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

Submitted to:

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## 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 proposed extension of three existing structural culverts, associated with the widening of the QEW. A foundation investigation has been carried out to determine the subsurface conditions at each of the proposed culvert extension locations, as identified in the following table:

<i><b>Culvert Location</b></i>	<i><b>Structure Site No.</b></i>	<i><b>Comments</b></i>
Station 18+635	18-285C	Northward extension of existing access tunnel, west of Third Street
Station 19+166	18-286C	Southward extension of Richardson Creek culvert, 100 m east of the QEW-Highway 406 interchange
Station 19+465	18-287C	Northward extension of Grapeview Creek culvert, 350 m east of the QEW-Highway 406 interchange

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 three culvert sites addressed in this report are located along the QEW in the vicinity of Third Street, Highway 406 and Martindale Road, in the City of St. Catharines, in the Region of Niagara. The overall surface topography along the QEW in this area is flat-lying to gently sloping toward Lake Ontario (to the north).

The access tunnel located about 200 m west of Third Street, is used for local access from the north to the south side of the QEW. At this site, the natural ground surface is at about Elevation 88 m and the QEW has been constructed on embankment fill with its grade at approximately Elevation 93 m. To the northeast of the access tunnel, an approximately 6 m high stockpile of earth fill is present.

The Richardson Creek culvert is located approximately 120 m east of Highway 406. At this location, the natural ground surface is at about Elevation 81 m and the QEW grade is at about Elevation 88 m.

The Grapeview Creek culvert is located approximately 400 m east of Highway 406. The natural ground surface in the vicinity of Grapeview Creek is at approximately Elevation 83 m, and the QEW grade at about Elevation 90 to 91 m.

### 3.0 INVESTIGATION PROCEDURES

A subsurface investigation was carried out by Golder at the culvert extension locations in May and June 2005. A total of six boreholes (Boreholes C1-1, C1-2, C2-1, C2-2, C3-1 and C3-2) were advanced, with two boreholes advanced within or near each of the three proposed culvert extensions. The borehole locations are shown on the Borehole Location and Soil Strata drawings contained in the Contract Documents.

The boreholes were drilled using a track-mounted drill rig, supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. The boreholes were advanced using solid stem augers to depths ranging from 7.9 m to 12.8 m below the existing ground surface. Samples of the overburden were obtained at 0.75 m and 1.5 m intervals of depth, using 50 mm outside diameter split-spoon samplers driven by an automatic hammer in accordance with the Standard Penetration Test (SPT) procedure. The water level in the open boreholes was observed throughout the drilling operations, and a standpipe piezometer was installed in one borehole at each culvert location to monitor the groundwater level at each site.

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 samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for testing. Index and classification tests (water content determinations, Atterberg limits tests, and grain size distribution tests) were carried out on selected soil samples.

The borehole locations were measured relative to known site features, and the ground surface elevations were determined from the digital terrain model (DTM) for this project. The borehole locations (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>Culvert Location</b></i>	<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>
Station 18+635 North Side	C1-1	4782054.3	321860.1	88.6
	C1-2	4782064.3	321860.1	88.3
Station 19+166 South Side	C2-1	4781948.3	322381.7	81.0
	C2-2	4781943.3	322380.9	81.0
Station 19+465 North Side	C3-1	4781976.0	322689.8	83.5
	C3-2	4781996.7	322712.9	82.0

## 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 siltstone interlayers as well as “occasional patches of gypsum” (Menzies and Taylor, 1998).

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<sup>1</sup> 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.

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

## **4.2 Site Stratigraphy**

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of the in situ and laboratory testing are given on the borehole records and on Figures 1 to 6 following the text of this report. 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 locations.

In summary, the native subsoil conditions encountered at the culvert extension sites consist of a thin surficial deposit of firm to very stiff clayey silt to silty clay, underlain by a till deposit that typically consists of stiff to hard clayey silt; at the Richardson Creek culvert site, the clayey silt till grades to a compact to very dense silty sand to sandy silt till; and at the Grapeview Creek culvert site, the clayey silt till contains water-bearing cohesionless interlayers that range in composition from silty sand to silt.

A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections. Stratigraphic profiles at the culvert locations are shown on the Borehole Location and Soil Strata drawings contained in the Contract Documents.

### **4.2.1 Topsoil**

Approximately 100 mm of topsoil was encountered immediately below the ground surface in Borehole C1-1, at the access tunnel location.

### **4.2.2 Fill**

Between 0.7 m and 1.5 m of fill was encountered immediately below the topsoil or ground surface in Boreholes C1-1 (at the access tunnel), C2-1 and C2-2 (at the Richardson Creek culvert), and C3-1 (at the Grapeview Creek culvert). The fill typically consists of clayey silt containing some sand, trace gravel, and trace quantities of organic material, except in Borehole C1-1 where the fill is comprised of silty sand containing some gravel and trace quantities of organic material.

The measured SPT “N” values within the fill range from 8 to 18 blows per 0.3 m of penetration; based on these results, the clayey silt fill has a stiff to very stiff consistency, and the silty sand fill has a compact relative density.

### **4.2.3 Surficial Clayey Silt to Silty Clay**

A 0.6 m to 1.5 m thick layer of surficial clayey silt was encountered immediately below the ground surface in Boreholes C1-2 and C3-2, and below the fill materials in Boreholes C2-1, C2-2 and C3-1. This surficial deposit consists of clayey silt containing some sand, trace to some gravel, and trace quantities of organic material. The results of grain size distribution testing conducted on two selected samples of the surficial clayey silt are shown on Figure 1.

Atterberg limits testing was carried out on three selected samples of this surficial deposit, and measured plastic limits of 16 to 23 per cent, liquid limits of 25 to 37 per cent, and plasticity indices of 10 to 14 per cent. The results, which are plotted on a plasticity chart on Figure 2, confirm that this material varies from a clayey silt of low plasticity to a silty clay of intermediate plasticity.

