



June 2011

FOUNDATION INVESTIGATION REPORT

Keele Street Underpass Highway 401 Eastbound Collector Rehabilitation from Jane Street to Avenue Road Toronto, Ontario G.W.P. 2368-09-00

Submitted to:
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GEOCRES No. 30M11-237

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REPORT





Table of Contents

1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION.....	1
3.0 INVESTIGATION PROCEDURES	2
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS	3
4.1 Regional Geology	3
4.2 Subsurface Conditions.....	3
4.2.1 Asphalt and Topsoil.....	4
4.2.2 Fill	4
4.2.3 Clayey Silt Till	4
4.2.4 Sand and Silt to Sandy Silt to Silt.....	5
4.2.5 Clayey Silt to Clay.....	5
4.2.6 Groundwater Conditions	6
5.0 CLOSURE.....	7

APPENDIX A Records of Boreholes from Current Investigation

Lists of Abbreviations and Symbols
Records of Boreholes 2010-1 to 2010-4

APPENDIX B Laboratory Test Results

Figure B1 Plasticity Chart – Clayey Silt Fill
Figure B2A Grain Size Distribution – Clayey Silt Till
Figure B2B Grain Size Distribution – Clayey Silt Till
Figure B3A Plasticity Chart – Clayey Silt Till
Figure B3B Plasticity Chart – Clayey Silt to Silty Clay Till
Figure B4 Grain Size Distribution – Sand and Silt to Sandy Silt to Silt
Figure B5 Plasticity Chart – Clayey Silt and Clay

APPENDIX C Records of Boreholes from Previous Investigation

Records of Boreholes 1 and 2



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by URS Canada Inc. on behalf of Ministry of Transportation, Ontario (MTO) to provide foundation engineering services in support of the rehabilitation of the Highway 401 eastbound collector lanes (EBC) between Jane Street and Avenue Road in Toronto, Ontario. Foundation engineering services are required under two phases:

- Phase 1: Foundation Engineering Assessment of existing foundations at six (6) structure locations, namely Keele Street Underpass; Dufferin Street Overpass; Ramp 401W – Dufferin Street N/S over Bridgeland Avenue; Ramp 401W – Yorkdale & Dufferin NB over Dufferin Street; Bathurst Street Overpass; and Avenue Road Underpass. This phase of the work has been completed and the results have been reported in a Technical Memorandum, dated July 21, 2010.
- Phase 2: Foundation Investigation, Design and Analyses under two components as follows:
 - Foundation Investigation and Design for:
 - Overhead Sign support structures; and
 - Temporary bridge deck support structure for Rapid Bridge Replacement (RBR) of Ramp 401W-Dufferin Street N/S bridge over Bridgeland Avenue; and
 - Foundation Investigation and/or Analysis and Design at six bridge structures: Keele Street Underpass; Dufferin Street Overpass; Ramp 401W – Dufferin Street N/S over Bridgeland Avenue; Ramp 401W – Yorkdale & Dufferin NB over Dufferin Street; Bathurst Street Overpass; and Avenue Road Underpass.

This report addresses the widening and rehabilitation of the Keele Street Underpass associated with the Phase 2 Foundation Investigation.

The terms of reference and scope of work for the foundation investigation are outlined in MTO's Request for Proposal (RFP) for Agreement No. 2009-E-0011, issued on December 16, 2009 and MTO's Addendum No. 1, dated June 14, 2010. The scope of work for the foundation engineering services is presented in Golder's scope change letter, dated September 16, 2010.

2.0 SITE DESCRIPTION

The Keele Street Underpass is a 3-span steel-girder structure with span lengths of 40.9 m, 42.0 m, and 40.3 m crossing Highway 401 in Toronto, Ontario. The Highway 401 grade is at about Elevation 172.5 m under the bridge structure and the Keele Street grade rises from about Elevation 178.9 m at the south approach to about Elevation 180.1 m at the north approach.

Based on the available drawings, the abutments and piers are supported on spread footings. Highway 401 is constructed in a cut at the Keele Street Underpass location and the Keele Street approach embankments consist of the existing native ground forming the topographic high ground in the area.



3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out in September and October 2010, at which time four boreholes (Boreholes 2010-1 to 2010-4) were advanced using a Diedrich D-50 turbo, a D-90 track-mounted and a D-120 track-mounted drill rigs, supplied and operated by Walker Drilling of Utopia, Ontario. Boreholes 2010-1 to 2010-4 were advanced at the locations shown on the Borehole Location and Soil Strata drawing contained in the Contract Documents.

Soil samples were obtained at 0.75 m and 1.5 m intervals of depth in the boreholes, using a 50 mm outside diameter split-spoon sampler in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). The groundwater conditions were observed in the open boreholes during and immediately following the drilling operations. A standpipe piezometer was installed in Boreholes 2010-1 and 2010-4 to monitor the groundwater level at the site. The piezometers consist of a 1.5 m long slotted screen installed within a filter sand pack, above which the borehole annulus is backfilled to ground surface with bentonite pellets; the details of the piezometer installation are shown on the Record of Borehole 2010-01 and 2010-04. The remaining boreholes were backfilled immediately below ground surface with bentonite pellets upon completion, in accordance with Ontario Regulation 903 (as amended by Ontario Regulation 372). The upper approximately 0.4 m was backfilled with cold patch asphalt in Boreholes 2010-2 and 2010-3.

The field work was monitored on a full-time basis by a member of Golder's technical staff who located the boreholes in the field, directed the drilling, sampling and in situ testing operations, and logged the boreholes. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and laboratory testing. Index and classification tests (water contents, Atterberg limits and grain size distributions) were carried out on selected soil samples. All geotechnical laboratory testing was completed to ASTM and MTO LS standards, as applicable.

The borehole locations were measured on-site relative to the existing bridge and site features and the ground surface elevations were obtained from the Digital Terrain Model for the site, provided by URS. The borehole locations, including MTM NAD83 northing and easting coordinates and ground surface elevations referenced to geodetic datum, are summarized below and are shown on the Borehole Location and Soil Strata drawing contained in the Contract Documents. Also shown on the Borehole Location and Soil Strata drawing contained in the Contract Documents are the locations of two boreholes advanced as part of the previous investigation at the site (Geocres No 30M11-084).

Borehole No.	MTM NAD83 Northing	MTM NAD83 Easting	Ground Surface Elevation	Borehole Depth
2010-1	4,842,588.7	306,315.7	179.5 m	43.1 m
2010-2	4,842,539.0	306,289.7	172.2 m	33.4 m
2010-3	4,842,502.5	306,327.7	172.5 m	28.3 m
2010-4	4,842,462.1	306,338.6	178.0 m	38.4 m
1*	4,842,588.8	306,281.9	178.8 m	15.7 m
2*	4,842,459.7	306,354.5	177.8 m	15.7 m

** Borehole locations obtained from the Digital Terrain Model as plotted relative to centerline of Highway 401 stations and off-sets.*



4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This section of Highway 401 is located within the physiographic region known as the Peel Plain, according to *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)¹.

A surficial till sheet, which generally follows the surface topography, is generally present throughout much of this area. The till is typically comprised of clayey silt to silty clay, with occasional sand to silt zones; it is mapped in this area as the Halton Till. Shallow, localized deposits of loose sand and silt and/or soft clay can overlie this uppermost till sheet, and these represent relatively recent deposits, formed in small glacial melt water ponds scattered throughout the Peel Plain and concentrated near river valleys, such as the West Don River valley. The recent sand, silt and clay and uppermost till deposits in this area overlie and are interbedded with stratified deposits of sand, silt and clay.

