FOUNDATION INVESTIGATION AND DESIGN REPORT

for

REPLACEMENT OF ENTRANCE CULVERT AT STA. 29+770
SITE NO. 35-456/C
IMPROVEMENT OF HIGHWAY 6 FROM ARTHUR (WELLS STREET) NORTHERLY TO SOUTH OF MOUNT FOREST
G.W.P. 342-97-00
TOWNSHIP OF ARTHUR
WELLINGTON NORTH COUNTY, ONTARIO

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.: 05KF104D5
Index No. 176FIR and 177FDR
Geocres No.: 40P15-40
March 30, 2007

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Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION INVESTIGATION REPORT
for
Replacement of Entrance Culvert at Sta. 29+770
Site No. 35-456/C
Improvement of Highway 6
From Arthur (Wells Street)
Northerly to South of Mount Forest
G.W.P. 342-97-00
Township of Arthur
Wellington North County, Ontario

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1. INTRODUCTION

Planned under this project is the improvement of an approximate 18 km long section of Highway 6 that extends from Arthur (Wells Street) northerly to south of Mount Forest in the Township of Arthur, Wellington North County, Ontario. This report was prepared for McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation of Ontario.

Improvement of the highway will involve replacement, extension or alterations of some 23 culverts including the replacement of an entrance culvert located at approximate Sta. 29+770, Site No. 35-456/C. For ease of reference, Peto MacCallum Ltd. (PML) identified this culvert by PML reference number C-23 sequentially to the previously reported culverts for the project.

This report provides a summary of the factual information obtained during the field investigation conducted at the location of the existing culvert.

2. SITE DESCRIPTION AND GEOLOGY

Highway 6 within the project limits is primarily situated in a rural setting with rolling terrain containing streams and swampy areas. Land use along the study corridor is mainly agricultural with some forested/swamp areas, local residential development and gravel pits.

The entrance culvert is located between Riverstown and Mount Forest about 1.4 km north of Side Road 4. The entrance culvert parallels Highway 6 and straddles the White Drain for access to a private gravel surfaced driveway on Lot 7, Concession WOSR (West of Owen Sound Road

Survey), as inferred from ETR sheet 156-6/38-0. The water in the White Drain flows northerly through the culvert.

The project area lies in the physiographic region known as the Dundalk Till Plain characterised by a gently undulating till plain. The principal surficial soil along the study corridor is a shallow medium textured sandy silt. Typically, the surficial soils overlie clay tills. Some of the low lying and valley areas are swampy with poor drainage (L.J.Chapman & D.F.Putnam, *The Physiography of Southern Ontario*, 3rd Edition, Ontario Research Foundation, 1984).

The bedrock in this section of the project belongs to the Salina Formation comprising dolostone, shale, gypsum and salt. The bedrock depth in the area is variable from approximate depths of 29 to 88 m.

The foundation frost penetration depth for design purposes is 1.6 m as shown on OPSD 3090.101.

3. INVESTIGATION PROCEDURES

The field work for this study was carried out on November 21, 2006 and comprised four boreholes drilled to depths of 1.7 to 8.1 m below existing grade. The approximate locations of the boreholes put down at the culvert along the centreline of the entrance road are shown on Drawing C23-1, appended.

The borehole numbers and figures are provided with prefix code C23 to reflect the specific culvert number for ease of reference.

The borehole layout was established in general accordance with the requirements noted in the Terms of Reference for the current investigation. PML selected the borehole locations in the field. The ground surface elevations at the boreholes were established in the field by PML using the benchmark provided by MRC. All elevations in this report are expressed in metres.

The boreholes were advanced using continuous flight solid stem augers, powered by a track-mounted drill rig, supplied and operated by a specialist drilling contractor working under the full-time supervision of a member of our engineering staff.

Representative samples of the soil were recovered at 0.75 and 1.5 m 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 tests were carried out on cohesive soil samples. These penetrometer results provide only an indication of the shear strength in view of possible disturbance of the samples recovered with the split spoon sampler.

Soils were identified visually in the field in accordance with the MTO Soil Classification procedures. 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 boreholes. All the boreholes were backfilled with a bentonite/cement mixture in accordance with the MTO and MOE (Reg. 903) guidelines for borehole abandonment procedures.

The recovered samples were returned to our laboratory for detailed visual examination and classification. The laboratory testing program consisting of moisture content determinations as well as 2 Atterberg limits tests and 4 grain size distribution analyses was carried out on selected samples. Atterberg limits were not determined on samples deemed to be non-plastic on the basis of visual and tactile examination. The results of the laboratory Atterberg limits testing and grain size distribution analyses are presented in the attached Figures C23-PC-1 and C23-GS-1 to 3 respectively.

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, boundary elevations, standard penetration test data, groundwater observations and moisture content determinations. The results of laboratory Atterberg limits testing and grain size distribution analyses conducted on selected samples are also shown on the Record of Borehole sheets.

The borehole locations are shown on Drawing C23-1. The boundaries between soil strata have been established only at the borehole locations. Between boreholes, the boundaries are assumed and may vary.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial fill underlain by clayey silt till. Cobbles and boulders were encountered within both the fill and the glacial till deposit at the culvert location. Groundwater was measured in two boreholes to be near the interface of the fill and the native soil. The strata encountered are summarised below.

4.1 Fill

Surficial fill making up the existing entrance road embankment was present in all the boreholes. The fill consisted of gravelly sand to sandy gravel, with cobbles and boulders identified in borehole C23-3 advanced closest to Highway 6. The thickness of the fill decreased gradually from 2.8 m just east of the culvert to 1.0 m in borehole C23-4 put down farthest from the highway. The fill was compact to dense and had a moisture content of 3 to 5%, locally 13%. Containing cobbles and boulders, borehole C23-3 was terminated within the fill at 1.7 m depth (elevation 419.4). In the other boreholes, the fill was penetrated at elevations 418.3 to 420.0.

The results of two grain size distribution analyses performed on the fill materials are presented in Figures C23-GS-1 and GS-2.

4.2 Topsoil

Silty topsoil was buried under the fill at a depth of 1.0 m (elevation 420.0) in borehole C23-4. Having a moisture content of about 23%, the topsoil was 400 mm thick and penetrated at 1.4 m depth (elevation 419.6).

4.3 Clayey Silt Till

Underlying the gravelly sand fill at 2.8 m depth (elevation 418.3) in borehole C23-1 and sandy gravel fill at a depth of 2.2 m (elevation 418.9) in borehole C23-2 was clayey silt till. This deposit was stiff to hard in consistency, with penetrometer tests indicating a shear strength of 50 to 225 kPa. The clayey silt till was not penetrated upon termination of both boreholes at respective depths of 8.1 and 7.7 m (elevations 413.0 and 413.4). Cobbles and boulders were encountered in the deposit in borehole C23-1.

The results of Atterberg limits testing and grain size distribution analysis on two samples of the cohesive deposit are shown in respective Figures C23-PC-1 and C23-GS-3. The liquid limit of the clayey silt till ranged from 19 to 21 and plastic limit from 13 to 15 (plasticity index of 6). The moisture content of the deposit varied between 11 and 19%.