The measured SPT “N” values within this stratum range from 4 to 17 blows per 0.3 m of penetration, indicating that the surficial clayey silt to silty clay has a firm to very stiff consistency.

### **4.2.4 Clayey Silt Till**

The fills and surficial clayey silt to silty clay are underlain by a cohesive till deposit that consists of clayey silt containing trace to some sand and trace gravel; cobbles were noted within the clayey silt till below 4.6 m depth in Borehole C1-1. Silty sand seams were observed within the clayey silt till in Boreholes C1-1 and C3-2, and thicker interlayers of silty sand to silt were encountered within the till at the Grapeview Creek culvert site (Boreholes C3-1 and C3-2); such interlayers are discussed separately under Section 4.2.6. The results of grain size distribution testing conducted on three selected samples of the clayey silt till are presented on Figure 3. The clayey silt till is at least 12 m thick at the access tunnel site (Boreholes C1-1 and C1-2), approximately 3.2 m to 3.8 m thick at the Richardson Creek culvert site (Boreholes C2-1 and C2-2), and at least 6.8 m to 9.9 m thick including interlayers at the Grapeview Creek culvert site (Borehole C3-1 and C3-2).

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

Atterberg limit testing was conducted on ten selected samples of the clayey silt till, and measured plastic limits of 12 to 17 per cent, liquid limits of 18 to 30 per cent, and plasticity indices of 6 to 13 per cent. The results, which are plotted on a plasticity chart on Figure 4, confirm that this till is a clayey silt of low plasticity.

The consistency of the clayey silt till deposit varies as follows:

- At the access tunnel site (Boreholes C1-1 and C1-2), the upper 3 m of the clayey silt till deposit has a firm to stiff consistency, based on measured SPT “N” values of 5 to 9 blows per 0.3 m of penetration; however, an in situ vane shear test measured an undrained shear strength exceeding 100 kPa, suggesting that this material has a stiff to very stiff consistency. Below this, the clayey silt till has a very stiff to hard consistency, based on measured SPT “N” values of 15 to 50 blows per 0.3 m of penetration.
- At the Richardson Creek culvert site (Boreholes C2-1 and C2-2), the clayey silt till has a stiff to very stiff consistency, based on measured SPT “N” values that range from 12 to 29 blows per 0.3 m of penetration.
- At the Grapeview Creek culvert site (Boreholes C3-1 and C3-2), the measured SPT “N” values range from 9 to 92 blows per 0.3 m of penetration, but are typically between 12 and 40 blows per 0.3 m of penetration. Based on these results, the clayey silt till at this culvert site typically has a stiff to hard consistency.

#### **4.2.5 Silty Sand to Sandy Silt Till**

In Boreholes C2-1 and C2-2 at the Richardson Creek culvert site, the clayey silt till grades to a non-plastic till below 6.1 m and 4.6 m depth, respectively; the surface of the non-plastic till was encountered in these boreholes between Elevations 74.9 m and 76.4 m, and the layer is 4.6 m thick as encountered in Borehole C2-1, where it was fully penetrated. A 0.8 m thick interlayer of non-plastic till was also encountered within the clayey silt till in Borehole C3-2 at the Grapeview Creek culvert site; the surface of this cohesionless till layer was encountered at about Elevation 79.7 m (approximately 2.3 m depth).

The non-plastic till varies in composition from silty sand, to sand and silt, to sandy silt, containing trace to some clay and trace gravel. The results of grain size distribution tests carried out on three selected samples of the silty sand to sandy silt till are shown on Figure 5. Boulders and cobbles were not encountered in this deposit during the borehole investigation. However, it should be noted that these glacially-derived soils may contain boulders and cobbles.

The measured SPT “N” values in the silty sand to sandy silt till are typically greater than 79 blows per 0.3 m of penetration, indicative of a very dense relative density. However, a measured SPT “N” value of 23 blows per 0.3 m of penetration was measured near the surface of this deposit in Borehole C2-2, indicating that the upper portion of the silty sand to sandy silt till at this location has a compact relative density.

#### **4.2.6 Silty Sand to Silt Interlayers Within Clayey Silt Till**

Wet cohesionless soil interlayers were encountered within the clayey silt till deposit in Boreholes C3-1 and C3-2, which were advanced at the Grapeview Creek culvert extension. The layers range in composition from a silty sand containing trace to some gravel, to silt containing trace clay and sand; the result of a grain size distribution test on one selected sample of the silt interlayer is shown on Figure 6.

The silty sand to silt interlayers were encountered at approximately Elevation 75.4 m to 74.4 m (about 7.6 m depth) in Boreholes C3-1 and C3-2, respectively. One of the silty sand interlayers was found to be approximately 3.1 m thick in Borehole C3-1, where it was fully penetrated; Borehole C3-2 was terminated after 0.6 m of penetration into a silt interlayer. A second silty sand interlayer was encountered at the base of Borehole C3-1, below Elevation 70.8 m (approximately 12.2 m depth); the borehole was terminated approximately 0.2 m into this interlayer.

The measured SPT “N” values within the silty sand to silt interlayers vary from 9 to 19 blows for the interlayers encountered at about 7.6 m depth (indicative of a loose to compact relative density). The interlayer encountered at the base of Borehole C3-1, below Elevation 70.8 m, has a very dense relative density, based on one measured SPT “N” value of greater than 100 blows per 0.3 m of penetration.

#### **4.2.7 Bedrock**

Red shale bedrock of the Queenston Formation was encountered at Elevation 70.3 m (at a depth of 10.7 m below ground surface) in Borehole C2-1, which is located at the Richardson Creek culvert extension. This borehole was extended 1.6 m into the shale bedrock by augering and split-spoon sampling. The measured SPT “N” values within the shale bedrock were greater than 100 blows per 0.3 m of penetration.