4.2 Subsurface Conditions

As part of the subsurface investigation, four boreholes (Boreholes 2010-1 to 2010-4) were advanced at the Highway 401-Keele Street Underpass bridge structure. The borehole locations, ground surface elevations and interpreted stratigraphic conditions are shown on the Borehole Location and Soil Strata drawing contained in the Contract Documents.

The detailed subsurface soil and groundwater conditions encountered in the boreholes advanced as part of the current investigation and the results of in situ and laboratory testing are given on the borehole records contained in Appendix A; the results of geotechnical laboratory testing are also presented on Figures B1 to B5 contained in Appendix B. The Record of Borehole No. 1 and No. 2 from the previous (MTO) investigation are presented in Appendix C.

The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic profile on the Borehole Location and Soil Strata drawing contained in the Contract Documents 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 general, the soils encountered at the site consist of a relatively thin layer of fill overlying a deposit of stiff to hard clayey silt till, which is underlain by a deposit of silt and sand to sandy silt to silt. In Boreholes 2010-1 and 2010-3, a deposit of clayey silt to silty clay was encountered underlying the cohesionless deposit.

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

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



4.2.1 Asphalt and Topsoil

Approximately 200 mm to 300 mm of topsoil was encountered immediately below the existing ground surface in Boreholes 2010-1 and 2010-4, which were advanced on the embankments adjacent to the abutments of the existing structure.

Approximately 0.4 m of asphalt associated with the existing road structure was encountered immediately below the existing ground surface in Boreholes 2010-2 and 2010-3, which were advanced from the Highway 401 grade at the pier locations.

4.2.2 Fill

Fill materials were encountered below the topsoil and asphalt in all boreholes. The fill layer is between about 0.2 m and 2.1 m thick, with the base of the fill encountered between Elevations 171.1 m and 177.2 m depending on the location of the boreholes relative to the Highway 401 grade or top of the embankments at the abutments.

The fill consists of clayey silt containing trace to some sand and gravel where encountered beneath the topsoil, and silty sand to sand containing trace gravel where encountered beneath the asphalt. The fill also contains organic materials. Atterberg limits testing carried out on one recovered sample of cohesive fill measured a plastic limit of 13 percent, a liquid limit of 24 percent, and a corresponding plasticity index of 11 percent. These results, which are plotted on a plasticity chart on Figure B1 in Appendix B, indicate that the deposit consists of clayey silt of low plasticity. The natural water content measured on selected samples of the fill ranges from 6 to 13 percent.

The Standard Penetration Test (SPT) "N" values measured within the fill range from 13 to 17 blows per 0.3 m of penetration, indicating a compact relative density within the cohesionless fill, and suggesting a stiff to very stiff consistency within the cohesive fill.

4.2.3 Clayey Silt Till

A deposit of clayey silt till was encountered directly below the fill in all boreholes at a depth between 0.6 m and 2.3 m below ground / pavement surface. The surface of the deposit ranges between Elevations 171.1 m and 177.2 m and the thickness of this deposit ranges from 23.3 m to 32.9 m.

The till deposit consists of clayey silt, with a plasticity of silty clay in places, and contains varying quantity of sand, and trace to some gravel. Silty sand to sand seams were also encountered within the deposit at various depths. The results of grain size distribution tests carried out on eight (8) selected samples of the till are provided on Figure B2 in Appendix B. Atterberg limits testing was carried out on fourteen (14) selected samples of this deposit and measured plastic limits varying from 10 to 18 percent, liquid limits varying from 17 to 37 percent, and plasticity indices varying from 6 to 19 percent. These results, which are plotted on a plasticity chart on Figure B3 in Appendix B, indicate that the till deposit generally consists of clayey silt of low plasticity. The natural water content measured on selected samples of the clayey silt till ranges from 8 to 23 percent.

The measured SPT "N" values within the clayey silt to silty clay till range from 9 to 135 blows per 0.3 m of penetration, suggesting a stiff to hard consistency.



4.2.4 Sand and Silt to Sandy Silt to Silt

A deposit of sand and silt to sandy silt to silt was encountered underlying the clayey silt till deposit in all boreholes. The surface of the deposit was encountered at depths between 23.9 m and 34.4 m below ground surface, corresponding to between Elevations 148.6 m and 143.6 m. Boreholes 2010-2 and 2010-4 terminated within this deposit, penetrating into it for a thickness of 3.4 m and 4.0 m, respectively. The deposit is 10.7 m and 3.1 m thick in Boreholes 2010-1 and 2010-3, respectively, where it was fully penetrated.

The sand and silt to sandy silt to silt deposit contains trace to some clay and trace gravel. The results of grain size distribution tests carried out on six (6) samples of the cohesionless deposit are provided on Figure B4 in Appendix B. The natural water content measured on the recovered samples of the sand and silt deposit range from 12 to 26 percent.

The measured SPT “N” values range from 36 blows to 140 blows per 0.3 m of penetration and as high as 100 blows per 0.1 m of penetration, indicating that the cohesionless deposit has a dense to very dense relative density.

A dynamic cone penetration test (DCPT) was driven from the bottom of Borehole 2010-2 from 27.8 m to 33.4 m below ground surface and terminated on a stratum exhibiting 200 blows per 0.2 m of penetration, at Elevation 138.8 m.

4.2.5 Clayey Silt to Clay

A clayey silt to clay deposit was encountered underlying the sand and silt to sandy silt to silt deposit in Boreholes 2010-1 and 2010-3, at a depth of 42.7 m (Elevation 136.8 m) and 27.0 m (Elevation 145.5 m) below ground surface, respectively. Both boreholes terminated within this deposit, penetrating it for a thickness of 0.4 m and 1.0 m in Boreholes 2010-1 and 2010-3, respectively.

This deposit consists of clayey silt containing some sand and occasional silty sand seams as encountered in Borehole 2010-1, and clay containing some gravel, trace sand and silt pockets as encountered in Borehole 2010-3. Atterberg limits testing was carried out on two selected samples of this deposit and measured plastic limits of 17 and 20 percent, liquid limits of 28 and 51 percent, and corresponding plasticity indices of 11 and 31 percent. These results, which are plotted on a plasticity chart on Figure B5 in Appendix B, indicate that the deposit in Borehole 2010-1 consists of clayey silt of low plasticity, and in Borehole 2010-3 it consists of clay of high plasticity. The natural water content measured on selected samples of the clayey silt and clay are 23 and 22 percent, respectively.

The measured SPT “N” values within the clayey silt and clay strata are 112 and 46 blows per 0.3 m of penetration, suggesting a hard consistency.

A dynamic cone penetration test (DCPT) was driven from the bottom of boreholes 2010-3 from 28.0 m to 28.3 m below ground surface, and terminated on a stratum exhibiting 300 blows per 0.23 m of penetration, at Elevation 144.2 m.



4.2.6 Groundwater Conditions

Details of the water levels observed in the open boreholes at the time of drilling are summarized on the Record of Borehole sheets following the text of this report. Two standpipe piezometers were installed in Boreholes 2010-1 and 2010-4 to monitor the groundwater level(s) at the site. The water levels measured within the open boreholes upon completion of drilling and in the piezometers are summarized below:

Borehole Number	Ground Surface Elevation (m)	Depth to Water Level (m)	Depth to Water Elevation (m)	Date
2010-1	179.5	25.9	153.6	June 3, 2011 in piezometer
2010-2	172.2	5.6	166.6	September 30, 2010 in open borehole
2010-3	172.5	26.4	147.9	October 1, 2010 in open borehole
2010-4	178.0	27.2	150.8	June 3, 2011 in piezometer

The water levels in Boreholes 2010-2 and 2010-3 were measured upon completion of drilling and are not representative of the stabilized groundwater level at this site which ranges from about Elevation 151 m to 154 m in June 2011. The higher water levels measured during or shortly after drilling operations suggest that perched groundwater conditions exist above and within the upper portion of the clayey silt till deposit which contains sand seams / interlayers.

