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**FOUNDATION INVESTIGATION AND DESIGN REPORT
BREAKAWAY AND OVERHEAD SIGNS
HIGHWAY 401 RECONSTRUCTION
GWP 65-00-00, AGREEMENT NO. 3006-E-0037
MINISTRY OF TRANSPORTATION –
SOUTHWESTERN REGION**

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LIST OF ABBREVIATIONS

LIST OF SYMBOLS

RECORDS OF BOREHOLES

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PART A – FOUNDATION INVESTIGATION REPORT

**BREAKAWAY AND OVERHEAD SIGNS
HIGHWAY 401 RECONSTRUCTION
GWP 65-00-00, AGREEMENT NUMBER 3006-E-0037
MINISTRY OF TRANSPORTATION – SOUTHWESTERN REGION**

1.0 INTRODUCTION

This report has been revised in order to provide more appropriate subsurface information for the overhead sign located over the Highway 401 eastbound lanes west of Belle River Road. The original report cited borehole 403 from Geocres Report No. 40J2-99 as the closest borehole. However, borehole 403 is on the westbound side of Highway 401 and borehole 404 from the same report is immediately adjacent to the subject overhead sign.

Golder Associates Ltd. (Golder) has been retained by Dillon Consulting Limited (Dillon) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the detail design work for GWP 65-00-00. The project involves the detail design for the widening and improvements of one of the sections of Highway 401 between Windsor and Tilbury and includes:

- Removal of the existing pavement structure full depth and reconstruction with a new concrete pavement structure;
- Widening of the existing roadway to a 6-lane cross section including 3.0 metre fully paved outside shoulders with rumble strips and 3.0 metre paved median shoulders with rumble strips;
- Construction of a concrete tall wall median barrier and a closed drainage system;
- Installation of partial illumination at the Belle River Road interchange;
- Interchange improvements at Belle River Road;
- Rehabilitation of Maidstone Township Road 3 Underpass Structure (Site No. 6-236);
- Rehabilitation and widening of the Belle River Structure (Site No. 6-84);
- Reconstruction of the Belle River Road Overpass Structure (Site No. 6-85);
- Rehabilitation and widening of the Duck Creek Structure, EBL and WBL (Site No. 6-86);
- Rehabilitation of four concrete culverts and replacement of one concrete culvert; and
- Upgrading of permanent highway signing.

The purpose of this foundation investigation was to determine the subsurface conditions at the proposed overhead and breakaway sign locations by drilling boreholes, and carrying out in-situ tests and laboratory tests on selected samples. The terms of reference for the scope of work are outlined in the MTO's Request for Proposal and in Golder's proposal P61-3151 dated January 4, 2007. The work was carried out in accordance with our Quality Control Plan for Foundation Engineering dated March 14, 2007 and our letter regarding foundation engineering services dated April 20, 2007.

Dillon provided Golder with preliminary drawings in digital format for this project.

2.0 SITE DESCRIPTION

2.1 General

GWP 65-00-00 extends along Highway 401 from 1.3 kilometres east of Puce Road easterly to 2.5 kilometres east of Belle River Road. GWP 65-00-00 includes the rehabilitation of one structure, the rehabilitation and widening of two structures, reconstruction of one structure, replacement of one culvert, rehabilitation of four culverts, interchange improvements at Belle River Road, reconstruction of the pavement to a six lane cross-section with a tall wall median barrier and closed drainage system and upgrading of permanent highway signing. The location of the project site is shown on the Key Plan, Figure 1. Upgrading of signage will include the erection of two breakaway signs and four overhead signs.

Highway 401 is one of the most important transportation facilities in Ontario and connects major urban centres in southern Ontario with Quebec and the United States of America. The subject section of Highway 401 is a Class I, controlled access, divided rural freeway. Along most of this section of highway, the existing cross-section consists of a 6.80 metre wide median with both the westbound and eastbound lanes consisting of 3.50 metre wide inner shoulders, two 3.75 metre wide lanes and 3.00 metre wide outer paved shoulders. In the vicinity of the Belle River Road (Essex County Road 27) Interchange, the outer shoulders are 2.50 metres with variable width speed change lanes.

There is a chainage equation at Belle River which marks the boundary between Rochester Township and Maidstone Township. Station 22+814 Maidstone (M) is equivalent to Station 10+000 Rochester (R) at this location.

2.2 Site Geology

The project is located in the Essex Clay Plain, a subregion of the physiographic region of southern Ontario known as the St. Clair Clay Plain, as identified in "The Physiography of Southern Ontario" by Chapman and Putnam (1984). The clay plain is described as a till plain that has been locally smoothed by shallow deposits which settled in depressions in the till. The prevailing soil type is reported to be the Brookston clay.

Based on the Ontario Department of Mines and Northern Affairs Preliminary Maps P.749 and P.750 entitled "Quaternary Geology of the Windsor-Essex Area" Western and Eastern Parts, respectively, the project area is reportedly located in predominantly clayey silt till.

The thickness of the overburden varies from 34 to 37 metres according to Preliminary Map P.815 entitled "Drift Thickness Series, Windsor-Essex Area (Eastern Part)" dated 1973. The subcropping bedrock is reported to be limestone of the Dundee formation of Middle Devonian

Age (Geological Survey of Canada, Map 1263A entitled "Geology, Toronto-Windsor Area", dated 1969).

3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out on October 16 and 17, 2007 at which time five boreholes (801 to 805) were drilled. In addition, borehole 404 from Geocres Report No. 40J2-99 has been included. The borehole locations are indicated on Drawing 1.

The as-drilled borehole locations, ground surface elevations and borehole depths are as follows:

<u>BOREHOLE</u>	<u>LOCATION (m)</u>		<u>GROUND SURFACE ELEVATION</u>	<u>BOREHOLE DEPTH</u>
	<u>Northing</u>	<u>Easting</u>	(m)	(m)
BREAKAWAY SIGNS				
801	4,677,609	284,334	184.34	3.05
802	4,677,596	284,734	184.15	3.05
OVERHEAD SIGNS				
803	4,677,504	286,221	183.81	6.10
804	4,677,507	287,724	183.03	6.10
805	4,677,471	288,722	182.25	6.10
403	4,677,510	287,220	187.44	8.08
404	4,677,479	287,229	187.56	8.08

The soil stratigraphy encountered in the boreholes is shown on the attached Record of Borehole sheets.

The boreholes were advanced using an all terrain vehicle mounted power auger supplied and operated by a specialist drilling contractor. Samples of the overburden were obtained at suitable intervals of depth using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures.

Groundwater conditions were monitored in the boreholes throughout the drilling operations. The boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 128/03.

