



June 29, 2011

## FOUNDATION INVESTIGATION AND DESIGN REPORT

**VARIABLE MESSAGE SIGN #16  
HIGHWAY 101 WESTBOUND  
APPROXIMATELY 4.5 KM EAST OF HIGHWAY 144  
TIMMINS AREA, ONTARIO  
MINISTRY OF TRANSPORTATION, ONTARIO  
GWP 5122-06-00**

**Submitted to:**

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230 Richmond Street West, 5th Floor  
Toronto, Ontario  
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**GEOCRES NO.: 42A-82**

**Report Number:** 10-1191-0006-16

**Distribution:**

6 Copies - Ministry of Transportation, Ontario, North Bay, ON (Northeastern Region)

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2 Copies - Golder Associates Ltd., Sudbury, ON

REPORT





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# **PART A**

**FOUNDATION INVESTIGATION REPORT  
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## **1.0 INTRODUCTION**

Golder Associates Ltd. (Golder) has been retained by IBI Group (IBI) on behalf of Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for a variable message sign (VMS #16) on Highway 101 westbound near Timmins, Ontario. The general location of the site is shown on the Key Plan on Drawing 1.

The terms of reference for the scope of work were outlined in Golder's Proposal P0-1191-0006, dated February 5, 2010 that formed part of IBI's agreement (Number 5009-E-0018) for this project. The work was carried out in accordance with Golder's Quality Control Plan for this project dated August 23, 2010. The site plan was provided to Golder by Trow Geomatics Inc. (Trow) on behalf of IBI in November 2010.

We understand that the proposed variable message sign will be mounted on a single pole supported by a spread footing.

## **2.0 SITE DESCRIPTION**

The site of the proposed VMS #16 is located on the north side of Highway 101 approximately 4.5 km east of the intersection with Highway 144 at Station 16+600 in Bristol Township near Timmins, Ontario. This section of Highway 101 consists of one westbound lane and one eastbound lane. The westbound gravel shoulder is approximately 3 m wide and a shallow drainage ditch parallels the gravel shoulder. The ground surface at the proposed structure location is at Elevation 305.9 m.

The topography of the site is generally flat-lying and the highway is bordered by trees along both sides of the highway. Based on observations of the existing topography, site drainage along the highway appears to be easterly and westerly from the sign location but overall from south to north as part of the watershed flow direction. The land use beyond the highway right-of-way in the proposed sign location is generally industrial. Two photographs of the site are presented on Figure 1.

## **3.0 INVESTIGATION PROCEDURES**

The subsurface investigation work for the VMS #16 structure was carried out on October 26, 2010, at which time one sampled borehole, numbered BH-VMS#16, was drilled on the shoulder of the westbound lane, as shown on Drawing 1.

The foundation investigation was carried out using a truck-mounted CME-55 drill rig supplied and operated by Landcore Drilling of Chelmsford, Ontario. The borehole was advanced to a depth of 11.3 m below the existing ground surface using 108 mm inside diameter (I.D.) hollow stem augers and soil samples were obtained at intervals of depth ranging from 0.75 m to 1.5 m, using a 50 mm outside diameter (O.D.) split-spoon sampler in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586-08). A field vane shear test was conducted in the cohesive stratum for assessment of undrained shear strength (ASTM D2573-08). Details of the subsurface conditions encountered at the borehole location are shown on the Record of Borehole following the text of this report. The borehole was backfilled with bentonite upon completion in accordance with Ontario Regulation 903 (as amended by O. Reg. 372).



The fieldwork was supervised throughout by a member of Golder's technical staff, who located the borehole, arranged for the clearance of underground services and for traffic protection, supervised the drilling, sampling and in situ testing operations, logged the borehole, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to Golder's Sudbury geotechnical laboratory, where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM standards, as appropriate. Classification testing (water contents, Atterberg limits and grain size distributions) was carried out on selected samples.

The borehole was located in the field by Golder based on the position staked in the field by IBI. The as-drilled borehole location and the ground surface elevation (referenced to Geodetic datum) was subsequently surveyed by Trow and forwarded to Golder. The approximate borehole location is shown on Drawing 1 and the borehole coordinates and ground surface elevation are provided below.

<b>Borehole Number</b>	<b>MTM NAD83 Zone 17 Northing (m)</b>	<b>MTM NAD83 Zone 17 Easting (m)</b>	<b>Ground Surface Elevation (m)</b>
BH-VMS#16	5362772.8	266407.7	305.9

## **4.0 GENERAL SITE GEOLOGY AND STRATIGRAPHY**

### **4.1 Regional Geology**

Based on terrain mapping by the Ontario Geological Survey<sup>1</sup>, the subsurface soils in the vicinity of the site consist of glaciolacustrine deposits comprising primarily sand.

### **4.2 Site Stratigraphy**

Detailed descriptions of the subsurface soil and groundwater conditions as encountered in Borehole BH-VMS#16, advanced during this investigation, together with the results of the laboratory tests carried out on selected samples, are given on the attached Record of Borehole sheet in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheet are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary beyond the borehole location.

In summary, the subsoil conditions at the site consist of granular fill (roadway shoulder materials) underlain by compact to very dense sand and silt, stiff clayey silt and loose sandy silt. A more detailed description of the subsurface conditions encountered in the borehole is provided in the following sections.

#### **4.2.1 Fill**

Two distinct layers of fill were encountered at the borehole location, comprised of a 0.3 m thick surface layer of moist, brown, sand and gravel containing trace to some silt underlain by a 0.9 m thick layer of moist to wet, light brown sand containing trace to some gravel and trace to some silt. The sand fill was encountered between Elevation 305.6 m and 304.7 m.