The water level(s) at the bridge site should be expected to fluctuate seasonally in response to changes in precipitation and snow melt, and should be expected to be higher during the spring season or during any period of heavy precipitation.



FOUNDATION REPORT - KEELE STREET UNDERPASS, HIGHWAY 401 EBC REHABILITATION

5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Nikol Kochmanová, EIT, and reviewed by Mr. Kevin Bentley, P.Eng., an Associate and Senior Geotechnical Engineer at Golder. Mr. Jorge Costa, P.Eng., a Designated MTO Contact and Principal with Golder, conducted an independent review and quality control audit of this report.

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NK/HJ/KB/JMAC/sm

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APPENDIX A

Records of Boreholes from Current Investigation



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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d :

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

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

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Cohesionless Soils

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

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS

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

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

V. MINOR SOIL CONSTITUENTS

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



LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

(a) Index Properties

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

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

1 OF 4 **METRIC**

CHECKED BY NK/HJ

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

RECORD OF BOREHOLE No 2010-1

2 OF 4 **METRIC**

PROJECT 09-1111-6007
 G.W.P. 2368-09-00 LOCATION N 4842588.7 ; E 306315.7 ORIGINATED BY PKS
 DIST Central HWY 401 BOREHOLE TYPE D-50 Turbo, 210 mm Diameter Hollow Stem Auger COMPILED BY TT
 DATUM Geodetic DATE October 6,7 and 12, 2010 CHECKED BY NK/HJ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						WATER CONTENT (%)	GR	SA	SI	CL			
								○ UNCONFINED	+ FIELD VANE										● QUICK TRIAXIAL	× REMOULDED	20
	--- CONTINUED FROM PREVIOUS PAGE ---																				
	CLAYEY SILT with sand, trace gravel (TILL) Stiff to hard Brown becoming grey below 3.8m Moist		13	SS	17																
			14	SS	17																
			15	SS	16																
			16	SS	16																
			17	SS	24																
			18	SS	33																
			19	SS	51																

Continued Next Page

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

MIS-MTO 001 09-1111-6007.GPJ GAL-MISS.GDT 6/8/11

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

PROJECT <u>09-1111-6007</u>		RECORD OF BOREHOLE No 2010-1		4 OF 4 METRIC	
G.W.P. <u>2368-09-00</u>		LOCATION <u>N 4842588.7 ; E 306315.7</u>		ORIGINATED BY <u>PKS</u>	
DIST <u>Central</u> HWY <u>401</u>		BOREHOLE TYPE <u>D-50 Turbo, 210 mm Diameter Hollow Stem Auger</u>		COMPILED BY <u>TT</u>	
DATUM <u>Geodetic</u>		DATE <u>October 6,7 and 12, 2010</u>		CHECKED BY <u>NK/HJ</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL	
								○ UNCONFINED	● QUICK TRIAXIAL	+	×	FIELD VANE	REMOULDED	w _p	w		w _L				
	--- CONTINUED FROM PREVIOUS PAGE ---																				
	END OF BOREHOLE																				
	NOTE: 1. Water level in piezometer at a depth of 27.1 m below ground surface (Elevation 152.4 m) on completion of installation. 2. Water level in piezometer at a depth of 14.4 m below ground surface (Elevation 165.1 m) on Oct. 20, 2010. 3. Water level in piezometer at a depth of 25.9 m below ground surface (Elevation 153.6 m) on June 3, 2011.																				

PROJECT 09-1111-6007		RECORD OF BOREHOLE No 2010-2		1 OF 3 METRIC	
G.W.P. 2368-09-00		LOCATION N 4842539.0 ; E 306289.7		ORIGINATED BY PKS/MS	
DIST Central HWY 401		BOREHOLE TYPE D-120 Track-mount, 108 mm Diameter Solid Stem Auger		COMPILED BY TT	
DATUM Geodetic		DATE September 29-30, 2010		CHECKED BY NK/HJ	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)					
								○ UNCONFINED	+ FIELD VANE						● QUICK TRIAXIAL	× REMOULDED				
172.2	ROAD SURFACE																			
0.0	ASPHALT																			
171.8																				
0.4	Sand, some gravel, some silt (FILL)																			
171.1	Compact Brown Moist		1	SS	17						○									
1.1	CLAYEY SILT with to some sand, trace to some gravel (TILL)																			
	Stiff to hard		2	SS	13															
	Grey Moist																			
			3	SS	13							┐┌		2 31 48 19						
			4	SS	15															
			5	SS	14						○									
			6	SS	14															
			7	SS	21						○									
			8	SS	18															
			9	SS	19							┐┌		10 13 54 23						
			10	SS	14															
			11	SS	16						○									
			12	SS	12															

Continued Next Page

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

MIS-MTO 001 09-1111-6007.GPJ GAL-MISS.GDT 6/8/11



2 OF 3 METRIC

PROJECT 09-1111-6007 RECORD OF BOREHOLE N0 2010-2 2 OF 3 METRIC

G.W.P. 2368-09-00 LOCATION N 4842539.0 ; E 306289.7 ORIGINATED BY PKS/MS

DIST Central HWY 401 BOREHOLE TYPE D-120 Track-mount, 108 mm Diameter Solid Stem Auger COMPILED BY TT

DATUM Geodetic DATE September 29-30, 2010 CHECKED BY NK/HJ

SOIL PROFILE					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES	GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT
<div><div><div><div>20</div><div>40</div><div>60</div><div>80</div><div>100</div></div><div><div>○ UNCONFINED + FIELD VANE</div><div>● QUICK TRIAXIAL × REMOULDED</div></div></div><div><div><div>PLASTIC LIMITNATURAL MOISTURE CONTENTLIQUID LIMIT</div><div>w_P w w_L</div><div>WATER CONTENT (%)</div><div>10 20 30</div></div></div><div><div><div>γ</div><div>kN/m³</div></div><div>GR SA SI CL</div></div></div>					
CLAYEY SILT with to some sand, trace to some gravel (TILL) Stiff to hard Grey Moist			NUMBERTYPE"N" VALUES		
---	CONTINUED FROM PREVIOUS PAGE ---				
	Silty sand seam between 18.5 m and 19.0 m depth		13 SS 13		157
					156
			14 SS 35		155
					154
			15 SS 57		153
					152
			16 SS 38		151
					150
			17 SS 34		149
					148
			18 SS 42		147
					146
147.8					145
24.4	SAND AND SILT, trace clay and gravel Dense Grey Wet		19 SS 36		144
					143
145.5					
26.7	SILT, trace sand and clay Very dense Grey Wet				
144.4			20 SS 100/0.25		
27.8	END OF BOREHOLE START OF DCPT at Elevation 144.8 m				