The field work was supervised on a full-time basis by experienced members of our engineering staff who arranged for underground utility locates, directed the drilling, sampling and in situ testing operations, logged the boreholes and cared for the samples obtained. The soil samples were identified in the field, placed in labelled containers and transported to Golder's London laboratory for further examination and routine testing. Index and classification tests consisting of water content determinations, grain size distribution analyses and Atterberg limits determinations

were carried out on selected samples. The results of the field and laboratory testing are given on the Record of Borehole sheets and in Appendix A.

4.0 SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of the in situ and laboratory testing are provided on the attached Record of Borehole sheets following the text of this report and in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and observations of drilling resistance and may represent transitions between soil types rather than exact planes of geological change. Further, the subsurface conditions may vary significantly between and beyond the borehole locations.

In summary, the boreholes drilled for the proposed breakaway and overhead signs encountered topsoil or the pavement structure underlain by clayey fill and deposits of silty clay till or clayey silt till to the termination of the boreholes.

A detailed description of the subsurface conditions encountered in the boreholes is provided on the Record of Borehole sheets and is summarized in the following sections.

4.2 Breakaway Signs (Boreholes 801 and 802)

4.2.1 Topsoil and Fill

Topsoil layers about 100 and 280 millimetres thick were encountered at ground surface in boreholes 801 and 802.

A layer of clayey fill material about 280 millimetres thick was encountered beneath the surficial topsoil in borehole 801 at elevation 184.2 metres.

A layer of buried topsoil of about 110 millimetres thick was encountered in borehole 801 beneath the fill layer at about elevation 184.0 metres.

4.2.2 Silty Clay Till

Silty clay till was found beneath the buried topsoil layer in borehole 801 from elevation 183.9 metres. The silty clay till is stiff to very stiff with N values, as determined in the standard penetration testing, of 11 to 22 blows per 0.3 metres. The borehole was terminated in the silty clay till after exploring it for 2.6 metres.

Water contents in the silty clay till ranged from 16 to 18 per cent. The silty clay till is of intermediate plasticity based a single Atterberg limits determination which indicated a plastic

limit of 18 per cent, a liquid limit of 38 per cent and plasticity index of 20 per cent. The results of the Atterberg limits testing are shown on Figure A-4. A grain size distribution curve for a sample of the silty clay till recovered from the standard penetration testing is shown on Figure A-2.

4.2.3 Clayey Silt Till

Clayey silt till was encountered beneath the topsoil in borehole 802 from elevation 183.9 metres. The borehole was terminated in the clayey silt till after exploring it for 2.8 metres. The N values of the clayey silt till ranged from 7 to 25 blows per 0.3 metres. The water content of the clayey silt till typically ranged from 17 to 22 per cent. A single Atterberg limits determination indicated plastic and liquid limits of 17 and 31 per cent, respectively, with a plasticity index of 14 per cent. The results of the Atterberg limits plasticity testing, as shown on Figure A-4, indicate an inorganic clayey soil of low plasticity.

The results of grain size testing carried out on a single sample of the clayey silt till recovered from the standard penetration testing conducted in borehole 802 are shown on Figure A-3.

4.2.4 Cobbles and Boulders

Although not specifically encountered in the boreholes, cobbles and boulders should be anticipated when excavating through the silty clay and clayey silt till deposits.

4.3 Overhead Signs (Boreholes 803 to 805 and 404)

4.3.1 Pavement Structure

Borehole 404 was drilled through the paved shoulder of Highway 401. A layer of asphalt approximately 210 millimetres thick was encountered at the surface of the borehole. Two layers of sand and gravel roadbase material with a combined thickness of about 310 millimetres were encountered beneath the asphalt in the borehole from elevation 187.4 metres.

4.3.2 Topsoil and Fill

Topsoil layers about 100 millimetres thick were encountered at ground surface in boreholes 803 to 805.

Layers of clayey fill materials about 260 to 360 millimetres thick were encountered beneath the surficial topsoil in boreholes 803 to 805 between elevation 182.2 and 183.7 metres. The average thickness of the clayey fill layers was 300 millimetres.

Beneath the pavement structure in borehole 404, clayey silt fill material associated with the roadway embankment was found to about elevation 183.6 metres. The clayey silt fill had N values which ranged from 7 to 15 blows per 0.3 metres. The water content of the clayey silt fill was 19 per cent based on a single sample. The clayey silt fill had corresponding plastic and liquid limits of 15 and 34 per cent, respectively, with a plasticity index of 19 per cent, as shown on Figure A-4, based on the results of one Atterberg limits determination.

The results of a grain size analysis carried out on a single sample of the clayey fill are shown on Figure A-1.

Buried topsoil layers were found in borehole 805 from elevation 181.9 metres and from elevation 183.6 metres in borehole 404. The buried topsoil layers were 200 millimetres thick in borehole 805 and 310 millimetres thick in borehole 404. The silty topsoil had a water content of 19 per cent.

4.3.3 Silty Clay Till

Stiff to hard silty clay till was found beneath the fill from elevations 182.6 to 183.4 metres in boreholes 803 and 804 and from elevation 181.7 metres below the buried topsoil in borehole 805. Grain size distribution curves for representative samples of the silty clay till material are presented on Figure A-2.

The silty clay till had N values of 10 to 34 blows per 0.3 metres and water contents varying from 15 to 21 per cent. The silty clay till is of intermediate plasticity with plastic limits of 17 to 19 per cent, liquid limits of 35 to 37 per cent and plasticity indices of 17 to 19 per cent. The results of the Atterberg limits testing are shown on Figure A-4.

4.3.4 Clayey Silt Till

Clayey silt till was encountered beneath the buried topsoil in borehole 404 from elevation 183.3 metres. Borehole 404 was terminated in the clayey silt till after exploring it for 3.8 metres. The N values of the clayey silt till ranged from 22 to 41 blows per 0.3 metres. The water content of the clayey silt till was 15 per cent based on a single sample. The clayey silt till had plastic and liquid limits of 16 and 32 per cent, respectively, and a plasticity index of 16 per cent. The results of a single Atterberg limits determination testing are shown on Figure A-4 and indicate an inorganic clayey soil of low plasticity.

The results of grain size analyses carried out on two samples of the clayey silt till retrieved from standard penetration testing in borehole 404 are shown on Figure A-3.

4.3.5 Cobbles and Boulders

Although not specifically encountered in the boreholes, cobbles and boulders should be anticipated in the silty clay till and clayey silt till deposits.

4.4 Groundwater Conditions

Groundwater conditions were observed in the boreholes during drilling. All boreholes advanced during the current investigation were observed to be dry both during and at the completion of drilling.

The long term groundwater level at the borehole locations are summarized in the following table and are based on the conditions encountered in the boreholes such as the colour change from brown to grey and encountered and measured water levels at neighbouring sites within the project area. Seasonal variations in the groundwater levels should be expected.

