Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION INVESTIGATION AND DESIGN REPORT

for

THREE CULVERTS AT STA. 13+274, 14+291 AND 15+034
HIGHWAY 69 FOUR-LANING FOR 21.5 KM
FROM 4.5 KM NORTH OF HIGHWAY 64
TO 8.7 KM NORTH OF HIGHWAY 637
G.W.P. 5379-02-00
DISTRICT 54, SUDBURY, ONTARIO

PHASE 1, STA. 12+200 TO 15+400
TOWNSHIP OF SERVOS

PETO MacCALLUM LTD.
165 CARTWRIGHT AVENUE
TORONTO, ONTARIO
M6A 1V5
Phone: (416) 785-5110
Fax: (416) 785-5120
Email: toronto@petomaccallum.com

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PML Ref.: 06TF055A
Index No.: 379FIR and 380FDR
Geocres No.: 41I-218
October 25, 2007

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From 4.5 km North of Highway 64
to 8.7 km North of Highway 637
G.W.P. 5379-02-00
District 54, Sudbury, Ontario

Phase 1, Sta. 12+200 to 15+400
Township of Servos

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1. INTRODUCTION

Four-laning of a 21.5 km long section of Highway 69 that extends from 4.5 km north of Highway 64 to 8.7 km north of Highway 637, some 45 km south of Sudbury, is planned. This report was prepared for Totten Sims Hubicki Associates (TSH) on behalf of the Ministry of Transportation of Ontario (MTO).

Planned within the 3.2 km long Phase 1 of the project is the installation of several concrete culverts less than 3 m in span. Three of these culverts have been recommended for foundation investigation and are dealt with in the report. For ease of reference, the culverts are identified by the reference numbers that correspond to those designated in the Request for Proposal (RFP). The Peto MacCallum Ltd. (PML) identification number and location of each culvert are given in the following table:

CULVERT REF. No.	APPROXIMATE STATION (New Highway 69, Servos Township)
C-3	13+274
C-7	14+291
C-9	15+034

This report summarises the results of the field investigation conducted at the locations of the above culverts. The subsurface conditions for the remaining culverts in Phase 1 of the project are to be provided in a Pavement Design Report under separate cover.

165 Cartwright Avenue, Toronto, Ontario M6A 1V5
Tel: (416) 785-5110 Fax: (416) 785-5120
E-mail: toronto@petomaccallum.com
BARRIE, BRAMPTON, HAMILTON, KITCHENER, TORONTO

2. SITE DESCRIPTION AND GEOLOGY

The Phase 1 section of the 21.5 km long section of Highway 69 to be four-laned is situated about 45 km south of Sudbury in a wooded region with open swampy areas. Land use includes forestry exploration and isolated cottage sites. The Highway 69 corridor runs between Lovering Lake to the east and Rock Bay to the west.

The study area is located in the Precambrian Laurentian peneplane. The topography is irregular in detail and dotted with areas of wet ground separated by steep rock ridges. Pleistocene lacustrine/fluvial deposits and recent swamp sediments have been laid down in depressions and are probably associated with the Nipissing post-glacial stage of the Great Lakes. Gravel and sand deposits were also encountered. Soil cover over the rock outcrops is generally sparse.

Metasedimentary rocks of the Huronian Supergroup and gneisses of the Grenville Province underlie the alignment. The area has undergone considerable folding, intrusive activity, regional metamorphism and faulting. The bedrock outcrops at many locations throughout the project section. In particular, the massive Servos Pluton outcrops along Highway 637 located immediately west of the north section of Phase 1 of the project.

3. INVESTIGATION PROCEDURES

The field work for this study was carried out during the period of March 8 to 23, 2007 and comprised a total of 16 boreholes advanced to depths of 0.9 to 16.4 m below existing grade. The approximate locations of the boreholes put down along each culvert are shown on Drawings C3-1, C7-1 and C9-1 for respective culverts C-3, C-7 and C-9.

The borehole numbers and figures are identified by the prefix codes C3, C7 and C9 to reflect the specific culvert number for ease of reference.

Due to the bouldery and variable terrain at the culvert locations, the field program was expanded from 3 boreholes to a minimum of 5 boreholes. The sampled boreholes drilled at the ends and

median of the culverts were supplemented by augur holes put down at the intersection of SBL and NBL centrelines with the culvert alignment.

The borehole locations were established in accordance with the MTO requirements indicated in the RFP and in general accordance with the requirements of the MTO Northeastern Region Pavement Design Practices and Guidelines (May 20, 1997). Callon Dietz Surveying Ltd. and SRQ Inc. laid out the reference lines of the new highway in the field and these lines were used by Peto MacCallum Ltd. (PML) to select the borehole locations. The ground surface elevations at the boreholes were determined by PML. The elevations in this report are expressed in metres.

The boreholes were advanced using a combination of continuous flight hollow and solid stem augers, powered by a track-mounted CME-55 drill rig, and percussion drilling. The equipment was supplied and operated by specialist drilling contractors working under the full-time supervision of members of PML engineering staff. Two boreholes at culvert C-3 and three boreholes at culvert C-7 were extended 2.8 to 3.5 m into bedrock using NXL rock coring equipment supplemented by casing and wash boring techniques. A casing run in the borehole put down at the west end of culvert C-3 veered off the inferred steeply inclined bedrock and bent so that a core barrel could not be advanced past 11.3 m depth and the attempt to core bedrock was abandoned.

Due to boulders/bedrock at surface at the location of culvert C-9 and as agreed with the MTO Pavements and Foundations Section, the methodology for subsurface investigation was modified to have all five boreholes along culvert C-9 advanced with a percussion drill rig (air-track) at least 3 m into bedrock.

Representative soil samples were recovered at frequent depth intervals using a conventional split spoon sampler during drilling. Standard penetration tests were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata. Penetrometer and in situ vane shear testing (using the MTO ‘N’ vane) was also performed to further assess the shear strength of the cohesive soils encountered. The penetrometer test results are typically less than the actual values due to sample disturbance. The results of the field tests and observations are reported on the appended Record of Borehole sheets.

The groundwater conditions at the borehole locations were assessed during drilling by visual examination of the soil, the sampler and drill rods as the samples were retrieved and, when appropriate, by measurement of the water level in the open borehole. Upon completion of drilling, all the boreholes were backfilled with a bentonite/cement mixture in accordance with the MTO and MOE Reg. 903 guidelines for borehole abandonment procedures.

Soils were identified in the field in accordance with the MTO Soil Classification procedures. The recovered samples were returned to our laboratory for detailed visual examination and classification. The laboratory testing programme consisting of moisture content determinations as well as three Atterberg limits tests and five grain size distribution analyses was carried out on selected samples. Atterberg limits determination was not attempted on samples deemed to be non-plastic by visual and tactile examination. The results of the laboratory Atterberg limits testing and grain size distribution analyses are presented in Figures identified with respective codes PC and GS.

4. SUMMARISED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, soil boundary elevations, standard penetration resistance values as well as in situ vane shear and penetrometer test data, groundwater observations. The results of laboratory Atterberg limits tests, grain size distribution analyses and moisture content determinations are also shown on the Record of Borehole sheets.

The borehole locations are shown on Drawings C3-1, C7-1 and C9-1. The boundaries between soil strata have been established at the borehole locations only. Between and beyond the boreholes, the boundaries are assumed and may vary.

A description of the subsurface stratigraphy at each culvert is summarised in the following subsections of the report.

4.1 Culvert C-3 at Sta. 13+274

Six boreholes were drilled along the alignment of this culvert. The subsurface stratigraphy revealed in the boreholes comprised a surficial peat / topsoil layer underlain by clayey silt / silty clay and/or sand. Cobbles and boulders were encountered in the sand. Bedrock was contacted or inferred at depths of 2.4 to 16.4 m (elevation 185.5 to 206.8). Groundwater was at elevation 201.5 to 203.8 upon completion of drilling.

4.1.1 Peat / Topsoil

A surficial deposit of peat was present in boreholes C3-1 and C3-2. This deposit had a thickness of 1.2 m thick in the former borehole and 0.8 m in the latter and was penetrated at elevation 200.7 and 202.2 respectively.

Topsoil was present surficially in borehole C3-5 advanced at the centreline of the new northbound lanes. The topsoil was 200 mm thick and penetrated at elevation 207.8.

4.1.2 Clayey Silt to Silty Clay

Overlain by the peat at a depth of 1.2 m (elevation 200.7) in borehole C3-1 was a localized cohesive deposit of clayey silt / silty clay. This deposit was 3.4 m in thickness and soft in consistency. The results of in situ vane testing carried out at 4 m depth yielded an undisturbed shear strength value of 20 kPa (soil sensitivity of 3). One penetrometer test indicated a shear strength of 25 kPa. The deposit was penetrated at a depth of 4.6 m (elevation 197.3).

The results of Atterberg limits testing and grain size distribution analysis conducted on a cohesive sample are presented in respective Figures C3-PC-1 and C3-GS-1. The clayey silt had liquid and plastic limits of 34 and 21 respectively, its plasticity index being 13. The deposit had a moisture content of 42 to 51%.

4.1.3 Sand / Boulders

Overlain by a 300 to 400 mm thick layer of boulders in boreholes C3-1, C3-4 and C3-6, cohesionless sand with cobbles and boulders was present surficially in borehole C3-3 and encountered below the topsoil, clayey soils or peat and roots at depths of 0.2 to 4.6 m (elevation 197.3 to 207.8) in the remaining boreholes. This unit had a variable thickness of 2.4 to 11.8 m where penetrated and was compact in relative density (SPT-'N' values of 11 to 28). The moisture content of the sand varied between 13 and 26%. The unit was penetrated at depths of 2.4 to 16.4 m (elevation 185.5 to 206.8) with the exception of borehole C3-5 terminated on a probable boulder at 1.5 m depth (elevation 206.5).

The results of grain size distribution analyses performed on two samples of this material are presented in Figure C3-GS-2.

4.1.4 Bedrock

Bedrock was contacted or inferred at depths of 2.4 to 16.4 m (elevation 185.5 to 206.8), with the bedrock surface elevation increasing in the direction from the west end of the culvert to its east end. The bedrock comprises a black gabbro (over a light grey to pink migmatite at the bottom of borehole C3-6) and exhibited a medium to high strength. A detailed description of the rock cores retrieved from boreholes C3-4 and C3-6 is given in Table 1, appended.

The measured core recovery was 100%. The RQD determined from the rock cores was in a range of 81 to 100%, thus indicating a good to excellent quality rock.

