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REPORT ON

**FOUNDATION INVESTIGATION AND DESIGN
PROPOSED CULVERT REPLACEMENTS
LAVALLEE CREEK CULVERT
(STRUCTURE SITE 15-180) AND
WILLOW MUNICIPAL DRAIN CULVERT
(STRUCTURE SITE 15-181)
HIGHWAY 7 TWINNING FROM 2.5 KM WEST
OF ASHTON STATION ROAD TO CARLETON PLACE
W.P. 252-99-00**

Submitted to:

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PART A

**FOUNDATION INVESTIGATION
PROPOSED CULVERT REPLACEMENTS
LAVALLEE CREEK CULVERT (STRUCTURE SITE 15-180) AND
WILLOW MUNICIPAL DRAIN CULVERT (STRUCTURE SITE 15-181)
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McCormick Rankin Corporation on behalf of the Ministry of Transportation, Ontario (MTO) to carry out a foundation investigation associated with the twinning of Highway 7 from two to four lanes in former West Carleton Township which is now part of the City of Ottawa and in Beckwith Township in Lanark County. The section of Highway 7 included in this assignment (W.P. 251-99-00) extends from 2.5 km west of Ashton Station Road to Carleton Place.

Foundation investigation services are required for the following components:

- Two new structural culverts at Lavallee Creek and the Willows Municipal Drain; and,
- High Fill embankments for the new County Road 17 interchange.

This report addresses the two new structural culverts.

The terms of reference for the original scope of work are outlined in the MTO's Request for Proposal (RFP) dated October 2005. The work was carried out in accordance with Golder's Quality Control Plan dated February, 2006.

2.0 SITE DESCRIPTION

Highway 7 is a two lane highway with ditches on either side. The existing Willows Municipal Drain culvert and Lavallee Creek culvert are located on Highway 7 at Stations 16+670 and 15+695, respectively. The Willows Drain culvert is located approximately 0.8 kilometres (km) west of Appleton Side Road, while the Lavallee Creek culvert is approximately 1.7 km west of Appleton Side Road, both of which are east of Carleton Place, Ontario. Both of the existing culverts are aligned approximately perpendicular to Highway 7 (i.e., have little to no skew). The existing Willows Municipal Drain culvert is a non-rigid open footing concrete culvert approximately 6100 millimetres (mm) wide by 1200 mm high. The existing Lavallee Creek culvert is a rigid frame open footing concrete culvert approximately 6096 mm wide by 1200 mm high. The Highway 7 pavement grade is at about Elevation 129.5 at the Willow Municipal Drain culvert and Elevation 128.0 at the Lavallee Creek culvert, with existing culvert inverts at about Elevation 126.8 m and Elevation 125.3 m, respectively. The flow in both culverts is from south to north.

3.0 INVESTIGATION PROCEDURES

Subsurface investigations were carried out at the culvert locations between September 12 and 18, 2006, at which time six boreholes (numbered 06-101 to 06-106, inclusive) were advanced at the locations shown on Drawings 1 and 2. Boreholes 06-101, 06-102 and 06-103 were advanced at locations along the proposed culvert replacement at the Willows Municipal Drain, while boreholes 06-104, 06-105 and 06-106 were advanced at locations along the proposed culvert replacement at Lavallee Creek.

The boreholes were advanced using 108 mm inside diameter (I.D.) continuous flight hollow stem augers on a track-mounted drill rig, supplied and operated by Marathon Drilling Ltd. of Ottawa, Ontario. The boreholes were advanced to depths ranging from 2.3 to 8.1 metres (m) below the existing ground surface at the Willows Municipal Drain culvert and between 10.2 and 12.4 m at the Lavallee Creek Culvert.

Soil samples were obtained at intervals ranging from 0.75 m to 1.5 m of depth, using a 50 mm outer diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures. In-situ vane testing (N vanes) was carried out within the cohesive deposits where possible.

All of the boreholes were advanced until auger refusal was encountered. Borehole 06-101 was then advanced approximately 3.6 m into the bedrock by coring using NQ-Size coring equipment.

Standpipe piezometers were installed in boreholes 06-102 and 06-106 to monitor the groundwater levels at the site. The standpipes consist of 50 mm diameter rigid PVC pipe with a 0.7 m long slotted screen section, installed within silica sand backfill and sealed by sections of minimum 1.2 m long of bentonite pellet backfill. The water levels in the standpipe piezometers were measured on October 16, 2006.

The boreholes were backfilled with bentonite pellets, mixed with native soils, and the site conditions restored following completion of work. The standpipe piezometers will be decommissioned following construction, unless instructed otherwise by the Ministry.

The field work was supervised throughout by members of our engineering and technical staff, who located the boreholes, supervised the drilling, sampling and in-situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled, and transported to our Ottawa geotechnical laboratory where the samples underwent further detailed visual examination and laboratory testing, including grain size distribution, water content, organic content, and Atterberg limit testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards as appropriate.

The borehole locations were determined by Golder to existing site features. The borehole elevations were determined by MRC from a digital terrain model based on the locations provided by Golder. The borehole locations, including MTM NAD83 northing and easting coordinates and ground surface elevations referenced to geodetic datum are summarized in the following table and are shown on Drawings 1 and 2.

Borehole No.	Borehole Location	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)
06-101	Willows Municipal Drain	5000722.3	336387.4	129.2
06-102	Willows Municipal Drain	5000723.5	336357.5	127.4
06-103	Willows Municipal Drain	5000749.3	336358.1	127.5
06-104	Lavallee Creek	5000072.8	335659.8	127.8
06-105	Lavallee Creek	5000069.0	335631.9	127.8
06-106	Lavallee Creek	5000090.2	335622.0	125.9

4.0 SITE GEOLOGY AND STRATIGRAPHY

4.1 Regional Geological Conditions

The study area for this assignment lies within the Smith Falls Limestone Plain, as delineated in *The Physiography of Southern Ontario*¹ that lies within the major physiographic region of the Ottawa-St. Lawrence Lowland.

The Smiths Falls Limestone Plain is characterized by shallow overburden deposits overlying sedimentary bedrock consisting of limestones, dolostones, sandstones and shales. The shallow overburden soils are typically between 1 m and 3 m in thickness and are commonly comprised of sandy to gravelly till derived from the Precambrian Shield to the north, overlain by glaciofluvial sediments that consist of layered sands and gravels. In the vicinity of and north of Carleton Place, clay has been deposited within depressions in the bedrock that have been caused by faulting. Large areas of the plain are covered with peat and muck, due to poor drainage as a consequence of the relatively flat topography and shallow depth to bedrock.¹

4.2 Site Stratigraphy

The detailed subsurface soil, bedrock and groundwater conditions as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole sheets. The stratigraphic boundaries shown on the Record of Borehole sheets 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 subsurface conditions at the Willows Municipal Drain culvert consist of topsoil overlying about 1.6 m of sand and gravel (embankment fill) and/or about 1.9 to 2.3 m of silty clay which has been weathered to a grey brown colour and a very stiff consistency. The silty clay deposit is underlain by a sandy silt till deposit which was proven to depths of 2.3 m and 3.0 m below original ground surface level, where auger refusal was encountered. The overburden was fully penetrated at one of the boreholes at a depth of 4.5 m below roadway shoulder level, where limestone and dolomitic limestone bedrock was encountered (at about Elevation 124.7).

The subsurface conditions at the Lavallee Creek culvert generally consist of between 2.3 and 2.4 m of fill material (embankment fill) and/or 0.2 to 1.0 m of peat overlying a deposit of silty clay. The upper 1.9 to 2.2 m of the silty clay has been weathered to a very stiff grey brown crust. The silty clay below the depth of weathering is grey in colour and extends to depths between 10.1 to

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

12.2 m. The silty clay is underlain by a thin deposit of sandy silt till which was proven to depths of between 10.2 and 12.4 m, where auger refusal was encountered.

A more detailed description of the subsurface conditions encountered in the boreholes put down for the present investigation at each culvert location is provided in the following sections, and stratigraphic profiles and sections of this site are shown on Drawings 1 and 2.

4.2.1 Willows Municipal Drain Culvert, Station 16+670

4.2.1.1 Topsoil and Fill Material

A silty clay topsoil layer was encountered at borehole 06-103, in the area of the proposed west bound lanes, with a thickness of about 0.3 m.

At borehole 06-101, located on the shoulder of the existing roadway, the upper 0.2 metres of the embankment fill material consists of silty topsoil. About 1.6 metres of embankment fill material exists below the topsoil layer, consisting primarily of sand and gravel with varying amounts of silt, sandy silt, and cobbles. Two standard penetration test N values in the sand and gravel fill of 5 and 20 blows per 0.3 m of penetration indicating a loose to compact state of packing. The results of grain size distribution testing of one sample of the fill material are shown on Figure 1. Silty clay fill material was encountered at the ground surface at borehole 06-102, with a thickness of about 0.3 m.

4.2.1.2 Silty Clay to Clay

The fill materials and topsoil, where present, are underlain by a deposit of silty clay. The silty clay deposit was fully penetrated in all of the boreholes to depths between about 2.2 and 4.1 m below the existing ground/embankment surface level, at about Elevation 125.1 to 125.2 m.

The silty clay deposit has been weathered to a grey brown colour. The measured SPT "N" values in this deposit ranged from 5 to 14 blows per 0.3 m of penetration, indicating a very stiff consistency.

