigation. However, these glacially-derived soils may contain boulders and cobbles.

The measured SPT “N” values within the lower silty sand to sand range from 34 to 100 blows per 0.3 m of penetration, indicating that this deposit has a dense to very dense relative density.

**4.2.5 Lower Till/Residual Soil**

Below the lower silty sand to sand deposit, Boreholes 102 to 104 encountered a deposit of clayey silt to sandy silt that has been classified as a till/residual soil. The surface of the till/residual soil was encountered between Elevations 69.4 m and 68.6 m (at approximately 16.8 m to 17.2 m below the Third Street cut grade). This lower till/residual soil deposit has a thickness of between 1.1 m and 2.1 m.

Boulders and cobbles were not encountered in this deposit during the borehole investigation. However, this deposit may contain boulders and cobbles.

One Atterberg limits test was carried out on a sample of the lower till/residual soil, and measured a plastic limit of 14 per cent, a liquid limit of 24 per cent, and a corresponding plasticity index of 10 per cent. This result, which is plotted on a plasticity chart on Figure 5, confirms that the cohesive portion of the deposit is a clayey silt of low plasticity.

The measured SPT “N” values within the till/residual soil range from 63 to greater than 100 blows per 0.3 m of penetration, indicating that this deposit has a hard consistency / very dense relative density.

#### 4.2.6 Bedrock

Bedrock was encountered in Boreholes 102 and 104, where it was confirmed by coring, and in Boreholes 103 and 105, where it was confirmed by split-spoon sampling.

The bedrock encountered in the borehole is red shale of the Queenston Formation. The shale bedrock, which typically contains limestone and siltstone interbeds, was encountered beneath the overburden soils at approximately Elevation 67.1 m to 68.1 m (about 18.3 m to 18.9 m below the Third Street cut grade). The recovered bedrock core consists of slightly weathered to fresh, very weak to medium strong, thinly bedded, fine-grained, calcareous red shale, containing interlayers of fresh, strong to very strong grey limestone. Thin seams of grey clay, between 5 mm and 38 mm thick, were encountered in the bedrock core obtained from Borehole 102.

Diametral point load testing was carried out on selected samples of the shale bedrock obtained from Boreholes 102 and 104. The correlated uniaxial compressive strength of the shale samples varies from 1 MPa to 24 MPa, as shown in the following table.

<i><b>Borehole No.</b></i>	<i><b>Rock Type</b></i>	<i><b>Sample Depth (m)</b></i>	<i><b>Sample Elevation (m)</b></i>	<i><b>Unconfined Compressive Strength</b></i>
102	Red	19.4	66.6	1 MPa
	Red	19.4	66.6	18 MPa
	Grey	19.4	66.6	4 MPa
	Red	21.5	64.5	10 MPa
	Red	19.3	66.7	24 MPa
104	Red	19.8	66.4	17 MPa
	Grey	21.0	65.2	15 MPa
	Red	22.2	64.0	11 MPa

**NOTE:** Approximate unconfined compressive strength determined using ISRM correlation (“Suggested Methods for Determining Point Load Strength”, International Society for Rock Mechanics Commission on Testing Methods, Int. J. Rock. Mech., Vol. 22, No. 2, 1985, pp. 51-60).

Details of the total and solid core recovery (TCR and SCR) and RQD measurements are shown on the Record of Drillhole sheets and the results are summarized in the following table:

<i><b>Borehole Number</b></i>	<i><b>Ground Elevation (m)</b></i>	<i><b>Total Core Length (m)</b></i>	<i><b>Core Run</b></i>	<i><b>Sample Elevation (m)</b></i>	<i><b>TCR (%)</b></i>	<i><b>SCR (%)</b></i>	<i><b>RQD (%)</b></i>
102	86.0	2.7	1	66.9 – 65.7	85	46	0
			2	65.7 – 64.2	97	82	55
104	86.2	3.1	1	66.7 – 65.2	98	90	43
			2	65.2 – 63.6	100	91	43

The measured Rock Quality Designation (RQD) values are between 0 and 55 per cent, indicating a very poor to fair quality rock. It should be noted that it is difficult to test the weaker shale in general as it is often difficult to obtain intact samples long enough for testing. Based on the laboratory point load testing results and approximate field measurements, the recovered shale bedrock from this site is typically very weak to medium strong.

#### 4.2.7 Groundwater Conditions

Two piezometers were installed at this site – one within the till deposit in Borehole 102, and one within the shale bedrock in Borehole 104 – to monitor the groundwater level(s) at the site. The following table summarizes the water level measurements for these piezometers.

<i><b>Borehole Number</b></i>	<i><b>Ground Surface Elevation</b></i>	<i><b>Piezometer Tip Elevation</b></i>	<i><b>Measured Groundwater Elevation</b></i>		
			<i><b>15 Dec 2004</b></i>	<i><b>13 May 2005</b></i>	<i><b>06 Dec 2005</b></i>
102	86.0 m	78.4 m	84.2 m	86.0 m	86.0 m
104	86.2 m	64.9 m	82.8 m	82.8 m	83.0 m


The piezometric water level associated with the bedrock is at about Elevation 83 m, while the piezometric water level associated with the clayey silt till is at about Elevation 86 m; these results indicate that there is a downward gradient at the site. It is expected that the water level associated with the till deposit as measured in Borehole 102 is influenced by the Third Street cut, since it is coincident with the road shoulder/ditch level.

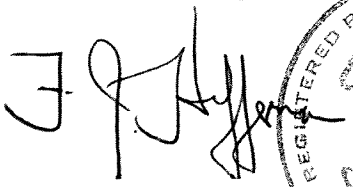
It should be noted that groundwater levels are expected to fluctuate seasonally and are expected to rise during wet periods of the year.

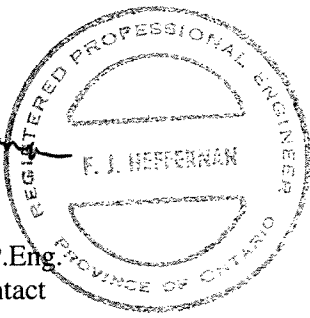
## 5.0 CLOSURE

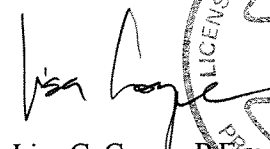
This Foundation Investigation Report was prepared by Ms. Beng Lay Teh and reviewed by Ms. Lisa Coyne, P.Eng., an Associate with Golder, and Ms. Anne Poschmann, P.Eng., a Principal with Golder Associates. Mr. Fintan Heffernan, a Designated MTO Contact for Golder, conducted an independent quality review of the report.