Continued Next Page

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

MIS-MTO 001 09-1111-6007.GPJ GAL-MISS.GDT 6/8/11

PROJECT <u>09-1111-6007</u>		RECORD OF BOREHOLE No 2010-2		3 OF 3 METRIC	
G.W.P. <u>2368-09-00</u>		LOCATION <u>N 4842539.0 ; E 306289.7</u>		ORIGINATED BY <u>PKS/MS</u>	
DIST <u>Central</u> HWY <u>401</u>		BOREHOLE TYPE <u>D-120 Track-mount, 108 mm Diameter Solid Stem Auger</u>		COMPILED BY <u>TT</u>	
DATUM <u>Geodetic</u>		DATE <u>September 29-30, 2010</u>		CHECKED BY <u>NK/HJ</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								○ UNCONFINED + FIELD VANE	w _p w w _L							
--- CONTINUED FROM PREVIOUS PAGE ---							● QUICK TRIAXIAL × REMOULDED									
138.8							142									
33.4	END OF DCPT at Elevation 138.8m NOTES: 1. Borehole caved from a depth of about 30.5 m to 27.4 m. Rods dropped under own weight from 29.6 to 30.5 m during DCPT. 2. Water level in open borehole at a depth of 5.6 m below ground surface (Elevation 166.6 m) 24 hours following completion of drilling.						141									



2 OF 3 METRIC

PROJECT 09-1111-6007 RECORD OF BOREHOLE N0 2010-3 2 OF 3 METRIC

G.W.P. 2368-09-00 LOCATION N 4842502.5 ; E 306327.7 ORIGINATED BY MS

DIST Central HWY 401 BOREHOLE TYPE D-120 Track-mount, 57 mm Diameter Solid Stem Auger COMPILED BY TT

DATUM Geodetic DATE October 1, 2010 CHECKED BY NK/HJ

[illegible]

Continued Next Page

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

MIS-MTO 001 09-1111-6007.GPJ GAL-MISS.GDT 6/8/11

PROJECT <u>09-1111-6007</u>		RECORD OF BOREHOLE No 2010-3		3 OF 3 METRIC	
G.W.P. <u>2368-09-00</u>		LOCATION <u>N 4842502.5 ; E 306327.7</u>		ORIGINATED BY <u>MS</u>	
DIST <u>Central</u> HWY <u>401</u>		BOREHOLE TYPE <u>D-120 Track-mount, 57 mm Diameter Solid Stem Auger</u>		COMPILED BY <u>TT</u>	
DATUM <u>Geodetic</u>		DATE <u>October 1, 2010</u>		CHECKED BY <u>NK/HJ</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL	
								○ UNCONFINED	+	FIELD VANE	● QUICK TRIAXIAL	×	REMOULDED	W _p	W		W _L				
	--- CONTINUED FROM PREVIOUS PAGE --- DCPT REFUSAL at Elevation 144.2 m NOTE: 1. Water level in open borehole at at depth of 24.6 m below ground surface (Elevation 147.9 m) on completion of drilling.																				

MIS-MTO.001 09-1111-6007.GPJ GAL-MASS.GDT 6/8/11

PROJECT 09-1111-6007		RECORD OF BOREHOLE No 2010-4		1 OF 3 METRIC	
G.W.P. 2368-09-00		LOCATION N 4842462.1 ; E 306338.6		ORIGINATED BY MS	
DIST Central HWY 401		BOREHOLE TYPE D-90 Track-mount, 108 mm Diameter Hollow Stem Auger		COMPILED BY TT	
DATUM Geodetic		DATE October 6-7, 2010		CHECKED BY NK/HJ	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × REMOULDED						
178.0	GROUND SURFACE														
0.0	TOPSOIL														
177.7															
0.3	Silty clay, trace to some sand and gravel, containing rootlets (FILL) Stiff to very stiff Brown Moist		1	SS	14						○				
			2	SS	17										
176.5															
1.5	CLAYEY SILT to SILTY CLAY with sand, trace to some gravel (TILL) Stiff to very stiff to Hard below about 32 m depth Brown becoming grey at depth of 4.4 m Moist		3	SS	13						○				
			4	SS	13										
	Containing sand pockets to a depth of 2.9m		5	SS	18						○				
			6	SS	18						○	—			
			7	SS	16						○	—			
			8	SS	11										
			9	SS	18										
			10	SS	15						○				
			11	SS	14						○	—			
			12	SS	23										
			13	SS	23						○				

Continued Next Page

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

MIS-MTO 001 09-1111-6007.GPJ GAL-MISS.GDT 6/8/11

PROJECT <u>09-1111-6007</u>		RECORD OF BOREHOLE No 2010-4		2 OF 3 METRIC	
G.W.P. <u>2368-09-00</u>		LOCATION <u>N 4842462.1 ; E 306338.6</u>		ORIGINATED BY <u>MS</u>	
DIST <u>Central</u> HWY <u>401</u>		BOREHOLE TYPE <u>D-90 Track-mount, 108 mm Diameter Hollow Stem Auger</u>		COMPILED BY <u>TT</u>	
DATUM <u>Geodetic</u>		DATE <u>October 6-7, 2010</u>		CHECKED BY <u>NK/HJ</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × REMOULDED	W _p	W	W _L		
	--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100						
	CLAYEY SILT to SILTY CLAY with sand, trace to some gravel (TILL) Stiff to very stiff to Hard below about 32 m depth Brown becoming grey at depth of 4.4 m Moist		14	SS	19									
			15	SS	24									
			16	SS	13									
			17	SS	12									
			18	SS	29									
			19	SS	26									
			20	SS	27									

Continued Next Page

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

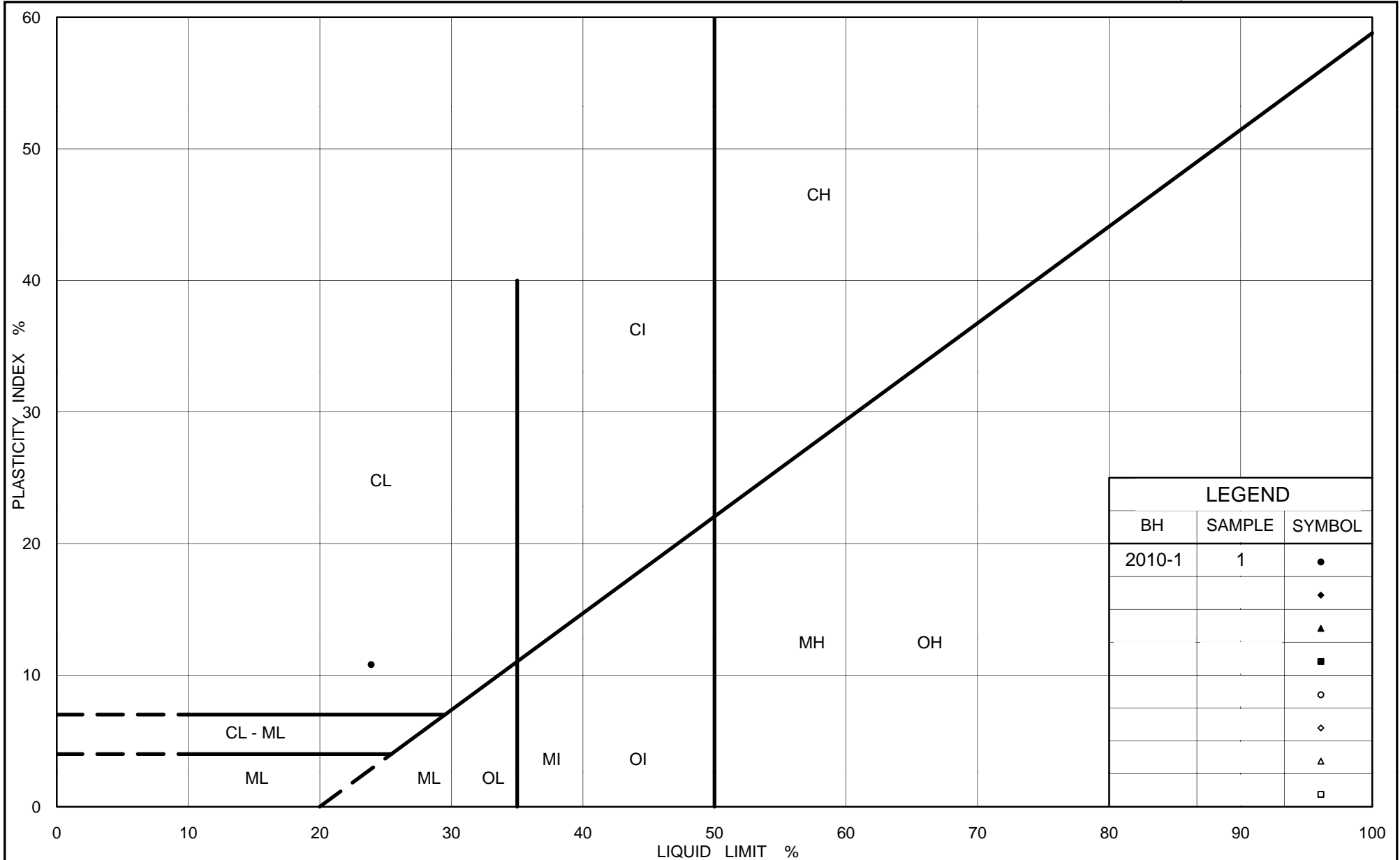
MIS-MTO 001 09-1111-6007.GPJ GAL-MISS.GDT 6/8/11