### **4.3 Groundwater Conditions**

The silty sand to sandy silt till soils and the seams/interlayers of silty sand to silt were observed to be wet during drilling operations. The water level observed in the open boreholes during and upon completion of drilling varied between 1.5 m and 6.0 m depth below the ground surface.

A standpipe piezometer was installed in one borehole at each site to monitor the groundwater level; the following table summarizes the water levels measured in the piezometers:

<b>Borehole No.</b>	<b>Culvert Location</b>	<b>August 8, 2005</b>		<b>December 6, 2005</b>	
		<b>Depth</b>	<b>Elevation</b>	<b>Depth</b>	<b>Elevation</b>
C1-1	Access tunnel	2.5 m	86.1 m	2.2 m	86.4 m
C2-1	Richardson	0.3 m	80.7 m	0.2 m above g.s.	81.2 m
C3-2	Grapeview	1.3	80.7 m	0.9 m	81.1 m

It should be noted that the groundwater levels at the culvert sites are anticipated to fluctuate as a result of seasonal variations in precipitation, runoff, temperature and creek water levels.

## 5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Shannon Palmer, EIT, and reviewed by Ms. Lisa Coyne, P. Eng., an Associate and geotechnical engineer with Golder. Mr. Fintan Heffernan, P.Eng., a Designated MTO Contact for Golder, conducted an independent review of the report.

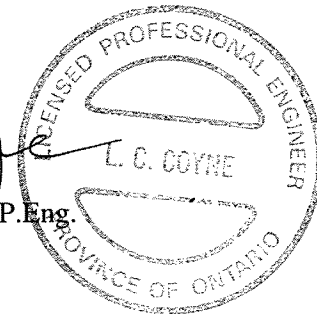
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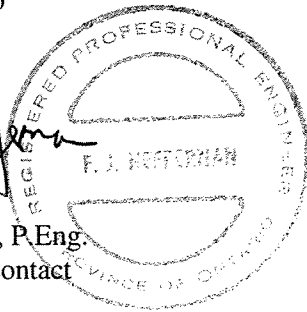
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SLP/LCC/FJH/lcc

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## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO	Drive open
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

	<u>kPa</u>	<u>psf</u>
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

#### (b) Cohesive Soils

$c_u, s_u$

#### 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
$SO_4$	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.

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## 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)

PROJECT 04-1111-002			RECORD OF BOREHOLE No C1-1			1 OF 2 METRIC											
W.P. 607-00-00			LOCATION N 4782054.3 ; E 321860.1			ORIGINATED BY PKS											
DIST Central HWY QEW			BOREHOLE TYPE 108 mm Diameter Solid Stem Augers			COMPILED BY KG											
DATUM Geodetic			DATE June 1, 2005			CHECKED BY LCC											
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 kN/m³	GR SA SI CL
							20 40 60 80 100	20 40 60 80 100	Wp	W	WL	10 20 30					
88.6	GROUND SURFACE																
88.0	TOPSOIL		1	SS	12												
87.8	Silty sand, some gravel, trace clay and topsoil (FILL)																
87.8	Compact Brown Moist		2	SS	8												
87.8	CLAYEY SILT, trace to some sand, trace gravel, containing silty sand seams (TILL)																
87.8	Stiff to hard Grey Moist to wet		3	SS	9												
			4	SS	9												
			5	SS	8												
			6	SS	8												
			7	SS	17												
	Containing shale fragments and cobbles below 4.6 m depth.																
			8	SS	23												
			9	SS	18												
			10	SS	19												
			11	SS	44												
			12	SS	50												
75.8																	
12.8																	


Continued Next Page

+<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


MIS-MTO 001 041111002AAMTO.GPJ GAL-MISS.GDT 5/1/07

PROJECT 04-1111-002		RECORD OF BOREHOLE No C1-2				1 OF 1 METRIC							
W.P. 607-00-00		LOCATION N 4782064.3 ; E 321860.1				ORIGINATED BY PKS							
DIST Central HWY QEW		BOREHOLE TYPE 108 mm Diameter Solid Stem Augers				COMPILED BY KG							
DATUM Geodetic		DATE June 2, 2005				CHECKED BY LCC							
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					
88.3	GROUND SURFACE						20 40 60 80 100						
0.0	CLAYEY SILT, some sand and gravel Stiff Brown/grey Moist		1	SS	11								
87.5			2	SS	5								
0.8	CLAYEY SILT, some sand, trace gravel (TILL) Firm to very stiff Grey Moist to wet		3	SS	5								
			4	SS	7								
			5	SS	5								
			6	SS	15								
			7	SS	16								
			8	SS	23								
80.1	END OF BOREHOLE												
8.2	Note: 1. Water level in open borehole at 3.0m depth upon completion of drilling operations.												