4.4 Silt

Directly beneath the topsoil at 1.4 m depth (elevation 419.6) in borehole C23-4 was non-plastic silt. This unit was compact in relative density (SPT-N-value of 14) and had a moisture content of about 21%. The borehole was terminated within the silt at a depth of 2.1 m (elevation 418.9).

4.5 Groundwater

Water was observed in two boreholes in the course of the field work. In the process of augering, it was detected at 2.3 m depth (elevation 418.8) in borehole C23-2. Upon completion of drilling, groundwater was measured in boreholes C23-1 and C23-2 at respective depths of 2.7 and 2.4 m (elevations 418.4 and 418.7). No water was observed in boreholes C23-3 and C23-4 during or upon completion of drilling. It is noteworthy that the depth of water in the White Drain under the culvert was about 0.9 m. The water level was at about elevation 419.1 at the time of the investigation.

The observed groundwater levels are subject to seasonal fluctuations and precipitation patterns.

5. CLOSURE

The field work was carried out under the supervision of Mr. G. Idzik, BASc and direction of Mr. C.M.P. Nascimento, P.Eng., Senior Project Engineer. The soil drilling equipment was supplied by Drilltech Drilling Inc.

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

Yours very truly

Peto MacCallum Ltd.

LICENSED PROFESSIONAL ENGINEER
G. DEGIL
100056241
PROVINCE OF ONTARIO

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

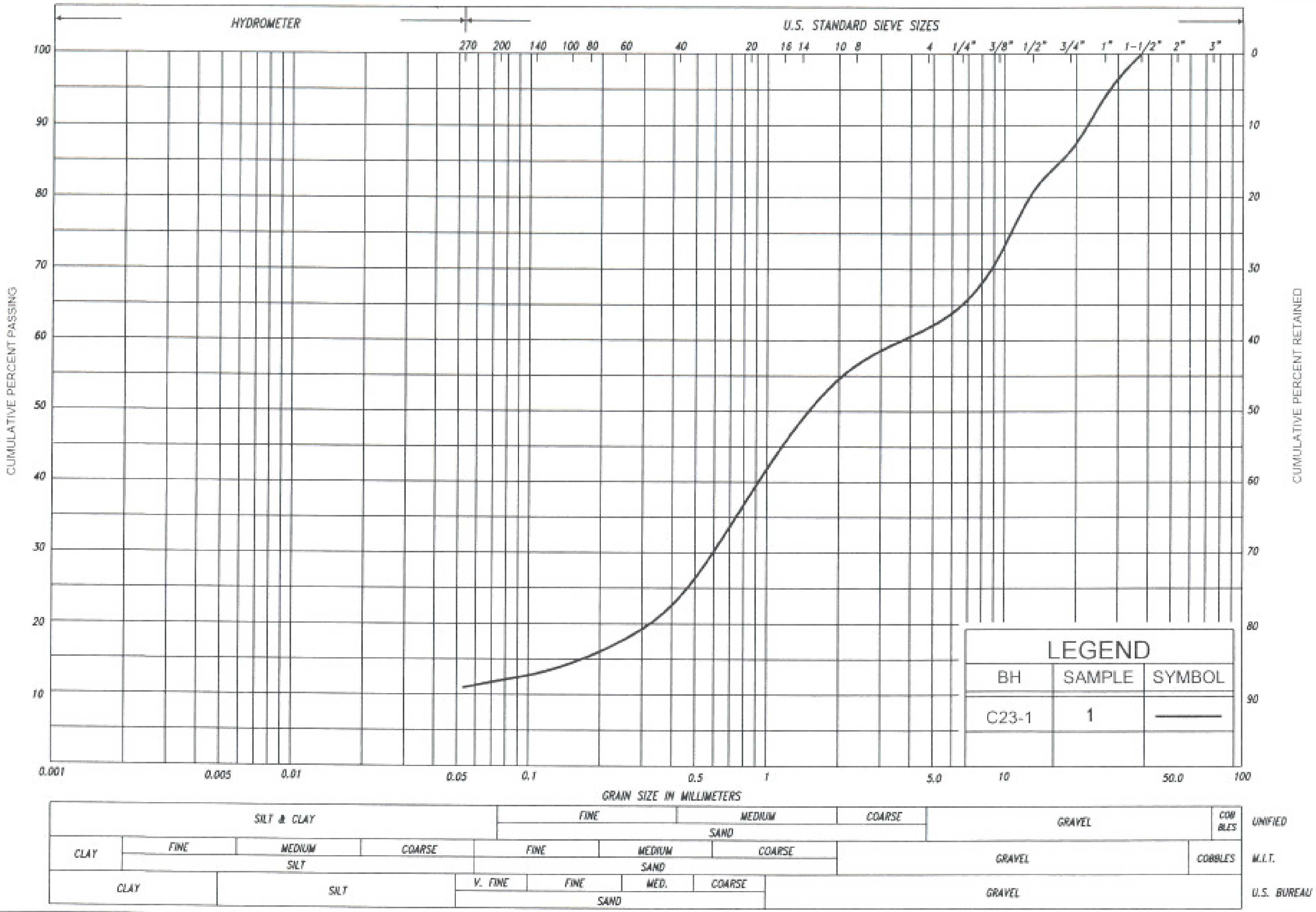
REGISTERED PROFESSIONAL ENGINEER
C M P Nascimento
PROVINCE OF ONTARIO