PROJECT		RECORD OF BOREHOLE		No 2010-4		3 OF 3		METRIC				
G.W.P. 09-1111-6007		LOCATION		N 4842462.1 ; E 306338.6		ORIGINATED BY		MS				
DIST Central HWY 401		BOREHOLE TYPE		D-90 Track-mount, 108 mm Diameter Hollow Stem Auger		COMPILED BY		TT				
DATUM Geodetic		DATE		October 6-7, 2010		CHECKED BY		NK/HJ				
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20 40 60 80 100	20 40 60 80 100	W _p W W _L		
--- CONTINUED FROM PREVIOUS PAGE ---												
	CLAYEY SILT to SILTY CLAY with sand, trace to some gravel (TILL) Stiff to very stiff to Hard below about 32 m depth Brown becoming grey at depth of 4.4 m Moist											
	Containing rock fragments from 32.0 m to 32.6 m		21	SS	135							
143.6												
34.4	Silty SAND, trace clay Very dense Wet Grey		22	SS	100/13							
			23	SS	100/13							
139.6			24	SS	100/11							
38.4	END OF BOREHOLE											
Notes:												
1. Water level in piezometer at a depth of 27.1 m below ground surface (Elevation 150.9 m) on completion of installation.												
2. Water level in piezometer at a depth of 27.8 m below ground surface (Elevation 150.2 m) on October 20, 2010.												
3. Water level in piezometer at a depth of 27.2 m below ground surface (Elevation 150.8 m) on June 3, 2011.												



APPENDIX B

Laboratory Test Results



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PLASTICITY CHART

Clayey Silt Fill

Figure No. B1

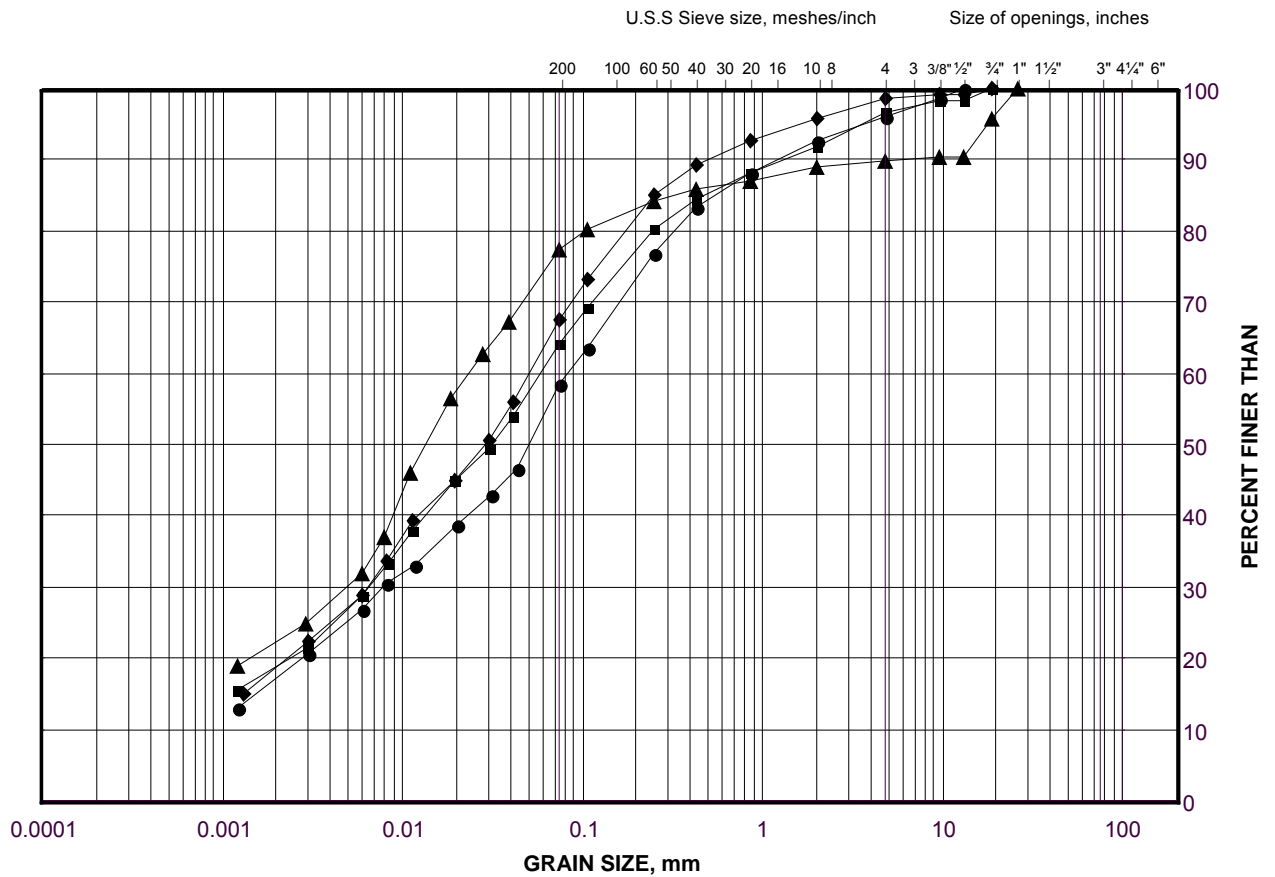
Project No. 09-1111-6007

Checked By:

GRAIN SIZE DISTRIBUTION

Clayey Silt Till

FIGURE B2A



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	2010-1	10	168.5
■	2010-1	13	164.0
◆	2010-2	3	169.6
▲	2010-2	9	162.8