4.1.5 Groundwater

Groundwater was observed in five boreholes in the course of the field work. In the process of augering, water was detected at depths of 0.3 to 3.0 m (elevation 201.6 to 208.0) in boreholes C3-1, C3-4 and C3-6. Upon completion of drilling, groundwater was measured in boreholes C3-1 to C3-4 to be at depths of 0.3 to 3.2 m (elevation 201.5 to 203.8). No water was

observed in borehole C3-5. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.2 Culvert C-7 at Sta. 14+291

Five boreholes were drilled along the alignment of this culvert. The subsurface stratigraphy revealed in the boreholes generally comprised a surficial topsoil / peat overlying clayey silt or silty clay. Bedrock was contacted or inferred at depths of 0.9 to 3.1 m (elevation 200.0 to 202.5). Groundwater was at elevation 202.6 in one borehole.

4.2.1 Topsoil / Peat

Topsoil was present surficially in boreholes C7-1 and C7-5 put down at both ends of the culvert. The topsoil was 150 to 200 mm thick and penetrated at elevation 203.9 in the former borehole and 202.9 in the latter.

A surficial deposit of peat was present in boreholes C7-2 and C7-3. The fine fibrous peat was 200 and 600 mm in thickness and penetrated at respective elevation 203.2 and 202.6.

4.2.2 Silty Clay / Clayey Silt

Directly beneath the topsoil at 0.2 m depth (elevation 203.9) in borehole C7-1 was cohesive silty clay. This stratum was 2.8 m thick and firm to stiff. Penetrometer testing on a sample of the silty clay indicated a shear strength of 100 kPa. The stratum was penetrated at a depth of 3.0 m (elevation 201.1).

Present surficially in borehole C7-4 and underlying the topsoil or peat at depths of 0.2 to 0.6 m (elevation 202.6 to 203.2) in boreholes C7-2, C7-3, C7-5 was cohesive clayey silt. This deposit was 0.7 to 2.8 m in thickness and firm to stiff in consistency. The clayey silt was penetrated at depths of 0.9 to 3.0 m (elevation 200.1 to 202.5).

The results of Atterberg limits testing and grain size distribution analyses conducted on two cohesive samples are presented in respective Figures C7-PC-1, C7-PC-2 and C7-GS-1, C7-GS-2. The liquid and plastic limits were 46 and 24 (plasticity index of 22) for the silty clay, 32 and 19 (plasticity index of 13) for the clayey silt, respectively. The cohesive soils had a moisture content ranging from 27 to 35%.

4.2.3 Sand

A localized 100 mm thick layer of cohesionless sand was encountered below the clayey silt at 3.0 m depth (elevation 200.1) in borehole C7-5 advanced at the east end of the culvert. The sand was judged to be compact in relative density and extended to bedrock at a depth of 3.1 m (elevation 200.0).

4.2.4 Bedrock

Bedrock was contacted or inferred at depths of 0.9 to 3.1 m (elevation 200.0 to 202.5). The bedrock comprises a grey to pink granitic gneiss. The strength of the rock ranged from generally medium to high with occasional low strength sections in the upper zone. A detailed description of the rock cores retrieved from boreholes C7-1, C7-3 and C7-5 is given in Table 1.

The measured core recovery varied between 40 and 100%. The RQD determined from the rock cores was in a range of 40 to 100%, thus indicating a poor becoming fair to excellent quality rock.

4.2.5 Groundwater

Water was observed in one borehole in the course of the field work. Upon completion of drilling, groundwater was measured in borehole C7-3 to be at 0.6 m depth (elevation 202.6). No water was observed in the remaining boreholes. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.3 Culvert C-9 at Sta. 15+034

Five boreholes were advanced using percussion drilling along the alignment of this culvert in view of the observed shallow depths to bedrock and site access difficulties. The probe holes were advanced at least 3 m (3.1 to 3.4 m) into the bedrock at each location.

Based on the information obtained during the geotechnical investigation at the site, the subsurface stratigraphy is inferred to comprise a surficial topsoil over sandy silt with numerous cobbles and boulders.

4.3.1 Topsoil

The inferred thickness of a surficial topsoil layer was 300 mm in all five boreholes.

4.3.2 Sandy Silt

Probable sandy silt locally containing numerous cobbles and boulders was revealed below the topsoil in all the boreholes and extended to depths of 1.2 to 2.4 m (elevation 196.5 to 201.7) where bedrock was encountered.

4.3.3 Bedrock

Bedrock was contacted below the probable sandy silt at depths of 1.2 to 2.4 m (elevation 196.5 to 201.7). The boreholes were extended 3.1 to 3.4 m into bedrock and terminated at depths of 4.3 to 5.8 m (elevation 193.4 to 198.3).

4.3.4 Groundwater

Groundwater was at elevation 200.6 and 202.9 in boreholes C9-1 and C9-2 due to influx of surface water into the boreholes. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

5. CLOSURE

Messrs. M. Rapsey, N. Lee-Bun and S. Aziz carried out the field investigation for this study under the supervision of Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and direction of Mr. B.R. Gray, MEng, P.Eng., MTO Designated Contact. The equipment was supplied by Aardvark Drilling Ltd. and Rude Drilling Ltd. The laboratory testing of selected soil samples was carried out at the PML laboratory in Toronto.

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. C.M.P. Nascimento, P.Eng., Senior Project Engineer. Mr. B.R. Gray, MEng, P.Eng., MTO Designated Contact, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

Grigory O. Degil, PhD, P.Eng.
Senior Foundation Engineer

Carlos M. P. Nascimento, P.Eng.
Senior Project Engineer

Signed and Stamped on Hard Copies

Brian R. Gray, MEng, P.Eng.
MTO Designated Contact

GD:gd-mi/lnr

TABLE 1

ROCK CORE DESCRIPTION

CORE RECOVERY					CORE DESCRIPTION	
HOLE NO.	**CORE NO.**	**DEPTH (m)**	**RECOVERY (%)**	**RQD (%)**	**DEPTH (m)**	**DESCRIPTION**
C3-4	7 8	6.5 – 7.7 7.7 – 9.3	100 100	88 87	6.5 – 9.3	GABBRO: Black, fine to medium crystalline, mainly biotite, with rust oxidation on partings, becoming light grey (migmatite) with black oxidation and/or red residue on partings, medium to high strength, unweathered, close to moderate spaced flat to dipping partings, rough planar, oxidized to silty, good quality.
C3-6	3 4 5	2.4 – 3.0 3.0 – 4.5 4.5 – 5.6	100 100 100	81 100 91	2.4 – 5.4 5.4 – 5.6	GABBRO: Black, fine to medium crystalline, mainly biotite, with light brown to rust silt on partings, green mineralization on vertical partings, medium to high strength, slightly weathered to unweathered, close to moderate spaced flat to dipping with some vertical partings, rough planar, tight to oxidized, good to excellent quality. MIGMATITE: Light grey to pink, fine to medium crystalline, high strength, unweathered, very close to moderate spaced dipping to vertical partings, rough planar, tight to oxidized, excellent quality.
C7-1	3 4 5 6	3.0 – 3.7 3.7 – 4.5 4.5 – 6.0 6.0 – 6.5	68 100 97 83	48 91 65 72	3.0 – 6.5	GRANITIC GNEISS: Light grey to pink, fine to medium crystalline, occ. dark bands, with occ. dark grey to black weathered brown layer, rust oxidation or silt on partings, generally medium to high (occ. low) strength, generally unweathered with a few moderately weathered zones, very close to moderate spaced flat to dipping with some vertical partings, smooth to rough planar, oxidized to silty, poor becoming fair to excellent quality.
C7-3	3 4	2.7 – 4.3 4.3 – 5.8	100 100	86 71	2.7 – 5.8	GRANITIC GNEISS: Medium grey, fine to medium crystalline, banded, with occ. pink and dark grey layers, occ. encrustation on partings, high strength, slightly weathered to unweathered, generally close to moderate (locally very close to close) spaced, flat to dipping partings, occ. vertical parting, rough planar, tight to oxidized, fair to good quality.
C7-5	4 5 6	3.1 – 3.5 3.5 – 4.4 4.4 – 6.1	40 100 100	40 100 84	3.1 – 6.1	GRANITIC GNEISS: Light grey, fine to medium crystalline, banded, becoming pink, medium to coarse crystalline with black inclusions, high strength, unweathered, close to wide spaced, flat partings, occ. vertical parting, rough planar, tight to oxidized, poor becoming good to excellent quality.

RQD: Rock Quality Designation

Originated: FP
Compiled: JFW
Checked: GD/CN

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS $\tilde{N}$.

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	>200
	VERY SOFT	*SOFT*	*FIRM*	*STIFF*	*VERY STIFF*	*HARD*

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	>50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	*POOR*	*FAIR*	*GOOD*	*EXCELLENT*

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	>3m
JOINTING	*VERY CLOSE*	*CLOSE*	*MOD. CLOSE*	*WIDE*	*VERY WIDE*
BEDDING	*VERY THIN*	*THIN*	*MEDIUM*	*THICK*	*VERY THICK*