The results of Atterberg limit testing on one sample of the weathered silty clay to clay indicates a plasticity index of 29 percent and a liquid limit of 60 percent, as shown on Figure 2, indicating a soil of high plasticity. The measured natural water content of the weathered silty clay ranges from 31 to 39 percent.

4.2.1.3 Sandy Silt Till

The silty clay is underlain by glacial till. The deposit is quite thin, ranging from 0.1 to 0.7 m in thickness at the borehole locations. The glacial till is considered to be a heterogeneous mixture of gravel, cobbles, and boulders in a matrix of sandy silt with some clay. The results of grain size distribution testing of one sample of the glacial till are provided on Figure 3. However, these samples were retrieved using a 50 mm diameter sampler and therefore do not reflect the cobble and boulder portions of the deposit.

One standard penetration test N value of about 15 blows per 0.3 metres of penetration indicates a compact state of packing.

The measured natural water content of one sample of the glacial till is 8 percent.

4.2.1.4 Auger Refusal and Bedrock

Practical refusal to augering was encountered at all the boreholes at depths between about 2.3 and 4.5 m below the existing ground/embankment surface level (Elevations 125.1 to 124.7 m).

Limestone and dolomitic limestone bedrock was confirmed at borehole 06-101 which was advanced beyond the auger refusal depth using rotary diamond drilling techniques. The borehole was advanced for an additional 3.6 m depth into bedrock. The Rock Quality Designation (RQD) values measured on recovered bedrock core samples typically ranged from about 70 to 91 percent, indicating a fair to excellent condition. However the upper 0.2 m of bedrock is slightly weathered.

The following table summarizes the bedrock surface depth and elevation as encountered at the borehole locations. It should be noted that the bedrock was cored in one of the boreholes; the surface of the limestone and dolomitic limestone bedrock was inferred in the two remaining boreholes by refusal to auger advancement.

Borehole Number	Ground Surface/Embankment Elevation (m)	Depth to Bedrock (m)	Bedrock Surface Elevation (m)
06-101	129.2	4.5	124.7 (Cored)
06-102	127.4	2.3	125.1 (Auger refusal)
06-103	127.5	3.0	124.5 (Auger refusal)

4.2.1.5 Groundwater Conditions

The groundwater level in the piezometer in Borehole 06-102 was measured on October 16, 2006. The piezometer was sealed into the silty clay deposit.

The groundwater level in the piezometer is summarized in the table below:

Borehole	Ground Surface Elevation (m)	Water Level Depth (m)	Water Level Elevation (m)	Date
06-102	127.4	0.36	127.0	October 16, 2006

It should be noted that groundwater levels in the area are subject to fluctuations both seasonally and with precipitation events.

4.2.2 Lavallee Creek Culvert, Station 15+695

4.2.2.1 Fill Material and Peat

Embankment fill material exists at ground surface at boreholes 06-104 and 06-105, put down through the shoulders of the existing roadway. The fill material extends to depths of 2.4 and 2.3 m below existing roadway embankment surface, respectively (Elevations 125.4 m and 125.5 m).

The fill materials consist of sand and/or silty sand and gravel and silt clay with traces of concrete, asphalt, organic matter, peat and occasional cobbles. Standard penetration test N values for the fill material ranging from 8 to 37 blows per 0.3 m of penetration indicate the material to be loose to dense.

The measured natural water content of one sample of the fill material is 28 percent.

Peat exists at the ground surface at borehole 06-106, put down within the future westbound lanes, with a thickness of about 1.0 m.

A buried peat layer was also encountered beneath the fill materials at borehole 06-104, with a thickness of about 0.2 m.

The results of organic content testing on two samples of the peat indicate organic contents of 10 and 18 percent. The measured natural water contents of the samples are 235 and 335 percent.

4.2.2.2 Silty Clay to Clay

The fill materials and/or peat are underlain by a thick deposit of silty clay. The silty clay deposit was fully penetrated in all of the boreholes at depths between about 10.1 and 12.2 m (Elevations 115.6 and 116.5 m).

At boreholes 06-104 and 06-106, the upper 0.7 and 0.4 m of the silty clay deposit, respectively is a grey green colour and contains traces of organic matter. More generally, the silty clay to a depth of about 1.9 to 2.4 m below the clay surface level has been weathered to a grey brown crust. The measured Standard Penetration Test "N" values within the weathered silty clay were between 5 and 11 blows per 0.3 m of penetration. In situ vane testing in borehole 06-106 indicates an undrained shear strength of greater than 96 kilopascals. These results indicate a very stiff consistency for this material.

The results of Atterberg limit testing on one sample of the weathered crust indicate a plasticity index of 24 percent and a liquid limit of 53 percent, as shown on Figure 4, indicating a weathered silty clay to clay of high plasticity. The measured natural water content of the weathered crust ranges from 40 to 42 percent.

The unweathered silty clay below the depth of weathering is grey in colour. The measured SPT "N" values within the unweathered silty clay ranged between 5 and 9 blows per 0.3 m of penetration. In situ vane testing in this material measured undrained shear strengths of greater than 96 kilopascals. These results indicate a very stiff consistency for the unweathered silty clay.

The results of Atterberg limit testing on two samples of the unweathered silty clay indicate a plasticity index which varies from 28 to 30 percent and a liquid limit which varies from 50 to 58 percent, as shown on Figure 5, indicating a silty clay to clay of high plasticity. The measured natural water content of the silty clay ranges from 39 to 45 percent.

At all three boreholes the portion of the deposit between about Elevations 118 and 121 m contained traces of black organic matter.

4.2.2.3 Sandy Silt Till

The silty clay is underlain by a thin deposit of sandy silt till. The sandy silt till is considered to consist of a heterogeneous mixture of gravel and cobbles in a matrix of sandy silt with a trace of clay. The deposit ranges from only 0.1 to 0.2 m thick and extends to the depth investigated at all of the boreholes, between about 10.2 and 12.4 m depth below the existing ground surface/embankment surface.

The results of grain size distribution testing on one sample of the till are shown on Figure 6. The measured natural water content of one sample of the glacial till is 16 percent.

4.2.2.4 Auger Refusal

Practical refusal to augering was encountered at all the boreholes at depths between about 10.2 and 12.4 m below the existing ground/embankment surface (Elevations 115.7 to 116.3 m).

The following table summarizes the bedrock surface depth and elevation as encountered at the borehole locations. It should be noted that the bedrock was not cored in any of the boreholes; however the surface of the bedrock was inferred in the three boreholes by refusal to auger advancement.

Borehole Number	Ground Surface/Embankment Elevation (m)	Depth to Bedrock (m)	Bedrock Surface Elevation (m)
06-104	127.8	11.5	116.3
06-105	127.8	12.4	115.4
06-106	125.9	10.2	115.7

4.2.2.5 Groundwater Conditions

The groundwater levels in the piezometers in Borehole 06-106 was measured on October 16, 2006. The piezometer was sealed into the silty clay deposit.

The groundwater level in the piezometer is summarized in the table below:

Borehole	Ground Surface Elevation (m)	Water Level Depth (m)	Water Level Elevation (m)	Date
06-106	125.9	0.22	125.7	October 16, 2006


It should be noted that groundwater levels in the area are subject to fluctuations both seasonally and with precipitation events.

4.0 CLOSURE

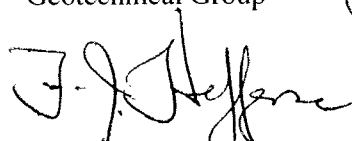
This report was prepared by Ms. Susan Trickey, EIT under the direction of the Project Manager, Mr. Michael Cunningham, P.Eng. This report was reviewed by Mr. Fintan J. Heffernan P.Eng., the designated MTO contact for this project.

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TABLE 1
COMPARISON OF FOUNDATION ALTERNATIVES
WILLOWS MUNICIPAL DRAIN CULVERT
W.P. 252-99-00

Foundation Option	Feasibility	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Rigid Frame Box Culvert – On Silty Clay	<ul style="list-style-type: none"> Feasible 	<ul style="list-style-type: none"> Minimizes excavation depth Sufficient bearing resistance available Minimal settlements 	<ul style="list-style-type: none"> Potential modest differential settlement, due to varying thickness of clay below founding level. 	<ul style="list-style-type: none"> Least expensive option 	<ul style="list-style-type: none"> Low risk option
Rigid Frame Box Culvert – On Glacial Till	<ul style="list-style-type: none"> Feasible 	<ul style="list-style-type: none"> Slightly higher available resistance 	<ul style="list-style-type: none"> Sandy silt till needs to be protected from disturbance. Deeper excavation Possible higher rate of groundwater inflow to excavation 	<ul style="list-style-type: none"> More expensive than founding on silty clay, due to deeper excavation 	<ul style="list-style-type: none"> Possible disturbance of glacial till
Rigid Frame Box Culvert – On Bedrock	<ul style="list-style-type: none"> Feasible 	<ul style="list-style-type: none"> Higher available resistance, though far in excess of requirements 	<ul style="list-style-type: none"> Deeper excavation Possible higher rate of groundwater inflow to excavation 	<ul style="list-style-type: none"> More expensive than founding on silty clay or glacial till 	<ul style="list-style-type: none"> Low risk option
Rigid Frame Box Culvert – On Granular Pad	<ul style="list-style-type: none"> Feasible 	<ul style="list-style-type: none"> Higher bearing resistance while maintaining founding level. 	<ul style="list-style-type: none"> Deeper excavation Possible higher rate of groundwater inflow to excavation 	<ul style="list-style-type: none"> Likely more expensive than founding on silty clay, due to additional granular fill placement. 	<ul style="list-style-type: none"> Difficulty in compacting granular pad in wet excavation conditions.
Rigid Frame Open Footing – On Glacial Till	<ul style="list-style-type: none"> Feasible 	<ul style="list-style-type: none"> Minimal settlements Slightly less excavation than founding on bedrock 	<ul style="list-style-type: none"> Deeper excavation Possible higher rate of groundwater inflow to excavation Subgrade protection required. 	<ul style="list-style-type: none"> Higher cost option 	<ul style="list-style-type: none"> Possible disturbance of glacial till
Rigid Frame Open Footing – On Bedrock	<ul style="list-style-type: none"> Feasible 	<ul style="list-style-type: none"> Higher bearing resistance available No total or differential settlement No subgrade protection required. 	<ul style="list-style-type: none"> Deeper excavation Possible higher rate of groundwater inflow to excavation 	<ul style="list-style-type: none"> Higher cost option 	<ul style="list-style-type: none"> Low risk option
Deep Foundations	<ul style="list-style-type: none"> Feasible, but not required. 		<ul style="list-style-type: none"> Piles would be short. Special measures required. 	<ul style="list-style-type: none"> Most expensive option 	<ul style="list-style-type: none"> Low risk option