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

PROJECT 04-1111-002			RECORD OF BOREHOLE No C2-1			1 OF 1 METRIC		
W.P. 607-00-00			LOCATION N 4781948.3 ; E 322381.7			ORIGINATED BY PKS		
DIST Central HWY QEW			BOREHOLE TYPE 108 mm Diameter Solid Stem Augers			COMPILED BY KG		
DATUM Geodetic			DATE May 31, 2005			CHECKED BY LCC		
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
81.0	GROUND SURFACE							PLASTIC LIMIT W <sub>p</sub> NATURAL MOISTURE CONTENT W LIQUID LIMIT W <sub>L</sub> WATER CONTENT (%)
0.0	Clayey silt, some sand, trace gravel and shale pieces (FILL) Stiff Brown Moist		1	SS	9			
80.2	CLAYEY SILT, some sand, trace gravel and organics Firm to very stiff Brown/grey Moist		2	SS	4		80	
0.8			3	SS	17		79	
78.7	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to very stiff Grey Moist to wet		4	SS	27		78	
2.3			5	SS	17		77	
	Containing shale fragments below 4.6 m depth		6	SS	14		76	
			7	SS	29		75	
74.9	SILTY SAND to SAND and SILT, trace clay and gravel containing shale fragments (TILL) Very dense Red Wet		8	SS	100/25		74	
6.1			9	SS	100/15		73	
			10	SS	100/20		72	
70.3	Red SHALE (BEDROCK)		11	SS	100/20		71	
10.7			12	SS	100/13		70	
68.7	END OF BOREHOLE						69	
12.3	Note: 1. Water level in open borehole at 3.7m depth upon completion of drilling operations. 2. Water level in piezometer at 0.3m depth on August 8, 2005. 3. Water level in piezometer at 0.2m above ground surface on December 6, 2005.							
						UNIT WEIGHT γ kN/m <sup>3</sup>		
						REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
						1 20 51 28		
						8 42 41 9		

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

PROJECT 04-1111-002			RECORD OF BOREHOLE No C2-2			1 OF 1 METRIC					
W.P. 607-00-00			LOCATION N 4781943.3 ; E 322380.9			ORIGINATED BY PKS					
DIST Central HWY QEW			BOREHOLE TYPE 108 mm Diameter Solid Stem Augers			COMPILED BY KG					
DATUM Geodetic			DATE May 31, 2005			CHECKED BY LCC					
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 (%)	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
81.0	GROUND SURFACE										
0.0	Clayey silt, some sand, trace gravel, shale pieces and organics (FILL) Stiff		1	SS	9						
80.2	Brown/grey Moist		2	SS	8						Organics
0.8	CLAYEY SILT, some sand, trace gravel and organics Stiff										
79.6	Grey Moist		3	SS	19						
1.4	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to very stiff		4	SS	13						
	Grey Moist		5	SS	12						
76.4			6	SS	13						
4.6	SANDY SILT, trace to some clay, trace gravel (TILL) Compact to very dense Grey to red Moist to wet		7	SS	23						5 25 58 12
			8	SS	100/18						
73.2			9	SS	100/23						
7.9	END OF BOREHOLE  Note: 1. Water level in open borehole at 6.0 m depth upon completion of drilling operations.										

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

PROJECT		04-1111-002		RECORD OF BOREHOLE No C3-1		1 OF 1 METRIC											
W.P.		607-00-00		LOCATION		N 4781976.0 ; E 322689.8											
DIST		Central HWY QEW		BOREHOLE TYPE		108 mm Diameter Solid Stem Augers											
DATUM		Geodetic		DATE		June 1, 2005											
				ORIGINATED BY		PKS											
				COMPILED BY		KG											
				CHECKED BY		LCC											
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	20 40 60 80 100	20 40 60 80 100	W <sub>p</sub>	W	W <sub>L</sub>	γ	GR	SA	SI	CL
83.5	GROUND SURFACE																
0.0	Clayey silt, some sand, trace gravel and organics (FILL) Stiff to very stiff Brown Moist		1	SS	18		83										
			2	SS	8												
82.0							82										
1.5	SILTY CLAY, some sand, trace gravel and organics Firm Grey Moist		3	SS	5												
81.2							81										
2.3	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff to hard Brown to grey Moist to wet		4	SS	17												
			5	SS	32		80										
			6	SS	32		79										
			7	SS	40		78										
	Containing shale fragments below 6.1 m depth		8	SS	43		77										
75.9							76										
7.6	SILTY SAND, trace gravel Loose to compact Grey/red Wet		9	SS	9		75										
			10	SS	19		74										
72.8							73										
10.7	CLAYEY SILT, some sand, trace gravel, containing shale fragments (TILL) Hard Red Wet		11	SS	92		72										
71.3																	
12.4	SILTY SAND and GRAVEL, containing shale fragments Very dense Red Wet END OF BOREHOLE		12	SS	100/18												
	Note: 1. Water level in open borehole at 2.3 m depth upon completion of drilling operations.																