<sup>1</sup> Ontario Geological Survey, Ministry of Northern Development and Mines, and Northeast Science and Information Section, Ministry of Natural Resources 2005. Digital Northern Ontario Engineering Geology Terrain Study (NOEGTS); Ontario Geological Survey, Miscellaneous Release--Data 160.



An SPT 'N'-value measured in the sand fill is 15 blows per 0.3 m of penetration, indicating a compact relative density.

A grain size distribution test was performed on one sample of the sand and gravel fill and the test result is presented on Figure B-1 in Appendix B.

The natural water content measured on two samples of the fill is 3 percent and 7 percent.

#### **4.2.2 Sand and Silt**

A deposit of wet, brown to grey sand and silt, trace clay, was encountered below the granular fill. The sand and silt deposit was encountered at Elevation 304.7 m and is 3.8 m thick.

The SPT 'N'-values measured within the sand and silt range from 25 blows to 83 blows per 0.3 m of penetration indicating a compact to very dense relative density.

Grain size distribution tests were carried out on two samples of the sand and silt and the results are presented on Figure B-2 in Appendix B.

The natural water content measured on two samples of the sand and silt is 22 percent and 24 percent.

#### **4.2.3 Clayey Silt**

A deposit of wet, grey, clayey silt with silt layers/seams and trace sand was encountered below the sand and silt deposit. The clayey silt deposit was encountered at Elevation 300.9 m and is 5.2 m thick.

The SPT 'N'-values measured within the clayey silt stratum range from 3 blows to 9 blows per 0.3 m of penetration. An in situ field vane test carried out within this stratum measured an undrained shear strength of 60 kPa and a sensitivity of 13 upon remoulding. The SPT 'N'-values together with the in situ vane suggest the deposit typically has a stiff consistency and is extra sensitive, exhibiting a loss of strength upon remoulding or shearing of the silt layers or seams.

Grain size distribution tests were carried out on two samples of the clayey silt stratum and the results are presented on Figure B-3 in Appendix B. Atterberg limit tests were carried out on two samples of the deposit and the results are presented on Figure B-4 in Appendix B. The liquid limits are 23 percent and 31 percent, the plastic limits are 15 percent and 17 percent and the plasticity indices are 6 percent and 16 percent. The results indicate the material is classified as a clayey silt of low plasticity.

The natural water content measured on two samples of the clayey silt deposit is 26 percent and 28 percent.

#### **4.2.4 Sandy Silt**

A deposit of wet, grey, sandy silt, trace clay, was encountered at Elevation 295.7 m. The borehole was terminated upon penetrating about 1.1 m into this deposit.

An SPT 'N'-value measured within the sandy silt is 6 blows per 0.3 m of penetration indicating a loose relative density.





#### **4.2.5 Groundwater Conditions**

Details of the groundwater conditions and water level observed in the open borehole at the time of drilling are summarized on the Record of Borehole sheet following the text of this report. The groundwater level observed in the open borehole was recorded at a depth of 1.1 m below the existing ground surface upon completion of drilling, corresponding to Elevation 304.8 m. It should be noted that this water level does not represent the stabilized water level and that the groundwater elevation will fluctuate seasonally depending on precipitation and local soil permeability and should be expected to rise during wet periods of the year.

### **5.0 CLOSURE**

The fieldwork for this project was carried out by Mr. Ed Savard from our Sudbury office under the coordination of Mr. David Muldowney, EIT. This report was prepared by Mr. David Muldowney, EIT and the technical aspects were reviewed by Mr. André Bom, P.Eng., and Mr. Jorge M. A. Costa, P.Eng., a Principal with Golder. Mr. Costa, also a Designated MTO Contact for Golder, conducted a quality control review of the report.





## Report Signature Page

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# PART B

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HIGHWAY 101 WESTBOUND  
APPROXIMATELY 4.5 KM EAST OF HIGHWAY 144  
TIMMINS AREA, ONTARIO  
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## 6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

### 6.1 General

This section of the report provides foundation design recommendations for the proposed variable message sign (VMS #16). The recommendations are based on interpretation of the factual data obtained from the borehole advanced during the subsurface investigation at this site and from site observations. The interpretation and recommendations provided are intended only to provide the designers with sufficient information to assess feasible foundation design alternatives and to design the proposed sign foundation. As such, where comments are made on construction, they are provided only in order to highlight those aspects which could affect the planning 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, scheduling and the like.

### 6.2 Sign Foundation

We understand the proposed sign will be located on the north side of Highway 101 at Station 16+600 facing the westbound traffic with the centre of the footing located approximately 4.5 m from the edge of the pavement.

Borehole BH-VMS#16 was advanced at Station 16+600 approximately 2.1 m from the centre of the proposed sign location (i.e. approximately 2.4 m from the edge of the pavement). Borehole BH-VMS#16 encountered granular fill to a depth of 1.2 m below the existing ground surface. A compact to very dense sand and silt deposit was encountered to a depth of 5.0 m and is underlain by stiff clayey silt to a depth of 10.2 m below ground surface. Below the clayey silt deposit, the borehole encountered a 1.1 m thick layer of loose sandy silt that extended to the borehole termination depth of 11.3 m below the existing ground surface. The unstabilized groundwater level in the open borehole upon completion of drilling is 1.1 m below the existing ground surface.

Overhead sign supports are typically designed with a standard caisson foundation in accordance with the requirements in MTO's *Sign Support Manual* (2007). However, for the proposed site, we understand from IBI that a site-specific design consisting of a single-pole mounted sign founded on a spread footing has been selected. Recommendations for foundation options are provided in Sections 6.2.1 and 6.2.2.

Table 1 (attached) summarizes the advantages, disadvantages, relative costs and risks/consequences of the foundation alternatives. Given the subsurface conditions at this sign location and a support foundation for a non-standard sign, a spread footing founded on the native soils is considered to be the preferred option from a foundations perspective.