TABLE 2
COMPARISON OF FOUNDATION ALTERNATIVES
LAVALLEE CREEK CULVERT
W.P. 252-99-00

Foundation Option	Feasibility	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Rigid Frame Box Culvert	<ul style="list-style-type: none"> • Feasible 	<ul style="list-style-type: none"> • Minimizes excavation depth 	<ul style="list-style-type: none"> • Construction may interfere with creek by-pass 	<ul style="list-style-type: none"> • Similar cost to open footing 	<ul style="list-style-type: none"> • Low risk option
Rigid Frame Open Footing	<ul style="list-style-type: none"> • Feasible 	<ul style="list-style-type: none"> • Narrower excavations, may facilitate creek by-pass 	<ul style="list-style-type: none"> • Deeper excavation • Mud slab required 	<ul style="list-style-type: none"> • Similar cost to box culvert 	<ul style="list-style-type: none"> • Low risk option
Deep Foundations	<ul style="list-style-type: none"> • Feasible, but not required. 			<ul style="list-style-type: none"> • Most expensive option 	<ul style="list-style-type: none"> • Low risk option

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		III. SOIL DESCRIPTION				
AS	Auger sample	(a)	Cohesionless Soils			
BS	Block sample		Density Index (Relative Density)	N		
CS	Chunk sample			Blows/300 mm		
DO	Drive open			Or Blows/ft.		
DS	Denison type sample			0 to 4		
FS	Foil sample			4 to 10		
RC	Rock core			10 to 30		
SC	Soil core			30 to 50		
ST	Slotted tube			over 50		
TO	Thin-walled, open					
TP	Thin-walled, piston					
WS	Wash sample					
II. PENETRATION RESISTANCE		(b)		Cohesive Soils		
Standard Penetration Resistance (SPT), N:			Consistency	C _{u2} S _u		
The number of blows by a 63.5 kg. (140 lb.)					Kpa	Psf
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.)						
DD- Diamond Drilling						
Dynamic Penetration Resistance; N _d :			IV. SOIL TESTS			
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 ⁰ cone						
attached to “A” size drill rods for a distance						
of 300 mm (12 in.).						
PH:	Sampler advanced by hydraulic pressure	w	water content			
PM:	Sampler advanced by manual pressure	w _p	plastic limited			
WH:	Sampler advanced by static weight of hammer	w _l	liquid limit			
WR:	Sampler advanced by weight of sampler and rod	C	consolidaiton (oedometer) test			
Peizo-Cone Penetration Test (CPT):		CHEM	chemical analysis (refer to text)			
An electronic cone penetrometer with		CID	consolidated isotropically drained triaxial test ¹			
a 60 ⁰ conical tip and a projected end area		CIU	consolidated isotropically undrained triaxial test			
of 10 cm ² pushed through ground			with porewater pressure measurement ¹			
at a penetration rate of 2 cm/s. Measurements		D _R	relative density (specific gravity, G _s)			
of tip resistance (Q _t), porewater pressure		DS	direct shear test			
(PWP) and friction along a sleeve are recorded		M	sieve analysis for particle size			
Electronically at 25 mm penetration intervals.		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 test (LV-laboratory vane test)			
		γ	unit weight			

Note:

1. Tests which are anisotropically consolidated prior 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 stresses (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
*	Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

(a) Index Properties (cont'd.)

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 (overconsolidated 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	Overconsolidation 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 $= (\text{Compressive strength})/2$

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERING STATE

Fresh: no visible sign of weathering

Faintly Weathered: weathering limited to the surface of major discontinuities.

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

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

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

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

BEDDING THICKNESS

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

JOINT OR FOLIATION SPACING

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

GRAIN SIZE

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

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

O:\ Templates\Rock Description Terminology

CORE CONDITION

Total Core Recovery

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

Solid Core Recovery (SCR)

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

Rock Quality Designation (RQD)

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

DISCONTINUITY DATA

Fracture Index

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

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

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

Description and Notes

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

Abbreviations

B –	Bedding	Ca-	Calcite
FO-	Foliation/Schistosity	P-	Polished
CL -	Cleavage	S-	Slickensided
SH -	Shear Plane/Zone	SM-	Smooth
VN-	Vein	R-	Ridged/Rough
F -	Fault	ST-	Stepped
CO-	Contact	PL-	Planar
J -	Joint	FL-	Flexured
FR-	Fracture	UE-	Uneven
MF -	Mechanical	W-	Wavy
A-	Angular	C-	Curved
BP-	Bedding Plane	H-	Hackly
BL-	Blast Induced	SL-	Sludge Coated
	Parallel To	TCA-	To Core Axis
	Perpendicular To	STR-	Stress Induced

MISS_MTO 06-1120-014-2000.GPJ ON MOT GDT 7/25/07

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

PROJECT: 06-1120-014-2000

RECORD OF DRILLHOLE: 06-101

SHEET 1 OF 1

LOCATION: N 5000722.3; E 336387.4

DRILLING DATE: September 12, 2006

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV.		RUN No	PENETRATION RATE (m/min)	FLUSH	COLOUR % RETURN	FR/FX-FRACTURE F-FAULT SM-SMOOTH FL-FLEXURED BC-BROKEN CORE CL-CLEAVAGE J-JOINT R-ROUGH UE-UNEVEN MB-MECH. BREAK SH-SHEAR P-POLISHED ST-STEPPED W-WAVY B-BEDDING VN-VEIN S-SLICKENSIDED PL-PLANAR C-CURVED										DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY				DIAMETRAL POINT LOAD INDEX (MPa)				NOTES WATER LEVELS INSTRUMENTATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
				DEPTH (m)	RECOVERY					R.Q.D. %	FRACT. INDEX PER 0.3	DIP w.r.t CORE AXIS		TYPE AND SURFACE DESCRIPTION	K _f cm/sec				2 4 6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
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DEPTH SCALE

1 : 50



LOGGED: D.J.S.

CHECKED: W.C.

MIS-RCK 001 06-1120-014-2000-ROCK GPJ GLDR CAN GDT 7/25/07

PROJECT <u>06-1120-014-2000</u>		RECORD OF BOREHOLE No 06-102		1 OF 1	METRIC
W.P. <u>252-99-00</u>	LOCATION <u>N 5000723.5; E 336357.5</u>	ORIGINATED BY <u>D.J.S.</u>			
DIST <u>HWY 7</u>	BOREHOLE TYPE <u>Power Auger 108mm I.D. Hollow Stem Auger</u>	COMPILED BY <u>N.B.H.S.</u>			
DATUM <u>Geodetic</u>	DATE <u>September 12, 2006</u>	CHECKED BY <u>M.I.C.</u>			

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						
127.4	GROUND SURFACE													
0.0	Silty clay, some organic matter, trace gravel (FILL)													
127.1	Dark brown													
0.3	SILTY CLAY (Weathered Crust) Very stiff Grey brown Moist						127							
			1	SS	6									
							126							
			2	SS	14									
125.2														
2.3	Inferred Sandy SILT (TILL) Brown Moist End of Borehole Auger Refusal Note: Water level in well screen at 0.36m depth below ground surface on Oct. 16, 2006.													