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

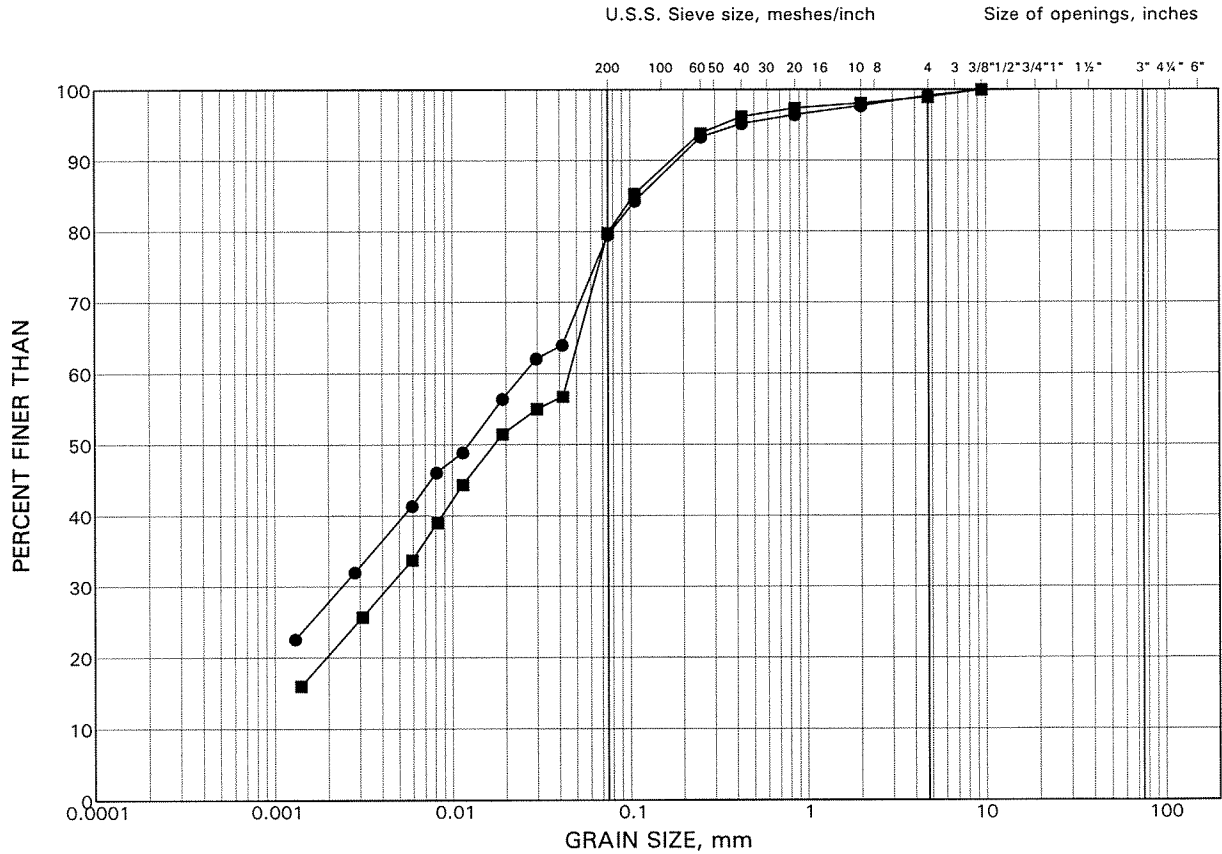
PROJECT		04-1111-002		RECORD OF BOREHOLE No C3-2		1 OF 1 METRIC								
W.P.		607-00-00		LOCATION		N 4781996.7 ; E 322712.9								
DIST		Central HWY QEW		BOREHOLE TYPE		108 mm Diameter Solid Stem Augers								
DATUM		Geodetic		DATE		May 31, 2005								
ORIGINATED BY		PKS		COMPILED BY		KG								
CHECKED BY		LCC												
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	
82.2	0.0	GROUND SURFACE							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED		10 20 30 W <sub>p</sub> W W <sub>L</sub>		kN/m <sup>3</sup> GR SA SI CL	
81.4	0.8	CLAYEY SILT, some sand, trace gravel and organics Firm Brown/grey Moist		1	SS	4		82					Organics	
		CLAYEY SILT, some sand, trace gravel (TILL) Stiff to hard Brown/grey Moist to wet		2	SS	12		81						
				3	SS	41		80						
79.9	2.3	SAND and SILT, some gravel, trace clay, containing cobbles (TILL) Very dense Brown Wet		4	SS	79		79					30 33 26 11	
79.2	3.1	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to very stiff Grey Wet		5	SS	22		78						
				6	SS	20		77						
		Containing silty sand seams below 4.9 m depth		7	SS	20		76						
				8	SS	9		75						
74.6	7.6	SILT, trace clay and sand Compact Grey Wet		9	SS	18		74					0 5 84 11	
74.0	8.2	END OF BOREHOLE												
		Note: 1. Water level in open borehole at 1.5m depth upon completion of drilling operations. 2. Water level in piezometer at 1.3m depth on August 8, 2005. 3. Water level in piezometer at 0.9m depth on December 6, 2005.												