<u>BOREHOLE</u>	<u>INFERRED GROUNDWATER LEVEL</u> (elevation - m)
801	182
802	181
803	180
404	181
804	181
805	180

5.0 MISCELLANEOUS

This investigation was carried out using equipment supplied and operated by Lantech Drilling Services Inc., an Ontario Ministry of the Environment licensed well contractor. The field operations were supervised by Mr. Michael Arthur under the direction of Mr. David J. Mitchell. The laboratory testing was carried out at Golder's London laboratory under the direction of Mr. Chris M. Sewell. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories and MTO.

This report was prepared by Ms. Dirka U. Prout, P. Eng. under the direction of the Project Manager, Mr. Philip R. Bedell, P. Eng. This report was reviewed by Mr. Fintan J. Heffernan, P. Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

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PART B - FOUNDATION DESIGN REPORT

OVERHEAD SIGNS

HIGHWAY 401 RECONSTRUCTION

GWP 65-00-00, AGREEMENT NUMBER 3006-E-0037

MINISTRY OF TRANSPORTATION – SOUTHWESTERN REGION

6.0 ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides our recommendations on the foundation aspects of the design of the proposed overhead signs to be constructed as part of GWP 65-00-00. The recommendations are based on our interpretation of the factual information obtained during the investigation. It should be noted that the interpretation and recommendations are intended for use only by the design engineer. Where comments are made on construction they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Based on the information provided, the overhead signs are to be located approximately as follows and the relevant boreholes are:

<u>LOCATION</u>	<u>DIRECTION</u>	<u>BOREHOLE</u>
22+265 (M)	Eastbound	803
10+450 (R)	Eastbound	404
10+950 (R)	Westbound	804
11+950 (R)	Westbound	805

6.2 Caisson Foundations for Overhead Signs

Caisson foundations for overhead sign supports should be designed in accordance with the requirements in MTO's *Sign Support Manual*. The *Sign Support Manual* includes a standard caisson foundation design (Section 4 and Standard Drawings SS118-3, SS118-4 and SS118-5), in which the caissons are extended 5 metres below the design frost depth (i.e. a total length of 6.2 metres below grade for this project), except where bedrock is encountered within this depth. The standard design is based on the following minimum soil conditions:

- **Case 1 (Cohesionless Soils):** Sand with a friction angle of 28 degrees surrounding the upper two-thirds of the portion of the caisson foundation below the frost depth, and sand with a friction angle of 30 degrees surrounding the lower third of the portion of the caisson below the design frost depth.
- **Case 2 (Cohesive Soils):** Soft clay with an undrained shear strength of 25 kilopascals (kPa) surrounding the upper two-thirds of the portion of caisson foundation below the frost depth, and "soft" clay with an undrained shear strength of 50 kPa surrounding the lower third of the portion of the caisson below the design frost depth.

Based on the review of the subsurface information, Case 2 applies and the subsurface soils at all of the proposed sign sites have undrained shear strengths that exceed the input parameters used in the modeling of the standard caisson foundations and, therefore, the standard caisson foundation design is suitable for these sites.

However, should detailed analysis of the caisson foundation be required, the following unfactored parameters may be used:

<u>SOIL TYPE</u>	<u>ANGLE OF FRICTION ϕ</u> (°)	<u>COHESION c_u</u> (kPa)	<u>TOTAL UNIT WEIGHT γ</u> (kN/m ³)	<u>SHAFT RESISTANCE FACTOR (α)</u>
Clayey Fill (embankment at Borehole 404)	25	75	19.0	0.3
Clayey Silt Till - Borehole 404	30	210	20.5	0.4
Silty Clay Till - Boreholes 803, 804, 805 above elevation 180 metres	28	160	20.0	0.4
- Boreholes 803, 804, 805 below elevation 180 metres	28	120	19.5	0.3

6.2.1 Vertical Loads

Based on the subsurface conditions encountered in the boreholes, the unit shaft resistance that may be used in the assessment of the vertical load carrying capacity of the caissons may be calculated using the following equation:

$$F_s = \alpha c_u d C$$

where α is a shaft resistance factor and d is the depth along the caisson, C is the circumference of the caisson and c_u is the average undrained shear strength of each layer.

The upper 1.2 metres below the ground surface should be neglected to account for frost action. While any portion of the caisson within fill materials would normally be neglected, the overhead sign foundation at station 10+450 (R) will be partially founded within the embankment clayey fill material, therefore, at this location, it will be necessary to utilize the fill to resist the applied loadings with the parameters for the fill given in the table in Section 6.2 above.

The component of vertical load carrying capacity that may be derived from end bearing for the standard 1.0 to 1.2 metre diameter caissons in the cohesive soils may be calculated using the following equation:

$$Q_b = 6c_u A_b$$

where c_u is the undrained shear strength of the cohesive founding layer and A_b is the cross-sectional area of the caisson.

A resistance factor of 0.4 should be applied to obtain the factored axial resistance at ultimate limit states (ULS). The axial resistance at serviceability limit states (SLS) is greater than at ULS and ULS values will govern design.

6.2.2 Lateral Loads

The lateral loads exerted by the caissons will be resisted by cohesive soils. The lateral resistance of the cohesive soils along the shaft is represented by a constant distribution with depth and given by $9c_u B$ where c_u is the undrained shear strength in kilopascals and B is the shaft diameter in metres. The unfactored lateral force resisted by a shaft of length L (in metres) is given by:

$$P = 9 c_u B (L - 1.5B)$$

The above equation is based on the assumption that the lateral geotechnical resistance acts over a width equal to 3 times the shaft diameter. Also, large deformations (lateral movement) would be required to fully mobilize lateral shaft resistance. A resistance factor of 0.5 should be applied to obtain the factored lateral resistance at ULS.

The passive resistance in front of the caisson within the upper 1.2 metres below the ground surface should be neglected in the design of the foundation to account for frost action.

Where an undrained shear strength, c_u , is provided, the undrained capacity of the caisson should be checked to determine whether the drained or undrained case will govern. In this case, the lateral resistance for the length of the caisson within cohesive soil should be calculated assuming an unfactored passive lateral pressure distribution varying linearly from $2 c_u$ at the surface to $9 c_u$ at a depth of three pile diameters and beyond acting over the actual width of the caisson. A resistance factor of 0.5 should be applied to this calculated lateral resistance in order to obtain the factored lateral geotechnical resistance.

In general, any portion of the caisson within fill and/or organic materials should be neglected; however, as indicated above, the overhead sign at Station 10+450 (R) will be partially founded within the embankment clayey fill material, therefore, at this location, it will be necessary to utilize the fill to resist the applied loadings with the parameters for the fill given in the table in Section 6.2, above.