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE
F V	FIELD VANE		

STRESS AND STRAIN

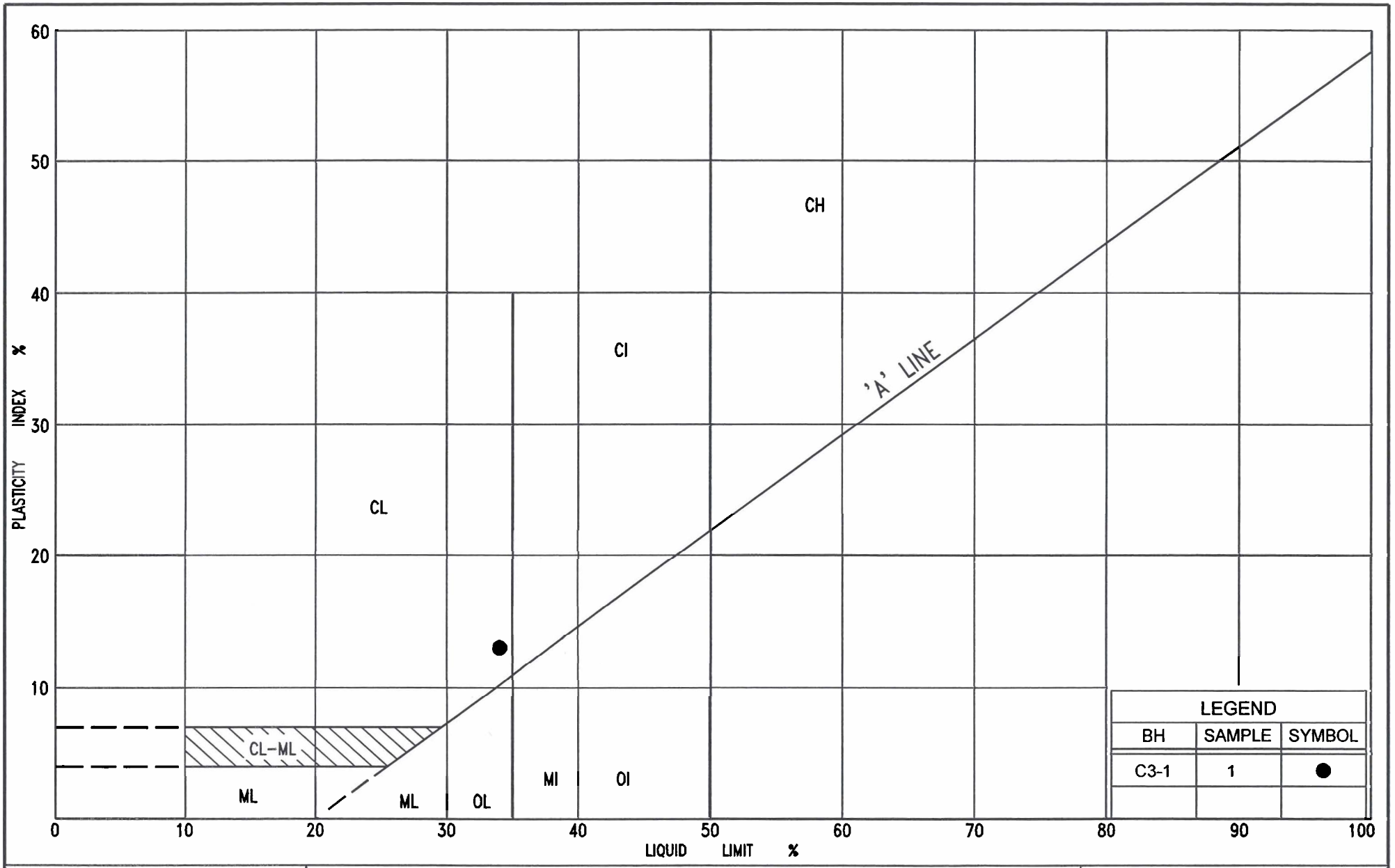
u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kN/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kN/m^3	UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL
e	1,%	VOID RATIO
n	1,%	POROSITY
w	1,%	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_P	%	PLASTIC LIMIT
w_S	%	SHRINKAGE LIMIT
I_P	%	PLASTICITY INDEX = $w_L - w_P$
I_L	1	LIQUIDITY INDEX = $\frac{w - w_P}{I_P}$
I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_P}$
DTPL		DRIER THAN PLASTIC LIMIT
APL		ABOUT PLASTIC LIMIT
WTPL		WETTER THAN PLASTIC LIMIT
e_{max}	1,%	VOID RATIO IN LOOSEST STATE
e_{min}	1,%	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	n PERCENT - DIAMETER
C_U	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

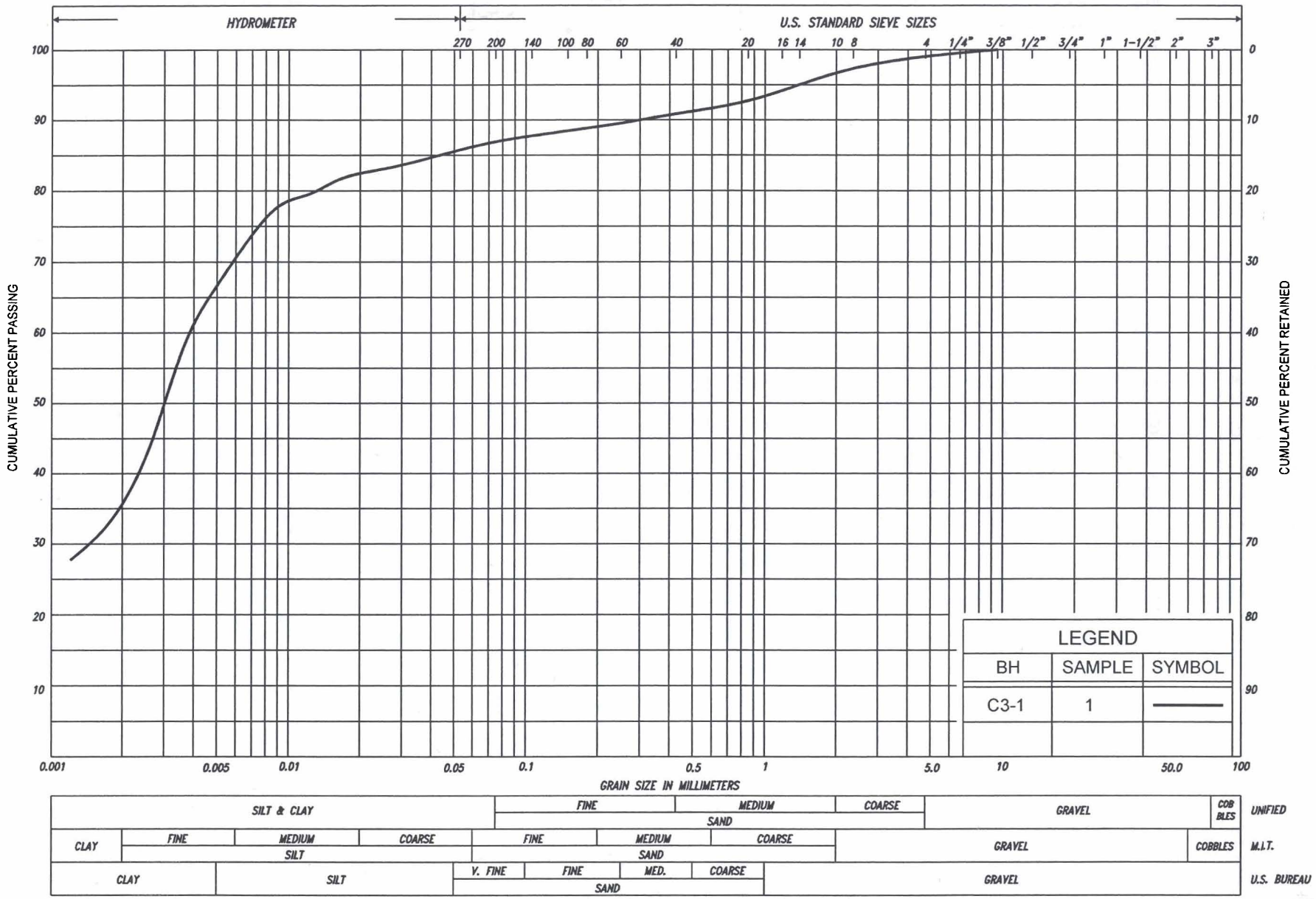


Ministry of Transportation
Ontario

PLASTICITY CHART

CLAYEY SILT, some sand, trace gravel

FIG No.	C3-PC-1
HWY:	69
G.W.P. No.	5379-02-00



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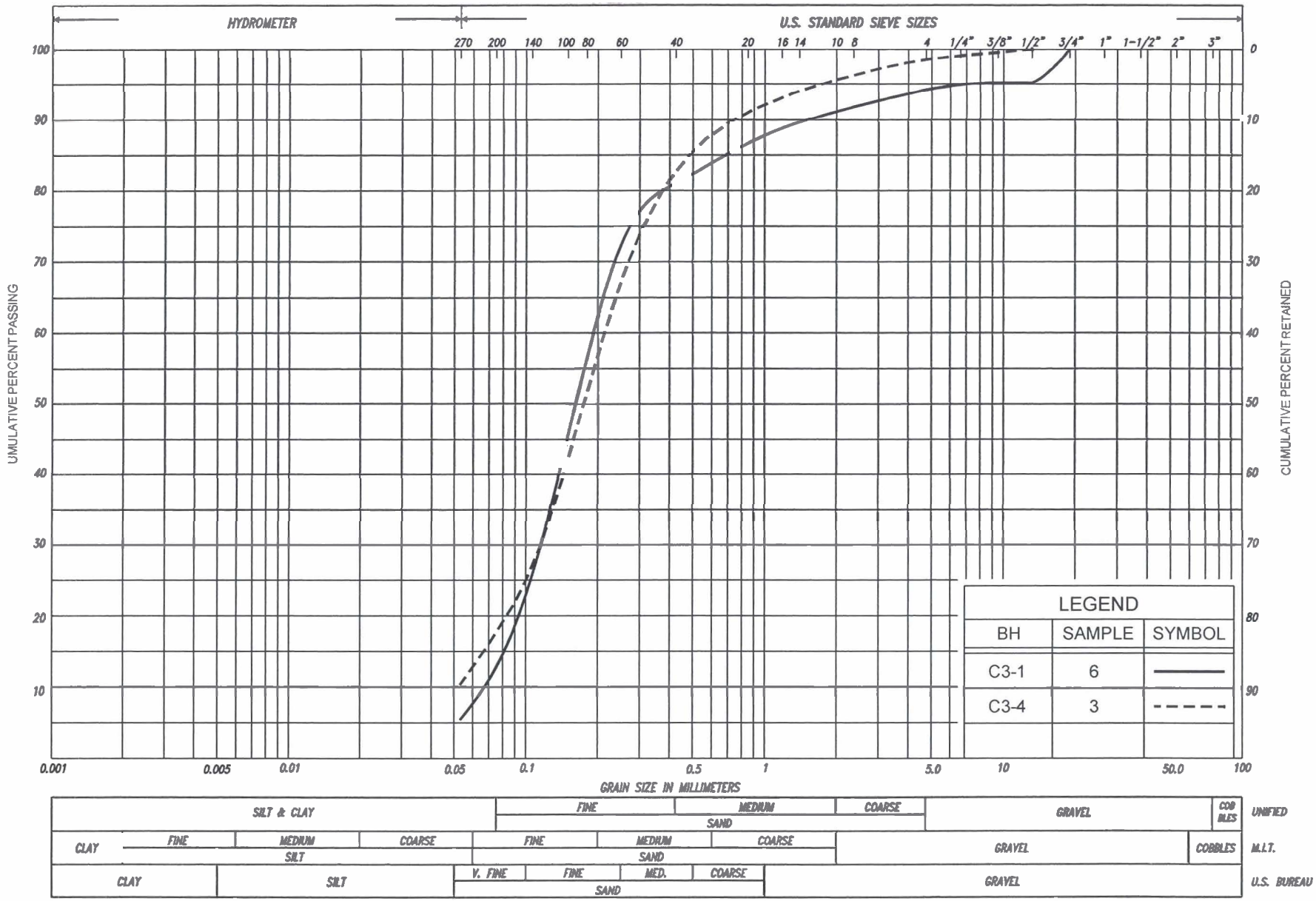
GRAIN SIZE DISTRIBUTION

CLAYEY SILT, some sand, trace gravel

FIG No.	C3-GS-1
HWY:	69
G.W.P. No.	5379-02-00



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GRAIN SIZE DISTRIBUTION

SAND, some silt, trace gravel

FIG No.	C3-GS-2
HWY:	69
G.W.P. No.	5379-02-00

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Ontario

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Foundation Design

RECORD OF BOREHOLE No C3-1 1 of 2 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 13+274, o/s 58.7m Lt. of CL Med ORIGINATED BY M.R.

DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A & NXL Rock Coring COMPILED BY G.D.