#### 6.2.1 Caisson Foundation

We understand from IBI's structural designer that the current proposed sign is larger and different in configuration than the standard Changeable Message Sign in the *Sign Support Manual* and a non-standard design would be required. As caissons are not the preferred foundation alternative for the support of the single-pole mounted sign, the specific design parameters (i.e. axial and lateral resistances) for a caisson foundation have not been included in this report.



## 6.2.2 Spread Footing

We understand from IBI that the preferred alternative foundation design for the support of VMS #16 is a spread footing, 5 m long and 2.5 m wide. The founding depth of the spread footing should be below the depth of frost penetration (i.e. 2.4 m below final ground surface) and is expected to be within the compact to very dense sand and silt deposit assuming the final ground surface at the sign location is consistent with the elevation of the ground surface at the borehole location.

As noted in Section 6.2, the unstabilized groundwater level in the borehole was encountered at a depth of 1.1 m below the existing ground surface corresponding to about 0.6 m above the bottom of the adjacent ditch elevation and about 1.5 m above the proposed founding elevation. At the time of our September 10, 2010 site visit with IBI, the ditch was observed to be dry. The hydraulic conductivity of the granular fill material and the sand and silt is considered moderate to high.

Based on the subsurface conditions encountered at the borehole location, and provided the groundwater level is maintained below the base of the excavation during construction, an open cut excavation of short duration may be possible for the proposed footing. The excavation for footing construction will extend through the fill material and into the sand and silt deposit. The excavation for the proposed footing should be carried out in accordance with the latest Occupational Health and Safety Act for Construction Projects (OHSA). When referencing OHSA, the fill materials and the sand and silt deposit should be considered as "Type 3 Soil". An excavation above the groundwater level should be sloped at a gradient of 1 horizontal (H) to 1 vertical (V) or flatter. An excavation below the groundwater level should be sloped at 2H to 1V or flatter. Depending on the season of construction, the groundwater level may be at or above the proposed founding depth. As such, open cut excavations may not be practical for the proposed footing construction due to the anticipated shallow groundwater level and the proximity of Highway 101 located adjacent to the proposed excavation, unless appropriate dewatering is carried out to adequately depress the groundwater level. However, given the anticipated size of the excavation, dewatering may be possible using standard construction techniques such as pumps and filtered sumps and the excavation side walls maintained at 1H to 1V. The sumps should be installed at least 1.0 m below the base of the excavation within a filtered pipe surround. The pumps should be installed immediately upon encountering the groundwater level and sufficient time should be given to allow for localized dewatering and lowering of the groundwater level prior to reaching the excavation base.

Provision for protection of the existing pavement structure will be required in accordance with MTO's Ontario Provincial Standard Specifications (OPSS) 539 (Temporary Protection Systems), designed to meet Performance Level 2. Relevant design parameters for the shoring are provided below.

Design Parameter	Granular Fill & Sand and Silt
Unit Weight above Groundwater Level $\gamma$ (kN/m <sup>3</sup> )	20
Unit Weight below Groundwater Level $\gamma'$ (kN/m <sup>3</sup> )	10
Friction Angle ( $^{\circ}$ )	30
$K_a^*$	0.33
$K_p^*$	3.0
$K_o^*$	0.5

\* Earth pressure coefficients for horizontal backfill.



For the cohesive soil, the passive pressure,  $P_p$  (kPa), and active pressure,  $P_a$  (kPa), acting on the shoring may be calculated using the following equations:

$$P_p = \sigma_z + 2 c_u$$
$$P_a = \sigma_z - 2 c_u$$

The  $c_u$  value for the clayey silt should be taken as 60 kPa.

During construction, stockpiles should be placed well away from the edge of the excavation, and their height should be controlled so they do not surcharge the sides of the excavation and/or the overall local embankment slope. For this site, the distance between the crest of the excavation and the toe of the stockpile should generally be greater than the diameter of the base of the stockpile.

Disturbance of the underlying materials during construction of the spread footing could influence the settlement of the structure. Therefore, OPSS 902 (Excavating and Backfilling – Structures) should be included in the Contract Documents, requiring inspection and approval of the foundation area by the Quality Verification Engineer (QVE) prior to footing construction, to ensure that the foundation area has been adequately prepared for construction of the spread footing.

The base of the excavation should be free of water and loose soil prior to placing concrete. Should the material(s) at bearing level become saturated or disturbed, we recommend that the affected material be removed immediately prior to placing concrete. We recommend that the prepared subgrade be protected using a 150 mm thick working slab comprised of a minimum 20 MPa concrete or a minimum 300 mm thick granular working pad consisting of compacted Granular 'B' Type II or Granular 'A' meeting the requirements in MTO's Special Provision (SP) SP110S13 (Aggregates). The working slab/pad would be placed across the bottom of the excavation immediately upon completion of the excavation and review by the QVE. The purpose of the working slab/granular pad is to limit disturbance of the native sand and silt and to provide a platform for construction of the spread footing.

### 6.2.3 Geotechnical Resistance

A spread footing constructed on the properly prepared subgrade at or below the depth given in Section 6.2.2 may be designed based on a factored geotechnical axial resistance of 300 kPa at Ultimate Limit States (ULS) for a footing rectangular in shape up to 5.0 m long by 2.5 m wide. For the same spread footing dimension indicated above, a geotechnical axial resistance value of 150 kPa for Serviceability Limit States (for 25 mm settlement) design may be assumed. Design of the proposed sign foundation should also be checked for and provisions made to resist buoyant forces, assuming a groundwater level at Elevation 304.8 m.

The ULS resistance and settlement are dependent on the footing size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the selected footing dimensions or founding depth differs from those given above.

The geotechnical resistances provided above are given under the assumption that the loads will be applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Clauses 6.7.4 and C6.7.4 of the *Canadian Highway Bridge Design Code (CHBDC, 2006)* and the related commentary.