MISS_MTO 06-1120-014-2000.GPJ ON_MOT.GDT 7/25/07

PROJECT 06-1120-014-2000		RECORD OF BOREHOLE No 06-103				1 OF 1		METRIC										
W.P. 252-99-00		LOCATION N 5000749.3; E 336358.1				ORIGINATED BY D.J.S.												
DIST HWY 7		BOREHOLE TYPE Power Auger 108mm I.D. Hollow Stem Auger				COMPILED BY N.B.H.S.												
DATUM Geodetic		DATE September 14, 2006				CHECKED BY M.I.C.												
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	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60						80	100	25
127.5	GROUND SURFACE																	
0.0	Silty clay TOPSOIL Dark brown																	
127.2																		
0.3	SILTY CLAY (Weathered Crust) Very stiff Grey brown Moist		1	SS	13													
			2	SS	9													
125.2																		
2.3	Sandy SILT, some gravel and clay (TILL) Compact Brown Wet		3	SS	15													
124.5																		
3.0	End of Borehole Auger Refusal																	

MISS_MTO 06-1120-014-2000 GPJ ON MOT GDT 7/25/07

MISS_MTO 06-1120-014-2000.GPJ ON MOT GDT 7/25/07

Continued Next Page

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

PROJECT <u>06-1120-014-2000</u>		RECORD OF BOREHOLE No 06-104		2 OF 2		METRIC	
W.P. <u>252-99-00</u>		LOCATION <u>N 5000072.8; E 335659.8</u>		ORIGINATED BY <u>D.J.S.</u>			
DIST <u>HWY 7</u>		BOREHOLE TYPE <u>Power Auger 108mm I.D. Hollow Stem Auger</u>		COMPILED BY <u>N.B.H.S.</u>			
DATUM <u>Geodetic</u>		DATE <u>September 18, 2006</u>		CHECKED BY <u>M.I.C.</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/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								20 40 60 80 100	20 40 60 80 100	W _p	W	W _L		
	--- CONTINUED FROM PREVIOUS PAGE ---							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x REMOULDED						
	SILTY CLAY Very stiff Grey Wet													
116.5							117							
116.3	Inferred Sandy SILT (TILL) Grey Wet													
11.5	End of Borehole Auger Refusal													

MISS_MTO 06-1120-014-2000.GPJ ON MOT GDT 7/25/07

+³, x³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT 06-1120-014-2000

RECORD OF BOREHOLE No 06-105

1 OF 2

METRIC

W.P. 252-99-00

LOCATION N 5000069.0; E 335631.9

ORIGINATED BY D.J.S.

DIST HWY 7

BOREHOLE TYPE Power Auger 108mm I.D. Hollow Stem Auger

COMPILED BY N.B.H.S.

DATUM Geodetic

DATE September 14, 2006

CHECKED BY M.I.C.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT 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 + FIELD VANE							w _p w w _L		
								● QUICK TRIAXIAL × REMOULDED									
127.8	GROUND SURFACE						20 40 60 80 100										
0.0	Sand and gravel (FILL) Brown																
127.4																	
0.4	Silty clay, some gravel, trace concrete, asphalt, and peal, occasional cobble (FILL) Very stiff Grey brown Moist		1	SS	16		127										
			2	SS	37		126										
125.5																	
2.3	SILTY CLAY (Weathered Crust) Very stiff Grey brown Moist to wet		3	SS	11		125										
			4	SS	11		124										
			5	SS	5												
123.3																	
4.5	SILTY CLAY Very stiff Grey Wet		6	SS	5		123										
			7	SS	5		122										
120.5																	
7.3	SILTY CLAY, trace black organic matter Very stiff Grey Wet		8	SS	5		120										

Continued Next Page

+ ³, × ³: Numbers refer to
Sensitivity

○ ³% STRAIN AT FAILURE

MISS_MTO 06-1120-014-2000 GPJ ON_MOT GDT 7/25/07

PROJECT		06-1120-014-2000		RECORD OF BOREHOLE No 06-105		2 OF 2		METRIC							
W.P.		252-99-00		LOCATION		N 5000069.0; E 335631.9		ORIGINATED BY							
DIST		HWY 7		BOREHOLE TYPE		Power Auger 108mm I.D. Hollow Stem Auger		COMPILED BY							
DATUM		Geodetic		DATE		September 14, 2006		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 × REMOULDED							
--- CONTINUED FROM PREVIOUS PAGE ---															
	SILTY CLAY Very stiff Grey Wet						20	40	60	80	100				
115.6															
115.4	Sandy SILT, some gravel, trace clay (TILL) Compact Grey Wet End of Borehole Auger Refusal		10	SS	>50									24 33 43 9	
12.4															

MISS_MTO 06-1120-014-2000.GPJ ON_MOT GDT 7/25/07

MISS_MTO 06-1120-014-2000.GPJ ON MOT GDT 7/25/07

Continued Next Page

+3, X3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

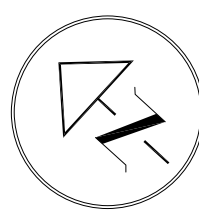
+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

MISS_MTO 06-1120-014-2000:GPJ ON_MOT.GDT 7/25/07


HWY. 7

WP No. 252-99-00

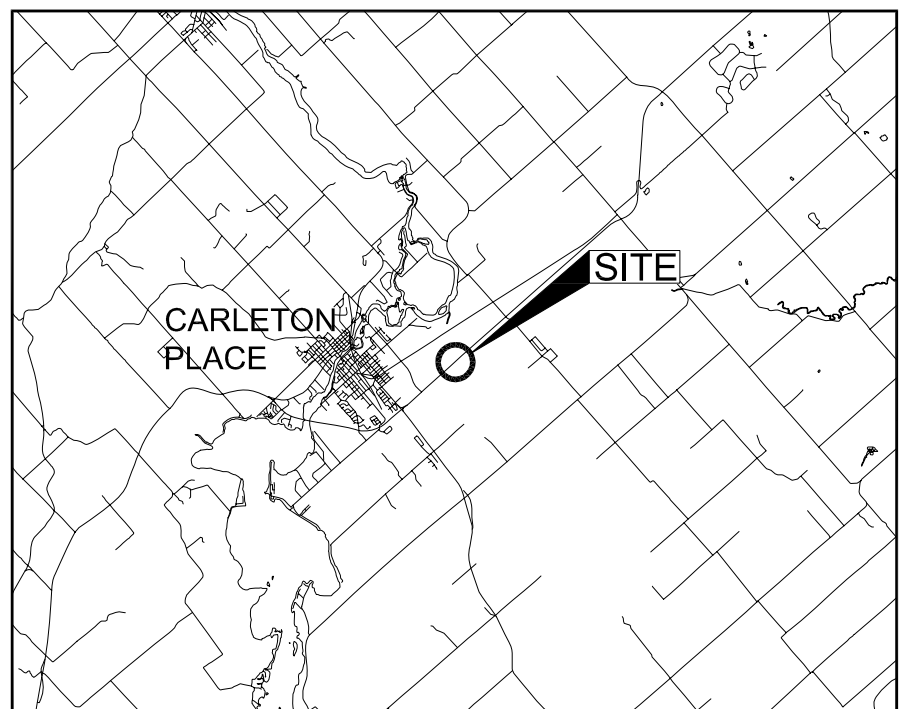
WILLOWS MUNICIPAL DRAIN
CULVERT-BOREHOLE LOCATIONS
AND SOIL STRATA



SHEET


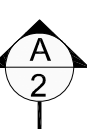



**Golder Associates**

Golder Associates Ltd.
OTTAWA, ONTARIO, CANADA



KEY PLAN

LEGEND

-  Borehole – Current Golder Associates Ltd. Investigation
-  Location of cross-section
-  Seal
-  Piezometer
- N Standard Penetration Test value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
-  Water Level in Piezometer (October 16, 2006)

No.	ELEVATION	LOCATION	
		NORTHING	EASTING
06-101	129.2	5000722.3	336387.4
06-102	127.4	5000723.5	336357.5
06-103	127.5	5000749.3	336358.1

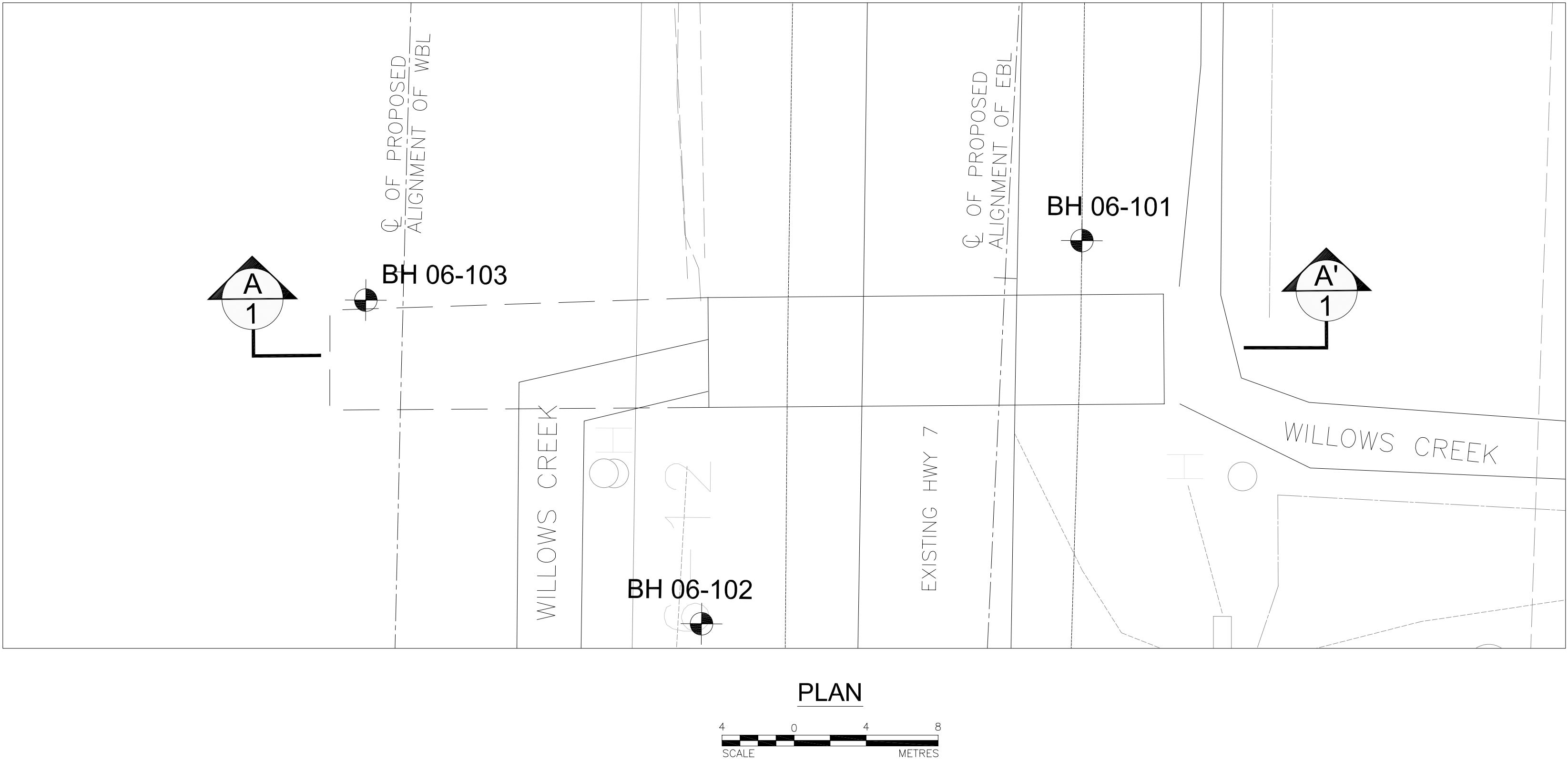
METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

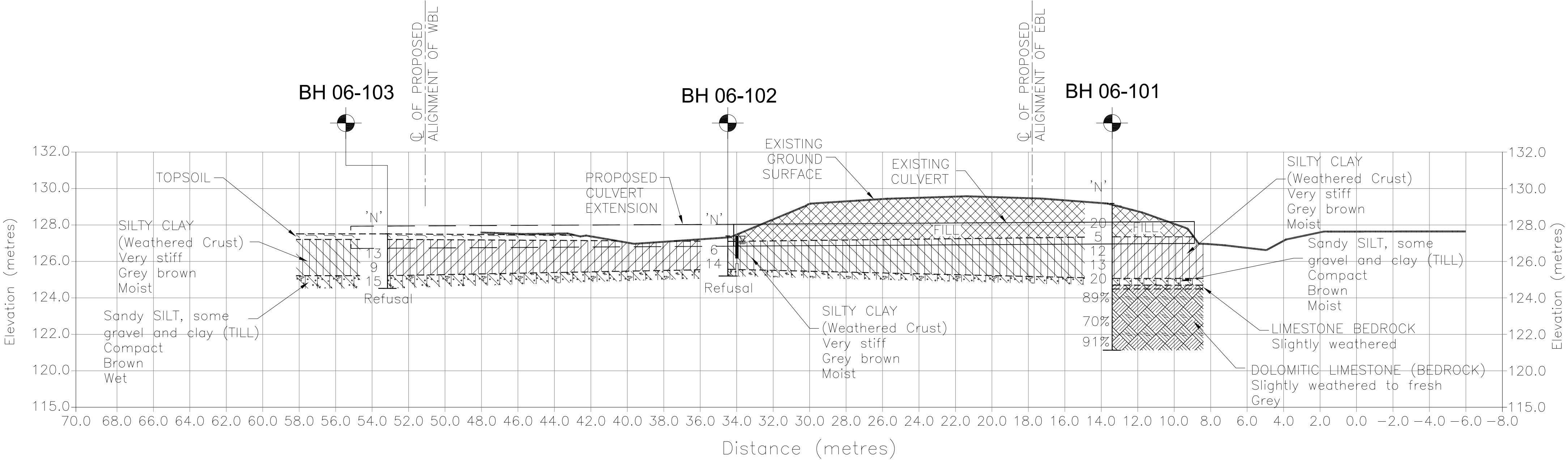
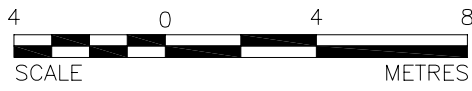
NOTES

This drawing is for subsurface information only. Any surface details 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.
Base plan provided in electronic format by McCormick Rankin Corporation

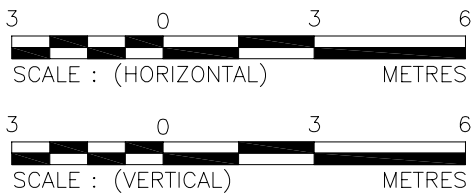
NO.	DATE	BY	REVISION
Geocres No. 31F-160			
HWY. 7	PROJECT NO. 06-1120-014-2000		DIST.
SUBM'D. M.I.C.	CHKD. M.I.C.	DATE: NOVEMBER 2006	SITE:
DRAWN: N.B.H.S.	CHKD.	APPD.	DWG. 1

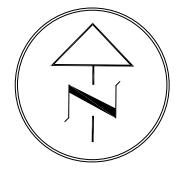
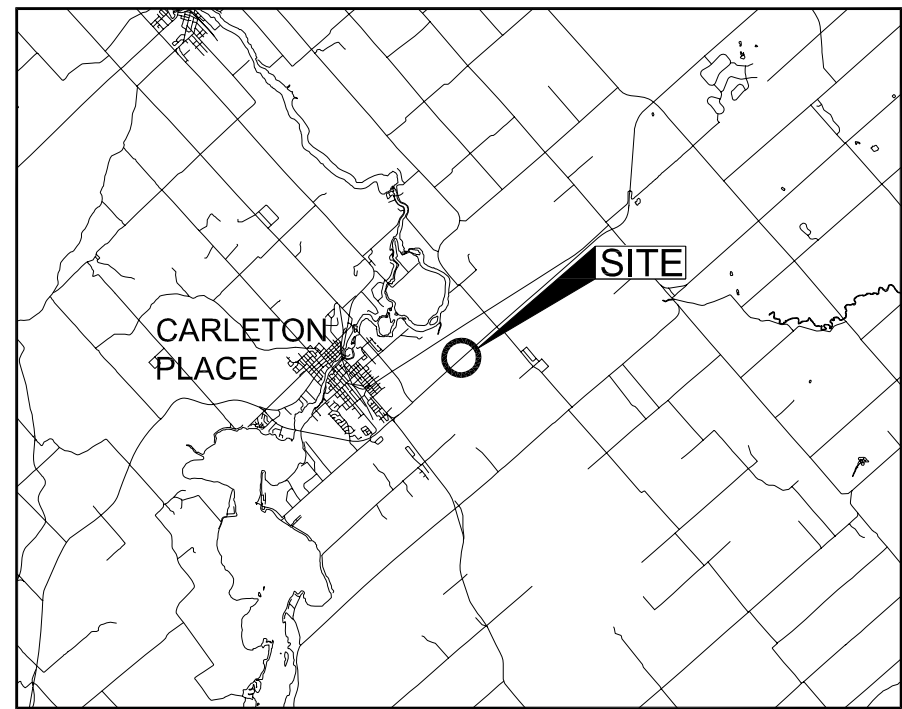


PLAN

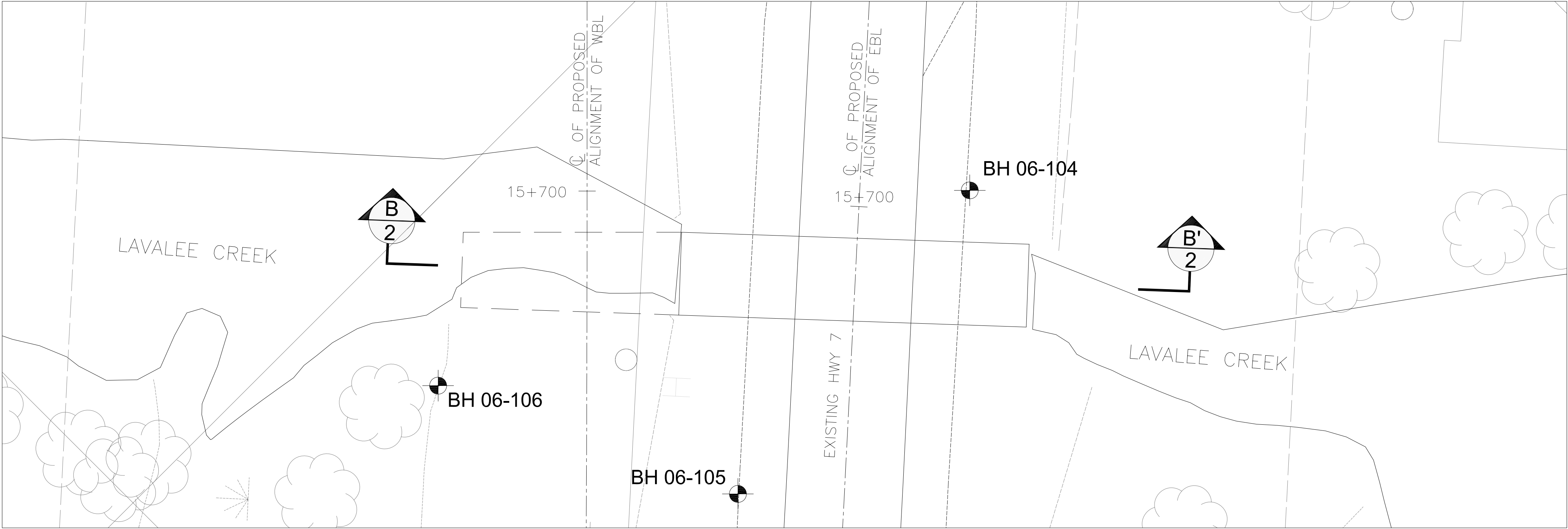


SECTION A-A'

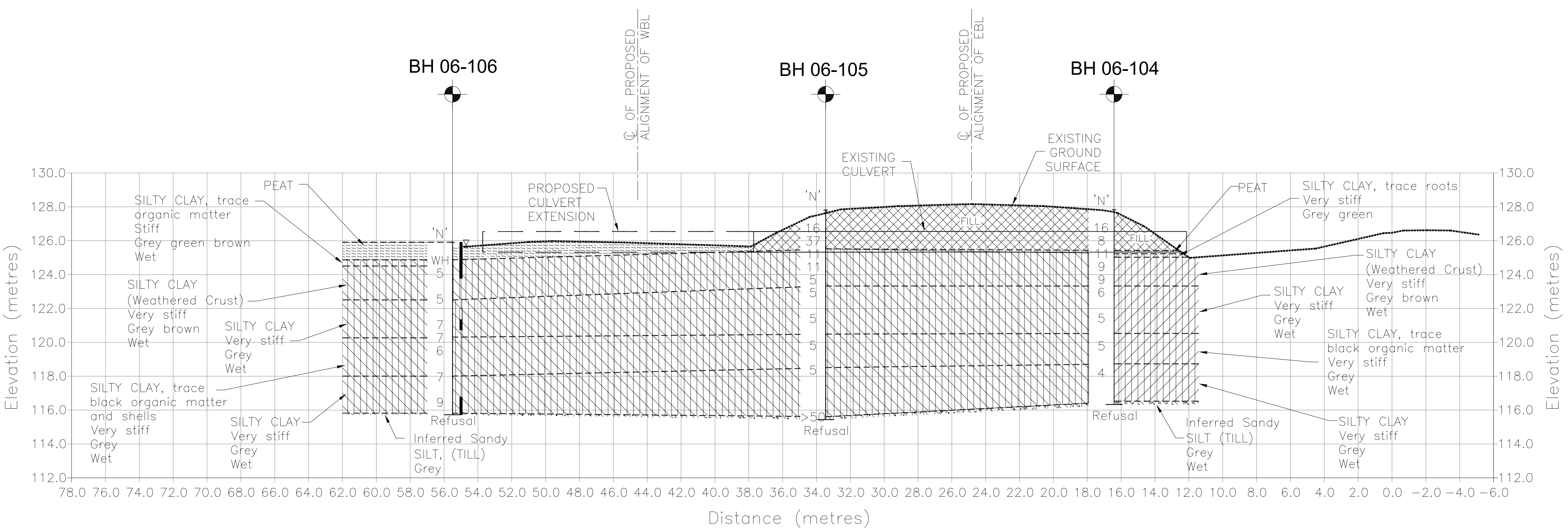
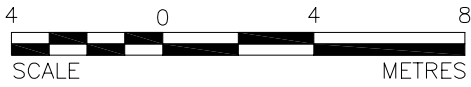




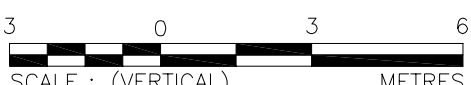
KEY PLAN



PLAN



SECTION B-B'



LEGEND			
	Borehole – Current Golder Associates Ltd. Investigation		
	Location of cross-section		
	Seal		
	Piezometer		
N	Standard Penetration Test value		
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)		
	Water Level in Piezometer (October 16, 2006)		
No.	ELEVATION	LOCATION	
		NORTHING	EASTING
06-104	127.8	5000072.8	335659.8
06-105	127.8	5000069.0	335631.9
06-106	125.9	5000090.2	335622.0

METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

NOTES

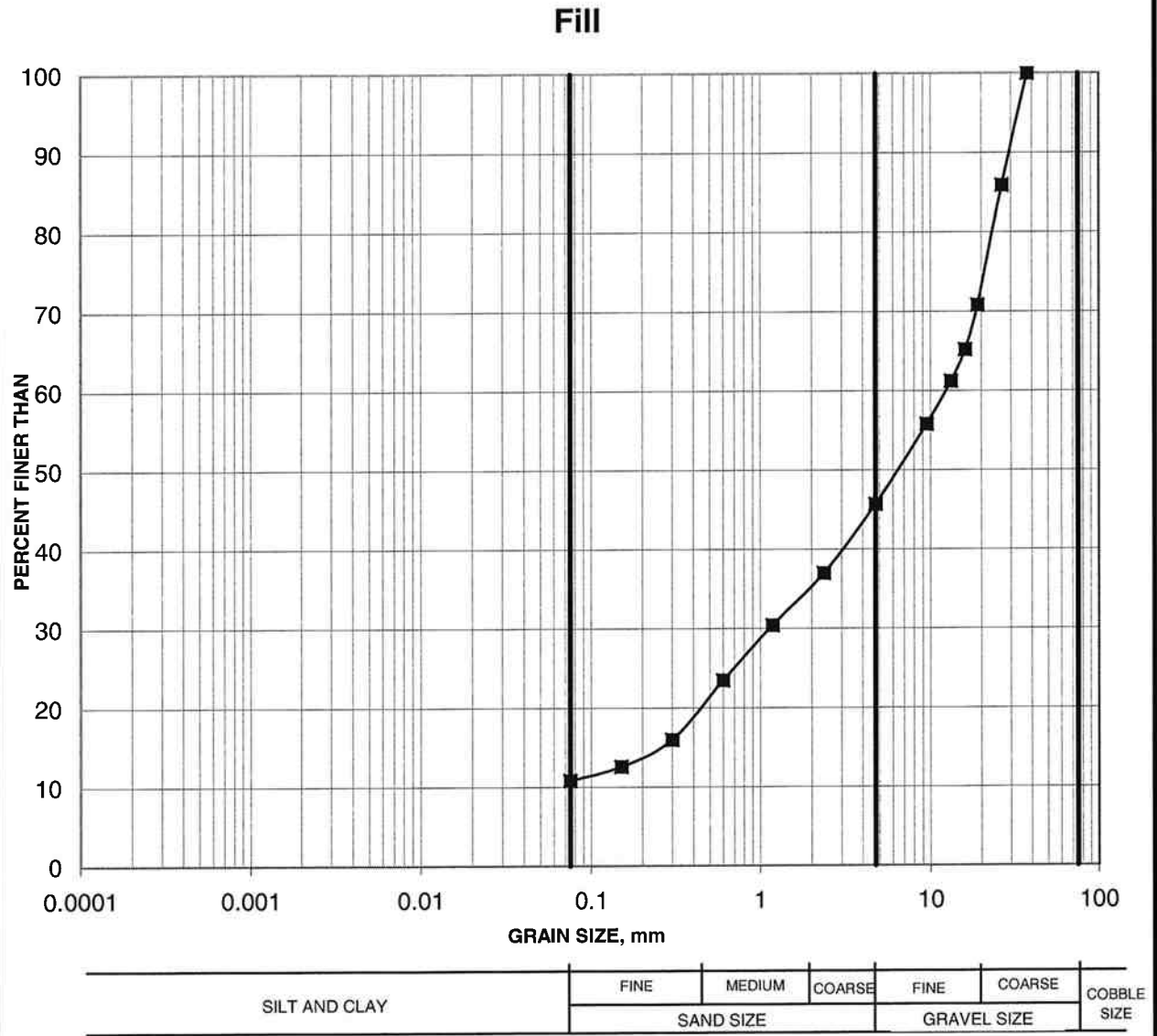
This drawing is for subsurface information only. Any surface details are for conceptual illustration. The boundaries between soil strata have been established only at borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

Base plan provided in electronic format by McCormick Rankin Corporation

NO.	DATE	BY	REVISION
Geocres No. 31F-160			
HWY. 7	PROJECT NO. 06-1120-014-2000	DIST.	
SUBM'D. M.I.C.	CHKD. M.I.C.	DATE: NOVEMBER 2006	SITE:
DRAWN: N.B.H.S.	CHKD.	APPD.	DWG. 2

GRAIN SIZE DISTRIBUTION

FIGURE 1



Borehole	Sample	Depth (m)
06-101	1	0.76-1.37

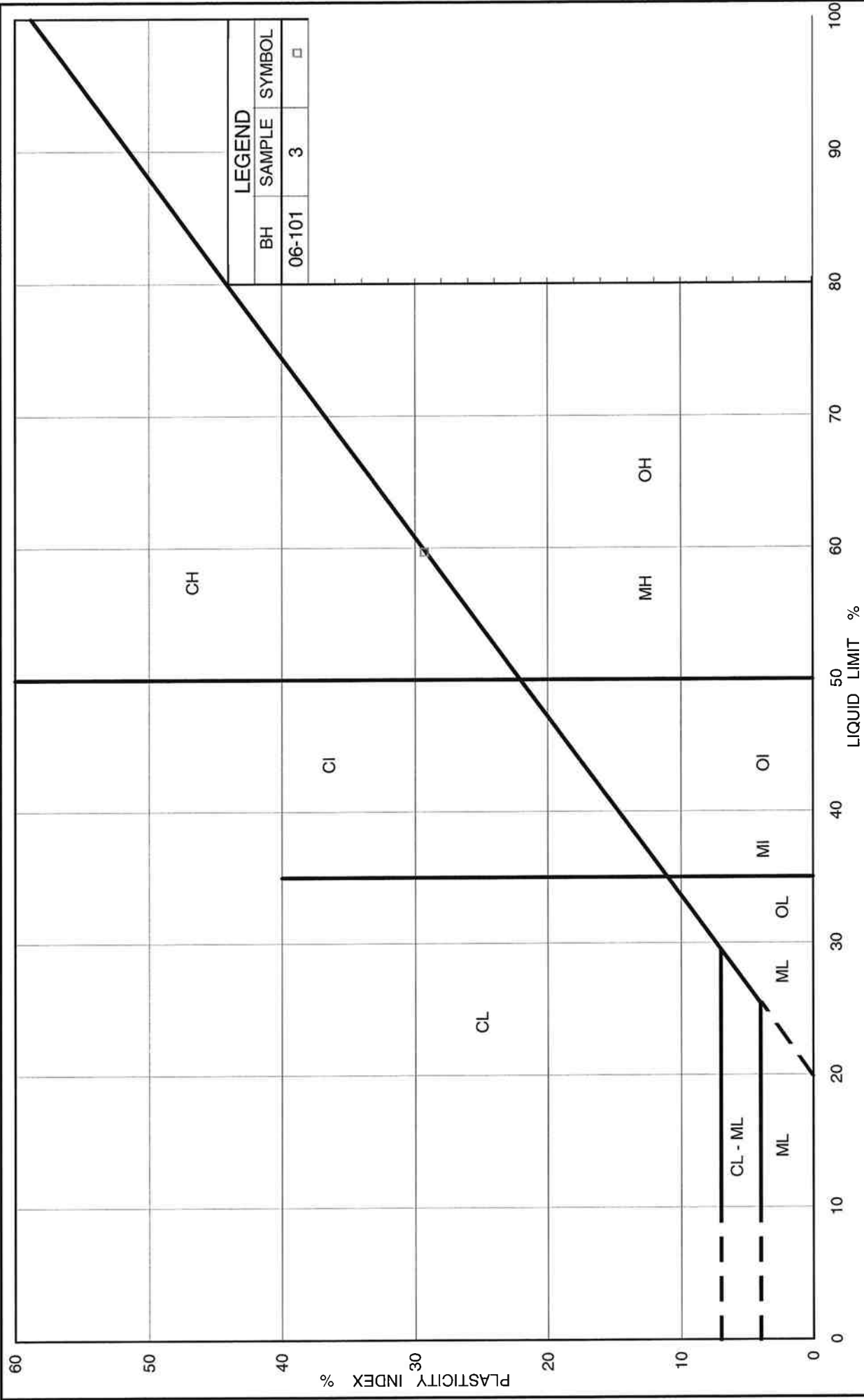


FIG No. 2
Project No. 061-120014

PLASTICITY CHART Weathered Silty Clay to Clay

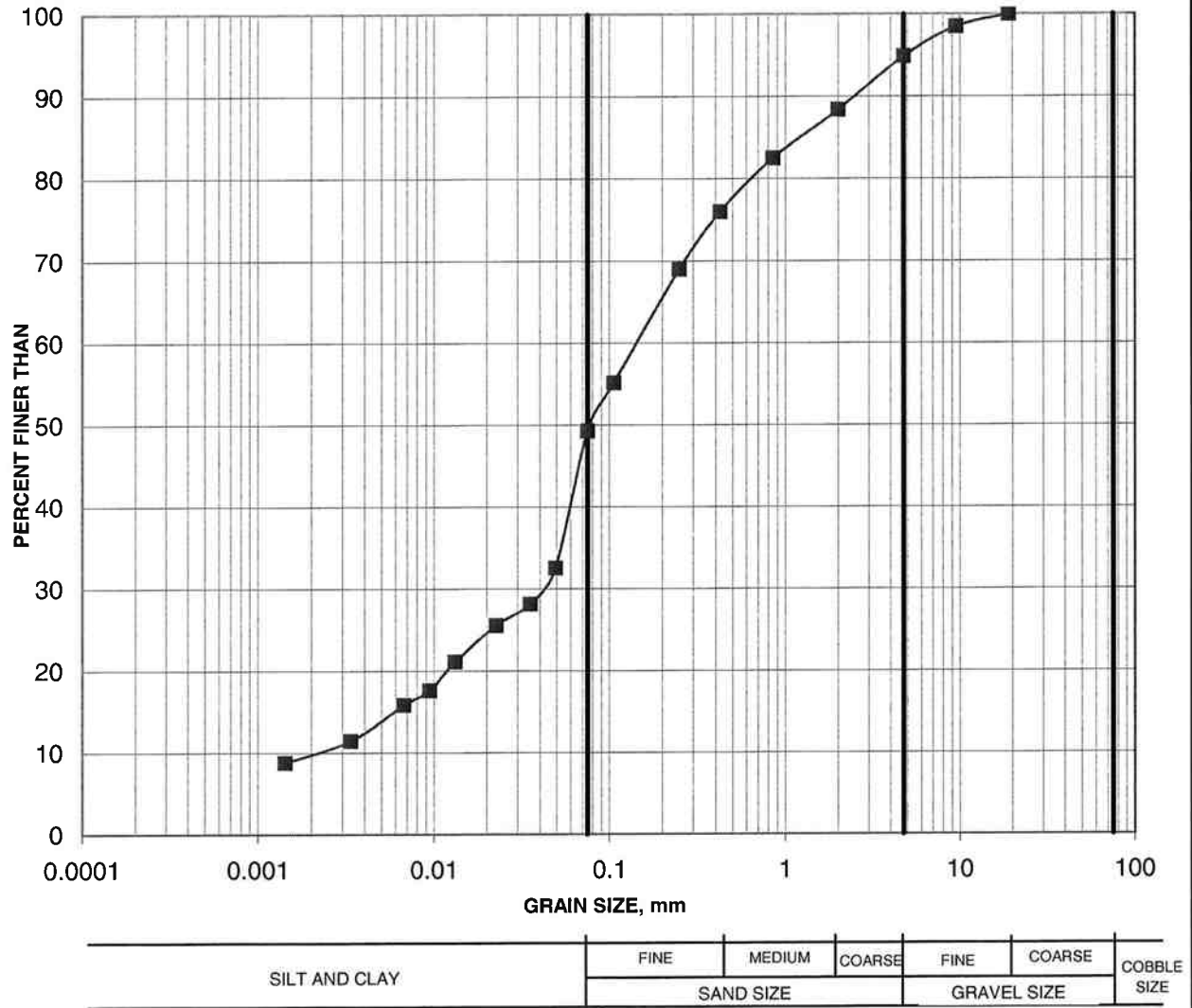
Ministry of Transportation



GRAIN SIZE DISTRIBUTION

FIGURE 3

Sandy Silt Till



Borehole	Sample	Depth (m)
06-101	5	3.81-4.42

Received:

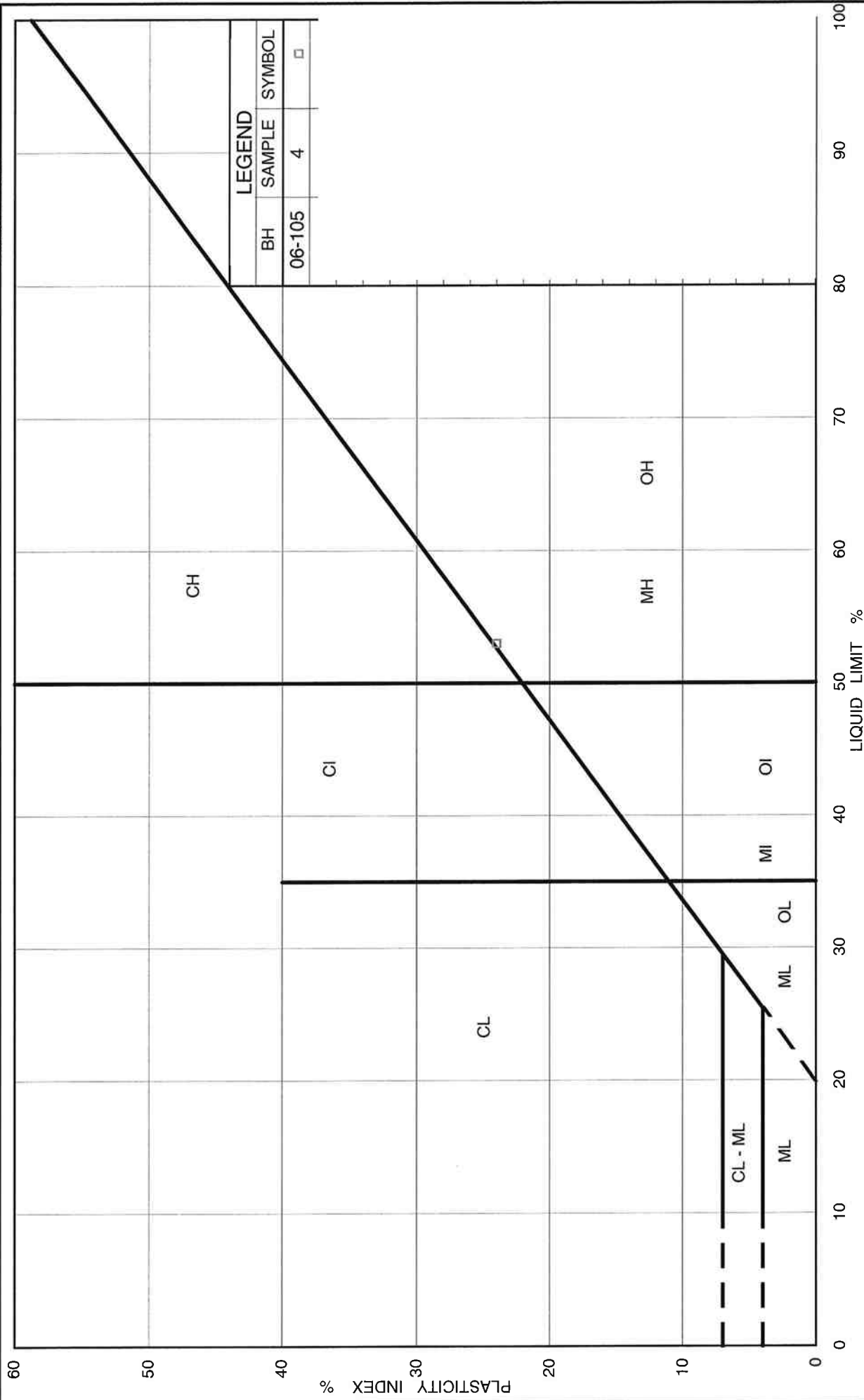
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Checked by: BaJ