6.3 Construction Considerations

A temporary liner will be required to support the sides of the excavation and permit cleaning and inspection of the base. Careful cleaning of the base of the caisson should be carried out prior to placement of concrete to remove all loosened or disturbed materials. Surface water run off should be directed away from the excavation. The caissons should be constructed and inspected in accordance with SP903S01.

7.0 MISCELLANEOUS

This report was prepared by Ms. Dirka U. Prout, P. Eng. under the direction of the Project Manager, Mr. Philip R. Bedell, P. Eng. This report was reviewed by Mr. Fintan J. Heffernan, P. Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

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LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

III. SOIL DESCRIPTION

(a) Cohesionless Soils

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

(b) Cohesive Soils

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

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

IV. SOIL TESTS

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

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

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 ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

RECORD OF BOREHOLE No 404

1 OF 1

METRIC

PROJECT 07-1130-035-1-8

G.W.P. 65-00-00

LOCATION N 4677478.7 ; E 287228.6

ORIGINATED BY DM

DIST 1 HWY 401

BOREHOLE TYPE HOLLOW STEM AUGER

COMPILED BY DCH

DATUM GEODETIC

DATE July 10, 2007

CHECKED BY

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		W _p	W	W _L		
187.56	ASPHALT SURFACE													1 18 46 35
0.00	ASPHALT													
0.21	FILL, crushed rock													
0.34	FILL, sand & gravel													
0.52	Brown													
	FILL, clayey silt, some sand, trace gravel		1	SS	8									
	Firm to very stiff													
	Brown & grey, mottled		2	SS	7									
			3	SS	14									
			4	SS	15									
183.60														
3.96	TOPSOIL, sandy silt, trace clay, trace organics	5	SS	14										
183.29	Compact													
4.27	Dark grey													
	CLAYEY SILT (TILL), trace sand	6	SS	22										
	Very stiff to hard													
	Brown becoming grey at about elev. 180.6m													
			7	SS	41									
179.48			8	SS	30									
8.08	END OF BOREHOLE													
	Borehole dry during drilling on July 10, 2007.													

RECORD OF BOREHOLE No 801

1 OF 1

METRIC

PROJECT 07-1130-035-1-8

G.W.P. 65-00-00

LOCATION N 4677608.9 ; E 284334.1

ORIGINATED BY MA

DIST 1 HWY 401

BOREHOLE TYPE HOLLOW STEM AUGER

COMPILED BY BRS

DATUM GEODETIC

DATE October 17, 2007

CHECKED BY

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		W _p	W	W _L		
184.34	GROUND SURFACE							20 40 60 80 100						GR SA SI CL
0.10	TOPSOIL, silty Brown						184							
0.38	FILL, clayey silt, trace sand, trace gravel, trace topsoil Brown													
0.49	TOPSOIL, silty Brown		1	SS	11							○		
	SILTY CLAY (TILL), some sand, trace gravel Stiff to very stiff Brown		2	SS	22		183					○		
							182							
181.29			3	SS	18							⦿		0 15 43 42
3.05	END OF BOREHOLE													
	Borehole dry during drilling on October 17, 2007.													

RECORD OF BOREHOLE No 802

1 OF 1

METRIC

PROJECT 07-1130-035-1-8
G.W.P. 65-00-00 LOCATION N 4677595.5 ; E 284733.9 ORIGINATED BY MA
DIST 1 HWY 401 BOREHOLE TYPE HOLLOW STEM AUGER COMPILED BY BRS
DATUM GEODETIC DATE October 17, 2007 CHECKED BY

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								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
184.15	GROUND SURFACE						20	40	60	80	100					
0.00	TOPSOIL, silty Brown															
0.28	CLAYEY SILT (TILL), some sand with silt seams, trace gravel Firm to very stiff Brown															
		1	SS	7												
		2	SS	14												
181.10			3	SS	25											
3.05	END OF BOREHOLE															
	Borehole dry during drilling on October 17, 2007.															

RECORD OF BOREHOLE No 803

1 OF 1

METRIC

PROJECT 07-1130-035-1-8
G.W.P. 65-00-00 LOCATION N 4677503.6 ; E 286221.4 ORIGINATED BY MA
DIST 1 HWY 401 BOREHOLE TYPE HOLLOW STEM AUGER COMPILED BY BRS
DATUM GEODETIC DATE October 15, 2007 CHECKED BY

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 × LAB VANE									
183.81	GROUND SURFACE							20 40 60 80 100										
0.10	TOPSOIL, silty Brown																	
0.38	FILL, clayey silt, trace sand, trace gravel Brown																	
	SILTY CLAY (TILL), some sand, trace gravel Stiff to hard Brown becoming grey at about elev. 180.2m		1	SS	14		183					○						
			2	SS	15		182					○						
			3	SS	34		181					○						
			4	SS	24		180					○						
			5	SS	12		179					○						
			6	SS	10		178											
			7	SS	10		177											
177.71	END OF BOREHOLE																	
6.10	Borehole dry during drilling on October 15, 2007.																	

RECORD OF BOREHOLE No 804

1 OF 1

METRIC

PROJECT 07-1130-035-1-8
G.W.P. 65-00-00 LOCATION N 4677506.6 ; E 287724.4 ORIGINATED BY MA
DIST 1 HWY 401 BOREHOLE TYPE HOLLOW STEM AUGER COMPILED BY BRS
DATUM GEODETIC DATE October 16, 2007 CHECKED BY

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									
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE						
183.03	GROUND SURFACE																
0.10	TOPSOIL, silty Brown																
182.57	FILL, clayey silt, trace sand, trace gravel, trace topsoil Brown																
0.46	SILTY CLAY (TILL), some sand, trace gravel Stiff to very stiff Brown becoming grey at about elev. 179.8m		1	SS	13									○			
			2	SS	23									○		0 18 45 37	
			3	SS	25									○			
			4	SS	16									○			
			5	SS	14									○			
			6	SS	10									○			
			7	SS	12									○			
176.93	END OF BOREHOLE																
6.10	Borehole dry during drilling on October 16, 2007.																