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

REGISTERED PROFESSIONAL ENGINEER
B. R. GRAY
PROVINCE OF ONTARIO

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

GD/CN/BRG:lr-mi



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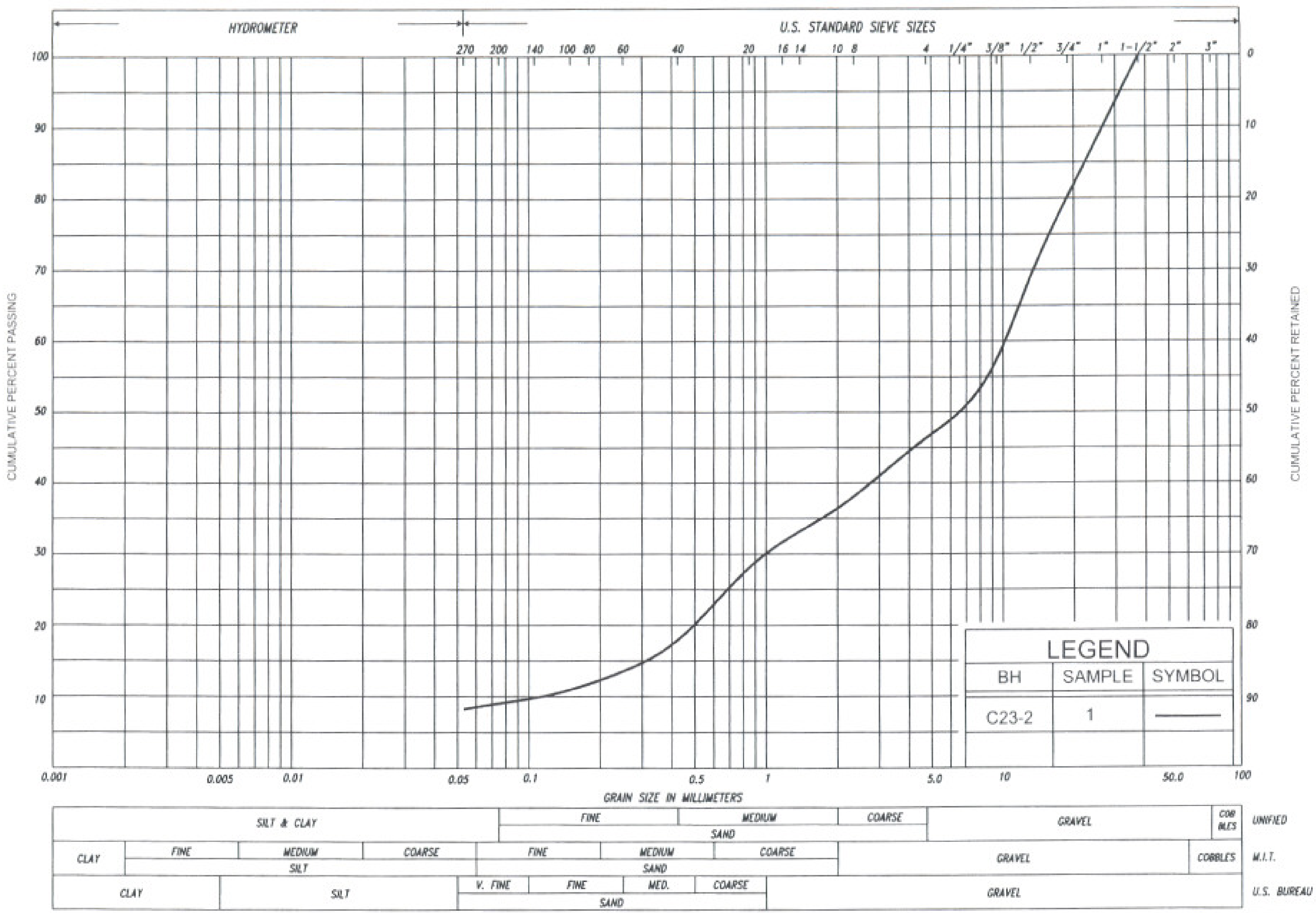
GRAIN SIZE DISTRIBUTION

GRAVELLY SAND, some silt
(FILL)

FIG No.	C23-GS-1
HWY	6
G.W.P. No.	342-97-00



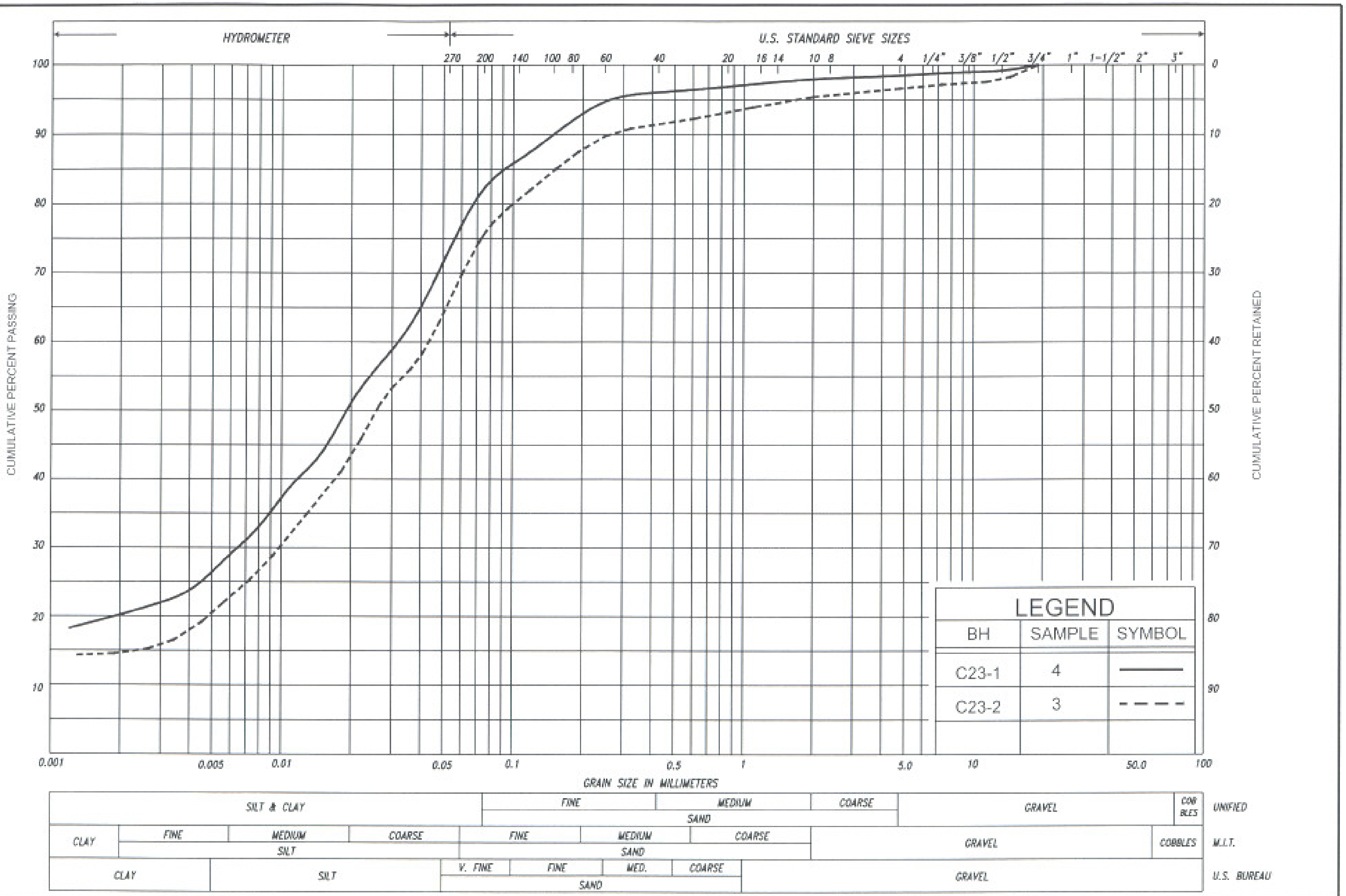
Ministry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

SANDY GRAVEL, trace silt

(FILL)