DATUM Geodetic DATE March 12&13, 2007 CHECKED BY G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
201.9	Ground Surface										
0.0 / 200.7	Peat					▼* ▽*	201				
1.2 / 197.3	Clayey silt to silty clay some sand, trace gravel Soft Blueish Grey Wet		1	SS	4		200				1 12 51 36
			2	SS	2		199				
			3	SS	1		198	3			
				FV							
4.6 / 197.0	Boulder		4	RC			197				
4.9	Sand trace to some silt trace gravel, occ. cobbles occ. layers of silty sand Compact Brown Wet		5	SS	12		196				
			6	SS	13		195				6 81 (13)
			7	SS	18		194				
			8	SS	19		193				
			9	SS	20		192				
			10	SS	21		191				
	Cont'd						190				
							189				
							188				
							187				

$+^{7}$, $\times^{5}$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C3-1 2 of 2 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 13+274, o/s 58.7m Lt. of CL Med ORIGINATED BY M.R.

DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A & NXL Rock Coring COMPILED BY G.D.

DATUM Geodetic DATE March 12&13, 2007 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
186.9											
			11	SS	19		186				
185.5											
16.4	End of borehole Refusal on probable bedrock										

* 2007 03 12&13

▽ Water level observed during drilling

▼ Water level measured after drilling

■ Penetrometer test

C.F.H.S.A- Denotes Continuous Flight Hollow Stem Augers

+7 , ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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Ontario

Peto MacCallum Ltd.
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RECORD OF BOREHOLE No C3-2 1 of 1 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 13+274, o/s 36.0m Lt. of CL Med ORIGINATED BY N.L.B.

DIST 54 HWY 69 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.

DATUM Geodetic DATE March 21, 2007 CHECKED BY G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
203.0	Ground Surface										
0.0 / 202.2	Peat, coarse, rootlets										
0.8 / 195.4	Sand some silt, some gravel cobbles and boulders Moist to wet					▼*	202 201 200 199 198 197 196				
7.6	End of borehole Refusal on probable bedrock										

* 2007 03 21

▼ Water level measured after drilling

+7 , ×5 : Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

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Ontario

Peto MacCallum Ltd.
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RECORD OF BOREHOLE No C3-3 1 of 1 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 13+274, o/s 18.8m Lt. of CL Med ORIGINATED BY N.L.B.

DIST 54 HWY 69 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.

DATUM Geodetic DATE March 21, 2007 CHECKED BY G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
205.0	Ground Surface										
0.0	Sand with organics to 0.6m with silt, with gravel cobbles and boulders Moist						204				
	Wet					▼*	203				
							202				
							201				
							200				
198.6							199				
6.4	End of borehole Refusal on probable bedrock										

* 2007 03 21

▼ Water level measured after drilling

+7 , ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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Ontario

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RECORD OF BOREHOLE No C3-4 1 of 1 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 13+274 CL Med ORIGINATED BY M.R.

DIST 54 HWY 69 BOREHOLE TYPE C.F.S.S.A & NXL Rock Coring COMPILED BY G.D.

DATUM Geodetic DATE March 14&19, 2007 CHECKED BY G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
206.8	Ground Surface										
0.0	Boulders										
0.3	Sand with silt, trace gravel cobbles Compact Brown Moist		1	SS	11		206				
			2	SS	22		205				
			3	SS	28	▼*▽*	204		○		1 81 (18)
			4	SS	19				○		
			5	SS	22		203		○		
			6	SS	20		202				
200.3							201				
6.5	Bedrock Gabbro: medium to high strength good quality		7	RC NQ	REC 100%		200				RQD 88%
			8	RC NQ	REC 100%		199				RQD 87%
197.5							198				
9.3	End of borehole										

* 2007 03 14

▽ Water level observed during drilling

▼ Water level measured after drilling

C.F.S.S.A- Denotes Continuous Flight Solid Stem Augers

+7 , ×5 : Numbers refer to Sensitivity

(%) STRAIN AT FAILURE (20, 15, 5, 10)

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C3-5 1 of 1 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 13+274, o/s 18.8m Lt. of CL Med ORIGINATED BY N.L.B.

DIST 54 HWY 69 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.

DATUM Geodetic DATE March 21, 2007 CHECKED BY G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
208.0	Ground Surface										
0.0	Topsoil										
0.2	Sand with silt, with gravel num. cobbles and boulders Brown Moist Grey Wet						207				
206.5											
1.5	End of borehole Refusal on probable boulder * Borehole dry										

ON_MOT VER3 06TF055A-CULVERT.GPJ ON_MOT.GDT 10/29/2007 12:10:16 PM

+7, ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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Ontario

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Foundation Design

RECORD OF BOREHOLE No C3-6 1 of 1 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 13+274, o/s 55.3m Rt. of CL Med ORIGINATED BY M.R.

DIST 54 HWY 69 BOREHOLE TYPE C.F.S.S.A & NXL Rock Coring COMPILED BY G.D.

DATUM Geodetic DATE March 20, 2007 CHECKED BY G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
209.2	Ground Surface										
0.0 / 208.8	Boulders						209				
0.4	Sand with silt, with gravel Compact Brown/ Moist grey		1	SS	22	▽*	208				
			2	SS	28						
206.8							207				
2.4	Bedrock Gabbro: medium to high strength good to excellent quality		3	RC NQ	REC 100%						RQD 81%
			4	RC NQ	REC 100%		206				RQD 100%
			5	RC NQ	REC 100%		205				RQD 91%
203.6	Mimatite: high strength excellent quality						204				
5.6	End of borehole										