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

# GRAIN SIZE DISTRIBUTION TEST RESULTS

Surficial Clayey Silt to Silty Clay

FIGURE 1



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

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	C2-1	2	79.9
■	C3-1	3	81.7

Date May, 2006  
Project 04-1111-002

**Golder Associates**

Prepared by LG  
Checked by *[Signature]*

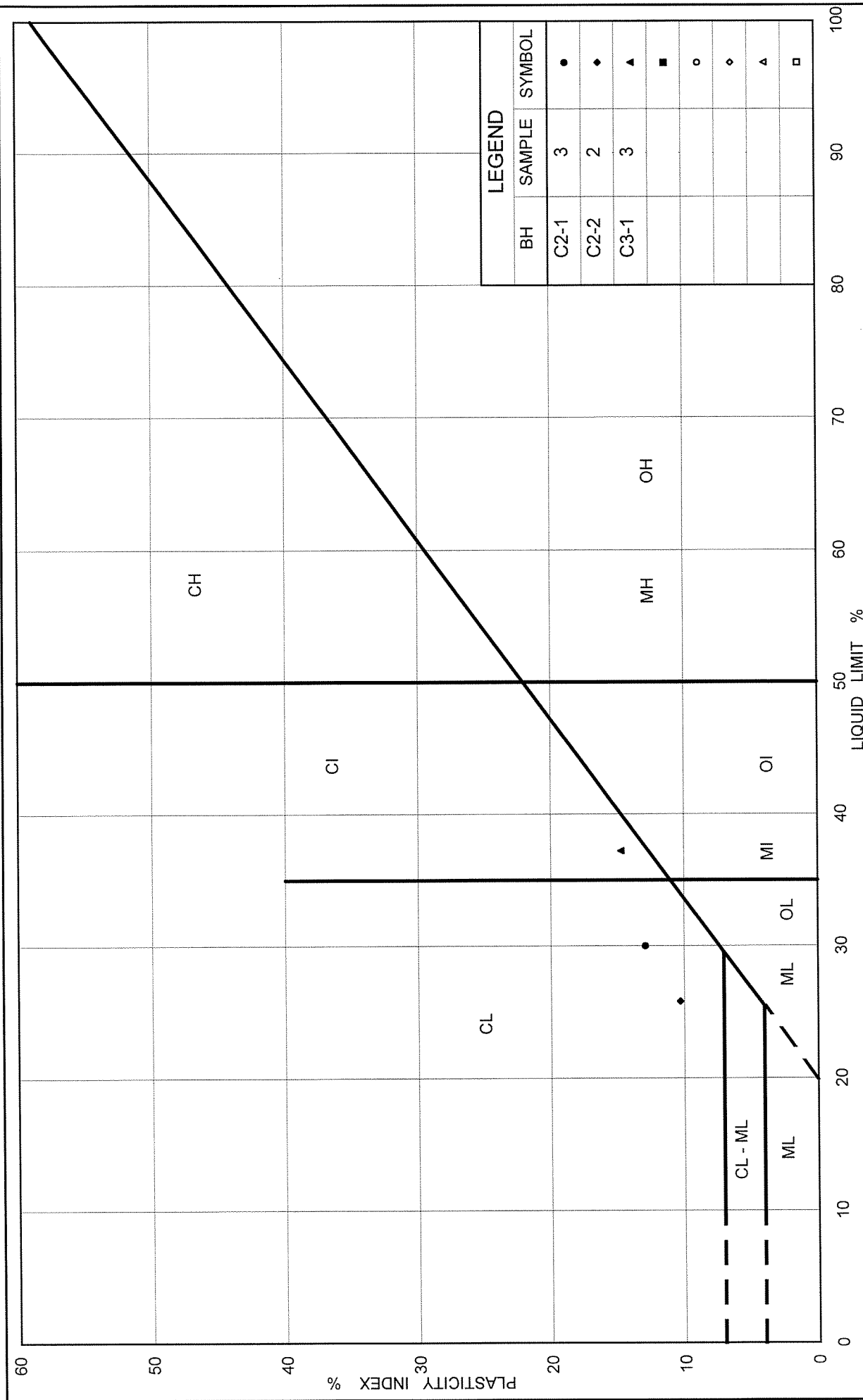


FIG No. 2

PLASTICITY CHART  
Surficial Clayey Silt to Silty Clay

Ministry of Transportation



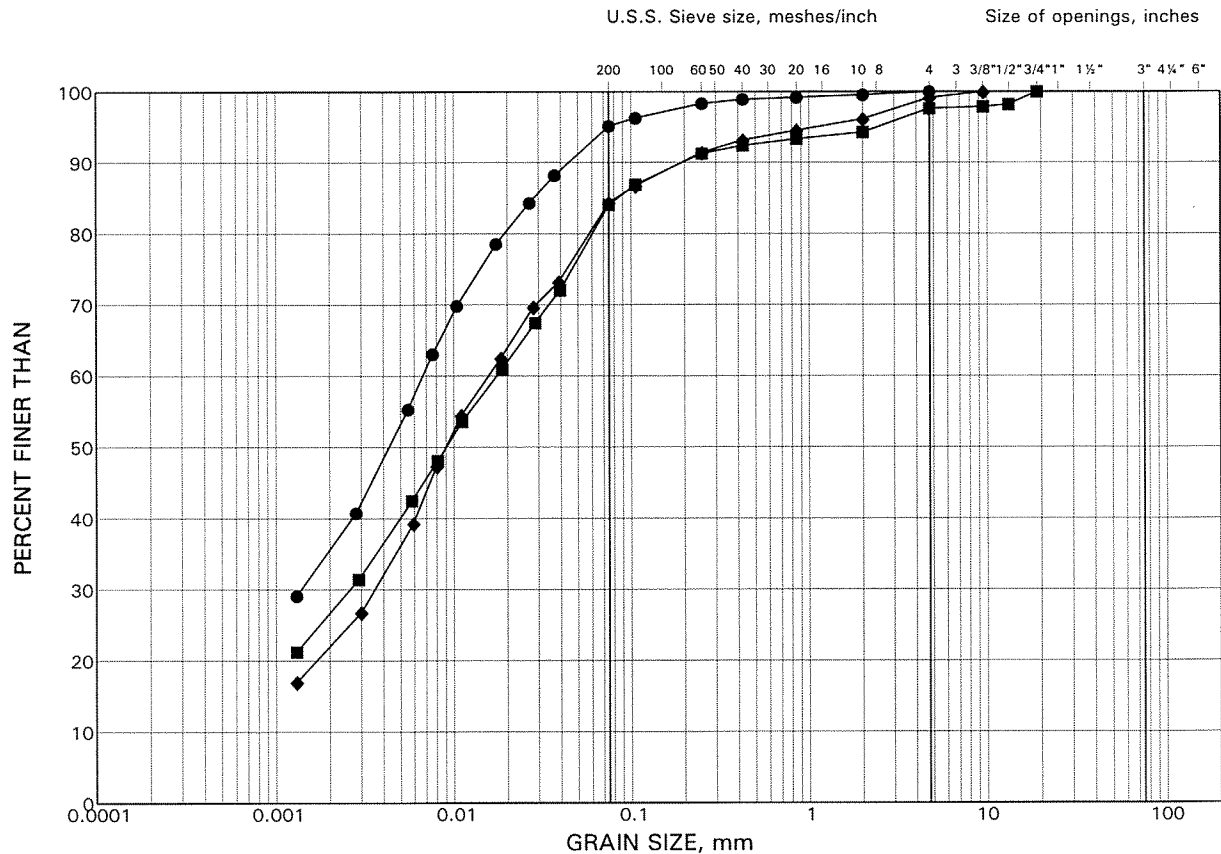
Ontario

Project No. 04-1111-002

# GRAIN SIZE DISTRIBUTION TEST RESULTS

Clayey Silt Till

FIGURE 3



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

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	C1-1	8	82.2
■	C1-2	3	86.5
◆	C3-1	7	78.6