Project Number: 09-1111-6007

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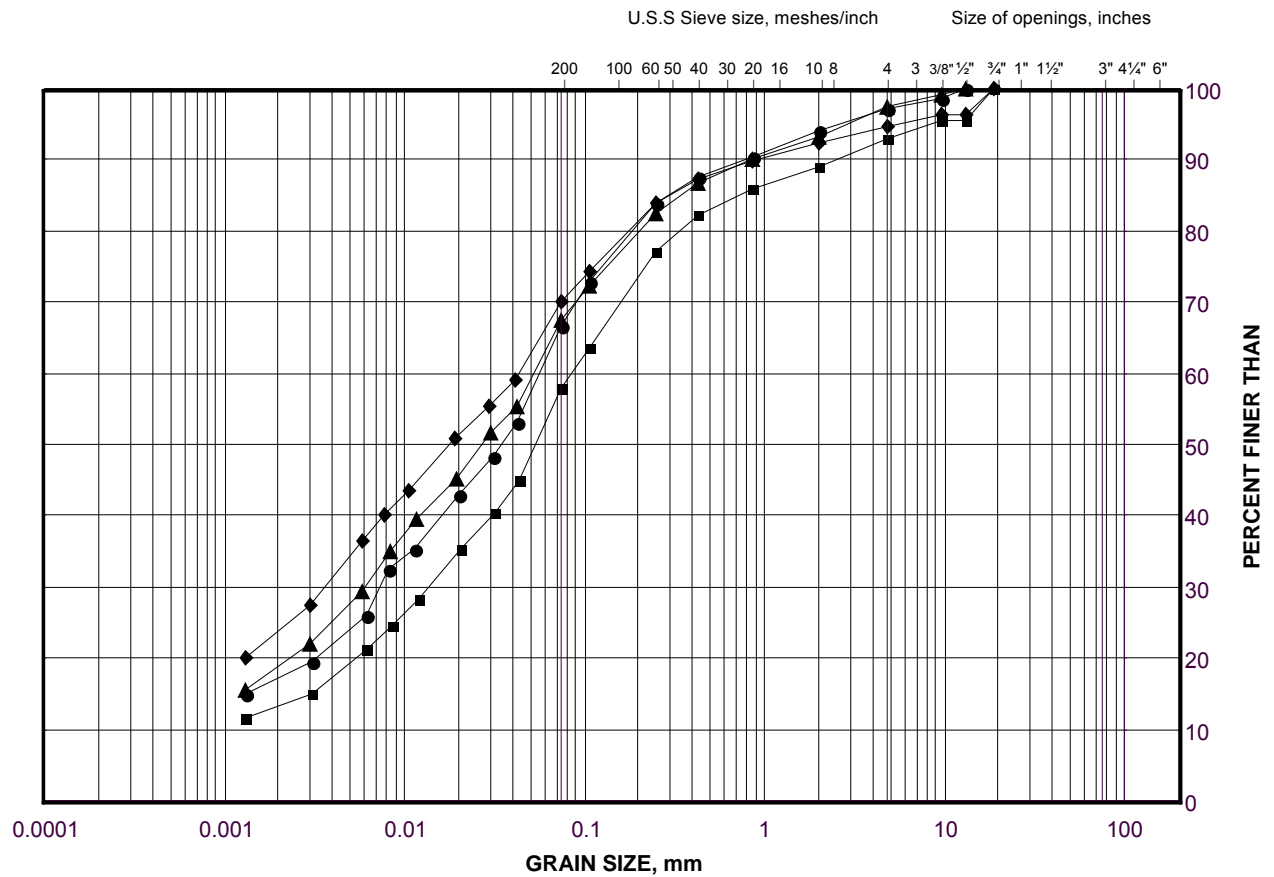
Golder Associates

Date: 03-Mar-11

GRAIN SIZE DISTRIBUTION

Clayey Silt Till

FIGURE B2B



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

LEGEND

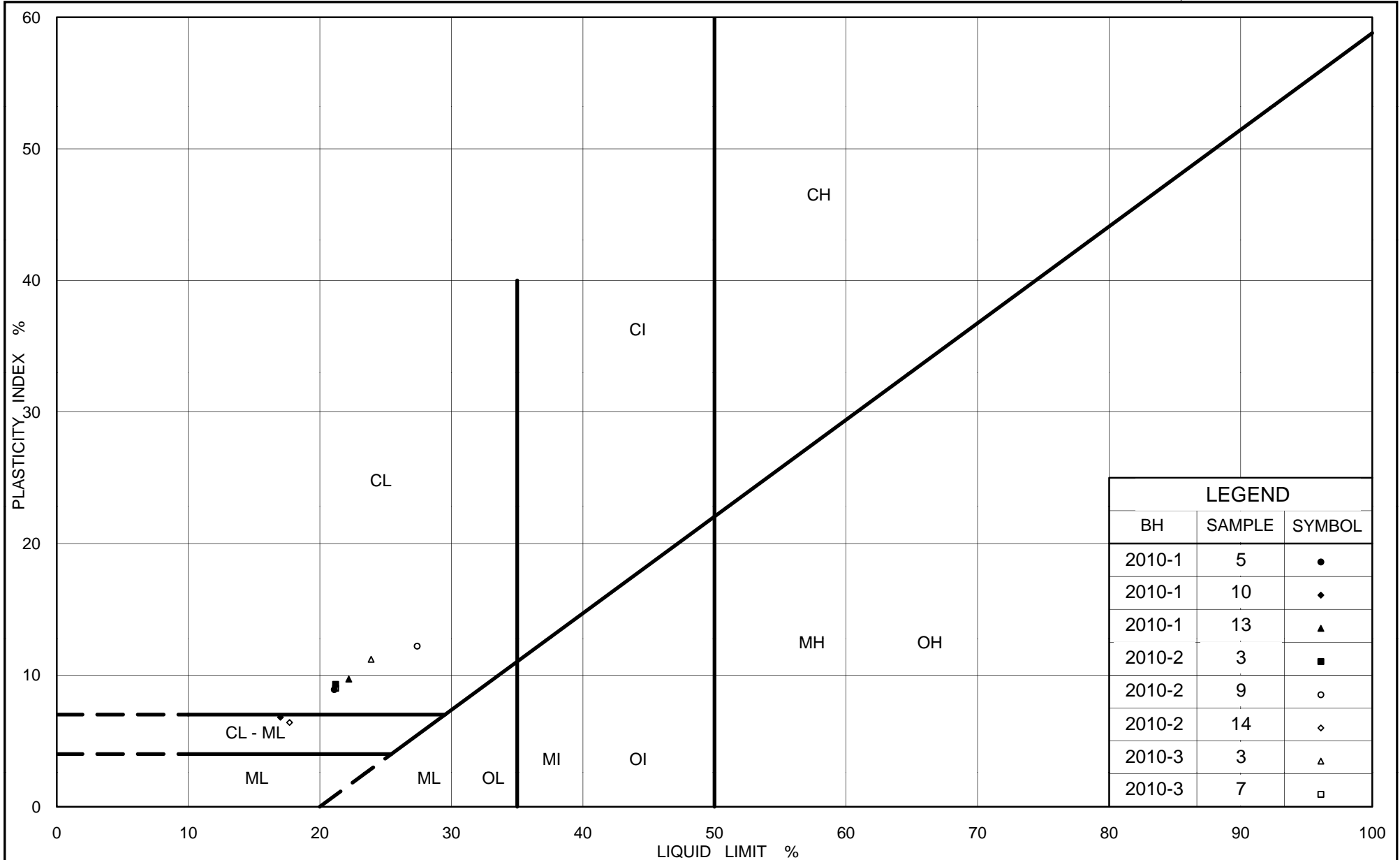
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	2010-4	16	159.4
■	2010-3	16	152.4
◆	2010-4	7	173.1
▲	2010-3	7	166.1