#### 6.2.4 Resistance to Lateral Loads

Resistance to lateral forces / sliding resistance between the concrete footings and the prepared subgrade should be calculated in accordance with Section 6.7.5 of the *CHBDC*. For a cast-in-place concrete footing constructed on a compacted granular pad, the coefficient of friction,  $\tan \phi'$ , can be taken as 0.45. For a cast-in-place concrete footing constructed on a concrete working slab, the coefficient of friction,  $\tan \phi'$ , can be taken as 0.55. The above noted values are unfactored.

### 6.3 Construction Considerations

The excavation around and above the spread footing should be backfilled using an approved granular material such as SP110S13 (Aggregates) Granular 'A' or 'B' (Type I or II) placed in 300 mm loose lifts and uniformly compacted to not less than 95 percent standard proctor maximum dry density of the material. The use of native excavated materials as backfill is not recommended.

The final grade surrounding the sign support should be sloped to promote surface water drainage and pavement structure drainage away from the pavement and sign support, to the adjacent ditch.

We recommend that a Non-Standard Special Provision (NSSP) be included in the Contract Documents to warn the contractor of the following item which is expected to affect the installation of the variable message sign foundation:

- **Control of overburden soils for spread footings:** Excavations for the sign foundation will be advanced through generally cohesionless soil which, if below the groundwater table, should be expected to be unstable. It should be anticipated that the excavations will have to be advanced using shoring, possibly in conjunction with controlled dewatering, in order to minimize ground loss during excavation and concrete placement. The contractor is responsible for ensuring that appropriate construction procedures and equipment are used for spread footing construction. An example NSSP to warn the contractor of such conditions is presented in Appendix C.

## 7.0 CLOSURE

This report was prepared by Mr. David Muldowney, a Geotechnical EIT, and the technical aspects were reviewed by Mr. André Bom, P.Eng., and Mr. Jorge M. A. Costa, P.Eng., a Principal with Golder. Mr. Costa, also a Designated MTO Contact for Golder, conducted a quality control review of the report.

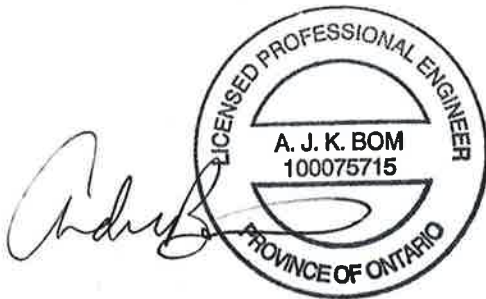


## Report Signature Page

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## REFERENCES

Occupational Health and Safety Act and Regulation for Construction Projects, January 2006.

Ministry of Transportation, Ontario, 2007. Sign Support Manual. Policy, Planning & Standards Division, Engineering Standards Branch, Bridge Office

Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA-S6-06, 2006. CSA Special Publication, S6.1-06. Canadian Standard Association.

## STANDARDS

### ASTM International

ASTM D1586-08      Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

ASTM D2573-08      Standard Test Method for Field Vane Shear Test in Cohesive Soil

### Ministry of Transportation Ontario Special Provisions

SP 110S13      Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

### Ontario Provincial Standard Drawings

OPSD 3090.100      Foundation Frost Depths for Northern Ontario

### Ontario Provincial Standard Specifications

OPSS 539      Construction Specification for Temporary Protection Systems

OPSS 902      Construction Specification for Excavating and Backfilling – Structures