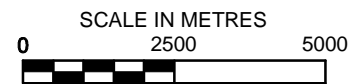
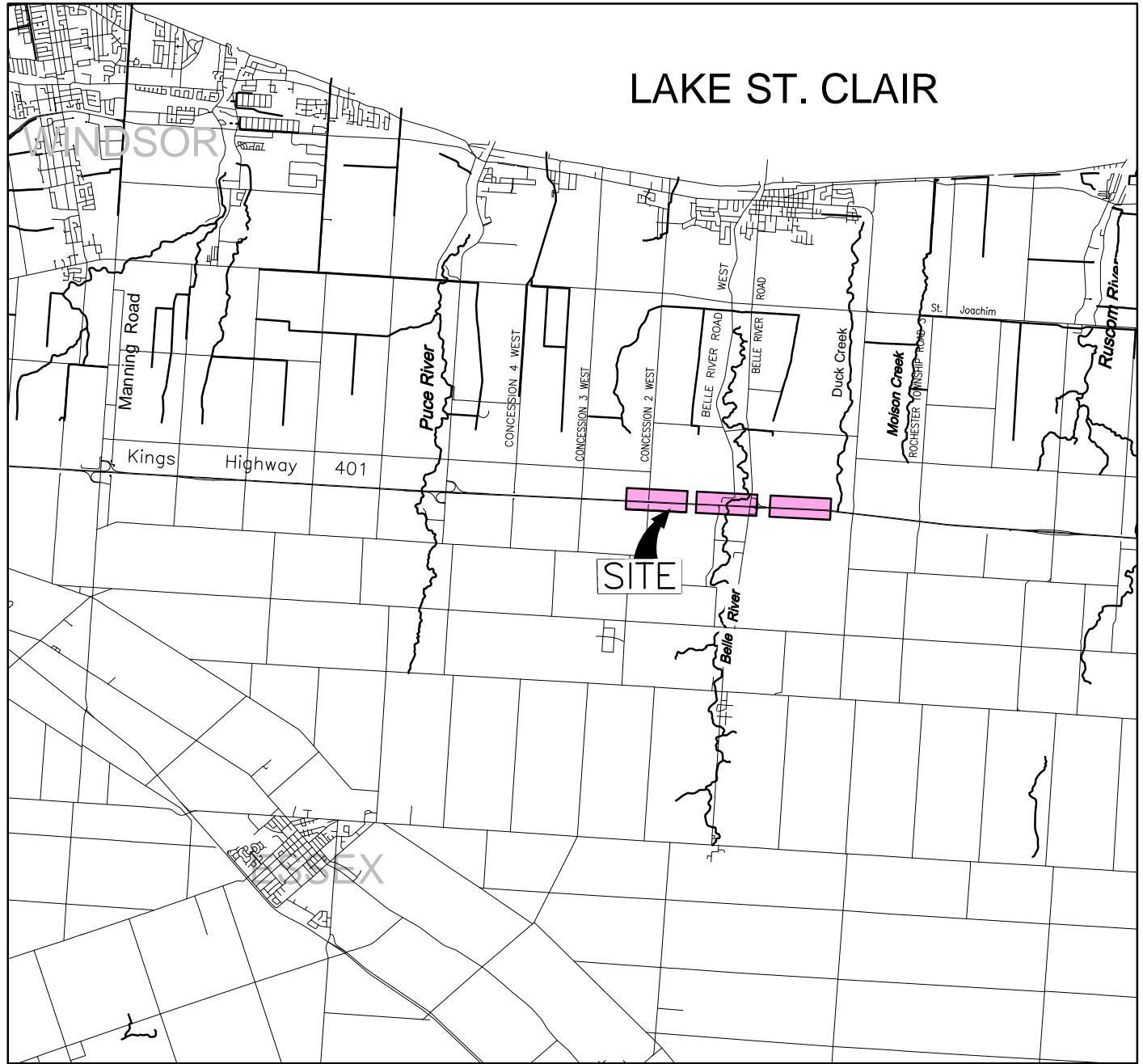
RECORD OF BOREHOLE No 805


1 OF 1

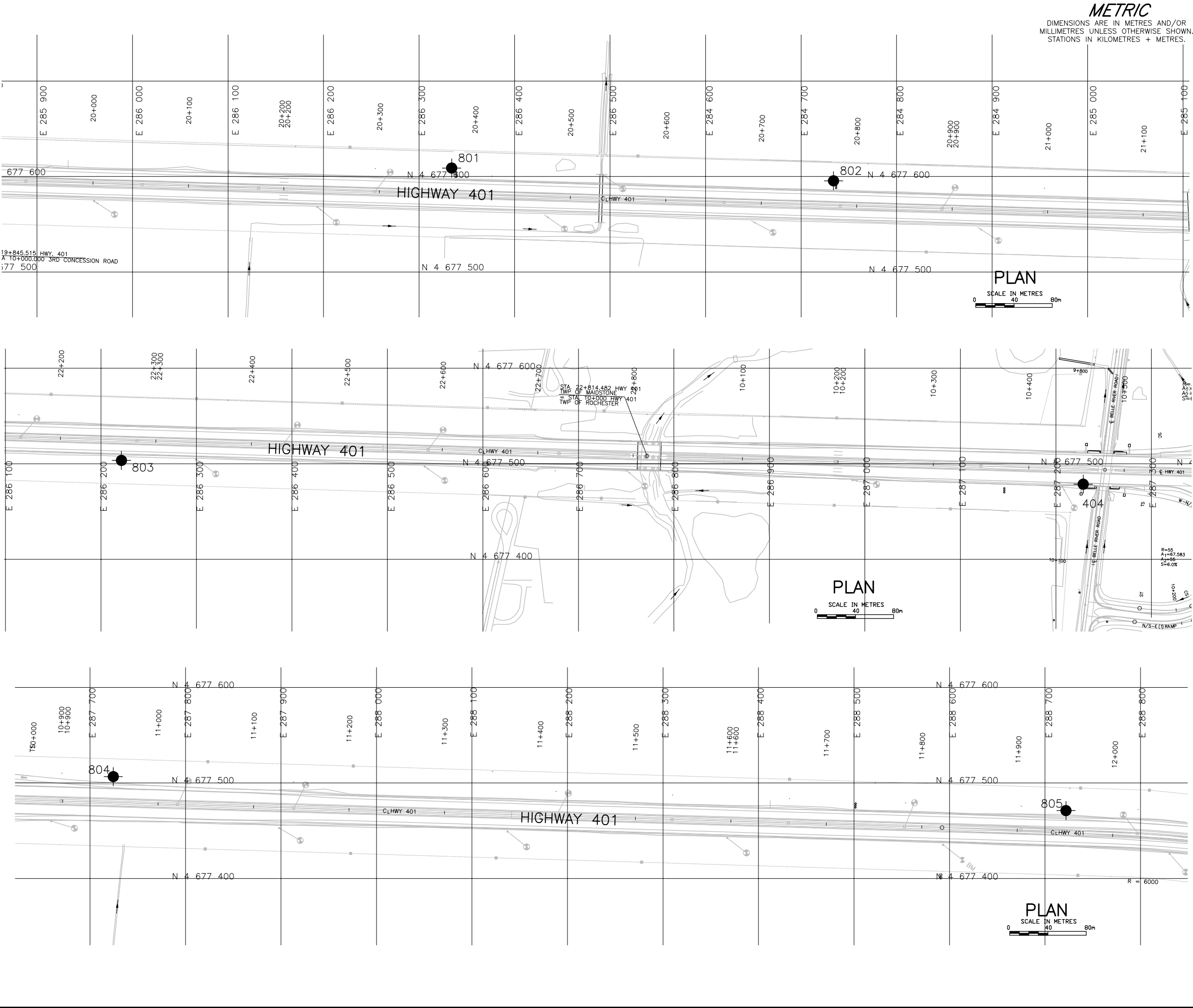
METRIC

PROJECT 07-1130-035-1-8
G.W.P. 65-00-00 LOCATION N 4677471.1 ; E 288721.9 ORIGINATED BY MA
DIST 1 HWY 401 BOREHOLE TYPE HOLLOW STEM AUGER COMPILED BY BRS
DATUM GEODETIC DATE October 16, 2007 CHECKED BY