FIG No.	C23-GS-2
HWY	6
G.W.P. No.	342-97-00

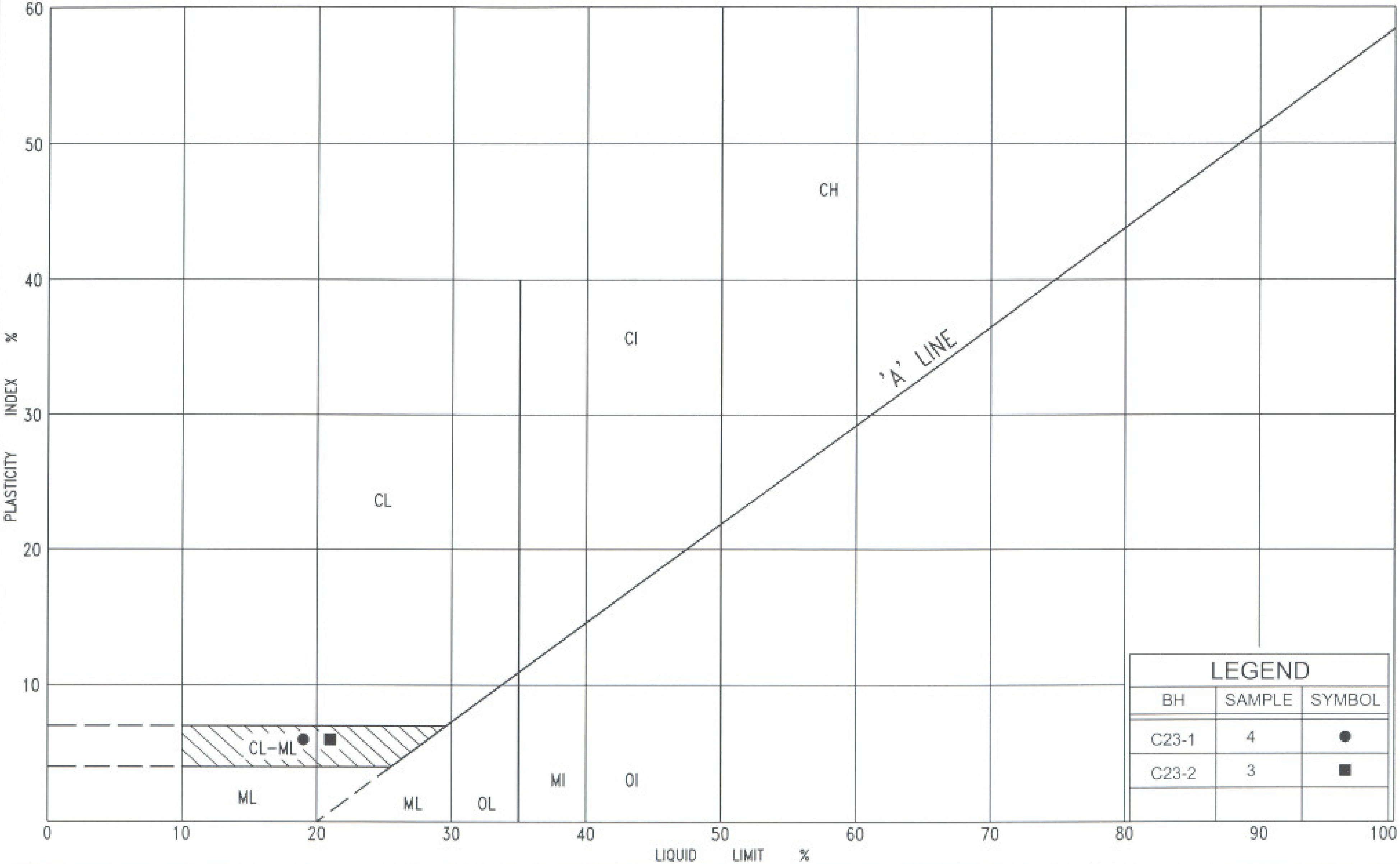


Ministry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, some sand, trace gravel
(TILL)

FIG No.	C23-GS-3
HWY	6
G.W.P. No.	342-97-00



LEGEND

BH	SAMPLE	SYMBOL
C23-1	4	●
C23-2	3	■

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PLASTICITY CHART

CLAYEY SILT, some sand, trace gravel (TILL)

FIG No.	C23-PC-1
HWY	6
G.W.P. No.	342-97-00

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 $\bar{N}$.

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

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C23-1

METRIC

G.W.P. 342-97-00	LOCATION Co ords. 4 867 797 N; 207 657 E		ORIGINATED BY G.I.
DIST Owen Sound HWY 6	BOREHOLE TYPE Continuous Flight Solid Stem Augers		COMPILED BY G.D.
DATUM Geodetic	DATE November 21, 2006		CHECKED BY G.D.

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
421.1	Ground surface						421				
0.0	Gravelly sand trace to some silt. Compact Brown Moist (FILL)		1	SS	22		420		○		38 50 (12)
			2	SS	20		419		○		
	occ. clayey silt pockets		3	SS	44	▼*			○		
418.3 / 2.8	Clayey silt some sand, trace gravel occ. cobbles and boulders. Very stiff to hard Brown Moist		4	SS	75/ 23cm		418	125 ■	○ (H)		2 15 63 20
	sand and gravel seams		5	SS	58		417, 416		○		
	silt seams. Grey (TILL)		6	SS	50/ 10cm		415	200 ■	○		
			7	SS	89/ 28cm		414		○		
413.0 / 8.1	End of borehole						413				

* 2006 11 21

▼ Water level measured after drilling

■ Penetrometer test

Legend: 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

✚7, ×5 : Numbers refer to Sensitivity   20 / 15 ○ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C23-2

METRIC

G.W.P. 342-97-00 LOCATION Co ords. 4 867 791 N; 207 653 E ORIGINATED BY G.I.

DIST Owen Sound HWY 6 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.

DATUM Geodetic DATE November 21, 2006 CHECKED BY G.D.

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
421.1	Ground surface					421				
0.0	Sandy gravel trace to some silt; Compact Brown Moist (FILL)	1	SS	18		420		o		53 38 (9)
		2	SS	16				o		
418.9 / 2.2	Clayey silt some sand, trace gravel; Stiff to hard Brown Moist				▼* ▽*	419				
		3	SS	10			■	⊢o⊣		3 20 62 15
		4	SS	30		418	■ 125	o		
	occ. silt seams	5	SS	50/13cm		417		o		
	occ. sand and gravel seams	6	SS	77		416		o		
	Grey (TILL)	7	SS	94/23cm		415	■ 225	o		
						414				
413.4		8	SS	50/13cm				o		
7.7	End of borehole									

* 2006 11 21

▽ Water level observed during drilling

▼ Water level measured after drilling

■ Penetrometer test

Legend: 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

+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 C23-3

METRIC

G.W.P. 342-97-00 | LOCATION Co ords. 4 867 800 N; 207 659 E | **ORIGINATED BY** G.I.

DIST Owen Sound **HWY** 6 | BOREHOLE TYPE Continuous Flight Solid Stem Augers | **COMPILED BY** G.D.

DATUM Geodetic | DATE November 21, 2006 | **CHECKED BY** G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT (WATER CONTENT %)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
421.1	Ground surface					*					
0.0	Gravelly sand, trace silt, occ. cobbles. Dense, Brown, Moist (FILL)						421				
			1	SS	68/ 20cm		420		o		
	num. cobbles, occ. boulders		2	SS	50/ 3cm				o		
419.4 / 1.7	End of borehole										

* Borehole dry on completion of drilling

Legend: SHEAR STRENGTH kPa — O UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE. DCPT and shear strength scale 20, 40, 60, 80, 100. Water content scale 20, 40, 60; w_P, w, w_L.

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

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

RECORD OF BOREHOLE No C23-4

METRIC

G.W.P. 342-97-00 **LOCATION** Co ords. 4 867 788 N; 207 651 E **ORIGINATED BY** G.I.

DIST Owen Sound **HWY** 6 **BOREHOLE TYPE** Continuous Flight Solid Stem Augers **COMPILED BY** G.D.

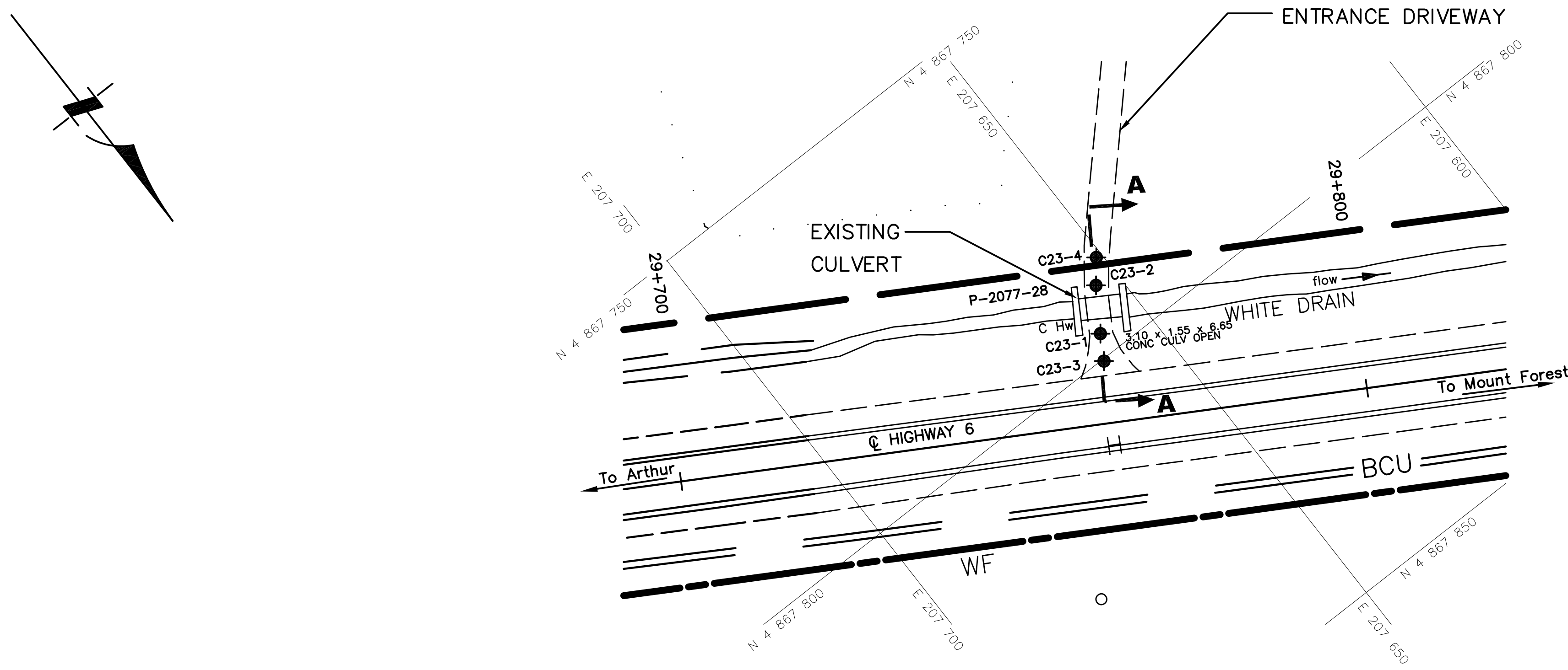
DATUM Geodetic **DATE** November 21, 2006 **CHECKED BY** G.D.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	SAMPLE TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
421.0	Ground surface					*					
0.0	Sandy gravel, trace to some silt. Compact, Dark brown, Moist (FILL)										
420.0 / 1.0	Topsoil		1	SS	25		420		~21		
419.6 / 1.4	Silt, with sand, trace gravel, organics, occ. clayey silt pockets. Compact, Dark brown, Moist		2	SS	14		419		~20		
418.9 / 2.1	End of borehole										

* Borehole dry on completion of drilling

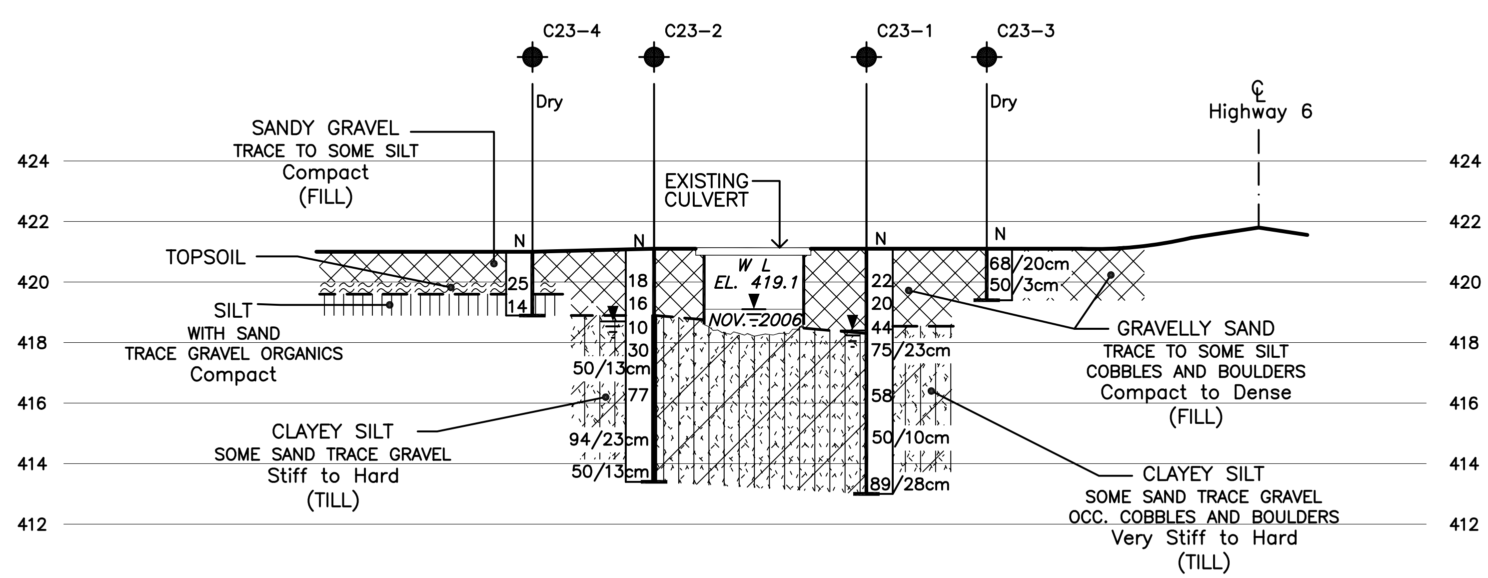
Legend: Shear strength: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE. Plastic limit w_P, Natural moisture content w, Liquid limit w_L.

+[7], ×[5]: Numbers refer to Sensitivity. 20/15/5/10: (%) STRAIN AT FAILURE



PLAN

SCALE 10 0 10 20m



SECTION A-A

SCALE 2.5 0 2.5 5m

METRIC

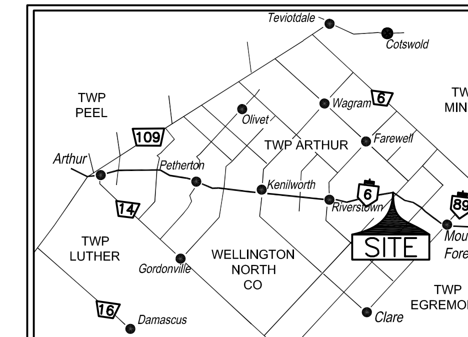
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES

CONT No
WP No 342-97-00

SHEET

HIGHWAY 6
ENTRANCE CULVERT AT STA. 29+770
BOREHOLE LOCATIONS AND SOIL PROFILE

Peto MacCallum Ltd. CONSULTING ENGINEERS



KEY PLAN
SCALE 2.5 0 5 10km

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 November 2006
- Head
- ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	CO-ORDINATES NORTH	EAST
C23-1	421.1	4 867 797	207 657
C23-2	421.1	4 867 791	207 653
C23-3	421.1	4 867 800	207 659
C23-4	421.0	4 867 788	207 651

– 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. 40P15-40

HWY No 6			DIST Owen Sound
SUBM'D GD	CHECKED CN	DATE Mar. 16, 2007	SITE 35-456C
DRAWN NA	CHECKED CN	APPROVED BRG	DWG C23-1

REF.: Plate No.156-6-38-0. dwg; dated January 2006, received from MRC, via email dated July 18, 2006

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

FOUNDATION DESIGN REPORT

for

REPLACEMENT OF ENTRANCE CULVERT AT STA. 29+770
SITE NO. 35-456/C
IMPROVEMENT OF HIGHWAY 6 FROM ARTHUR (WELLS STREET) NORTHERLY TO SOUTH OF MOUNT FOREST
G.W.P. 342-97-00
TOWNSHIP OF ARTHUR
WELLINGTON NORTH COUNTY, ONTARIO

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

Distribution:
5 cc: McCormick Rankin Corporation for distribution to MTO, Project Manager + one digital copy (PDF format)
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PML Ref.: 05KF104D5
Index No. 177FDR
Geocres No.: 40P15-40
March 30, 2007

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Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION DESIGN REPORT
for
Replacement of Entrance Culvert at Sta. 29+770
Site No. 35-456/C
Improvement of Highway 6
From Arthur (Wells Street)
Northerly to South of Mount Forest
G.W.P. 342-97-00
Township of Arthur
Wellington North County, Ontario

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1. INTRODUCTION

This report provides foundation engineering comments and recommendations for the proposed replacement of an entrance culvert located at Sta. 29+770, Site 35-456/C, while improving an approximate 18 km long section of Highway 6 that extends from Arthur (Wells Street) northerly to south of Mount Forest in the Township of Arthur, Wellington North County, Ontario. The report was prepared for McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation of Ontario (MTO).

The entrance culvert parallels Highway 6 and straddles the White Drain for access to a private gravel surfaced driveway on Lot 7, Concession WOSR (West of Owen Sound Road Survey), as inferred from ETR sheet 156-6/38-0. The culvert is concrete non-rigid frame open footing in type and has a span of 3.66 m, height of 1.60 m and length of 6.55 m. This report pertains to design and construction of the proposed culvert replacement and associated bedding/backfill zones.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial fill underlain by clayey silt till. Cobbles and boulders were encountered within both the fill and the glacial till deposit at the culvert location. Groundwater was measured in two boreholes to be near the interface of the fill and the native soil, about elevation 418.4 to 418.8. The water level in the White Drain was at about elevation 419.1 at the time of the investigation.

It is understood that the existing grades over the culvert will not be raised or lowered.

It is considered that both the open footing and box culvert options are feasible for the proposed culvert replacement. Cobbles and boulders found within the fill and native till soils many cause excavation difficulties. The construction will likely require a temporary diversion of the White Drain channel or pumping from a dam and pump arrangement in view of the expectedly high flow in the Drain.

It is noted that no responsibility or liability is assumed by the consultants for alerting the contractor and “red-flagging” all critical issues. The requirement to deliver acceptable construction quality remains the responsibility of the contractor.

A list of the standard specifications referenced in this report is compiled in Table 1. All elevations in this report are expressed in metres.

2. FOUNDATIONS

The invert of the existing open footing culvert is estimated to be near elevation 419.0 at both ends. The existing subgrade founding level of the spread footings is interpreted to be at elevation 417.4 to account for the minimum 1.6 m soil cover for frost protection (OPSD 3090.101).

The subgrade material revealed in the boreholes just below the subgrade level comprises very stiff clayey silt till. The groundwater level at the time of the field investigation was at elevation 418.4 to 418.7, about 1.0 to 1.3 m above the inferred subgrade level.

Based on the proposed road grade of the highway (elevation 421.5) and invert levels of the culvert, the embankment fill height at the culvert location is assessed to be about 2.5 m.

The replacement culvert may be an open footing culvert founded at or below the 1.6 m frost protection depth, elevation 417.4. Also feasible is a precast or cast-in-place concrete box culvert placed at the current elevation 419.0 design invert level. The founding subgrade of the precast box culvert is estimated to be at elevation 418.6, i.e. 0.4 m lower than the invert level to accommodate the thickness of the concrete culvert base slab, bedding thickness (150 mm) and levelling course (75 mm). The alternative cast-in-place box culvert may be placed at about elevation 418.8 since the bedding and levelling courses are not considered to be required.

It is recommended that the existing culvert footings be removed and fill or disturbed subgrade soils resulting from the removal of the existing culvert and present below the new box culvert founding levels subexcavated to facilitate the preparation of the founding subgrade. The excavation levels should be restored to the new foundation levels using engineered fill, mass concrete or unshrinkable fill upon approval by the geotechnical engineer.

It is considered that very stiff clayey silt till found in the boreholes within the zone of influence of the new foundations is capable of adequately supporting the stress imposed by the embankment and culvert foundation loads.

The replacement culvert foundations constructed on the clayey silt till should be designed using the following geotechnical resistances at the ultimate and serviceability limit states (ULS and SLS) for the minimum 0.5 m wide open footing or 3.6 m wide replacement box culvert:

CULVERT TYPE	SOIL TYPE	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL RESISTANCE AT SLS (kPa)
Open Footing	Very stiff clayey silt till	375	250
Box Culvert	Stiff to very stiff clayey silt till	250	150

The following parameters should be used for sliding resistance of cast-in-place culvert foundations. The friction angle and cohesion for precast concrete culverts should be reduced by a factor of 0.67.

PARAMETER	GRANULAR A OR GRANULAR B, TYPE II	STIFF TO VERY STIFF CLAYEY SILT TILL	VERY STIFF CLAYEY SILT TILL
Friction Angle, degrees	35	0	0
Cohesion, kPa	0	100	150
Unit Weight, kN/m^3	22.8	20.0	20.0

The resistance at SLS allows for 25 mm settlement of the founding medium. Total and differential settlements along the culvert length are expected to be negligible in view of the relatively low net bearing pressure exerted by the culvert foundations. Therefore, provision for camber is not considered necessary for the replacement culvert.

Preparation of the subgrade for construction of the culvert replacement should be performed and monitored in accordance with OPSS 902 and SP 902S01. This should include site review by qualified geotechnical personnel during preparation of the subgrade as well as during placement and compaction of the granular fill or, if required, mass concrete fill.

The topsoil and any other deleterious soils revealed at and below the subgrade should be excavated prior to placement of the granular bedding base below the box culverts and replaced with compacted granular fill, mass concrete fill or unshrinkable fill. Under the foundations of the open footing culverts, any grade differences should be made up with mass concrete fill.

Granular fill placed under the box culverts to accommodate any variation in the level of the native surface and/or replace any deleterious soils extending below the design founding level should comprise Granular A material compacted to at least 95% of the target density with conformance to OPSS 501 and SP 105S10. The limit of the granular fill zone should extend sideways a minimum 0.3 m beyond the culvert base and down to the subgrade at 45° to the horizontal and be established by a site specific survey.

The geometry of the subgrade preparation, cover backfill and frost taper treatment for the open footing or box culverts should be carried out in accordance with OPSD 803.010, OPSS 422 and SP 422S01. The granular base/bedding material for a precast box culvert should comprise a minimum 150 mm thick layer of Granular A material.

A frost penetration depth of 1.6 m should be employed for the design, as previously indicated in the report. It is assumed that the local traffic will be diverted for the reconstruction of the culvert.

The excavations are not expected to extend into the existing Highway 6 embankment. Consequently, road protection will not be required. It is anticipated that conventional sump pumping techniques will not suffice to control seepage of groundwater into the footing excavations and more positive groundwater control measures be needed at the site. Further comments in this regard are provided in subsequent sections of the report.

3. CULVERT BACKFILL

Backfill adjacent to the culverts should be placed in accordance with OPSD 803.010, OPSD 3121.150, OPSS 422 and SP 422S01.

Backfill should be brought up simultaneously on each side of the culvert and operation of heavy equipment within 0.5 times the height of the culvert (each side) should be restricted to minimise the potential for movement and/or damage of the culvert due to the lateral earth pressure induced by compaction.

The replacement culvert must be designed to support the stress imposed by the overlying fill as well as to resist the unbalanced lateral earth pressure and compaction pressure exerted by the backfill adjacent to the culvert walls.

The lateral earth and water pressure, p (kPa), should be computed using the equivalent fluid pressures presented in Section 6.9 of the Canadian Highway Bridge Design Code (CHBDC) or employing the following equation assuming a triangular pressure distribution.

$$p = K(\gamma h_1 + \gamma' h_2 + q) + \gamma_w h_2 + C_p$$

where p = lateral earth pressure (kPa)

K = lateral earth pressure coefficient

γ = unit weight of backfill material above design water level (kN/m^3)

γ' = unit weight of submerged backfill material below design water level (kN/m^3)

= $\gamma - \gamma_w$

γ_w = unit weight of water

= 9.8 kN/m^3

h_1 = depth below final grade (m), above design water level

h_2 = depth below design water level (m)

q = any surcharge load (kPa)

C_p = compaction pressure (refer to clause 6.9.3 of CHBDC)

The following parameters are recommended for design:

PARAMETER	GRANULAR A OR GRANULAR B TYPE II	EXCAVATED MATERIAL (*)
Angle of Internal Friction, degrees	35	30
Unit Weight, kN/m^3	22.8	20.0
Coefficient of Active Earth Pressure (K_a)	0.27	0.33
Coefficient of Earth Pressure At Rest (K_o)	0.43	0.50
Coefficient of Passive Earth Pressure (K_p)	3.69	3.00

(*) Assumes that excavated materials used for backfill are inorganic mainly cohesionless soils.

The design should consider both the maximum water level in the stream and the stabilised groundwater level conditions. The groundwater level measured during the field investigation was in a range of 1.0 to 1.3 m above the founding subgrade level. The water level at the culvert may vary seasonally. The maximum stream water level will be dictated by flood flow conditions and should be defined by the project hydraulic engineer.

The coefficient of earth pressure at rest should be employed to design rigid and unyielding walls.

A weeping tile system and/or weep holes should be installed to minimise the build-up of hydrostatic pressure behind walls. The weeping tiles should be surrounded by a properly designed granular filter or non-woven Class II geotextile (with an FOS of 75-150 µm according to OPSS 1860) placed to prevent migration of fines into the system. The drainage pipe should be placed on a positive grade and lead to a frost free outlet.

4. HEADWALLS AND WINGWALLS

For the proposed wing walls, the previous recommendations and geotechnical parameters for culvert foundations and backfill should be used for design of the foundations. The wall founding levels should match those of the culvert where the walls are designed integral with the culvert structure. For walls designed separately from the culvert structure, the founding levels should be established 1.6 m below the culvert invert level for adequate frost protection.

The design of the walls should be checked for sliding resistance using the geotechnical parameters provided in Section 2 for cast-in-place concrete foundations.

A weeping tile system and/or weep holes should be installed to minimise the build-up of hydrostatic pressure behind the walls as indicated in the previous section of the report.

5. EXCAVATION AND GROUNDWATER CONTROL

Excavation to the anticipated founding level of the culvert replacement is expected to extend through the fill and topsoil into the native deposit of clayey silt till. Provision for excavation of cobbles and boulders at the site should be allowed. Subject to adequate groundwater control, excavation of the soils should be feasible using conventional equipment.

According to the Occupational Health and Safety Act (Ontario Regulation 213/91) criteria, the in-situ stiff clayey silt till as well as fill materials are typically classified as Type 3 soils necessitating temporary cut slopes to be inclined at 1H:1V (horizontal to vertical). The native very stiff clayey silt till is regarded as Type 2 soil. The OHSA requires that the slopes be cut to the requirements of the soil type with the highest number that is present in the slope. The need to excavate flatter sideslopes below the groundwater table or if excessively soft/wet materials or concentrated seepage zones are encountered locally during construction should also be considered.

It is anticipated that a roadway protection scheme will not be required to support the walls of the excavation and adjacent traffic lanes during construction because the excavation for the new culvert construction will not affect the travel lanes of the highway.

The groundwater level observed in the boreholes at the time of the field investigation was 1.0 to 1.3 m above the inferred level of excavation. It is anticipated that dewatering with conventional sump pumps will not be sufficient to control seepage of groundwater into the excavation for installation of the culvert. More positive groundwater control measures need to be implemented at the site to ensure the integrity of the existing embankment and maintain basal stability.

The groundwater control system should be installed by a specialist contractor. The design of the groundwater control system should be left to the Contractor's discretion so that the system meets a performance specification to maintain and control the groundwater at least 0.6 m below the excavation base.

It will be necessary to implement measures to control water flow in the stream. Conventional procedures such as dam and pump and/or temporary diversion of the stream should be sufficient. Observed groundwater levels are subject to seasonal fluctuations and precipitation patterns.

It is recommended that the work be carried out during the dry summer months to minimise the amount of groundwater inflow to be handled and the volume of surface water, if any, to be diverted from the construction area.

All construction work should be carried out in accordance with the Occupational Health and Safety Act and with local/MTO regulations.

6. EMBANKMENT FILL

The height of embankment at the culvert location is envisaged to be within 2.5 m. No grade raise is anticipated.

The anticipated subgrade for the embankments comprises stiff to very stiff clayey silt till. Topsoil was encountered below the fill in one of the approach boreholes. The construction specifications for grading in OPSS 206 should be followed. In particular, the topsoil and other excessively loose, soft, organic or otherwise deleterious materials within the limits of the embankment fill should be subexcavated prior to fill placement. This measure is critical in minimising differential settlement between the existing and new embankment fill. The benching of the earth slopes should follow the OPSD 208.010 procedures and geometry. The new embankment fill should be placed and compacted in accordance with OPSS 501 and SP 105S10. The material should comprise Granular A material compacted to at least 95% of the target density.

It is considered that the subgrade soils are capable of supporting the 2.5 m high embankments. The maximum total settlement of the embankment platform surface is assessed to be in the order of 5 to 10 mm from the settlement of new fill. The settlement of the subsoil is expected to be negligible because no grade raise is anticipated. The settlement of the fill is expected to be essentially complete during the fill placement.

The highway and driveway embankment side slopes should be restored to the same inclination as existing and should be inclined no steeper than 2H:1V. A vegetation cover or other measures should be established to control surface runoff and minimise erosion of the embankment slopes.

7. EROSION CONTROL

The protective measures noted in the OPSD 800 series to deal with erosion (inlet/outlet treatment, headwalls, cut-off walls) are considered to be appropriate. The backfill should comprise OPSS Granular A or Granular B Type II materials. The cut-off walls should extend below the upper edge of the new box culverts and to a depth at least equal to the fluctuation of the water level at the culvert location to prevent flow below the culvert that could erode the granular base/bedding material as well as extend laterally to protect the granular backfill material. The requirements of CHBDC clauses 1.10.5.6 and 1.10.11.6.5 should be applied.

Inlet and outlet protection in accordance with OPSS 511 and 1004 and OPSD 810.010 is recommended to prevent erosion adjacent to the culvert as well as scour that could undermine the culvert and/or embankment foundation. The actual design requirements (length and width of the aprons at the inlet/outlet of the culvert as well as the rock size, apron thickness and height of erosion protection on the embankment slope) will be dictated by stream hydraulics, stream configuration, the water level in the stream and should be established by a hydraulic engineer. A non-woven Class II geotextile with an FOS of 75-150 µm, according to OPSS 1860, should be placed below the rip-rap to minimise the potential for erosion of fine particles from below the treatment.

All newly constructed embankment slopes and retained soils behind the headwalls and wing walls (if provided) should be covered with topsoil and seeded (as per OPSS 570 and 572) as soon after grading as possible to prevent erosion. Where slopes are inclined at 2.5H:1V or steeper, the permanent slopes should be protected with erosion control blankets. Also, sod (as per

OPSS 571) shall be placed where it currently exists with a view to aesthetics. Additional appropriate erosion control measures for the project should be assessed using the following erodibility K factor:

SOIL TYPE	**K FACTOR**
Clayey Silt Till	0.5

8. DISCUSSION OF FOUNDATION ALTERNATIVES

The foundation options for replacement of the entrance culvert may be an open footing culvert as well as a precast or cast-in-place concrete box culvert. The following table summarises the advantages, disadvantages and inferred risks/consequences of the open footing and box culvert alternatives:

COMPARISON OF OPTIONS FOR REPLACEMENT OF ENTRANCE CULVERT AT STA. 29+770

CULVERT LOCATION	OPEN FOOTING		PRECAST CONCRETE BOX CULVERT		CAST-IN-PLACE CONCRETE BOX CULVERT	
	ADVANTAGES	DISADVANTAGES	ADVANTAGES	DISADVANTAGES	ADVANTAGES	DISADVANTAGES
C-23 Sta. 29+770	Cut-off walls not required between footings Design incorporates full frost protection	Erosion control of soil between footings is required Relatively longer construction schedule than precast concrete culvert construction	Concrete base provides erosion protection Shorter construction schedule than cast-in-place concrete culvert construction.	Only partial frost protection is incorporated – frost tapers are required Cut-off walls are required	Concrete base provides erosion protection Cast-in-place concrete provides higher sliding resistance than precast concrete	Only partial frost protection is incorporated – frost tapers are required Cut-off walls are required Longer construction schedule than precast concrete culvert construction

The precast concrete option constructed at the design invert level is considered to be less costly than cast-in-place concrete alternatives since construction will be expedited with the forming and setting time required for cast-in-place concrete construction. It is expected, however, that the construction of cut-off walls will offset some of the cost advantages of the box culvert construction.

From the foundation perspective, any of the alternative types of culvert (open footing, precast or cast-in-place concrete box culvert) is feasible. However, the box culvert provides a more effective erosion protection of the culvert invert materials.

It is noted that the culvert type selection also depends on other considerations such as potential fish habitat and commercially available (off the shelf) precast culvert sizes. These facets are to be evaluated by MRC.

9. CLOSURE

This report was prepared by Mr. G.O. Degil, 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.

LICENSED PROFESSIONAL ENGINEER
G. DEGIL
100056241
PROVINCE OF ONTARIO

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

REGISTERED PROFESSIONAL ENGINEER
C M P Nascimento
PROVINCE OF ONTARIO

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

REGISTERED PROFESSIONAL ENGINEER
B. R. GRAY
PROVINCE OF ONTARIO

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

GD/CN/BRG:lr-mi

TABLE 1

LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT

DOCUMENT	TITLE	DATE
OPSS 206	Construction Specification for Grading	November 2000
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Culverts in Open Cut	April 2004
OPSS 501	Construction Specification for Compacting	November 2005
OPSS 511	Construction Specification for Rip-Rap, Rock Protection and Granular Sheeting	November 2004
OPSS 570	Construction Specification for Topsoil	August 1990
OPSS 571	Construction Specification for Sodding	November 2001
OPSS 572	Construction Specification for Seed and Cover	November 2003
OPSS 902	Excavation and Backfilling of Structures	November 2002
OPSS 1004	Material Specification for Aggregates – Miscellaneous	November 2006
OPSS 1860	Material Specification for Geotextiles	November 2004
SP 105S10	Construction Specification for Compaction	November 2004
SP 105S19	Construction Specification for Protection Systems	November 2006
SP 422S01	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers	April 2000
SP 902S01	Excavation and Backfilling of Structures	June 2006
OPSD 208.010	Benching of Earth Slopes	November 2003
OPSD 803.010	Backfill and Cover for Concrete Culverts	November 2006
OPSD 803.030	Frost Treatment - Pipe Culverts, Frost Penetration Line Below Bedding Grade	November 2005
OPSD 803.031	Frost Treatment - Pipe Culverts, Frost Penetration Line Between Top of Pipe and Bedding Grade	November 2005
OPSD 810.010	Rip-Rap Treatment for Culvert Outlets	November 2001
OPSD 3090.101	Foundation Frost Depth for Southern Ontario	November 2005
OPSD 3121.150	Minimum Granular Backfill Requirements – Retaining Walls	November 2005