### Ontario Water Resources Act

Ontario Regulation 372/07      Amendment to Ontario Regulation 903

Ontario Regulation 903/90      Wells

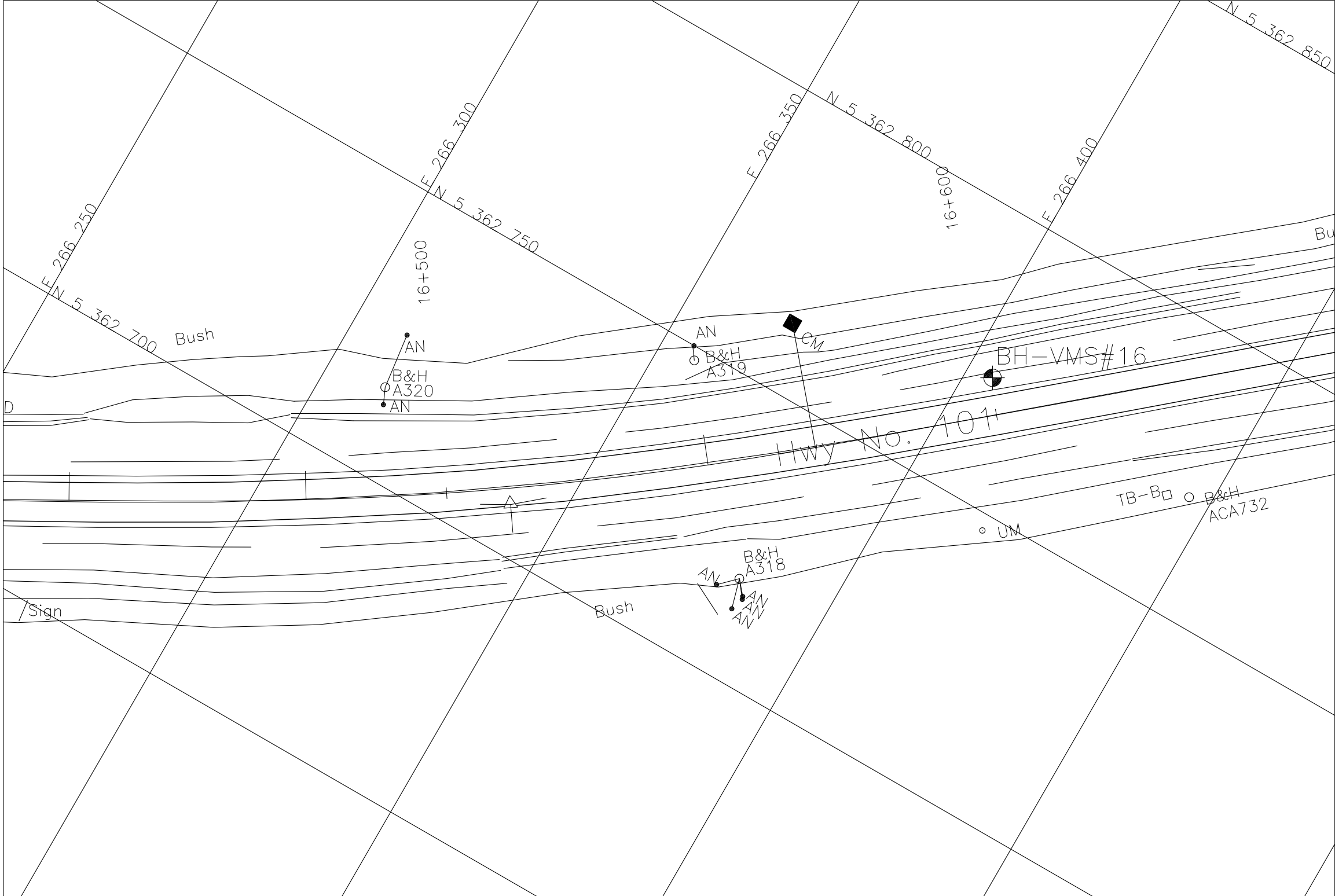


Table 1: Evaluation of Foundation Alternatives

Options	Rank	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Spread Footing	1	<ul style="list-style-type: none"><li>■ Conventional construction.</li><li>■ Design easily adaptable for non-standard sign size/configuration.</li></ul>	<ul style="list-style-type: none"><li>■ Temporary shoring required for support of excavation side wall to footing subgrade elevation.</li><li>■ Depending on water level at time of construction, local dewatering of excavation may be required.</li></ul>	<ul style="list-style-type: none"><li>■ Much lower overall cost compared to caisson.</li><li>■ Additional costs required for control of overburden as applicable.</li></ul>	<ul style="list-style-type: none"><li>■ Risk of requiring dewatering during construction depending on season of construction.</li></ul>
Caisson	2	<ul style="list-style-type: none"><li>■ Typical foundation alternative for sign of standard size, but would have to be modified for the proposed sign at this site.</li></ul>	<ul style="list-style-type: none"><li>■ Non-standard caisson design is required for non-standard sign size.</li><li>■ Temporary liner for soil support likely required during installation.</li><li>■ Dewatering within liner for concrete placement in the dry or placement by tremie methods below water.</li><li>■ May require a levelling pad (fill or excavation of slope) to accommodate drilling equipment.</li></ul>	<ul style="list-style-type: none"><li>■ Cost many times higher than spread footings, due to need to mobilize drilling rig to site.</li></ul>	<ul style="list-style-type: none"><li>■ Risk of need for placement of concrete by tremie methods if unable to dewater within caisson liner.</li></ul>

Note: This table should be read in conjunction with the Foundation Investigation and Design Report.

Compiled by: AB    Reviewed by: JMAC



METRIC  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No.  
WP No.5122-06-00

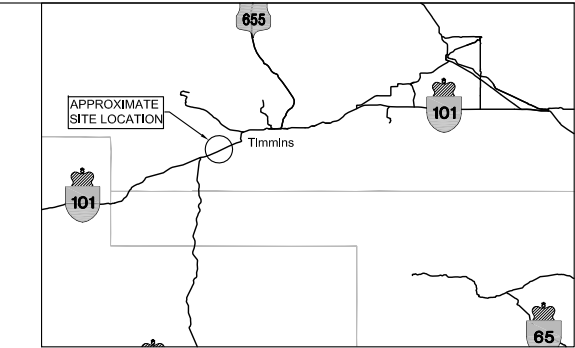


VARIABLE MESSAGE SIGN #16  
HIGHWAY 101 WESTBOUND, TIMMINS  
BOREHOLE LOCATION

SHEET



Golder Associates Ltd.  
SUDBURY, ONTARIO, CANADA



KEY PLAN  
N.T.S



LEGEND

BH-VMS #16  
Approximate Borehole Location

No.	ELEVATION(m)	CO-ORDINATES	
		NORTHING	EASTING
BH-VMS#16	305.9	5362772.8	266407.7

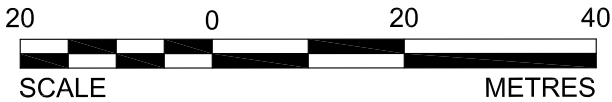
NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Key plan provided in digital format by IBI, drawing file no.TM-TWG-keyplan.dwg, received December 7, 2010  
Base plan provided in digital format by TROW Geomatics inc, drawing file no.Ntb-01007030Hwy101.dwg, received December 7, 2010



NO.	DATE	BY	REVISION
Geocres No.42A82			
HWY. 101		PROJECT NO.10-1191-0006	DIST.
SUBM'D. DAM	CHKD. AB	DATE: JUNE 2011	SITE:
DRAWN: PL	CHKD.	APPD. JMAC	DWG. 1



Figure 1 – Photographs of VMS #16 Site, Timmins Area

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**Photograph 1: Highway 101 looking east (September 2010)**



**Photograph 2: Highway 101 looking west (September 2010)**





# APPENDIX A

## Record of Borehole



## LIST OF SYMBOLS

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

### 1. 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
FoS	Factor of Safety
V	volume
W	weight

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. 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

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

#### (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





## 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.).

<b>PH:</b>	Sampler advanced by hydraulic pressure
<b>PM:</b>	Sampler advanced by manual pressure
<b>WH:</b>	Sampler advanced by static weight of hammer
<b>WR:</b>	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.