Date May, 2006  
Project 04-1111-002

**Golder Associates**

Prepared by LG  
Checked by *fel*

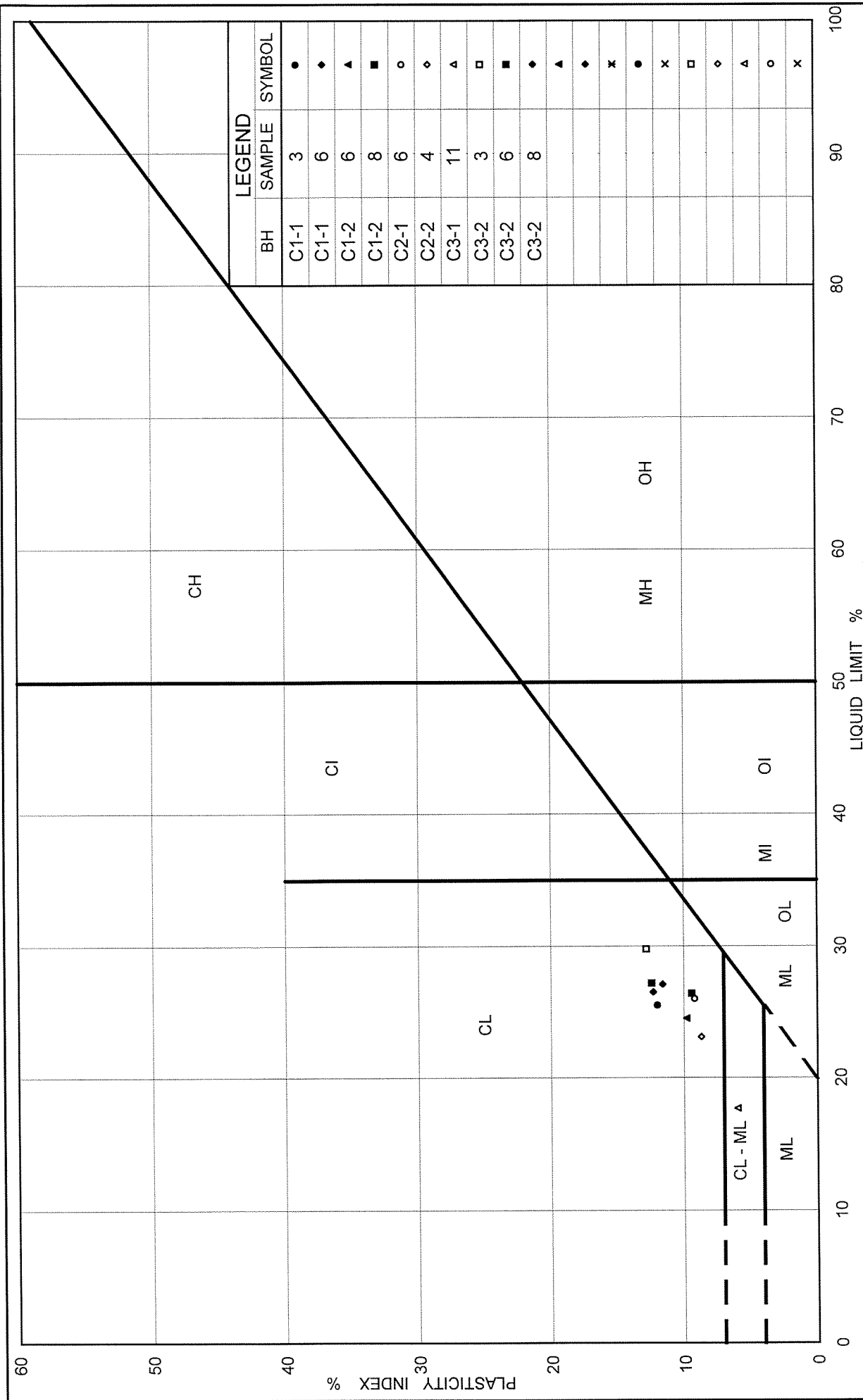


FIG No. 4

PLASTICITY CHART  
Clayey Silt Till

Ministry of Transportation



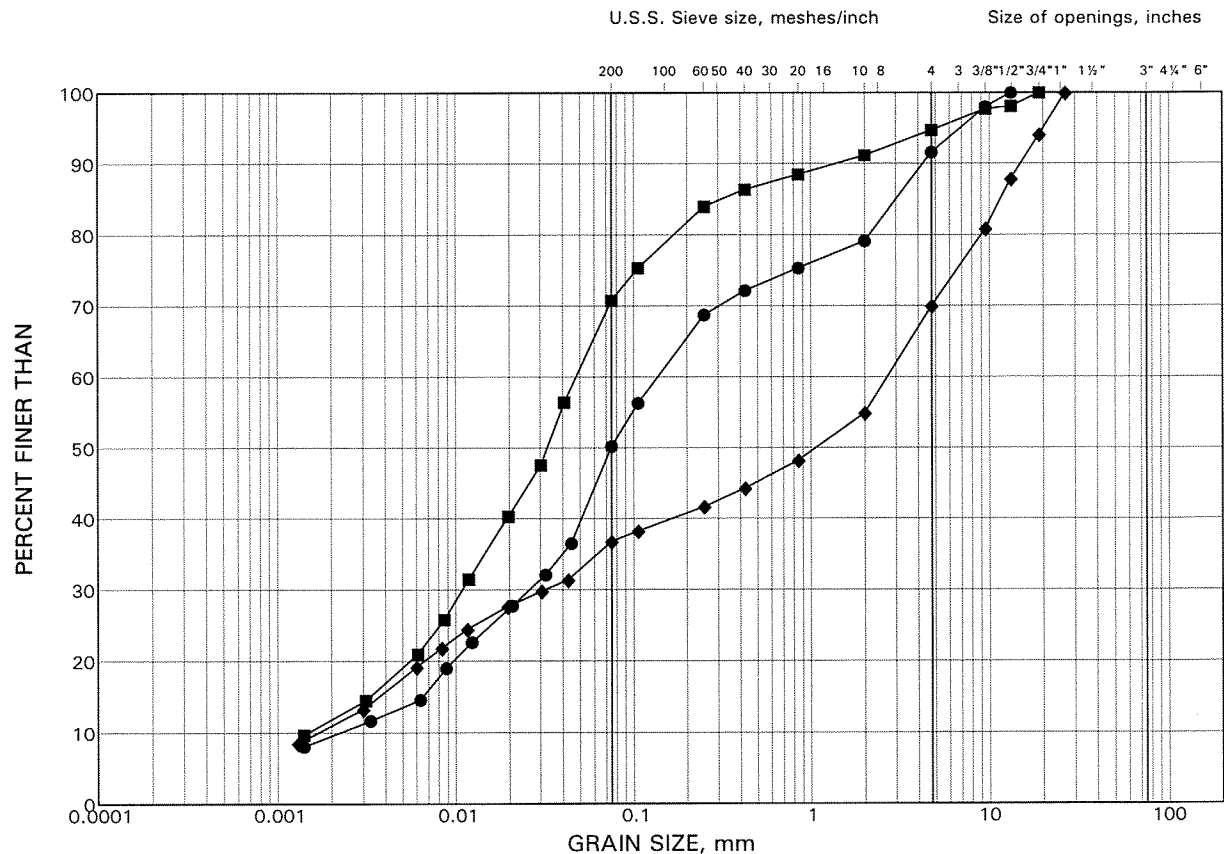
Ontario

Project No. 04-1111-002

# GRAIN SIZE DISTRIBUTION TEST RESULTS

Silty Sand to Sandy Silt Till

FIGURE 5



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

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	C2-1	10	71.8