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 (%)				
								○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × LAB VANE						
182.25	GROUND SURFACE							20 40 60 80 100							GR SA SI CL
0.10	TOPSOIL, silty Brown														
0.36	FILL, clayey silt, trace sand, trace gravel, trace topsoil Brown														
0.56	TOPSOIL, silty Brown		1	SS	12							○			
	SILTY CLAY (TILL), some sand, trace gravel Stiff to very stiff Brown becoming grey at about elev. 178.0m		2	SS	12										
			3	SS	25							○	—		2 14 45 39
			4	SS	23										
			5	SS	19							○			
			6	SS	15										
			7	SS	13							○			
176.15	END OF BOREHOLE														
6.10	Borehole dry during drilling on October 16, 2007.														



PROJECT		BREAKAWAY AND OVERHEAD SIGNS HIGHWAY 401 RECONSTRUCTION GWP 65-00-00			
TITLE		KEYPLAN			
 Golder Associates LONDON, ONTARIO		PROJECT No. 07-1130-035-1-8		FILE No. 07113003518-R01001	
		CADD	BRS	Nov. 5/07	SCALE AS SHOWN
		CHECK			REV. 0
					FIGURE 1



CONT No.
WP No. 65-00-00

BREAKAWAY AND OVERHEAD SIGNS
HIGHWAY 401 RECONSTRUCTION

BOREHOLE LOCATIONS

SHEET

Golder Associates Ltd.
LONDON, ONTARIO, CANADA

KEY PLAN
SCALE
1000 0 1000m

Borehole – Current Investigation

LEGEND

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
801	184.34m	4 677 608.9	284 334.1
802	184.15m	4 677 595.5	284 733.9
803	183.81m	4 677 503.6	286 221.4
804	183.03m	4 677 506.6	287 724.4
805	182.25m	4 677 471.1	288 721.9
404	187.56m	4 677 478.7	287 228.6

NOTES

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

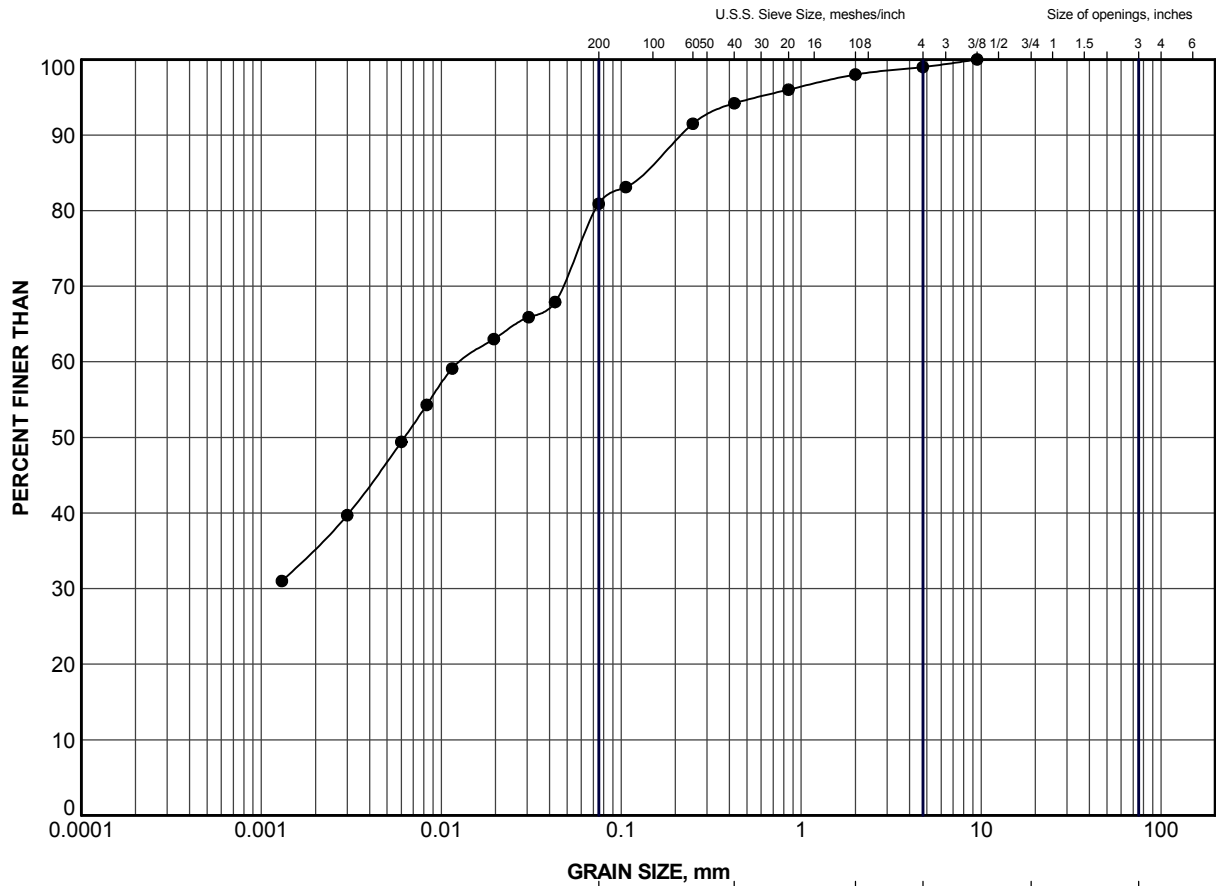
The boundaries between soil strata have been established only at borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REFERENCE

Base plans provided in digital format by DILLON CONSULTING LIMITED.


1	Jan. 28	DUP	INCLUSION OF BH404	
NO.	DATE	BY	REVISION	
Geocres No. 40J2-97				
HWY.	401	PROJECT NO. 07-1130-035-1-8		DIST.
SUBM'D.	DUP	CHKD.	DUP	DATE: Jan. 29/08
DRAWN:	BRS	CHKD.	DUP	APPD.
				DWG. 1

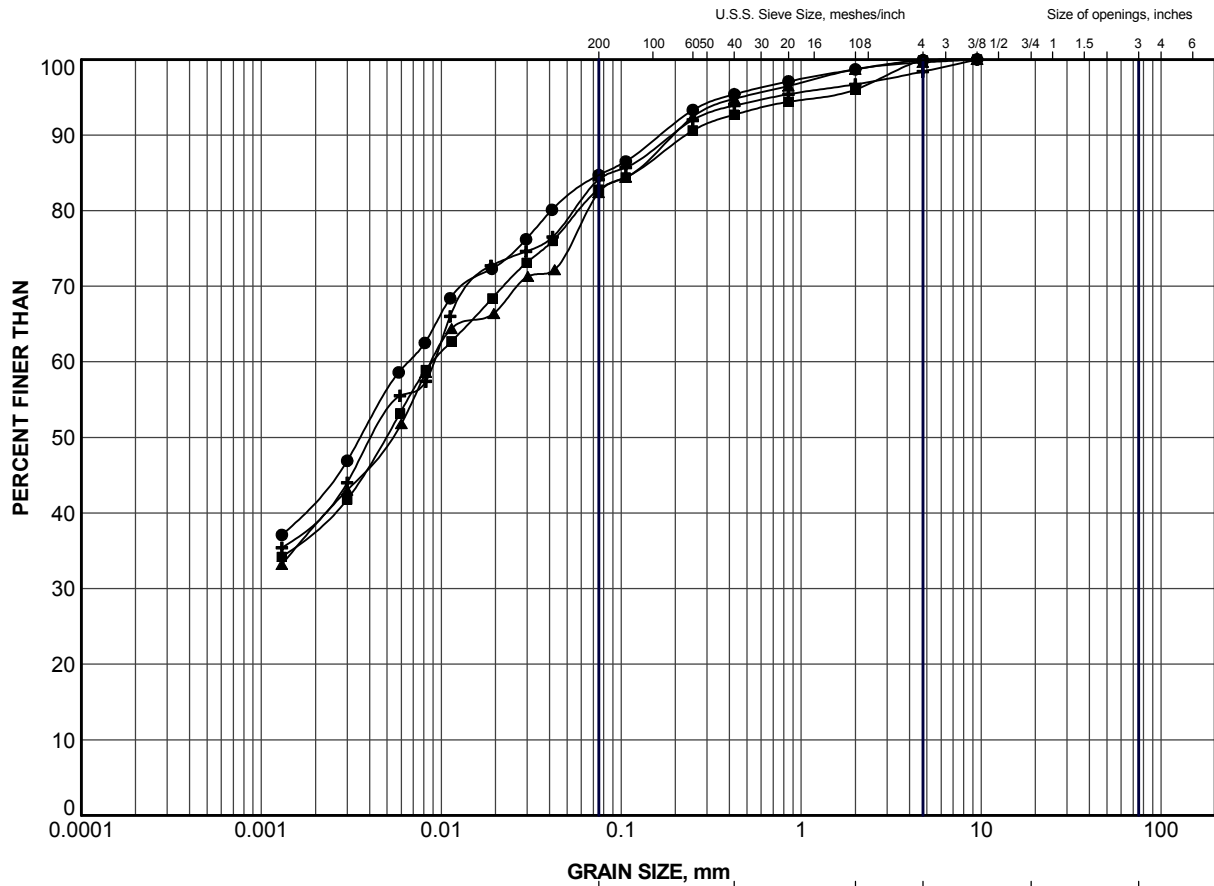
APPENDIX A
LABORATORY TEST DATA



LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	404	2	185.8

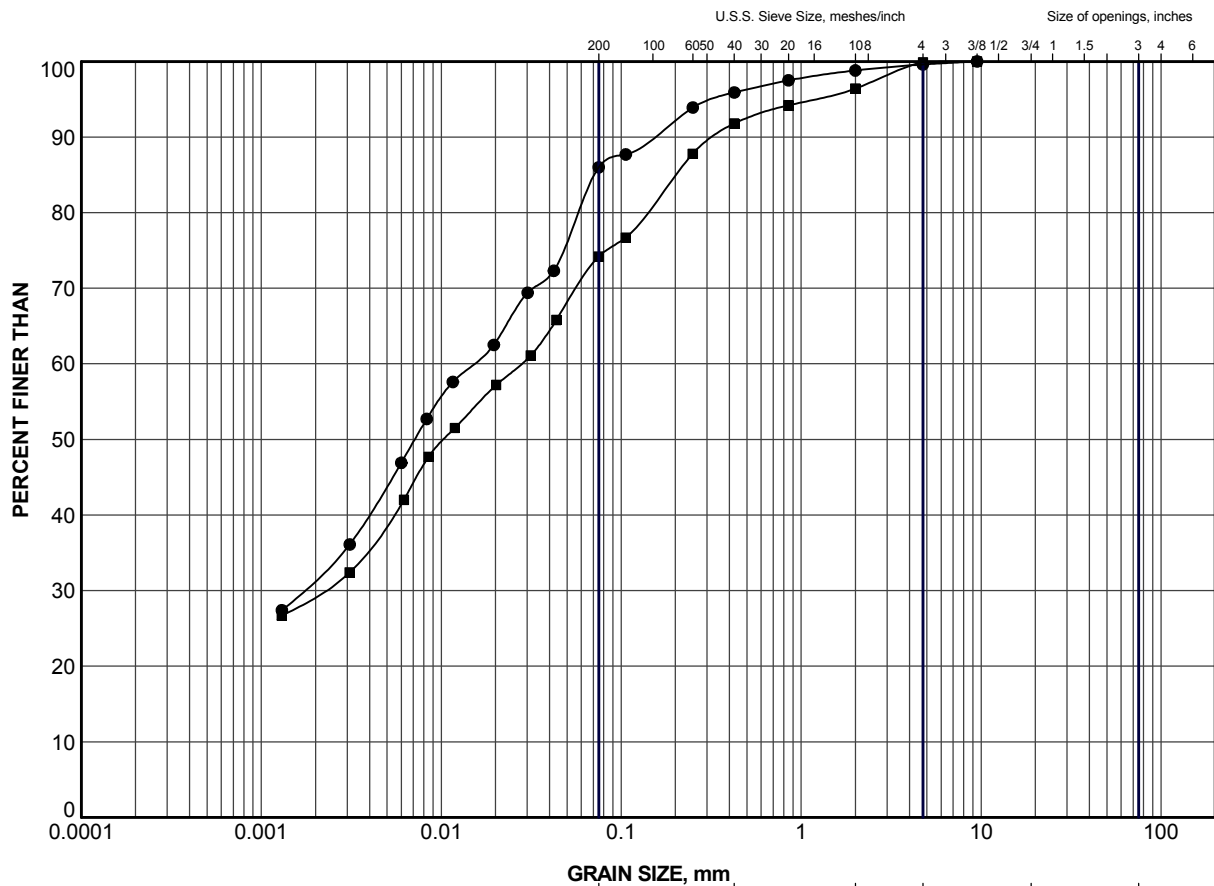
PROJECT				BREAKAWAY AND OVERHEAD SIGNS HIGHWAY 401 GWP 65-00-00			
TITLE				GRAIN SIZE DISTRIBUTION FILL			
PROJECT No.		07-1130-035-1-8		FILE No.		0711300351-8-F0100A1	
DRAWN		LMK		SCALE		N/A	
CHECK				REV.			
		Jan 30/08					
 Golder Associates LONDON, ONTARIO				FIGURE A-1			