### 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 <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.

### 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

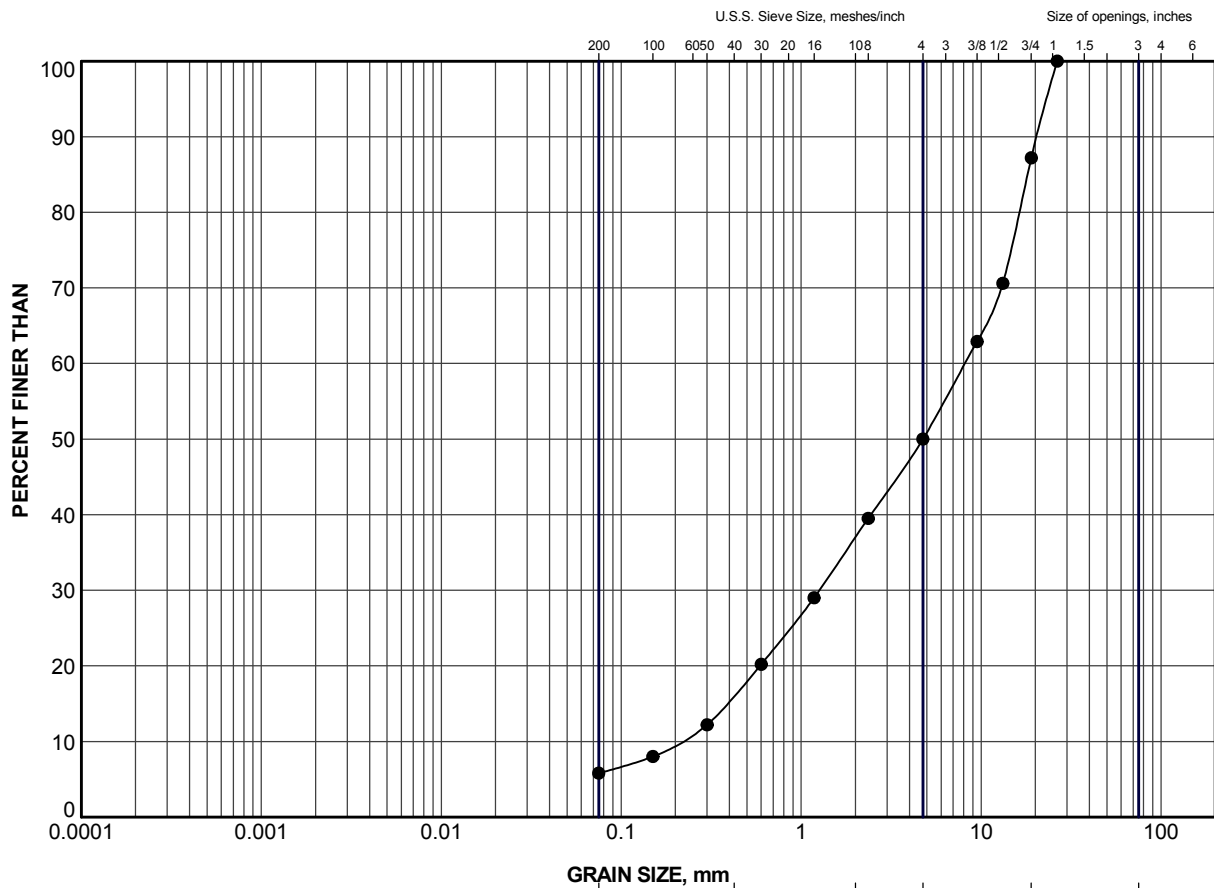


+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE



# APPENDIX B


## Laboratory Test Results

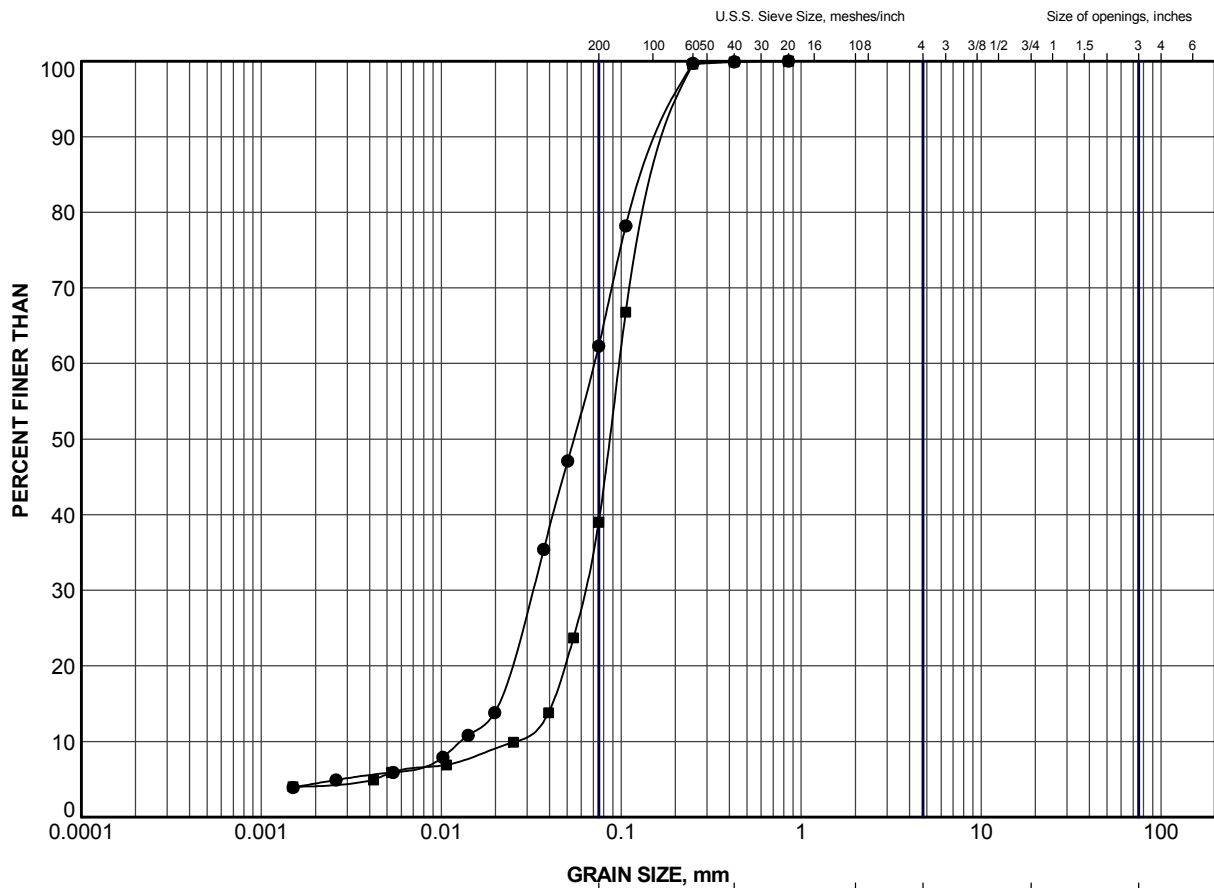


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-VMS#16	1	305.7