### GOLDER ASSOCIATES LTD.

  
for Beng Lay Teh  
Geotechnical Group

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



  
Lisa C. Coyne, P.Eng.  
Associate



BLT/LCC/ASP/FJH/blt/lcc

N:\ACTIVE\2004\1111\04-1111-002 MH QEW WIDENING ST. CATHARINES\6 - REPORTS\CONTRACT FI REPORTS\04-1111-002 FIR01 07JAN THIRD STREET.DOC

## 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.)

#### 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 cm<sup>2</sup> 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 <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	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 <sub>4</sub>	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
$\gamma$	unit weight

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

S:\FINALDATA\ABBREV\2000\LOFA-D00.DOC

## LIST OF SYMBOLS

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

### I. General

$\pi$	3.1416
$\ln x$ ,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\epsilon$	linear strain
$\epsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	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
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )
e	void ratio
n	porosity
S	degree of saturation

#### (a) Index Properties (continued)

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

#### (b) Hydraulic Properties

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

#### (c) Consolidation (one-dimensional)

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

#### (d) Shear Strength

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

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

# LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

## WEATHERING STATE

**Fresh:** no visible sign of weathering.

**Faintly weathered:** weathering limited to the surface of major discontinuities.

**Slightly weathered:** penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

**Moderately weathered:** weathering extends throughout the rock mass but the rock material is not friable.

**Highly weathered:** weathering extends throughout rock mass and the rock material is partly friable.

**Completely weathered:** rock is wholly decomposed and in a friable condition but the rock texture and structure are preserved.

## BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	> 2 m
Thickly bedded	0.6 m to 2m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	< 6 mm

## JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	> 3 m
Wide	1 - 3 m
Moderately close	0.3 - 1 m
Close	50 - 300 mm
Very close	< 50 mm

## GRAIN SIZE

Term	Size*
Very Coarse Grained	> 60 mm
Coarse Grained	2 - 60 mm
Medium Grained	60 microns - 2 mm
Fine Grained	2 - 60 microns
Very Fine Grained	< 2 microns

Note: \* Grains >60 microns diameter are visible to the naked eye.

## CORE CONDITION

### Total Core Recovery

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

### Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

### Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varies from 0% for completely broken core to 100% for core in solid sticks.

## DISCONTINUITY DATA

### Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

### Dip with Respect to (W.R.T.) Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

### Description and Notes

An abbreviated description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

### Abbreviations

B - Bedding	P - Polished
FO - Foliation/Schistosity	S - Slickensided
CL - Cleavage	SM - Smooth
SH - Shear Plane/Zone	R - Ridged/Rough
VN - Vein	ST - Stepped
F - Fault	PL - Planar
CO - Contact	FL - Flexured
J - Joint	UE - Uneven
FR - Fracture	W - Wavy
MF - Mechanical Fracture	C - Curved
- Parallel To	
⊥ - Perpendicular To	



PROJECT 04-1111-002		<b>RECORD OF BOREHOLE No 101</b>				1 OF 1 <b>METRIC</b>										
W.P. 607-00-00		LOCATION N 4782028.0 ; E 322026.0				ORIGINATED BY PKS										
DIST Central HWY QEW		BOREHOLE TYPE 108 mm Diameter Solid Stem Augers				COMPILED BY SP/BLT										
DATUM Geodetic		DATE December 9, 2004				CHECKED BY ASP										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
93.1	GROUND SURFACE															
0.0	Asphalt															
0.2	Sand and gravel (FILL) Compact to dense Brown Moist		1	SS	25											
			2	SS	34											
91.6																
1.5	Silty SAND Loose to compact Brown Moist		3	SS	9											
			4	SS	16											
90.4																
2.7	CLAYEY SILT, some sand, trace gravel, containing shale fragments (TILL) Very stiff to hard Brown to grey Moist		5	SS	38											
			6	SS	32											
			7	SS	32											
			8	SS	21											
			9	SS	19											
			10	SS	18											
83.3	END OF BOREHOLE															
9.8	Note: 1. Borehole dry on completion of drilling.															



MIS-MTO 001 041111002AAMTO.GPJ GAL-MISS.GDT 17/10/06

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

PROJECT 04-1111-002			RECORD OF BOREHOLE No 102			1 OF 2 METRIC						
W.P. 607-00-00			LOCATION N 4782029.4 ; E 322050.6			ORIGINATED BY PKS						
DIST Central HWY QEW			BOREHOLE TYPE 108 mm Diameter Hollow Stem Augers			COMPILED BY SP/BLT						
DATUM Geodetic			DATE November 23, 2004			CHECKED BY ASP						
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE		"N" VALUES	SHEAR STRENGTH kPa					
86.0	GROUND SURFACE											
0.0	Sand and gravel (FILL) Compact Brown Moist		1	SS	14							
85.2	CLAYEY SILT with sand to some sand, trace to some gravel (TILL) Stiff to hard Grey to red Moist to wet		2	SS	9							
0.8			3	SS	12							
			4	SS	13							
			5	TO	-							
			6	SS	12							
			7	SS	17							
			8	SS	15							
			9	SS	32							
			10	SS	65							
			11	SS	29							
			12	SS	38							
			13	SS	75							
72.0	Silty SAND, some gravel, trace clay, containing shale fragments Very dense Red Wet											
14.0												

Continued Next Page


+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

PROJECT 04-1111-002		RECORD OF BOREHOLE No 102				2 OF 2 METRIC										
W.P. 607-00-00		LOCATION N 4782029.4 ; E 322050.6				ORIGINATED BY PKS										
DIST Central HWY QEW		BOREHOLE TYPE 108 mm Diameter Hollow Stem Augers				COMPILED BY SP/BLT										
DATUM Geodetic		DATE November 23, 2004				CHECKED BY ASP										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								WATER CONTENT (%)
--- CONTINUED FROM PREVIOUS PAGE ---																
69.2	Silty SAND, some gravel, trace clay, containing shale fragments Very dense Red Wet		14	SS	100											14 61 21 4
16.8	CLAYEY SILT, some sand, trace to some gravel, containing shale fragments (Till/Residual Soil) Hard Red Wet		15	SS	100/25											
67.1			16	SS	100											
18.9	SHALE (BEDROCK) containing clay seams and limestone interlayers Red  Bedrock cored between 19.1 m and 21.8 m depths.  For bedrock coring details, refer to Record of Drillhole 102.		17	SS	100/13											
64.2																
21.8	END OF BOREHOLE  Notes: 1. Water encountered at 9.1 m depth (Elevation 76.9 m) during drilling. 2. Water levels in piezometer measured at 1.8 m depth (Elev. 84.2 m) on Dec 15, 2004 and at ground surface on Dec 6, 2005.															