Project Number: 09-1111-6007

Checked By: _____

Golder Associates

Date: 02-Mar-11



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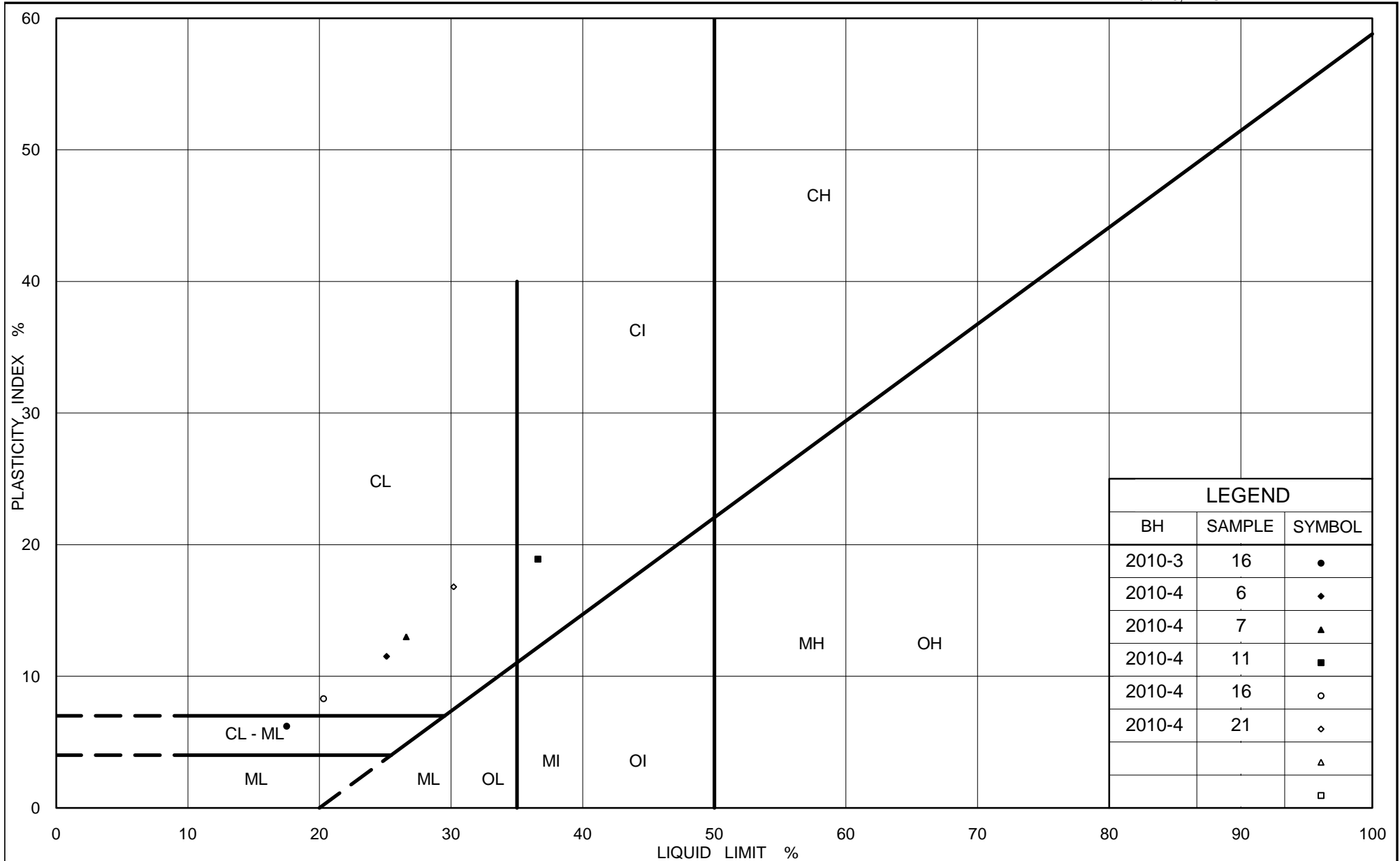
PLASTICITY CHART

Clayey Silt Till

Figure No. B3A

Project No. 09-1111-6007

Checked By:



Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt to Silty Clay/Till

Figure No. B3B

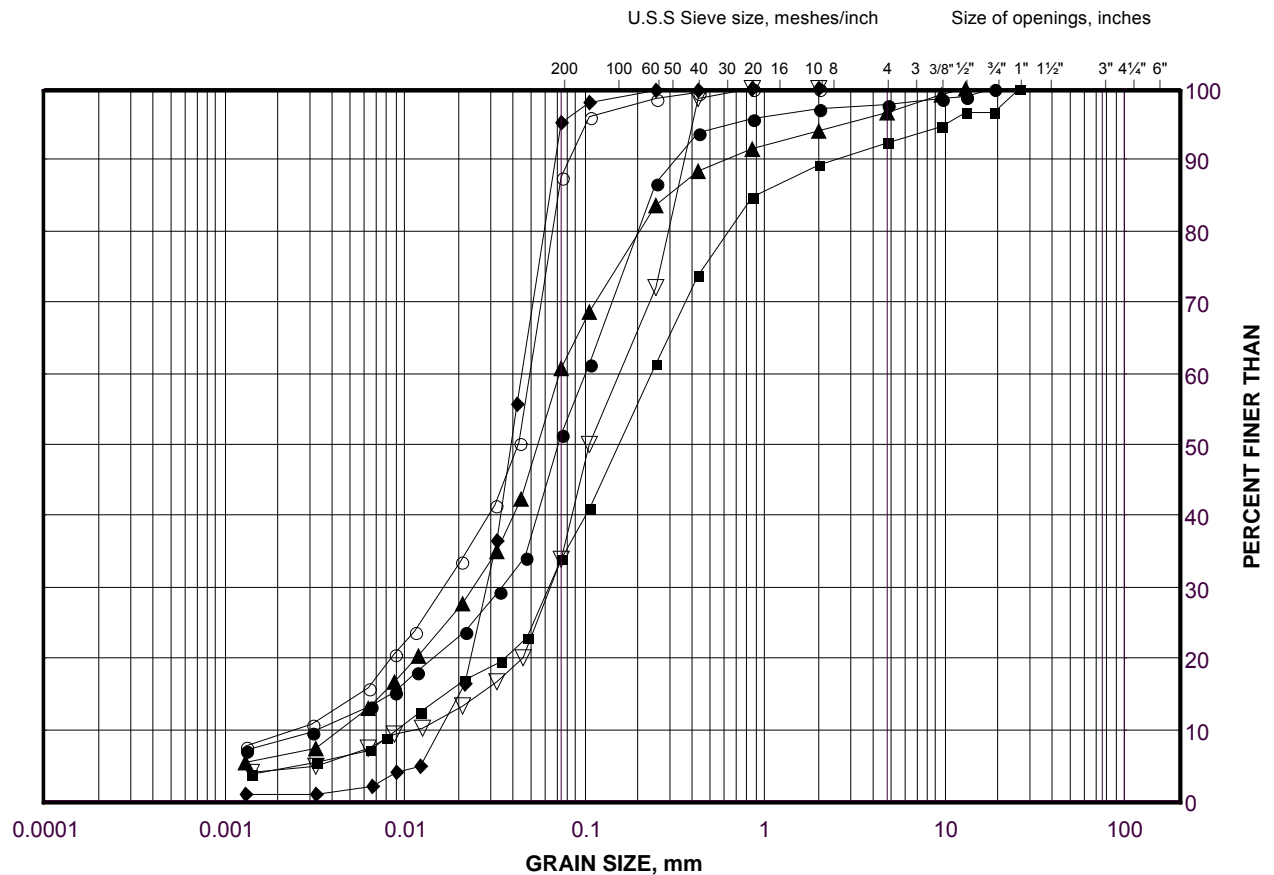
Project No. 09-1111-6007

Checked By:

GRAIN SIZE DISTRIBUTION

Sand and Silt to Sandy Silt to Silt

FIGURE B4



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

LEGEND

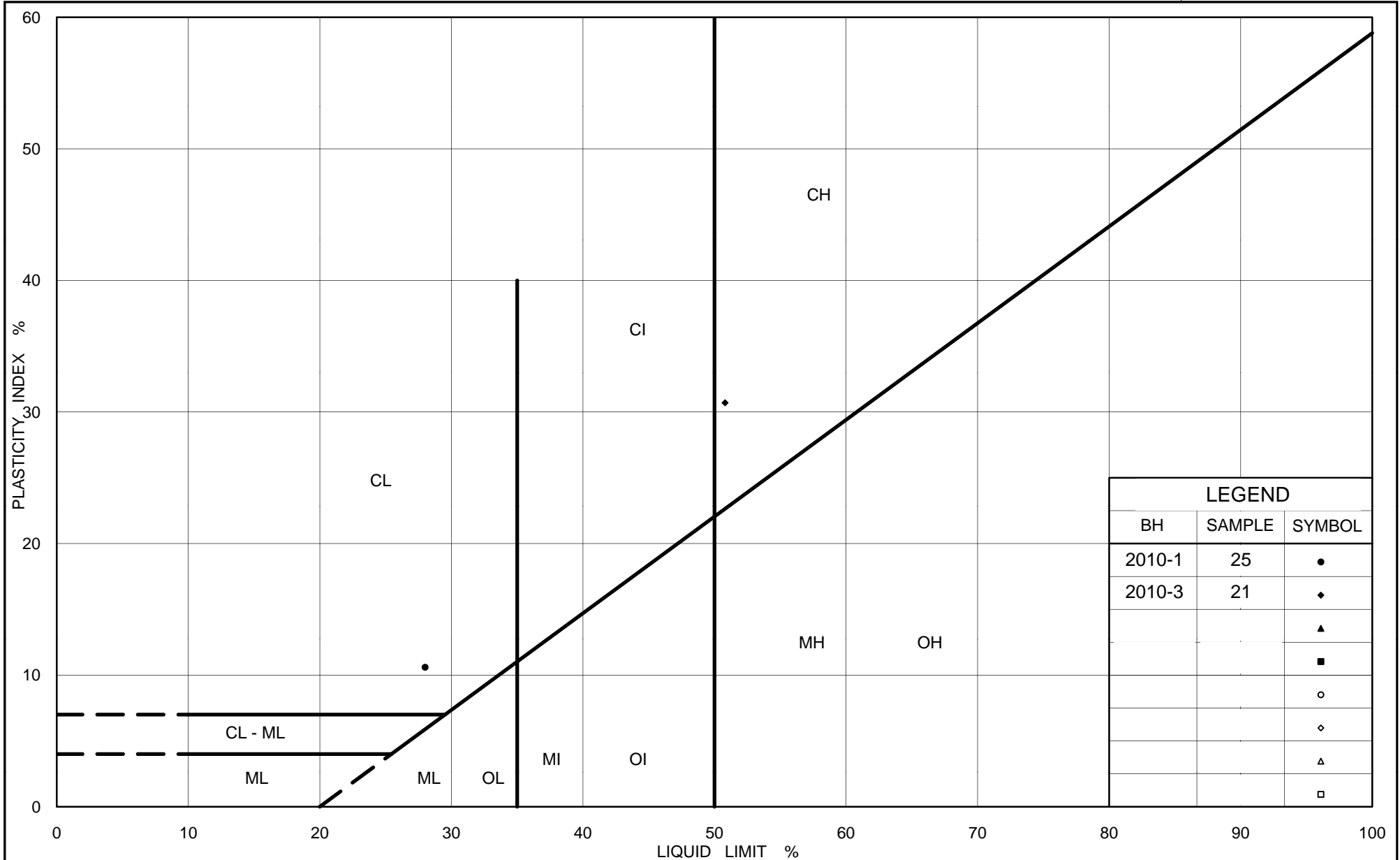
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	2010-2	19	147.5
■	2010-3	20	146.3
◆	2010-2	20	144.6
▲	2010-1	21	145.7
▽	2010-4	22	142.8
○	2010-1	24	138.0

Project Number: 09-1111-6007

Checked By: _____

Golder Associates

Date: 10-Jan-11



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PLASTICITY CHART Clayey Silt and Clay

Figure No. B5

Project No. 09-1111-6007

Checked By:



APPENDIX C

Records of Boreholes from Previous Investigation

RECORD OF BOREHOLE NO. 1

FOUNDATION SECTION

JOB 63-F-87

LOCATION Stn. 229+23 and 227' to rt. of E. Hwy. 401

ORIGINATED BY B.M.G.

W.P. 231-60

BORING DATE Aug. 13, 1963.

COMPILED BY B.M.G.

DATUM G.S.C.

BOREHOLE TYPE Pennsylvania Auger - 3 1/2" Ø

CHECKED BY A.G.S.

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE				LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W			BULK DENSITY P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		BLOWS / FOOT	20	40	60	80	100	WP	WL	
								SHEAR STRENGTH P.S.F.				WATER CONTENT % 10 20 30			
586.7	Groundlevel					590									
0.2	0.6														
	Topsoil														
	Clayey silt-some sand and gravel.		1	SS	43	580									
	(Glacial till).		2	SS	31										
	V. stiff to hard.		3	SS	26	570									
	Brown changing to grey at Elev. 575.7		4	SS	31										
			5	SS	29	560									
			6	SS	56										
			7	SS	33	550									
			8	SS	25										
			9	SS	35	540									
163.1	535.2		10	SS	27										
5.7	51.6					530									
	End of borehole.														

WL
Elev. 555.7

RECORD OF BOREHOLE NO. 2

FOUNDATION SECTION

JOB 63-F-87

LOCATION Stn. 228+40 and 219' to left of E. Hwy. 401

ORIGINATED BY B.M.G.

W.P. 231-60

BORING DATE Aug. 14, 1963.

COMPILED BY B.M.G.

DATUM G.S.C.

BOREHOLE TYPE Pennsylvania Auger - 3 1/2" Ø

CHECKED BY A.G.S.

SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT — WL PLASTIC LIMIT — WP WATER CONTENT — W			BULK DENSITY P.C.F.	REMARKS	
ELEV. DEPTH	DESCRIPTION	STRAT. PLCT	NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	BLOWS / FOOT					WATER CONTENT %				
							20	40	60	80	100	WP	W			WL
							SHEAR STRENGTH P.S.F.									
												10 20 30				
583.3	Groundlevel															
	Topsoil & road fill.															
3.0	Clayey silt - some sand and gravel (Glacial till) V. stiff to hard. Brown changing to grey at Elev. 570		1	SS	35	580										
			2	SS	45	570										
			3	SS	32											
			4	SS	29	560										
			5	SS	41											
			6	SS	38	550										
			7	SS	32											
			8	SS	52	540										
			9	SS	37											
			10	SS	34											
531.8																
51.6	End of borehole.					530										

WD

Elev. 552.3

WL
Elev. 552.3

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