PROJECT					
HIGHWAY 101 WESTBOUND VMS #16					
TITLE					
GRAIN SIZE DISTRIBUTION SAND AND GRAVEL (FILL)					
 <b>Golder Associates</b> SUDBURY, ONTARIO		PROJECT No. 10-1191-0006		FILE No. 1011910006.GPJ	
		DRAWN	JJL	Jun 2011	SCALE N/A
		CHECK	AB	Jun 2011	REV.
		APPR		Jun 2011	
<b>FIGURE B-1</b>					

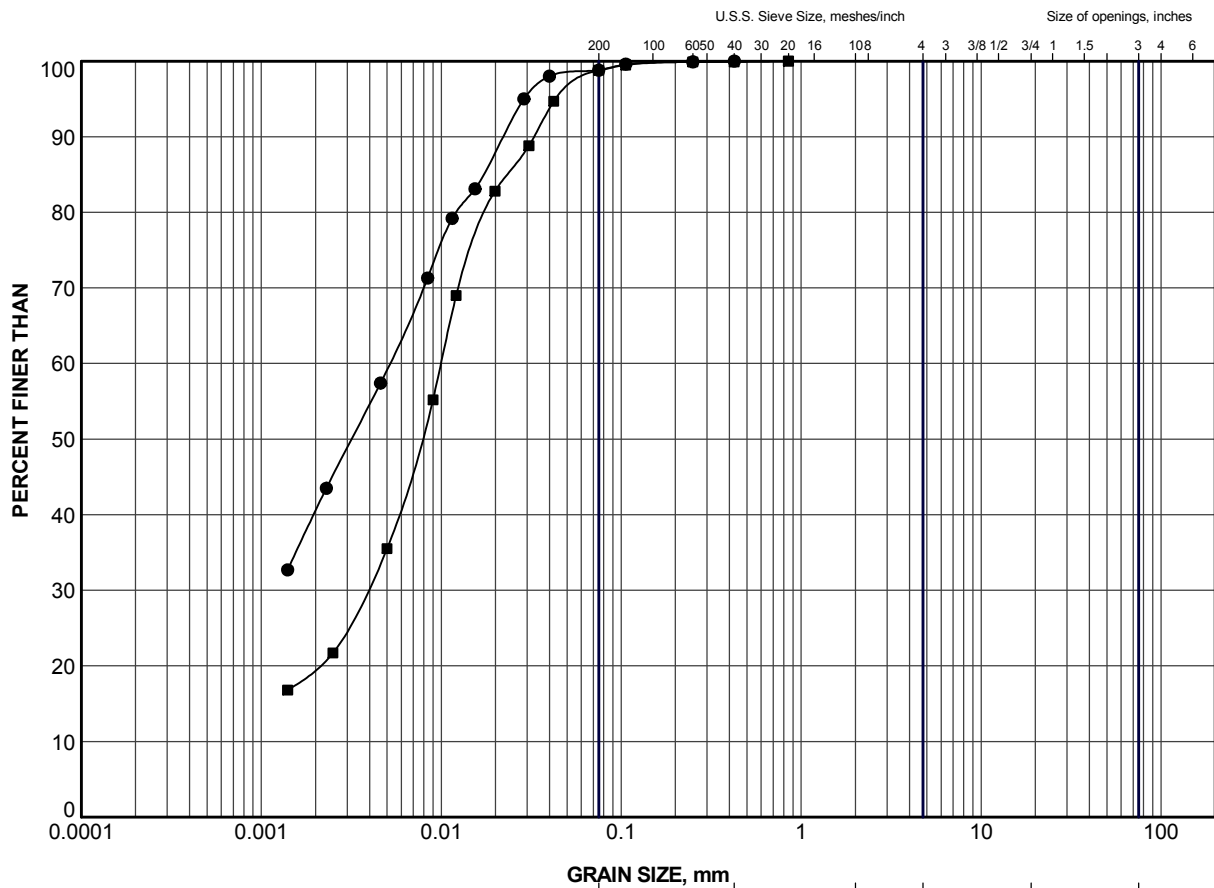


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-VMS#16	4	304.0
■	BH-VMS#16	6	302.5