■	C2-2	7	76.1
◆	C3-2	4	79.4

Date May, 2006  
Project 04-1111-002

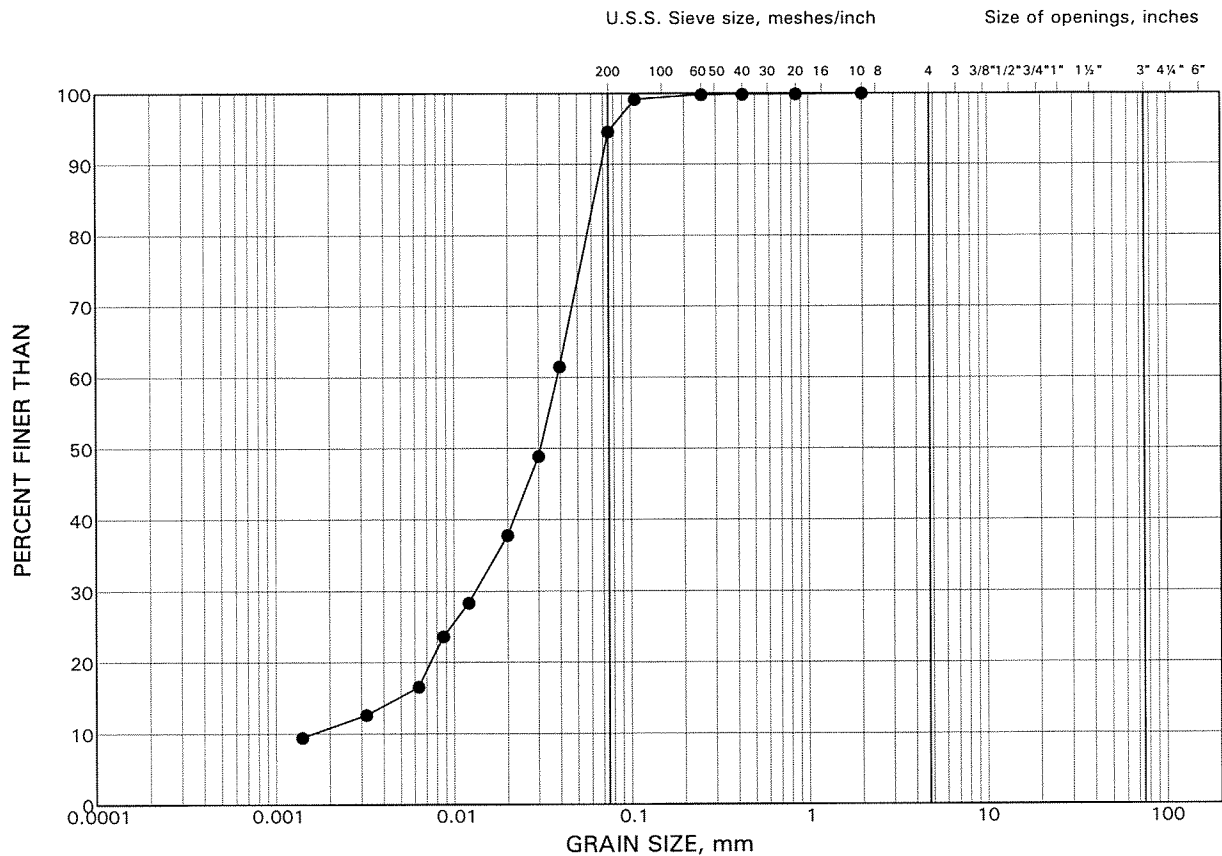
**Golder Associates**

Prepared by LG  
Checked by *pl*

# GRAIN SIZE DISTRIBUTION TEST RESULT

## Silty Sand to Silt Interlayers in Clayey Silt Till

FIGURE 6



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

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
•	C3-2	9	74.1

Date May, 2006  
Project 04-1111-002

**Golder Associates**

Prepared by LG  
Checked by *ll*