LEGEND		
BH	SAMPLE	SYMBOL
06-105	4	□



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FIG No. 4

PLASTICITY CHART

Weathered Silty Clay to Clay

Project No. 061-120014

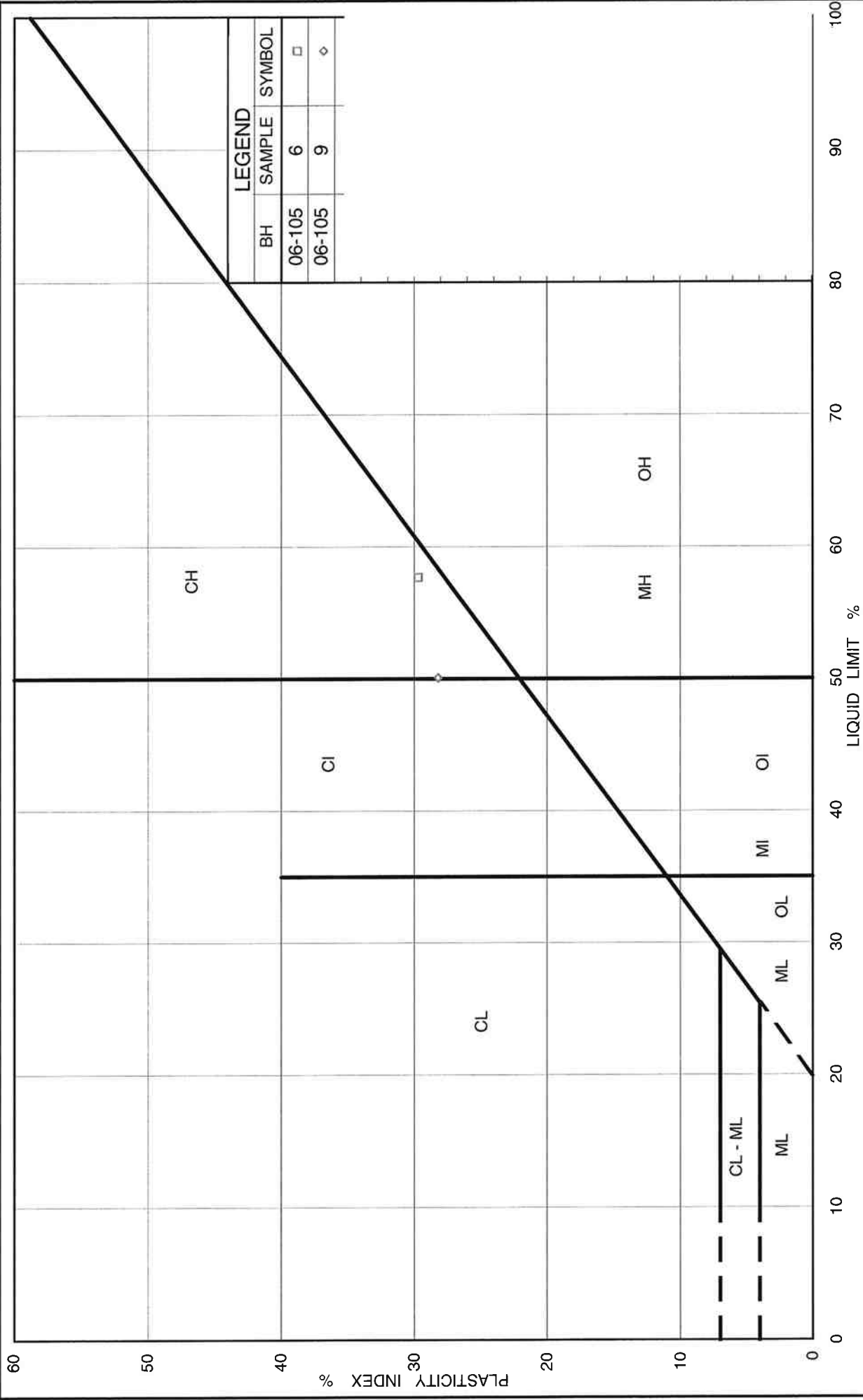


FIG No. 5
Project No. 061-120014

PLASTICITY CHART Unweathered Silty Clay to Clay

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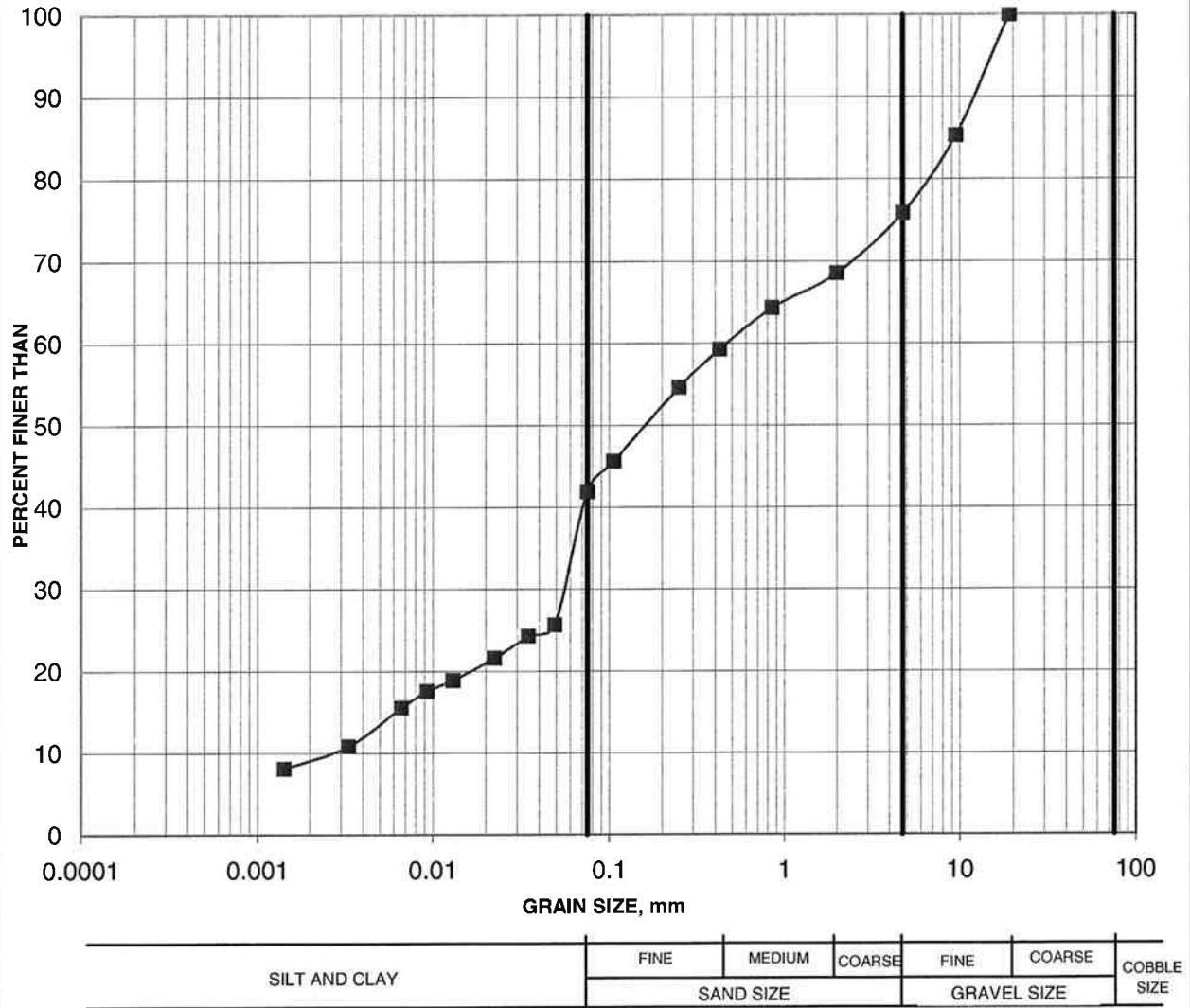


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GRAIN SIZE DISTRIBUTION

FIGURE 6

Sandy Silt Till



Borehole	Sample	Depth (m)
06-105	10	12.19-12.34

Received:

Project: 061120014

Golder Associates

26-Jul-07

Created by: MaD

Checked by: BaJ