PROJECT					
HIGHWAY 101 WESTBOUND VMS #16					
TITLE					
GRAIN SIZE DISTRIBUTION					
SAND AND SILT					
PROJECT No.		10-1191-0006		FILE No. 1011910006.GPJ	
DRAWN	JJL	Jun 2011	SCALE	N/A	REV.
CHECK	AB	Jun 2011			
APPR		Jun 2011			
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B-2</b>		

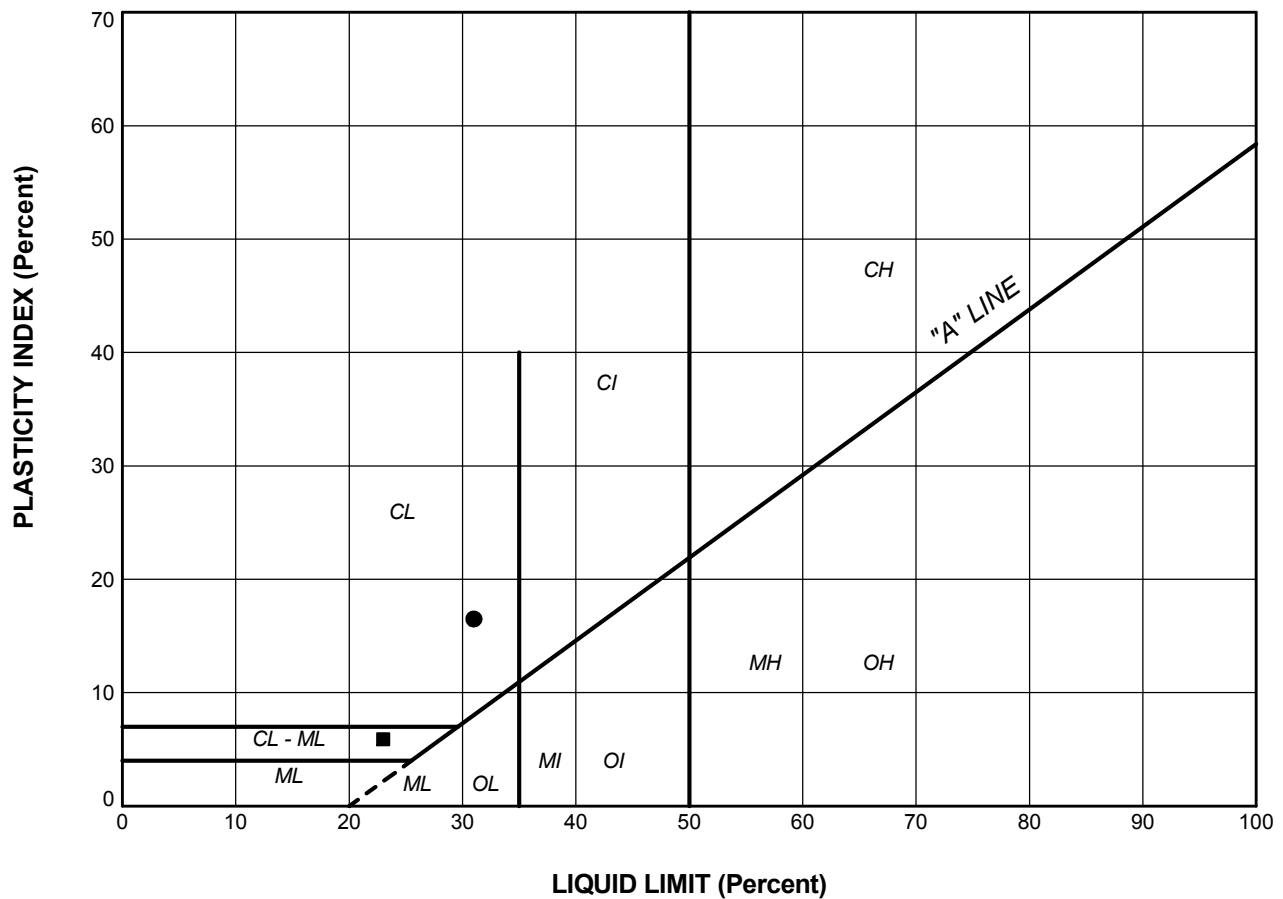


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

#### LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-VMS#16	9	299.5
■	BH-VMS#16	11	296.4

PROJECT				
HIGHWAY 101 WESTBOUND VMS #16				
TITLE				
GRAIN SIZE DISTRIBUTION				
CLAYEY SILT				
PROJECT No.		10-1191-0006		FILE No.
DRAWN		J.J.L. Jun 2011		SCALE N/A
CHECK		AB Jun 2011		REV.
APPR		Jun 2011		
 <b>Golder Associates</b> SUDBURY, ONTARIO		<b>FIGURE B-3</b>		



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BH-VMS#16	9	31.0	14.5	16.5
■	BH-VMS#16	11	23.0	17.1	5.9

PROJECT					
HIGHWAY 101 WESTBOUND VMS #16					
TITLE					
PLASTICITY CHART					
CLAYEY SILT					
PROJECT No. 10-1191-0006			FILE No. 1011910006.GPJ		
DRAWN	JJL	Jun 2011	SCALE	N/A	REV.
CHECK	AB	Jun 2011			
APPR		Jun 2011			
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B-4</b>		



# APPENDIX C

## Non-Standard Special Provisions





## **CONTROL OF OVERBURDEN SOILS FOR FOUNDATION EXCAVATION**

### **Non-Standard Special Provision**

The Contactor is hereby notified that the overburden soils at the VMS #16 sign location include cohesionless and water-bearing sand and silt, which are susceptible to soil cave-in, sloughing and boiling. The Contractor shall ensure that appropriate construction procedures and equipment are employed to maintain the excavation open and adequately cleaned to allow for construction of the sign foundation in-the-dry.

END OF SECTION

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