* 2007 03 20

▽ Water level observed during drilling

C.F.S.S.A- Denotes Continuous Flight Solid Stem Augers

+7 , ×5 : Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

METRIC

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

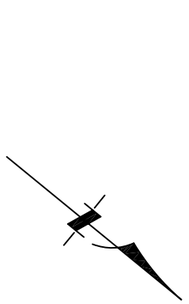
CONT No

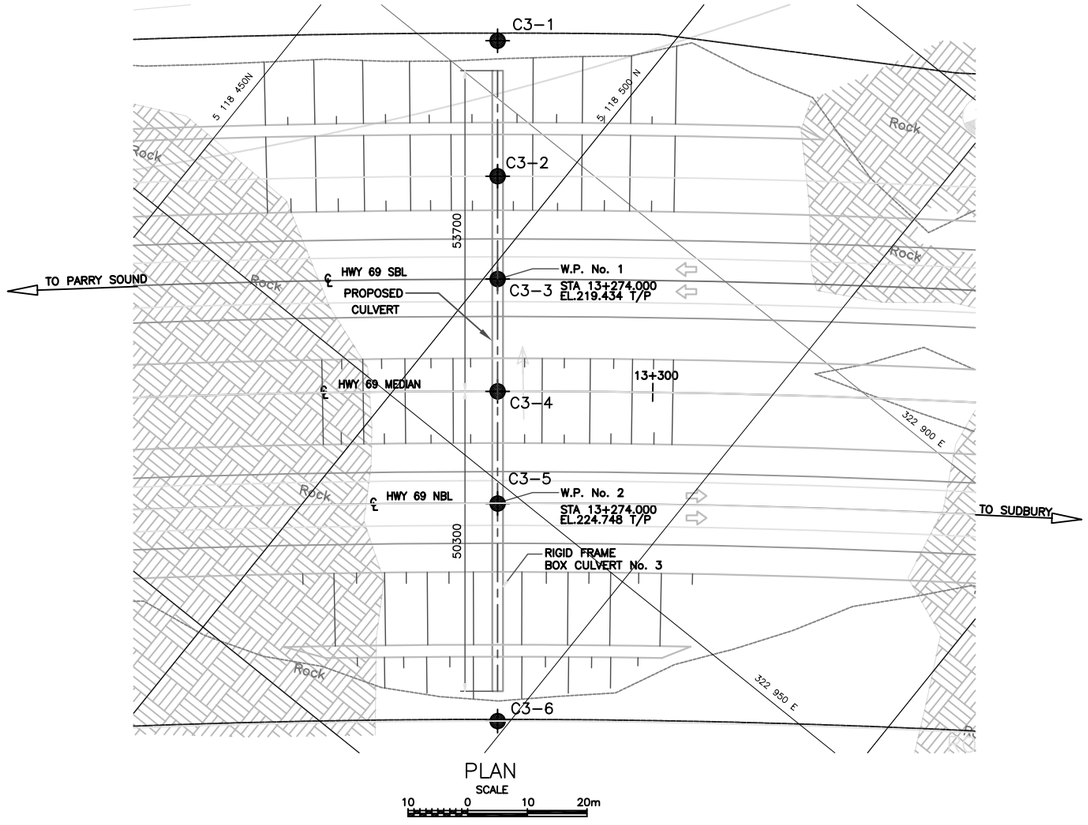
GWP No 5748-04-00

SHEET

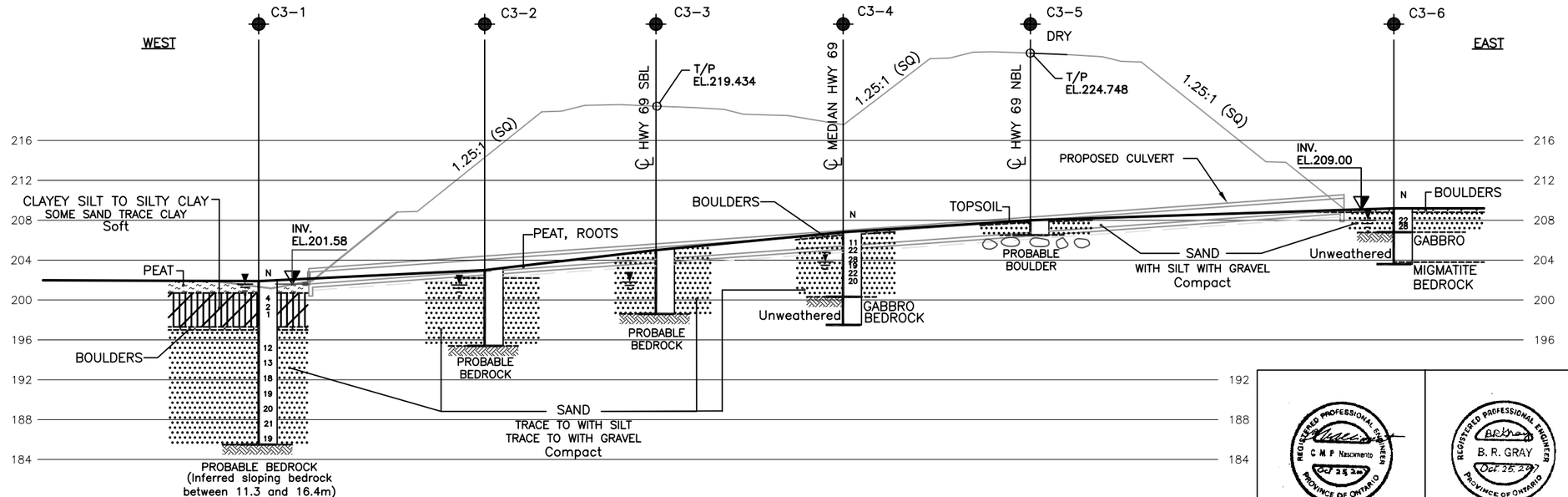
CULVERT AT STA. 13+274
HIGHWAY 69
BOREHOLE LOCATIONS AND SOIL STRATA

Peto MacCallum Ltd.
CONSULTING ENGINEERS

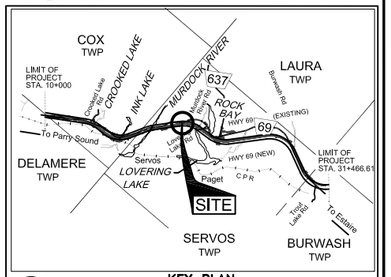




PLAN
SCALE
10 0 10 20m



℄ CULVERT PROFILE
SCALE
5 0 5 10m



KEY PLAN
SCALE
2 0 2 4 6km

LEGEND

- Borehole
- Dynamic Cone Penetration Test (Cone)
- Borehole & Cone
- N Blows/0.3m (Std. Pen Test, 475 J / blow)
- CONE Blows/0.3m (60° Cone, 475 J / blow)
- W L at time of investigation Mar 2007
- Head ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	STATION	OFFSET CL MEDIAN
C3-1	201.9	13+274	58.7m Lt.
C3-2	203.0	13+274	36.0m Lt.
C3-3	205.0	13+274	18.8m Lt.
C3-4	206.8	13+274	CL
C3-5	208.0	13+274	18.8m Rt.
C3-6	209.2	13+274	55.3m Rt.

NOTE:

1. THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.

REGISTERED PROFESSIONAL ENGINEER — C M P Nascimento — OCT 25 20 — PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER — B. R. GRAY — Oct. 25. 20 — PROVINCE OF ONTARIO

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

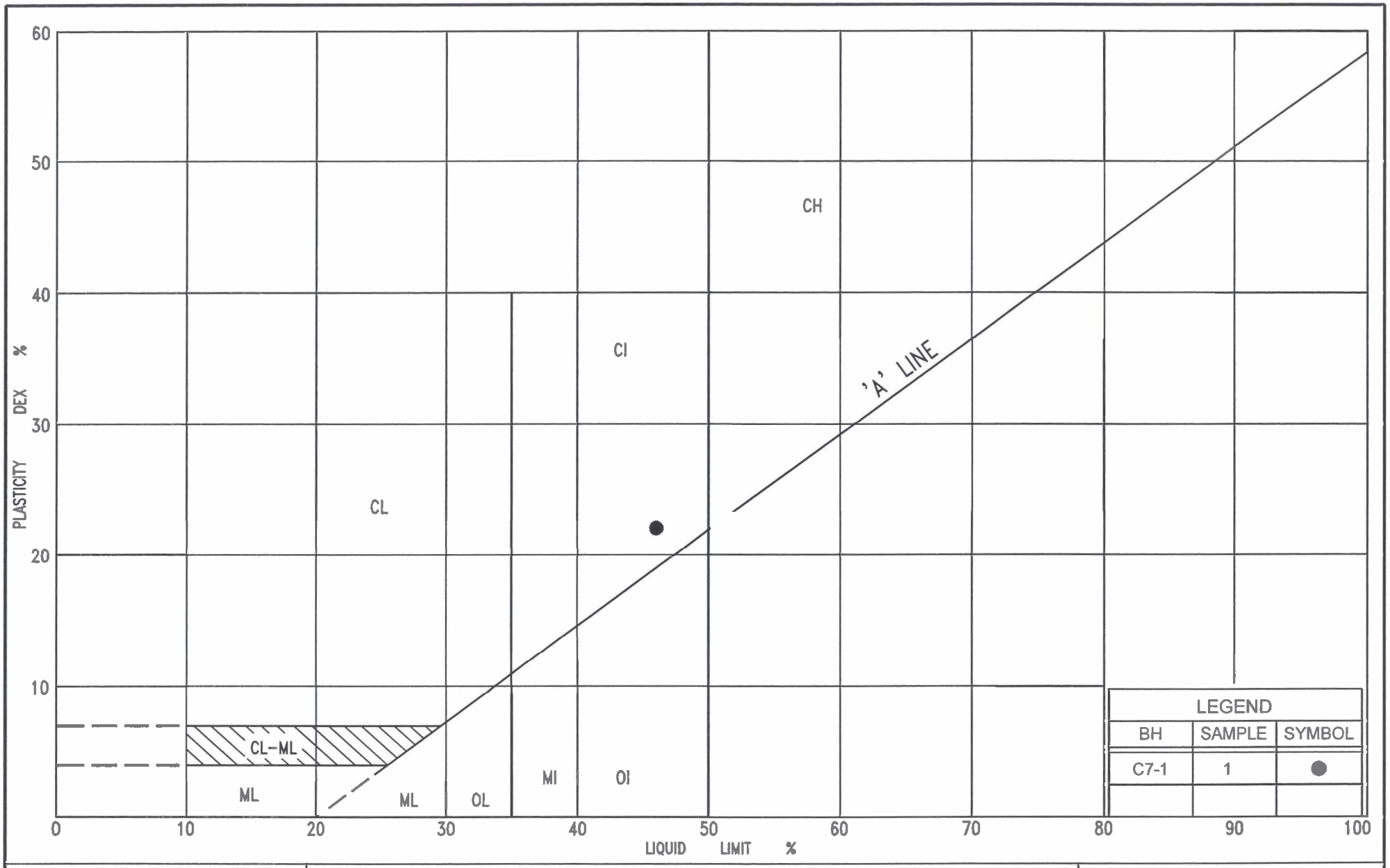
REVISIONS

DATE	BY	DESCRIPTION

Geocres No. 41I-218

REF No.: TSH DRAWING: HWY 69 CULV3.dwg dated: June 2007, received via email dated June 19, 2007

HWY No 69				DIST	SUDBURY
SUBM'D FP	CHECKED GD	DATE	OCT 25, 2007	SITE	--
DRAWN NA	CHECKED CN	APPROVED	BRG	DWG	C3-1



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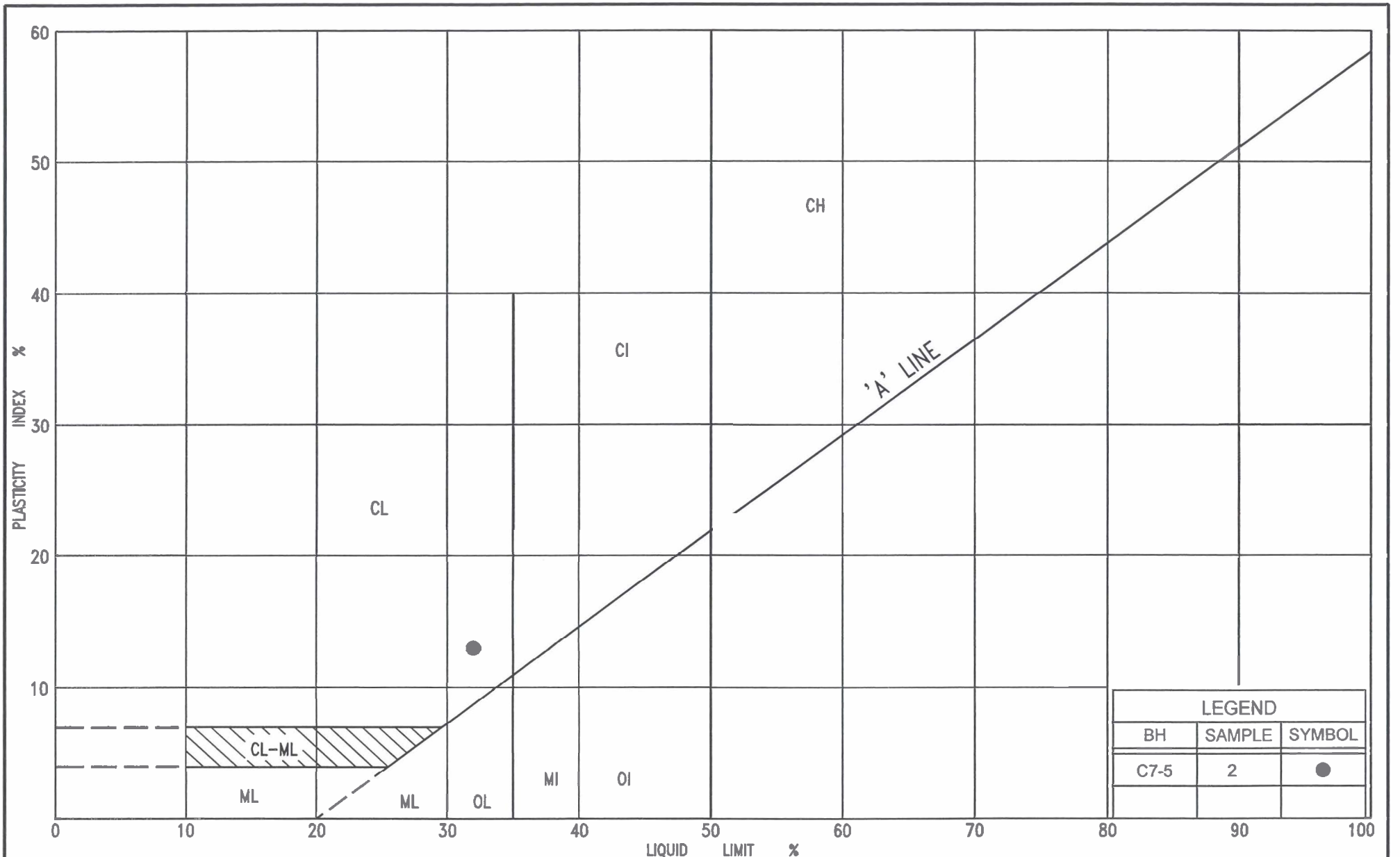
PLASTICITY CHART
SILTY CLAY, trace sand