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	801	3	181.7
■	803	4	180.5
▲	804	2	181.3
+	805	3	179.7


PROJECT				BREAKAWAY AND OVERHEAD SIGNS HIGHWAY 401 RECONSTRUCTION GWP 65-00-00			
TITLE				GRAIN SIZE DISTRIBUTION SILTY CLAY (TILL)			
PROJECT No.		07-1130-035-1-8		FILE No.		071130035-1-8.GPJ	
DRAWN		BRS		SCALE		N/A	
CHECK		Dec 05/07		REV.			
 Golder Associates LONDON, ONTARIO				FIGURE A-2			

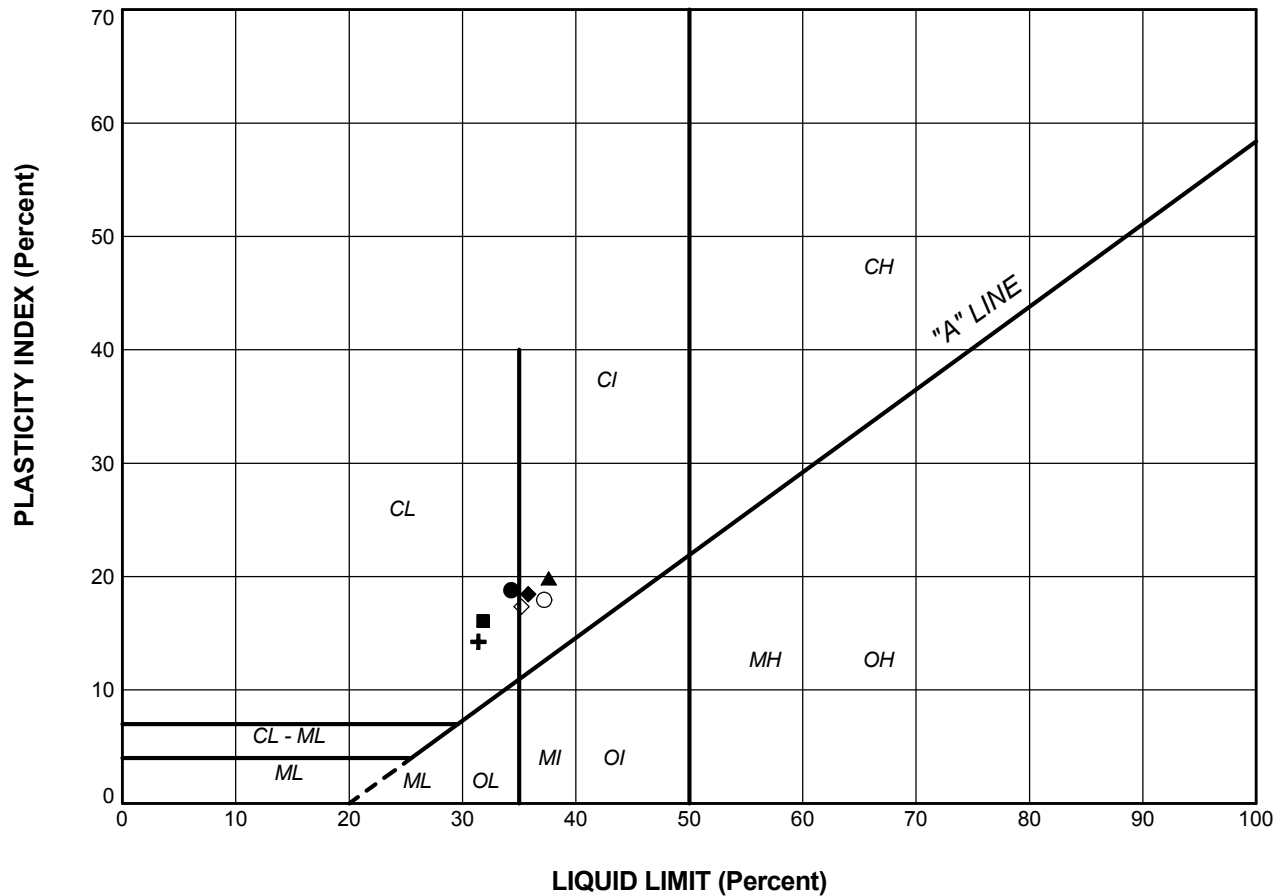


CLAY AND SILT	SAND SIZE, mm			GRAVEL SIZE, mm		Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	404	6	182.8
■	802	2	182.4

PROJECT				BREAKAWAY AND OVERHEAD SIGNS HIGHWAY 401 GWP 65-00-00			
TITLE				GRAIN SIZE DISTRIBUTION CLAYEY SILT (TILL)			
PROJECT No.		07-1130-035-1-8		FILE No.		0711300351-8-F0100A3	
SCALE		N/A		REV.			
DRAWN	LMK	Jan 30/08		FIGURE A-3			
CHECK							
 Golder Associates LONDON, ONTARIO							



LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
<u>FILL, CLAYEY SILT</u>					
●	404	2	34.3	15.5	18.8
<u>CLAYEY SILT (TILL)</u>					
■	404	6	31.8	15.7	16.1
+	802	2	31.4	17.2	14.3
<u>SILTY CLAY (TILL)</u>					
▲	801	3	37.6	17.8	19.9
◆	803	4	35.8	17.4	18.5
◇	804	2	35.2	17.9	17.4
○	805	3	37.2	19.3	18.0

PROJECT				BREAKAWAY AND OVERHEAD SIGNS HIGHWAY 401 GWP 65-00-00			
TITLE				PLASTICITY CHART			
PROJECT No.		07-1130-035-1-8		FILE No.		0711300351-8-F0100A4	
DRAWN	LMK	Jan 29/08		SCALE	N/A	REV.	
CHECK				FIGURE A-4			