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE



+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3</sup>% STRAIN AT FAILURE

PROJECT 04-1111-002			RECORD OF BOREHOLE No 103			2 OF 2 METRIC		
W.P. 607-00-00			LOCATION N 4781995.6 ; E 322053.0			ORIGINATED BY PKS		
DIST Central HWY QEW			BOREHOLE TYPE 108 mm Diameter Hollow Stem Augers			COMPILED BY SP/BLT		
DATUM Geodetic			DATE December 2, 2004			CHECKED BY ASP		
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100 PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W <sub>p</sub> W W <sub>L</sub> WATER CONTENT (%)
--- CONTINUED FROM PREVIOUS PAGE ---								
68.6	Silty SAND, some gravel Dense to very dense Red Wet		14	SS	66		70	
17.2	Sandy SILT, some gravel, containing shale fragments (TILL/RESIDUAL SOIL) Very dense Red Wet		15	SS	77		69	
67.5	SHALE (BEDROCK) Red		16	SS	100/25		68	
18.5	END OF BOREHOLE							
Note: 1. Water level in open borehole at 12.2 m depth (Elev. 73.6 m) on completion of drilling.								

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

PROJECT		04-1111-002		RECORD OF BOREHOLE No 104		2 OF 2 METRIC										
W.P.		607-00-00		LOCATION		N 4781993.6 ; E 322070.0										
DIST		Central HWY QEW		BOREHOLE TYPE		108 mm Diameter Hollow Stem Augers										
DATUM		Geodetic		DATE		November 22, 2004										
				ORIGINATED BY		PKS										
				COMPILED BY		SP/BLT										
				CHECKED BY		ASP										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
	--- CONTINUED FROM PREVIOUS PAGE ---						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					W <sub>p</sub> W W <sub>L</sub> 10 20 30				GR SA SI CL
71.0																
15.2	Silty SAND, some gravel, trace clay, containing shale fragments Very dense Red Wet		14	SS	59											
69.4																
16.8	CLAYEY SILT, some sand, trace gravel, containing shale fragments (Till/Residual Soil) Hard Red Wet		15	SS	63											
67.9																
18.3	SHALE (BEDROCK) containing grey limestone layers  Bedrock cored between 19.5 m and 22.6 m depths.  For bedrock coring details, refer to Record of Drillhole 104.		16	SS	100/15											
63.6																
22.6	END OF BOREHOLE  Notes:  1. Water level at 9.1 m depth (Elev. 77.1 m) in open borehole on completion of overburden drilling.  2. Water level in piezometer measured at 3.4 m depth (Elev. 82.8 m) on Dec 15, 2004 and 3.2 m depth (Elev. 83 m) on Dec 6, 2005.  3. Coring was attempted at 18.3 m depth but was abandoned due to blockage of core bit. Casing was advanced and coring started at 19.5 m depth.															

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



PROJECT: 04-1111-002

**RECORD OF DRILLHOLE: 104**

SHEET 1 OF 1

LOCATION: N 4281993.6 ;E 322070.0

DRILLING DATE: November 26, 2004

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: D-50

DRILLING CONTRACTOR: Walker Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE (mm/min)	FLUSH	COLOUR % RETURN	JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate										BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage										PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular										PO - Polished K - Slickensided SM - Smooth Ro - Rough MB - Mechanical Break										BR - Broken Rock										NOTES WATER LEVELS INSTRUMENTATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
									RECOVERY					R.Q.D. %	FRACT. INDEX PER 0.3 m	DISCONTINUITY DATA										HYDRAULIC CONDUCTIVITY K, cm/sec					Diametral Point Load Index (MPa)					RMC -Q AVG.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
									TOTAL CORE %	SOLID CORE %	R.O.D. %	FRACT. INDEX PER 0.3 m	B Angle			DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	K, cm/sec	Diametral Point Load Index (MPa)	RMC -Q AVG.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
		Continued from Soil Log		66.69																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				

DEPTH SCALE

1 : 50



LOGGED: PKS/SP

CHECKED: BLT/ASP

MIS-MTO 001 041111002AAMTO.GPJ GAL-MISS.GDT 17/10/06

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

PROJECT 04-1111-002			RECORD OF BOREHOLE No 105			2 OF 2 METRIC										
W.P. 607-00-00			LOCATION N 4782027.2 ; E 322069.1			ORIGINATED BY PKS										
DIST Central HWY QEW			BOREHOLE TYPE 108 mm Diameter Solid Stem Augers			COMPILED BY SP/BLT										
DATUM Geodetic			DATE November 19, 2004			CHECKED BY ASP										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
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					10 20 30 ○ 3% STRAIN AT FAILURE				
71.2																
15.2	Silty SAND to SAND, some gravel, trace clay, containing shale and limestone fragments Dense to very dense Red Wet		14	SS	42		71									
							70									
			15	SS	75		69									
68.1							68									
67.8	SHALE (BEDROCK) Red		16	SS	100.00											
18.6	END OF BOREHOLE															
	Note:  1. Water level in open borehole at 6.1 m depth (Elev. 80.3 m) on completion of drilling.															

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

PROJECT 04-1111-002		<b>RECORD OF BOREHOLE No 106</b>				1 OF 1 <b>METRIC</b>								
W.P. 607-00-00		LOCATION N 4782020.0 ; E 322090.2				ORIGINATED BY PKS								
DIST Central HWY QEW		BOREHOLE TYPE 108 mm Diameter Solid Stem Augers				COMPILED BY SP/BLT								
DATUM Geodetic		DATE December 9, 2004				CHECKED BY ASP								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
92.5	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100					
0.0	Asphalt													
0.2	Sand and gravel (FILL) Dense to very dense Brown Moist		1	SS	57									
			2	SS	38									
91.0														
1.5	Silty SAND Compact to dense Brown Moist to wet		3	SS	30									
90.2														
2.3	CLAYEY SILT, trace to some sand, trace gravel, containing sandy silt seams, and shale fragments (TILL) Very stiff Grey Moist to wet		4	SS	27									
			5	SS	30									
			6	SS	29									
			7	SS	23									
			8	SS	21									
			9	SS	19									
			10	SS	18									
82.7	END OF BOREHOLE													
9.8	Note: 1. Borehole was dry on completion of drilling.													

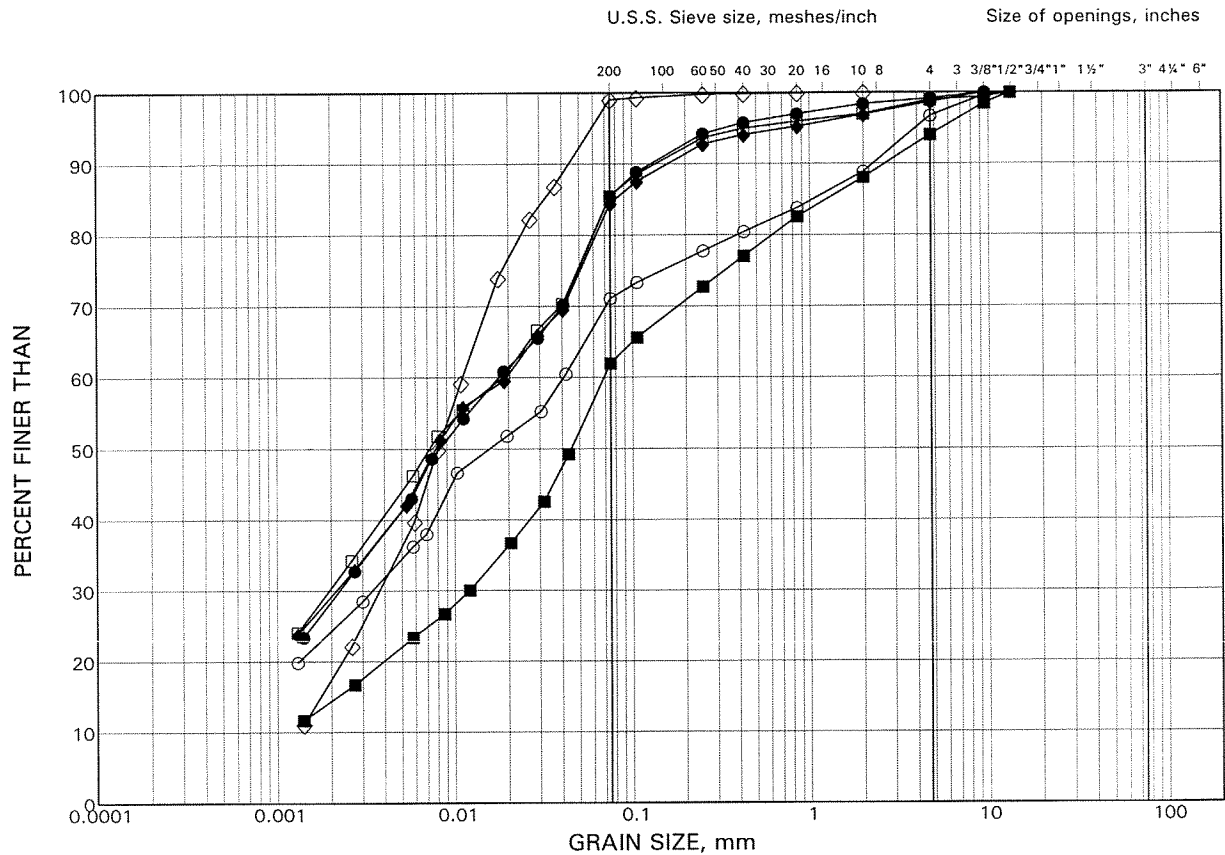
MIS-MTO 001 041111002AAMTO.GPJ GAL-MISS.GDT 17/10/06

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

# GRAIN SIZE DISTRIBUTION TEST RESULTS

## Clayey Silt Till

FIGURE 1



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	101	10	83.7
■	102	11	75.0
◆	103	3	84.0
○	104	12	73.7
□	105	5	83.1
◇	106	4	92.9

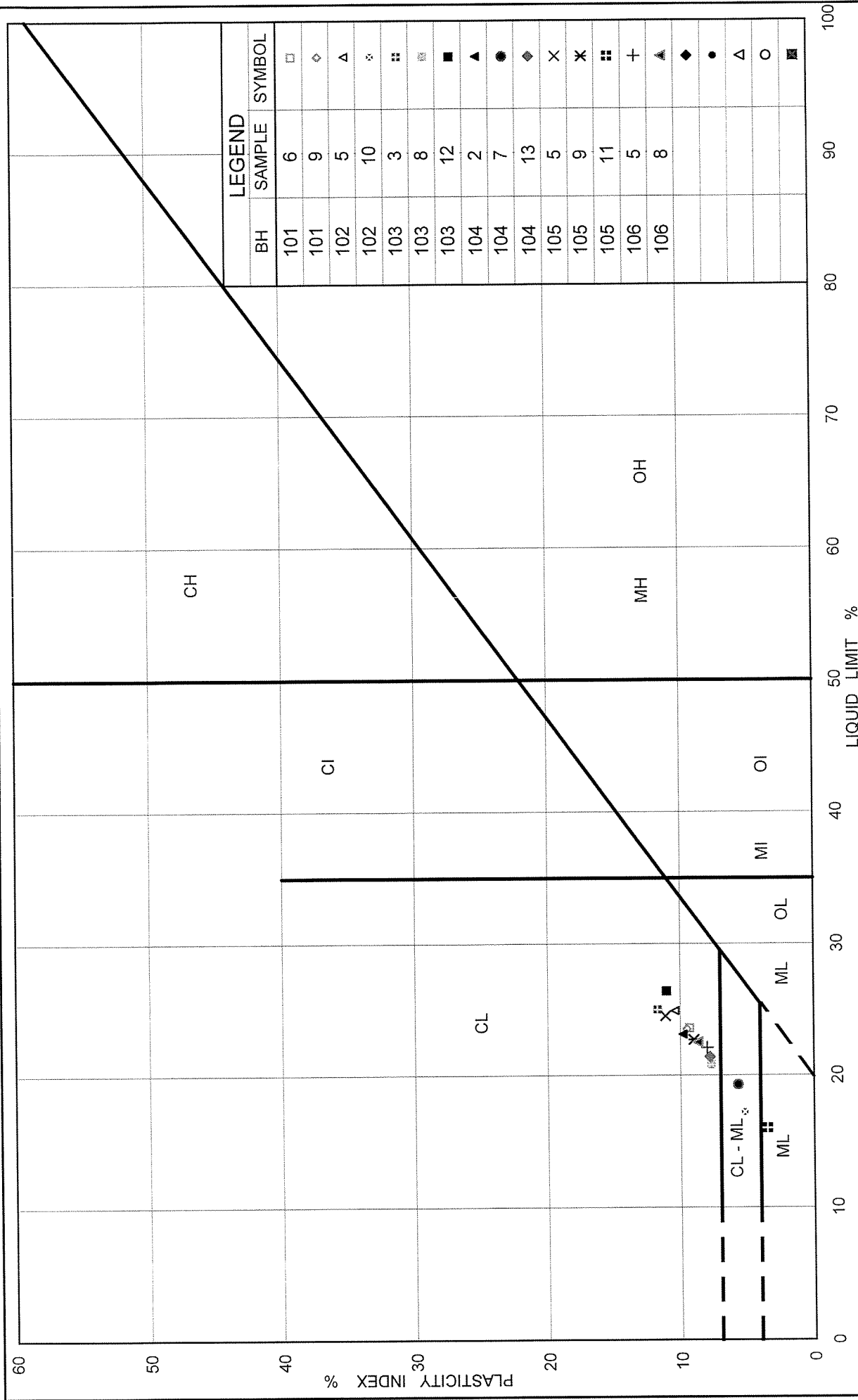


FIG No. 2

# PLASTICITY CHART

Clayey Silt Till to Silty Sand Till

Ministry of Transportation



Ontario

Project No. 04-1111-002-1

# OEDOMETER CONSOLIDATION SUMMARY

FIGURE 3A

## SAMPLE IDENTIFICATION

Project Number	04-1111-002-1	Sample Number	5
Borehole Number	102	Sample Depth, m	3.0-3.8

## TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	7		
Date Started	12/30/2004		
Date Completed	01/15/2005		

## SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m <sup>3</sup>	22.00
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m <sup>3</sup>	19.15
Area, cm <sup>2</sup>	31.65	Specific Gravity, measured	2.72
Volume, cm <sup>3</sup>	60.13	Solids Height, cm	1.364
Water Content, %	14.91	Volume of Solids, cm <sup>3</sup>	43.17
Wet Mass, g	134.92	Volume of Voids, cm <sup>3</sup>	16.97
Dry Mass, g	117.41	Degree of Saturation, %	103.2

## TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv. cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
0.00	1.900	0.393	1.900				
4.83	1.898	0.392	1.899	102	7.50E-03	2.18E-04	1.60E-07
9.46	1.894	0.389	1.896	190	4.01E-03	4.55E-04	1.79E-07
19.51	1.886	0.383	1.890	171	4.43E-03	4.19E-04	1.82E-07
38.91	1.875	0.375	1.881	124	6.05E-03	2.98E-04	1.77E-07
77.57	1.862	0.365	1.869	124	5.97E-03	1.77E-04	1.04E-07
154.88	1.846	0.354	1.854	124	5.88E-03	1.09E-04	6.27E-08
38.91	1.853	0.359	1.850			3.18E-05	
9.46	1.864	0.367	1.859			1.97E-04	
4.83	1.870	0.371	1.867			6.82E-04	
9.46	1.868	0.370	1.869	154	4.81E-03	2.27E-04	1.07E-07
19.51	1.865	0.367	1.867	46	1.61E-02	1.57E-04	2.47E-07
38.91	1.860	0.364	1.863	218	3.37E-03	1.36E-04	4.48E-08
77.57	1.851	0.357	1.856	338	2.16E-03	1.23E-04	2.59E-08
154.88	1.842	0.351	1.847	135	5.35E-03	6.13E-05	3.21E-08
309.59	1.822	0.336	1.832	99	7.19E-03	6.80E-05	4.79E-08
619.07	1.789	0.312	1.806	85	8.13E-03	5.61E-05	4.47E-08
1237.82	1.746	0.280	1.768	124	5.34E-03	3.66E-05	1.91E-08
2475.08	1.697	0.244	1.722	103	6.10E-03	2.08E-05	1.25E-08
1237.82	1.706	0.251					
309.59	1.727	0.266					
77.57	1.750	0.283					
19.51	1.779	0.304					
4.83	1.799	0.319					

Notes:

k calculated using cv based on t<sub>90</sub> values.

## SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.78	Unit Weight, kN/m <sup>3</sup>	23.43
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m <sup>3</sup>	20.45
Area, cm <sup>2</sup>	31.65	Specific Gravity, measured	2.72
Volume, cm <sup>3</sup>	56.30	Solids Height, cm	1.364
Water Content, %	14.60	Volume of Solids, cm <sup>3</sup>	43.17
Wet Mass, g	134.55	Volume of Voids, cm <sup>3</sup>	13.14
Dry Mass, g	117.41		

Prepared By: LFG

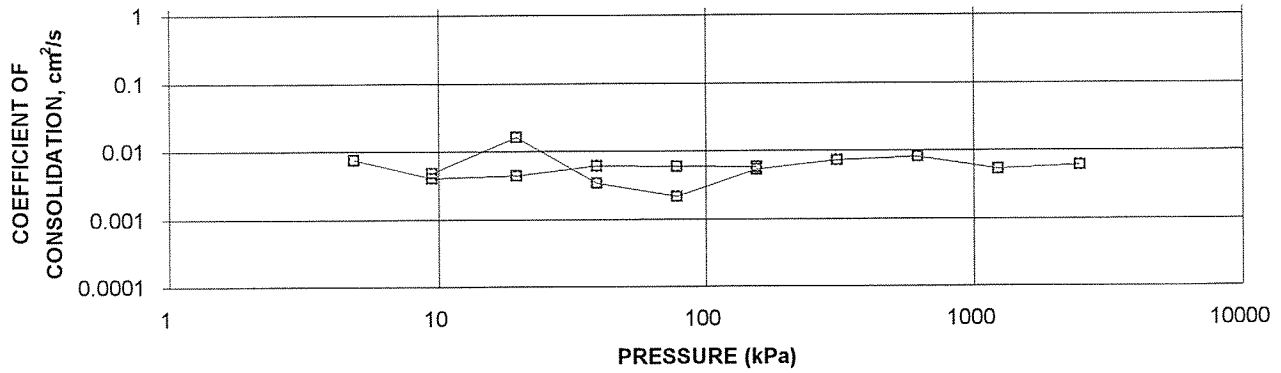
Golder Associates

Checked By: MM

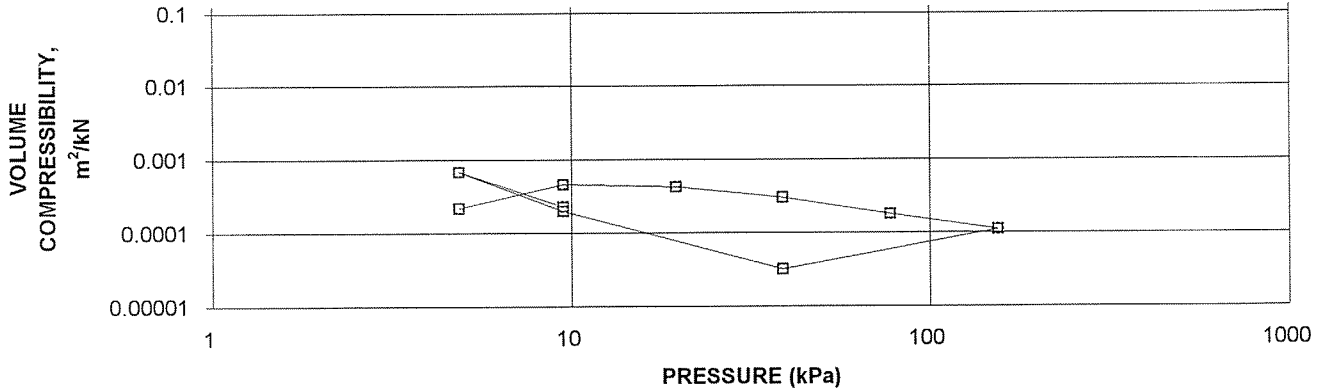
# OEDOMETER CONSOLIDATION SUMMARY

FIGURE 3B

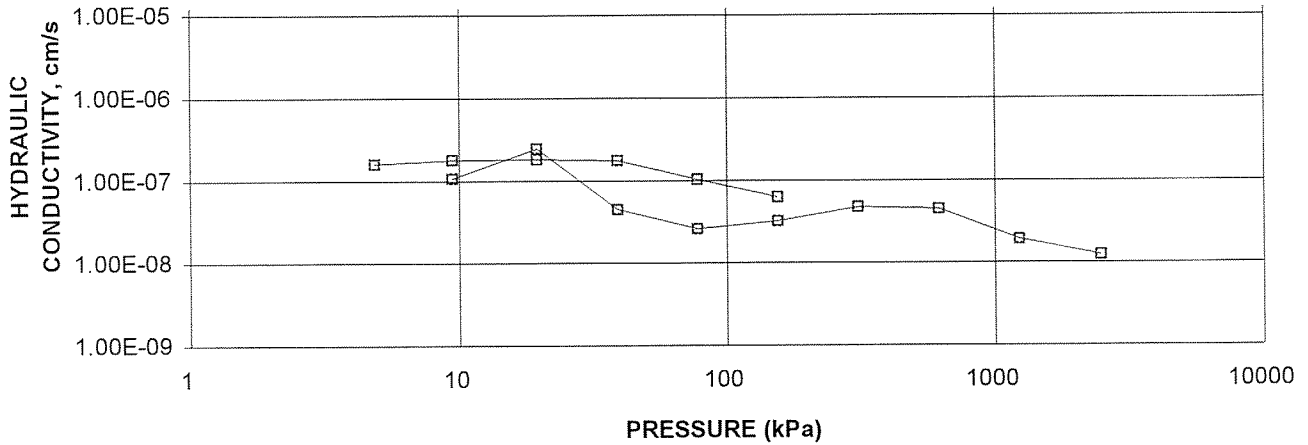
CONSOLIDATION TEST  
CV cm<sup>2</sup>/s VS PRESSURE (kPa)  
BH 102 SA 5



CONSOLIDATION TEST  
MV m<sup>2</sup>/kN vs PRESSURE (kPa)  
BH 102 SA 5



CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs PRESSURE  
BH 102 SA 5



Project No. 04-1111-002-1

Prepared By: LFG

Golder Associates

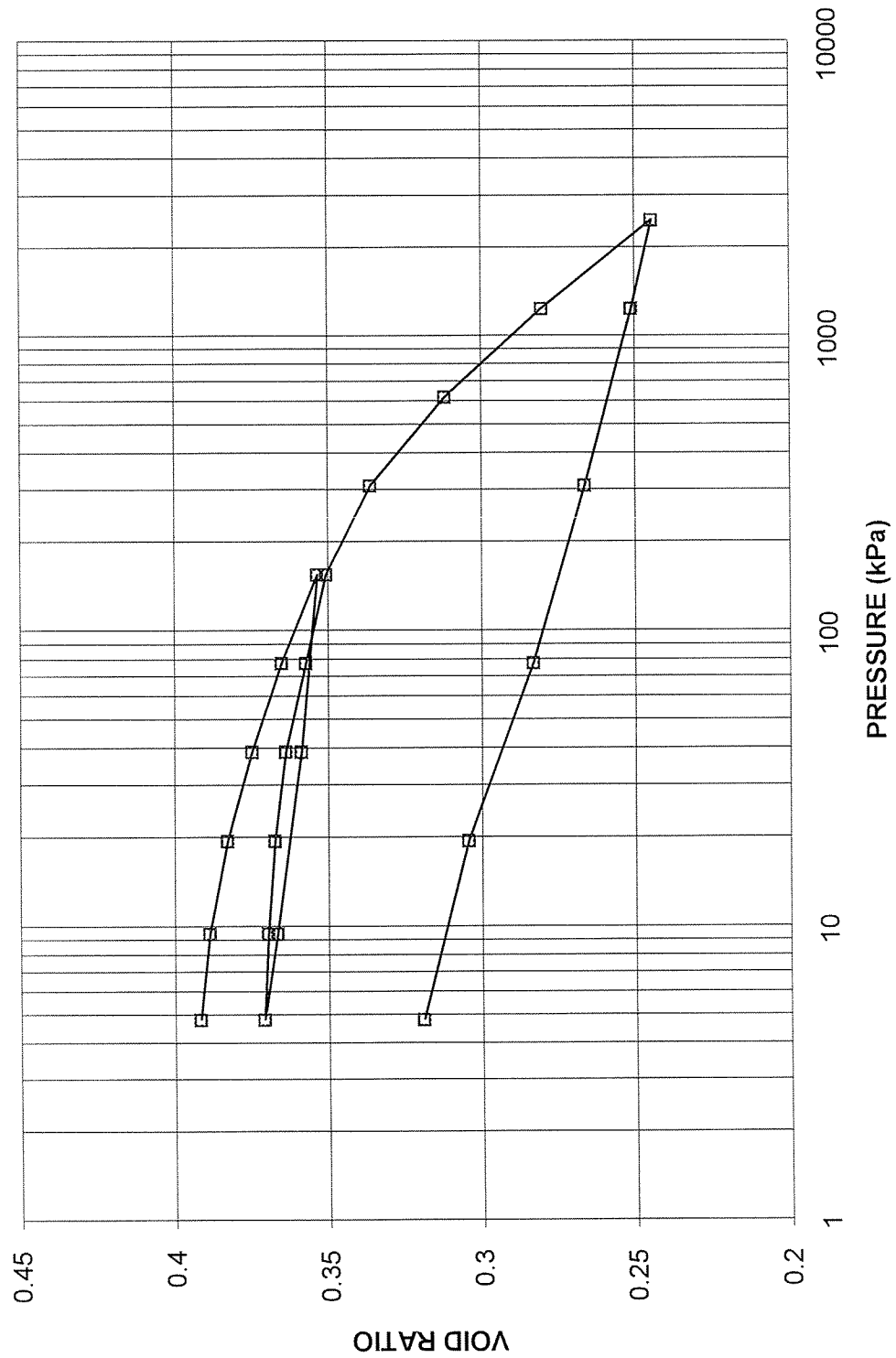
Checkey By: MM



**CONSOLIDATION TEST RESULTS**  
**Clayey Silt Till**

**FIGURE 3C**

CONSOLIDATION TEST  
 VOID RATIO vs PRESSURE  
 BH 102 SA 5



Project No. 04-1111-002-1  
 Prepared By: LFG

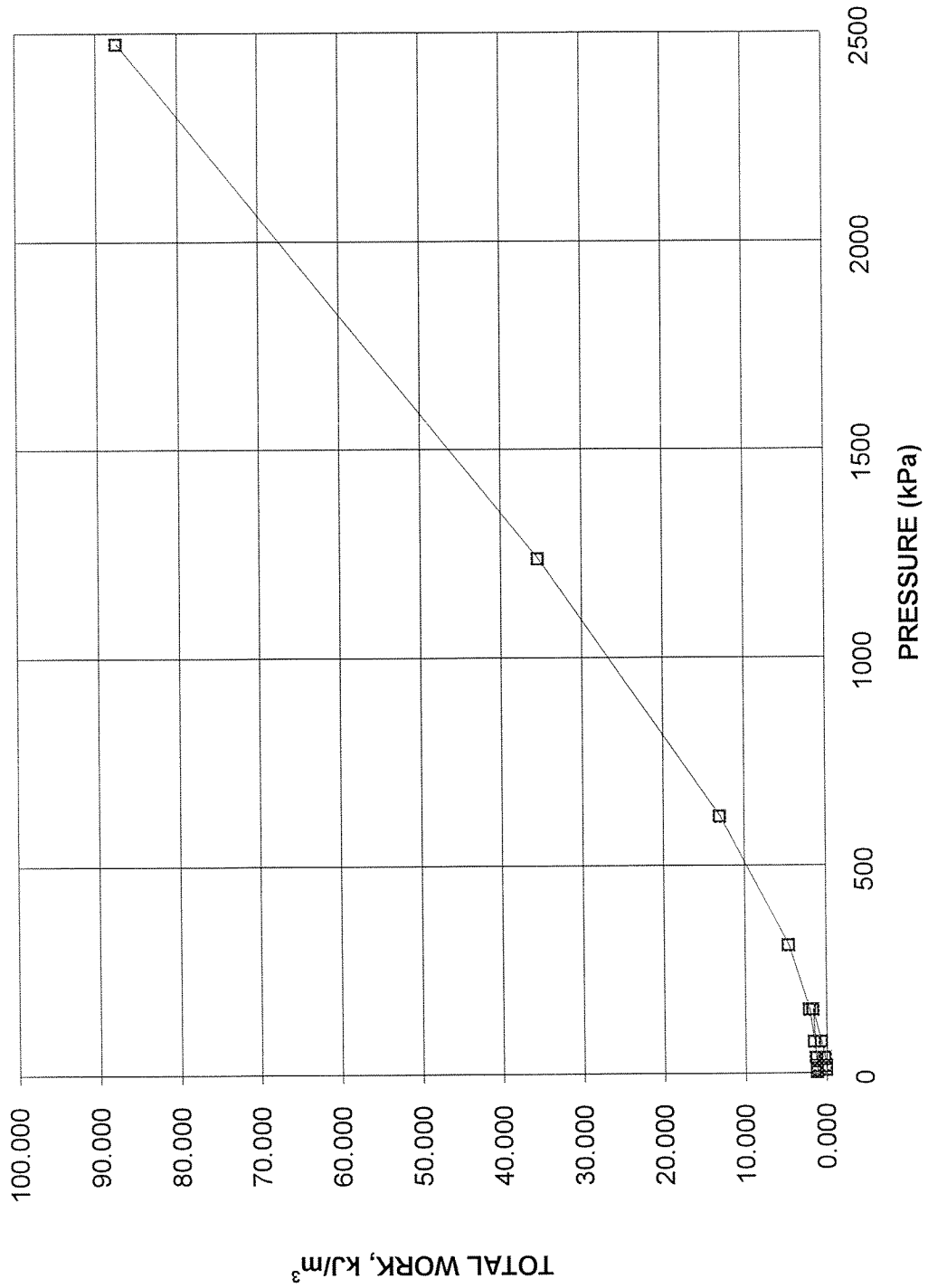
**Golder Associates**

Checked By: MM

**CONSOLIDATION TEST RESULTS**  
Clayey Silt Till

**FIGURE 3D**

CONSOLIDATION TEST  
TOTAL WORK,  $\text{kJ/m}^3$  vs PRESSURE  
BH 102 SA 5



Project No. 04-1111-002-1

Prepared By: LFG

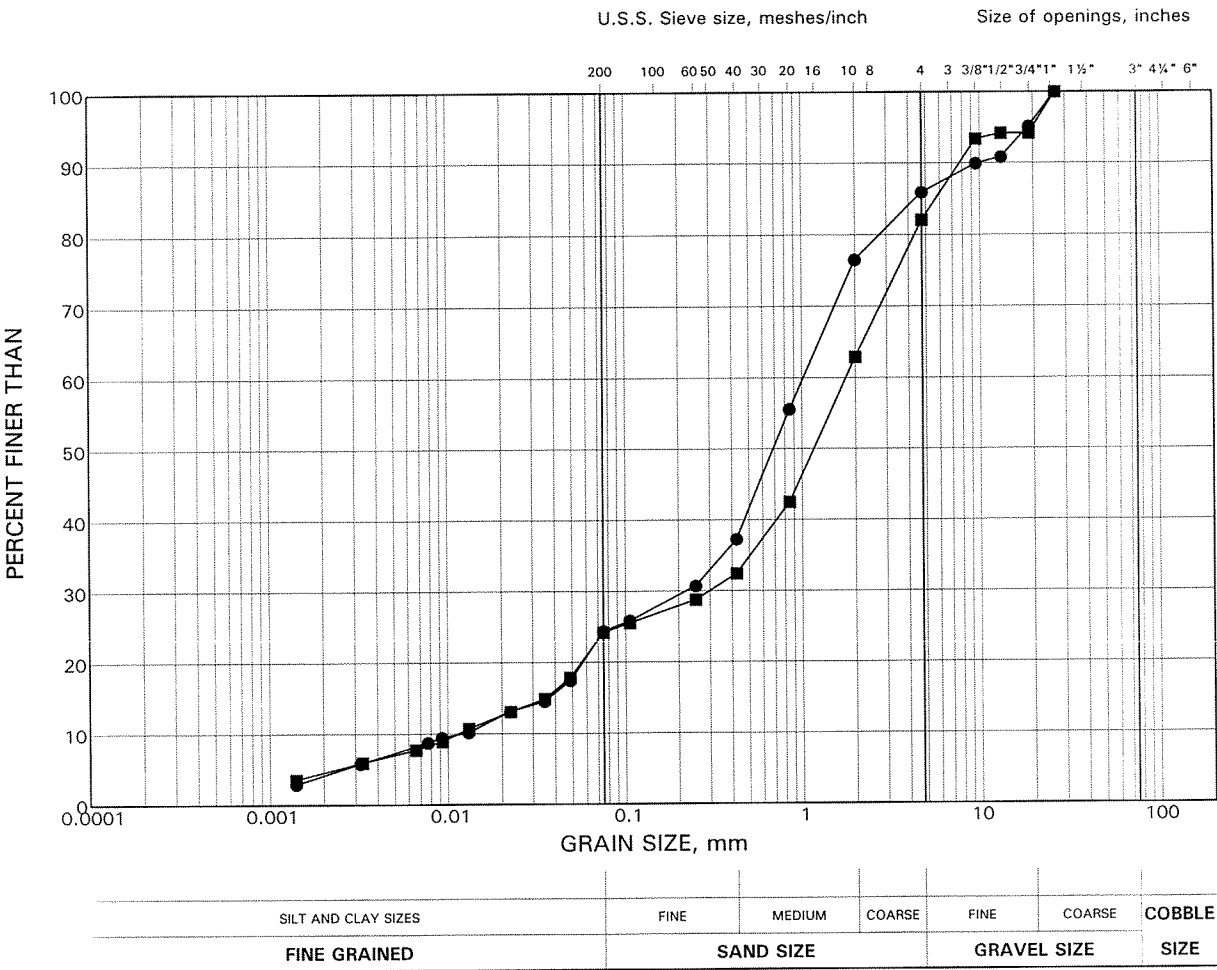
**Golder Associates**

Checked By: MM

# GRAIN SIZE DISTRIBUTION

## Lower Silty Sand to Sand

FIGURE 4



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	102	14	70.5
■	105	15	69.3

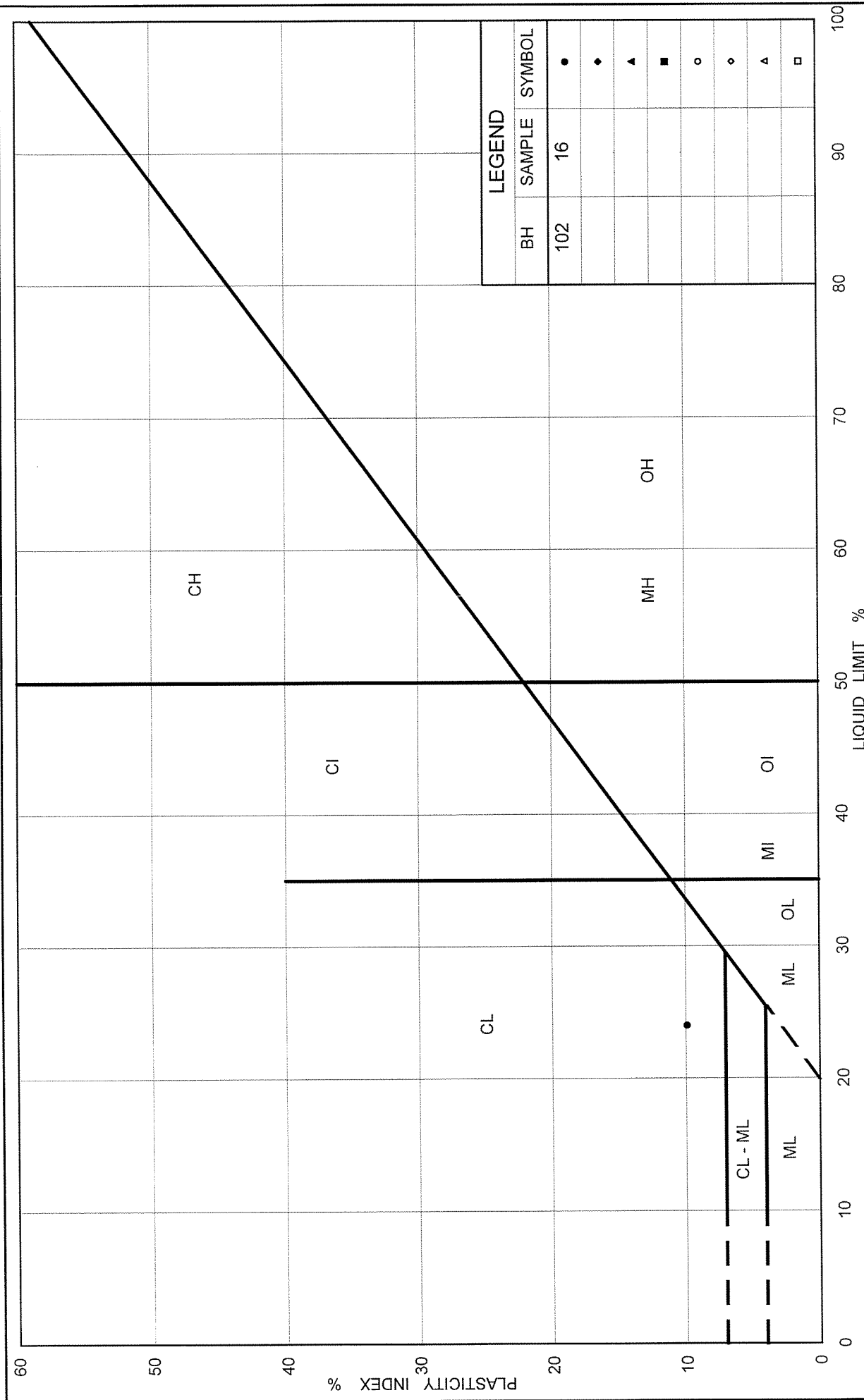


FIG No. 5

# PLASTICITY CHART

## Lower Till / Residual Soil

Ministry of Transportation



Ontario

Project No. 04-1111-002-1