FIG No.	C7-PC-1
HWY:	69
G.W.P. No.	5379-02-00



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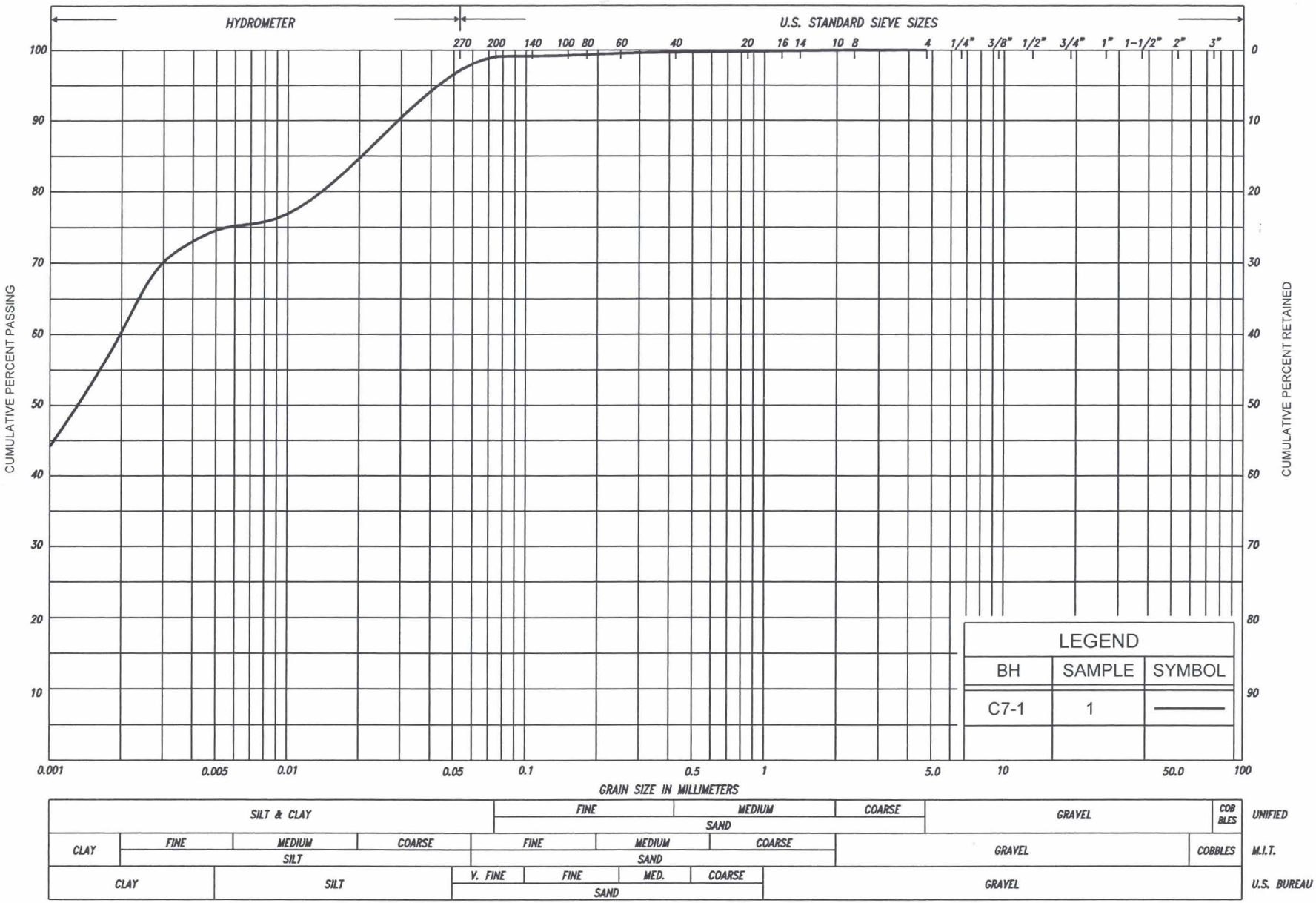
PLASTICITY CHART
CLAYEY SILT, trace sand

FIG No.	C7-PC-2
HWY:	69
G.W.P. No.	5379-02-00



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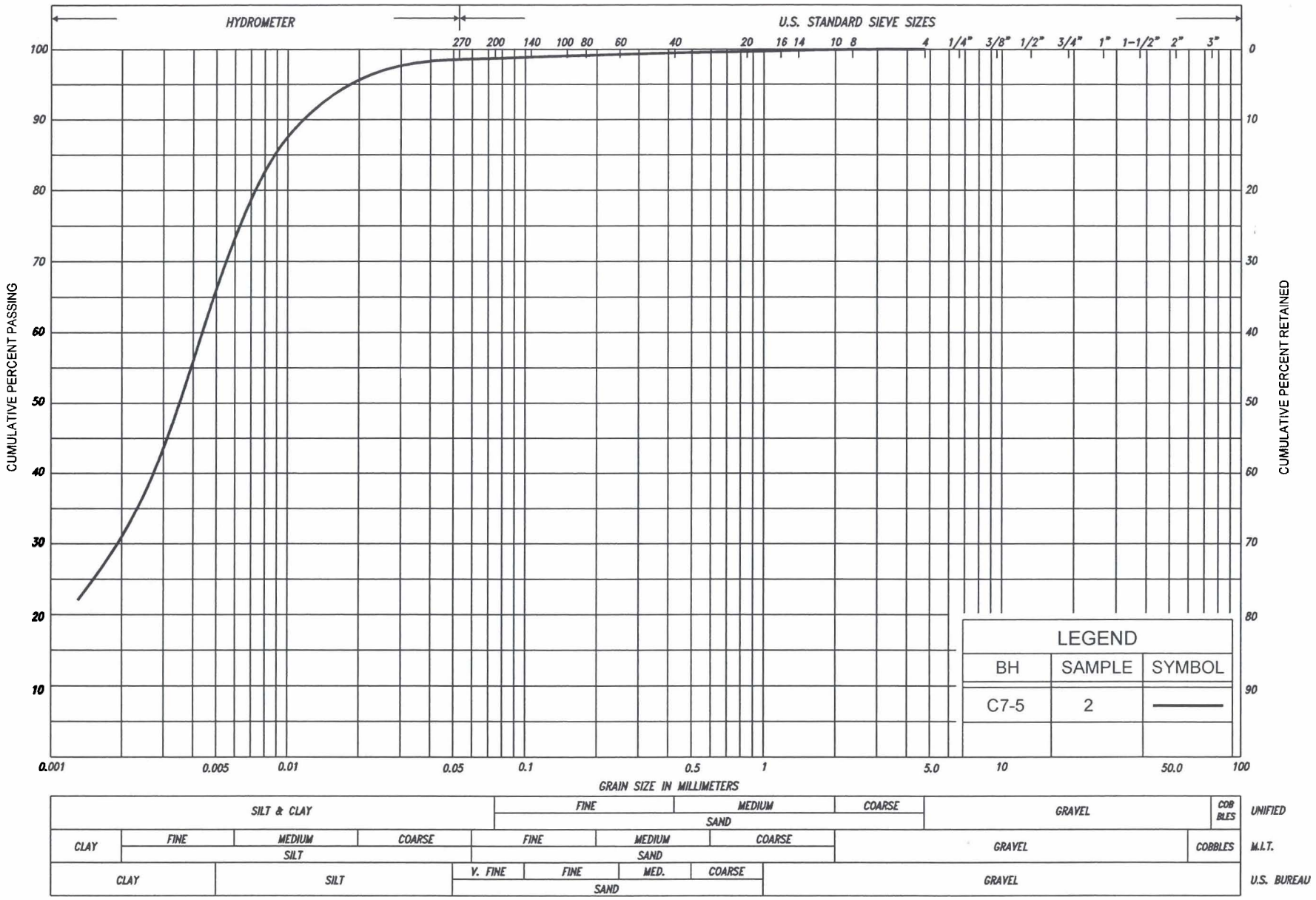
GRAIN SIZE DISTRIBUTION

SILTY CLAY, trace sand

FIG No.	C7-GS-1
HWY:	69
G.W.P. No.	5379-02-00



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Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, trace an

FIG No.	C7-GS-2
HWY:	69
G.W.P. No.	5379-02-00

Ministry of Transportation
Ontario

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Foundation Design

RECORD OF BOREHOLE No C7-1 1 of 1 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 14+289, o/s 44.1m Lt. of CL Med ORIGINATED BY N.L.B.

DIST 54 HWY 69 BOREHOLE TYPE C.F.S.S.A & NXL Rock Coring COMPILED BY G.D.

DATUM Geodetic DATE March 22, 2007 CHECKED BY G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
204.1	Ground Surface										
0.0	Topsoil						204				
0.2	Silty clay, trace sand organics to 0.5m Firm ___ Brown/ ___ Wet ___ occ. thin layers of silt		1	SS	13			■	○		0 1 39 60
	Stiff Mottled Moist brown/grey		2	SS	11		203		○		
201.1							202				
3.0	Bedrock Granitic gneiss: medium to high, occ. low strength poor becoming fair to excellent quality		3	RC NQ	REC 68%		201				RQD 48%
			4	RC NQ	REC 100%		200				RQD 91%
			5	RC NQ	REC 97%		199				RQD 65%
197.6			6	RC NQ	REC 83%		198				RQD 72%
6.5	End of borehole										

* Borehole dry

■ Penetrometer test

C.F.S.S.A- Denotes Continuous Flight Solid Stem Augers

+7, ×5 : Numbers refer to Sensitivity

(%) STRAIN AT FAILURE (20, 15, 5, 10)

Ministry of Transportation
Ontario

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Foundation Design

RECORD OF BOREHOLE No C7-2 1 of 1 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 14+291, o/s 18.8m Lt. of CL Med ORIGINATED BY N.L.B.

DIST 54 HWY 69 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.

DATUM Geodetic DATE March 22, 2007 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
203.4	Ground Surface					*					
0.0	Peat										
0.2	Clayey silt some sand, trace gravel						203				
202.5	Brown Moist										
0.9	End of borehole Refusal on probable bedrock										

* Borehole dry

+7 , ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C7-3 1 of 1 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 14+293 CL Med ORIGINATED BY N.L.B.

DIST 54 HWY 69 BOREHOLE TYPE C.F.S.S.A & NXL Rock Coring COMPILED BY G.D.

DATUM Geodetic DATE March 22&23, 2007 CHECKED BY G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
203.2	Ground Surface										
0.0 / 202.6	Peat, fine fibrous Dark brown					▼*	203				
0.6	Clayey silt, trace sand thin sand partings Firm to stiff Brown/ grey Moist		1	SS	5		202		○		
			2	SS	9		201		○		
200.5											
2.7	Bedrock Granitic gneiss: high strength fair to good quality		3	RC NQ	REC 100%		200				RQD 86%
			4	RC NQ	REC 100%		199				RQD 71%
197.4							198				
5.8	End of borehole										

* 2007 03 23

▼ Water level measured after drilling

C.F.S.S.A- Denotes Continuous Flight Solid Stem Augers

+7 , ×5 : Numbers refer to Sensitivity

(%) STRAIN AT FAILURE (20, 15, 5, 10)

RECORD OF BOREHOLE No C7-4

METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 14+291, o/s 18.8m Rt. of CL Med ORIGINATED BY N.L.B.

DIST 54 HWY 69 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.

DATUM Geodetic DATE March 23, 2007 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	*					
203.2	Ground Surface										
0.0	Clayey silt, organics to 0.3m Mottled brown/grey Moist						203				
202.3 0.9	End of borehole Refusal on probable bedrock										

* Borehole dry

+7, ×5 : Numbers refer to Sensitivity

20 / 15—○—5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C7-5 1 of 1 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 14+291, o/s 45.9m Rt. of CL Med ORIGINATED BY N.L.B.

DIST 54 HWY 69 BOREHOLE TYPE C.F.S.S.A & NXL Rock Coring COMPILED BY G.D.

DATUM Geodetic DATE March 23, 2007 CHECKED BY G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
203.1	Ground Surface					*	203				
0.0	Topsoil										
0.2	clayey silt, trace sand Stiff to firm Grey Moist to wet		1	SS	8		202				
			2	SS	5		201		c		0 1 68 31
200.1			3	SS	2/5cm						
3.0	Sand, some silt Compact Grey Wet		4	RC NQ	REC 40%		200				RQD 40%
200.0	Bedrock										
3.1	Granitic gneiss: high strength poor becoming good to excellent quality		5	RC NQ	REC 100%		199				RQD 100%
			6	RC NQ	REC 100%		198				RQD 84%
197.0											
6.1	End of borehole						197				

* Borehole dry

C.F.S.S.A- Denotes Continuous Flight Solid Stem Augers

+7, ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

METRIC

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

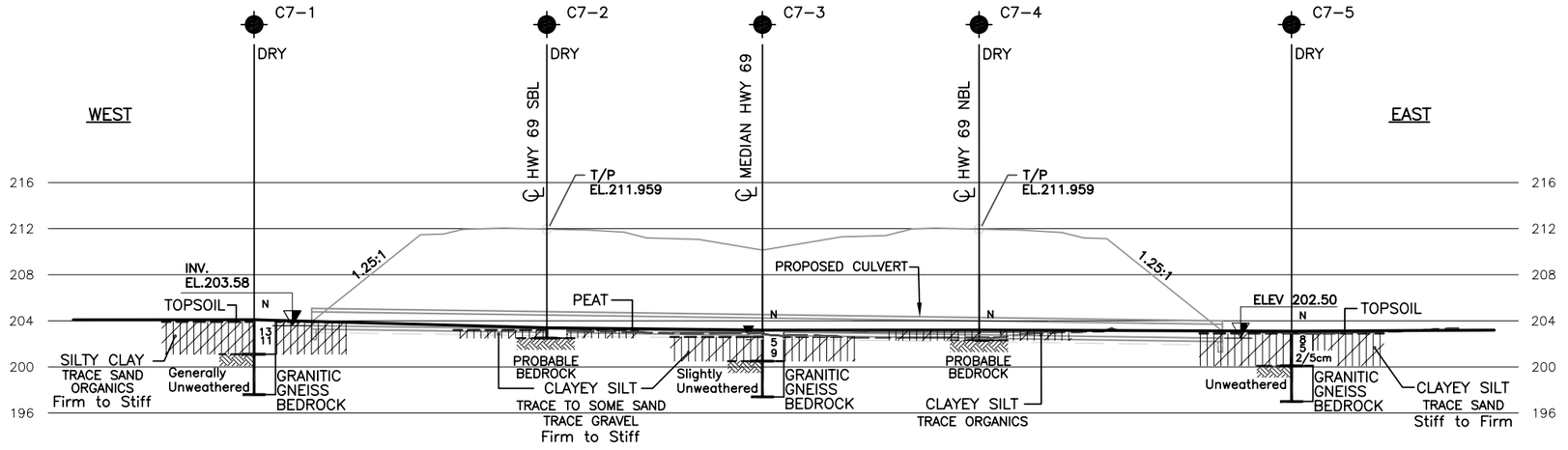
CONT No
GWP No 5748-04-00

CULVERT AT STA. 14+293
HIGHWAY 69
BOREHOLE LOCATIONS AND SOIL STRATA

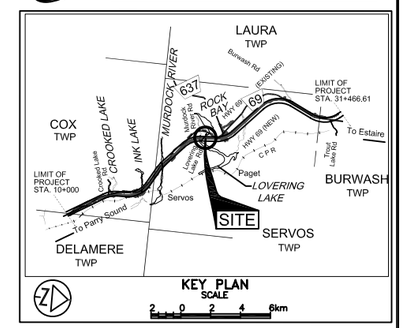
SHEET

Peto MacCallum Ltd.
CONSULTING ENGINEERS

PLAN
SCALE
10 0 10 20m



℄ CULVERT PROFILE
SCALE
5 0 5 10



KEY PLAN
SCALE
2 0 2 4 6km

LEGEND

- Borehole
- Dynamic Cone Penetration Test (Cone)
- Borehole & Cone
- N — Blows/0.3m (Std. Pen Test, 475 J / blow)
- CONE — Blows/0.3m (60° Cone, 475 J / blow)
- W L at time of investigation Mar 2007
- Head ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	STATION	OFFSET CL MEDIAN
C7-1	204.1	14+289	44.1m Lt.
C7-2	203.4	14+291	18.8m Lt.
C7-3	203.2	14+293	CL
C7-4	203.2	14+291	18.8m Rt.
C7-5	203.1	14+291	45.9m Rt.

NOTE:
1. THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.

REGISTERED PROFESSIONAL ENGINEER — C. M. P. Nascimento — Oct 25, 2007 — PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER — B. R. GRAY — Oct. 25, 2007 — PROVINCE OF ONTARIO

REF No TSH Drawing: HWY 69 CULV7, dated June 2007 received via email on June 19, 2007

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

REVISIONS			
DATE	BY	DESCRIPTION	

Geocres No. 41I-218

HWY No	69			DIST	54
SUBM'D	GD	CHECKED CN	DATE OCT. 25, 2007	SITE	
DRAWN	NA	CHECKED CN	APPROVED BRG	DWG	C7-1

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C9-1 1 of 1 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 15+007, o/s 48.0m Rt. CL Med ORIGINATED BY S.A.

DIST 54 HWY 69 BOREHOLE TYPE Percussion Drilling COMPILED BY G.D.

DATUM Geodetic DATE March 08, 2007 CHECKED BY G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
202.9	Ground Surface										
0.0	Topsoil										
0.3	Probable sandy silt num. cobbles and boulders						202				
201.7											
1.2	Bedrock Red/brown						201				
							200				
							199				
198.3											
4.6	End of borehole										

Note: Surface water entering borehole during drilling

* 2007 03 08

▽ Water level observed during drilling

▼ Water level measured after drilling

+7, ×5 : Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C9-2 1 of 1 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 15+023, o/s 18.8m Rt. CL Med ORIGINATED BY S.A.

DIST 54 HWY 69 BOREHOLE TYPE Percussion Drilling COMPILED BY G.D.

DATUM Geodetic DATE March 08, 2007 CHECKED BY G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
200.6	Ground Surface							20 40 60 80 100	20 40 60		
0.0	Topsoil										
0.3	Probable sandy silt						200				
							199				
198.2											
2.4	Bedrock Grey/brown						198				
							197				
							196				
194.8							195				
5.8	End of borehole										

Note: Surface water entering borehole during drilling

* 2007 03 08

▽ Water level observed during drilling

▼ Water level measured after drilling

+7, ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C9-3 1 of 1 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 15+034 CL Med ORIGINATED BY S.A.

DIST 54 HWY 69 BOREHOLE TYPE Percussion Drilling COMPILED BY G.D.

DATUM Geodetic DATE March 08, 2007 CHECKED BY G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
201.5	Ground Surface					*		20 40 60 80 100	20 40 60		
0.0	Topsoil										
0.3	Probable sandy silt num. cobbles and boulders						201				
200.0							200				
1.5	Bedrock Red/brown						199				
							198				
196.9							197				
4.6	End of borehole										

* Borehole dry

+7, ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C9-4 1 of 1 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 15+045, o/s 18.8m Lt. CL Med ORIGINATED BY S.A.

DIST 54 HWY 69 BOREHOLE TYPE Percussion Drilling COMPILED BY G.D.

DATUM Geodetic DATE March 08, 2007 CHECKED BY G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
200.7	Ground Surface					*					
0.0	Topsoil										
0.3	Probable sandy silt num. cobbles and boulders						200				
199.5											
1.2	Bedrock Red/brown						199				
							198				
							197				
196.4											
4.3	End of borehole										

* Borehole dry

+7 , ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C9-5 1 of 1 METRIC

G.W.P. 5379-02-00 LOCATION Hwy 69(New), Sta. 15+066, o/s 57.0m Lt. CL Med ORIGINATED BY S.A.

DIST 54 HWY 69 BOREHOLE TYPE Percussion Drilling COMPILED BY G.D.

DATUM Geodetic DATE March 08, 2007 CHECKED BY G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
197.7	Ground Surface					*					
0.0	Topsoil										
0.3	Probable sandy silt num. cobbles and boulders						197				
196.5											
1.2	Bedrock Red/brown						196				
							195				
							194				
193.4											
4.3	End of borehole										

* Borehole dry

+7, ×5 : Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

METRIC

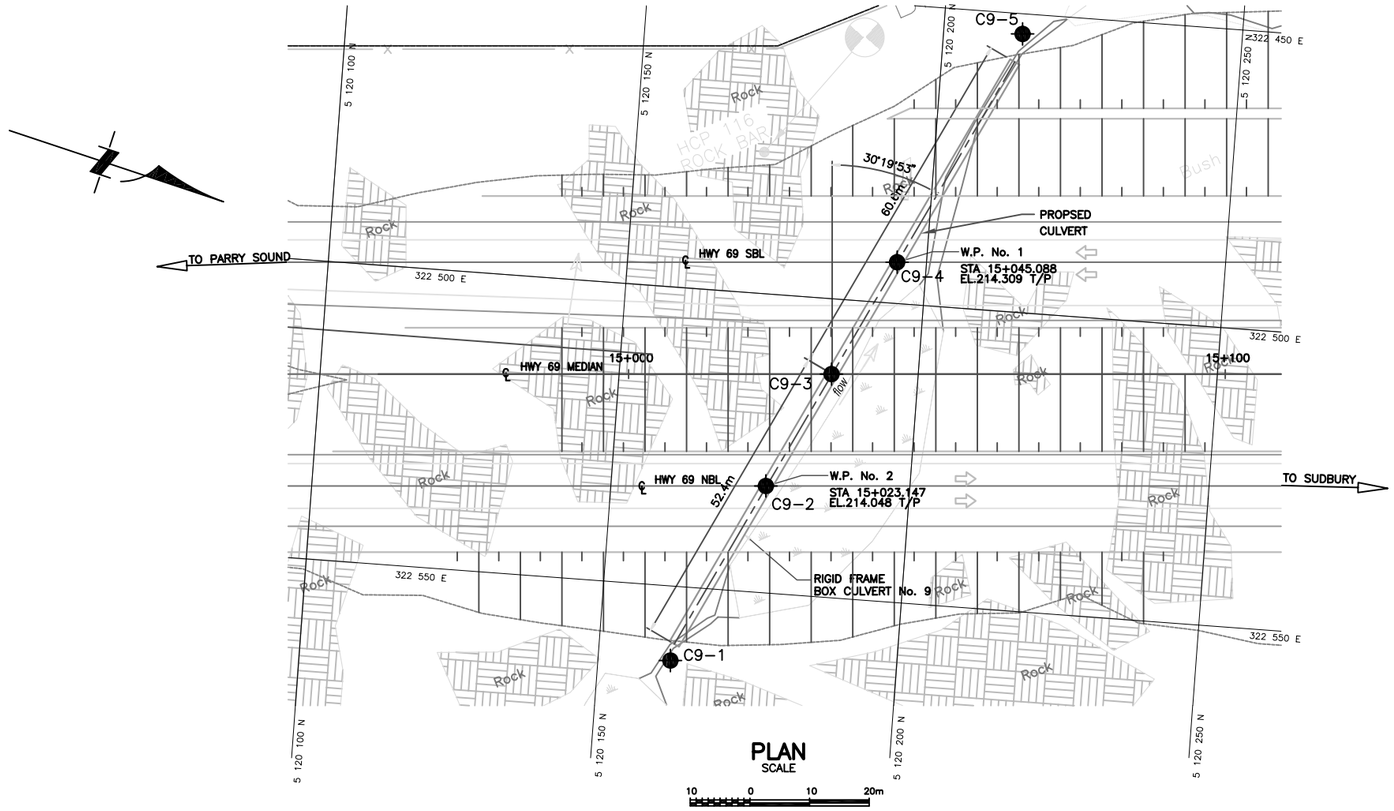
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES

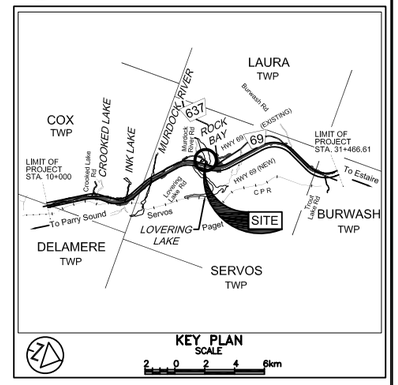
CONT No
GWP No 5379-02-00

CULVERT AT STA. 15+034
HIGHWAY 69
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Peto MacCallum Ltd.
CONSULTING ENGINEERS

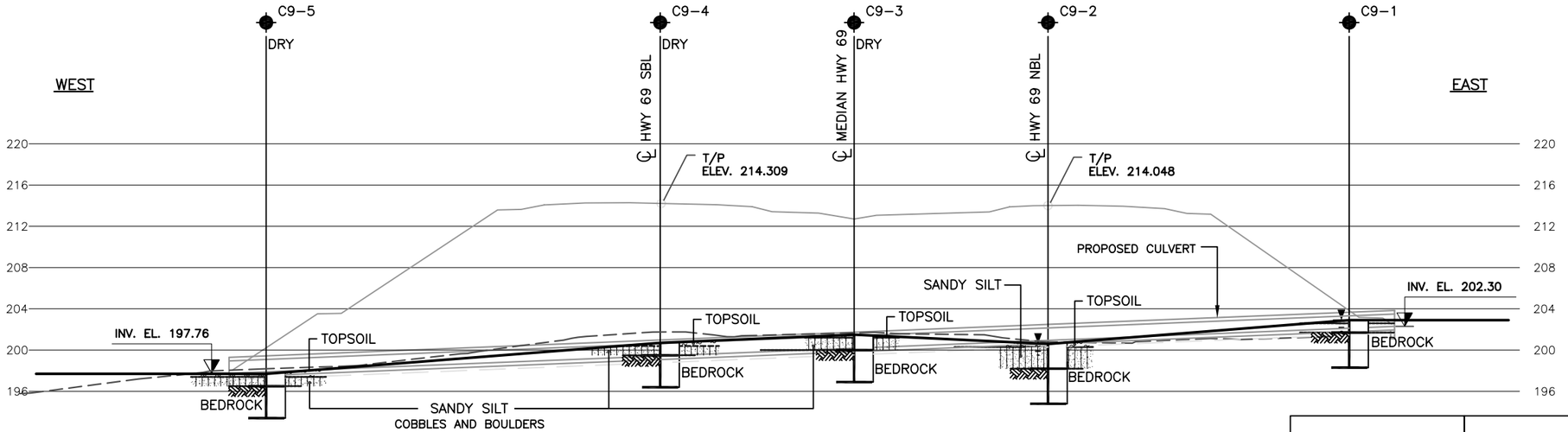




LEGEND

- Borehole
- Dynamic Cone Penetration Test (Cone)
- Borehole & Cone
- N Blows/0.3m (Std. Pen Test, 475 J / blow)
- CONE Blows/0.3m (60° Cone, 475 J / blow)
- W L at time of investigation Mar-Apr 2007
- Head ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	STATION	OFFSET CL MEDIAN
C9-1	202.9	15+007	48.0m Rt.
C9-2	200.6	15+023	18.8m Rt.
C9-3	201.5	15+034	CL
C9-4	200.7	15+045	18.8m Lt.
C9-5	197.7	15+066	57.0m Lt.



℄ CULVERT PROFILE
SCALE
5 0 5 10m

NOTE:

1. THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.

REGISTERED PROFESSIONAL ENGINEER C M P Nascimento Oct 25, 2007 PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER B. R. GRAY Oct. 25, 2007 PROVINCE OF ONTARIO

REF No TSH Drawing: HWY 69 CULV9, dated June 2007 received via email dated June 19, 2007

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

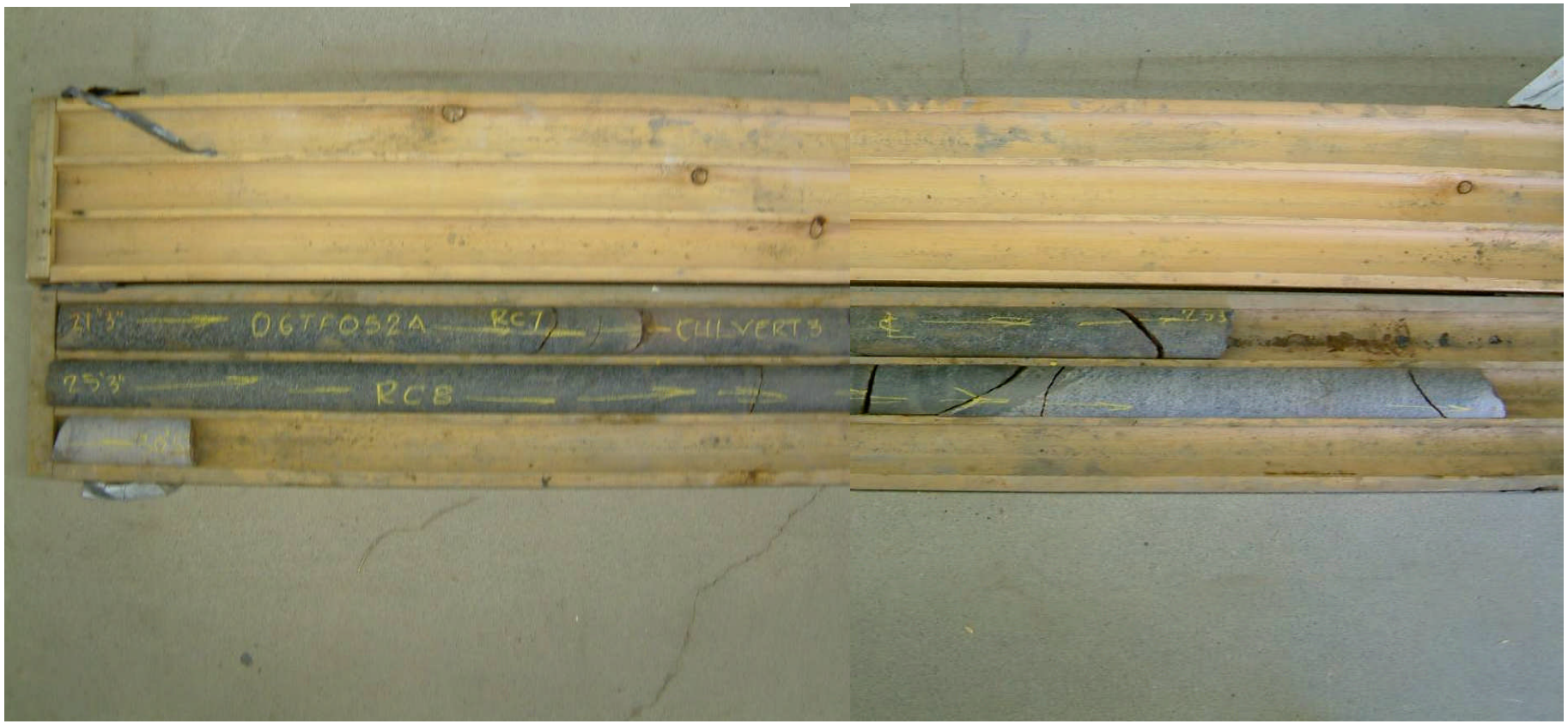
REVISIONS			
DATE	BY	DESCRIPTION	

Geocres No. 41I-218

HWY No	69			DIST	54
SUBM'D	MR	CHECKED CN	DATE OCT. 25, 2007	SITE	--
DRAWN	NA	CHECKED CN	APPROVED BRG	DWG	C9-1

APPENDIX A

Rock Core Photographs



Culvert 3, borehole C3-4, samples RC-7 and RC-8

Culvert 7, borehole C7-1, samples RC-3, RC-4, RC-5 and RC-6

Culvert 7, borehole C7-3, samples RC-3 and RC-4

Culvert 7, borehole C7-5, samples RC-4, RC-5 and RC-6

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS $\tilde{N}$.

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	>200
	VERY SOFT	*SOFT*	*FIRM*	*STIFF*	*VERY STIFF*	*HARD*

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	>50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	*POOR*	*FAIR*	*GOOD*	*EXCELLENT*

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	>3m
JOINTING	*VERY CLOSE*	*CLOSE*	*MOD. CLOSE*	*WIDE*	*VERY WIDE*
BEDDING	*VERY THIN*	*THIN*	*MEDIUM*	*THICK*	*VERY THICK*

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE
F V	FIELD VANE		

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kN/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kN/m^3	UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL
e	1,%	VOID RATIO
n	1,%	POROSITY
w	1,%	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_P	%	PLASTIC LIMIT
w_S	%	SHRINKAGE LIMIT
I_P	%	PLASTICITY INDEX = $w_L - w_P$
I_L	1	LIQUIDITY INDEX = $\frac{w - w_P}{I_P}$
I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_P}$
DTPL		DRIER THAN PLASTIC LIMIT
APL		ABOUT PLASTIC LIMIT
WTPL		WETTER THAN PLASTIC LIMIT
e_{max}	1,%	VOID RATIO IN LOOSEST STATE
e_{min}	1,%	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	n PERCENT - DIAMETER
C_U	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE