



FOUNDATION INVESTIGATION AND DESIGN REPORT

for

**ROTH MUNICIPAL DRAIN CULVERT REPLACEMENT
RESURFACING 9.0 KM OF HIGHWAY 7 & 8 FROM
1.68 KM WEST OF WATERLOO REGIONAL ROAD 1,
EASTERLY TO 0.88 KM WEST OF WATERLOO REGIONAL ROAD 51
G.W.P. 335-97-00
TOWNSHIP OF PERTH EAST, ONTARIO**



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PML Ref.: 05TF036B
Index No.: 018FIR and 019FDR
Geocres No.: 40P7-53
February 28, 2006



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for

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RESURFACING 9.0 KM OF HIGHWAY 7 & 8 FROM
1.68 KM WEST OF WATERLOO REGIONAL ROAD 1,
EASTERLY TO 0.88 KM WEST OF WATERLOO REGIONAL ROAD 51
G.W.P. 335-97-00
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FOUNDATION INVESTIGATION REPORT
for
Roth Municipal Drain Culvert Replacement
Resurfacing 9.0 km of Highway 7 & 8
from 1.68 km West of Waterloo Regional Road 1,
Easterly to 0.88 km West of Waterloo Regional Road 51
G.W.P. 335-97-00
Township of Perth East, Ontario

1. INTRODUCTION

Planned under this project is the resurfacing a 9 km long section of Highway 7 & 8 that extends approximately from 1.7 km west of Waterloo Regional Road 1 easterly to 0.9 km west of Waterloo Regional Road 51 in the Township of Perth East, Ontario. This report was prepared for McCormick Rankin Corporation on behalf of the Ministry of Transportation of Ontario.

The resurfacing of Highway 7 & 8 will involve the replacement of a culvert where the Roth Municipal Drain crosses the highway at approximate Station 26+195, Highway 7 & 8 chainage. The existing culvert is a cast-in-place concrete rigid frame box structure with a size of 1.83 m wide by 1.52 m high and 25.3 m long. Construction of an approximately 2.4 m diameter concrete pipe culvert some 13 m to the east of the existing culvert is envisaged.

A previous site investigation was carried out in January 2005 by Jacques Whitford Ltd. (JWL) and reported under job No. ONT10907. The record of borehole sheets were used in the preparation of this report.

The report provides a summary of the factual information obtained during the field investigation conducted at the location of the proposed culvert replacement.

2. SITE DESCRIPTION AND GEOLOGY

Highway 7 & 8 within the project limits is primarily situated in a rural setting with slightly undulating terrain. Land use along the study corridor is mainly agricultural, with municipal ditches as integral features of the landscape. Farm residences and driveway are located in the vicinity of the site. A water pond is located north of the highway and access road.

The project area lies in the physiographic region known as the Stratford Till Plain characterised by a faint knoll-and-sag relief with an overall slope towards the southwest. The principal soils along



the study corridor are represented by heavy-textured calcareous silty clay / clayey silt till and sand/gravel. The till is fairly uniform and widespread in the region once covered by the Huron ice lobe. The more level parts of the plain are poorly drained (L.J.Chapman & D.F.Putnam, *The Physiography of Southern Ontario*, 3rd Edition, Ontario Research Foundation, 1984).

3. INVESTIGATION PROCEDURES

The records of boreholes previously prepared by JWL were reviewed for the preparation of this report. Copies of the records dated January 20 and 21, 2005 are provided in Appendix A.

The field work for this study was carried out on September 28, 2005 and comprised one borehole advanced to a depth of 9.6 m below existing grade. The approximate location of the borehole drilled near the north end of the proposed new culvert at the access road, along with a stratigraphic cross-section using the existing subsurface information, is shown on Drawing 1, appended.

For ease of reference, the borehole number is provided with prefix code "R" to reflect the name of the Roth municipal drain and distinguish it from the four boreholes (numbered 1 to 4) previously drilled along the alignment of the proposed culvert.

Peto MacCallum Ltd. (PML) selected the borehole location in the field. The ground surface elevation at the borehole was surveyed by PML using benchmark HCP #254 located at Station 26+141 some 8 m south of the highway centreline (elevation 358.65 m). All elevations in this report are expressed in meters.

PML estimated the ground surface elevations at the locations of the previously drilled JWL boreholes for use in this report because elevations were not provided on the records of the JWL boreholes.

The borehole was advanced using continuous flight solid stem augers, powered by a track-mounted CME-55 Bombardier 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 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 testing was also performed to further assess the shear strength of the cohesive soils encountered.

Soils were identified visually in the field in accordance with the MTO Soil Classification procedures. The ground water conditions at the borehole location 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 an open borehole. The borehole was backfilled with a bentonite/cement mixture in accordance with the MTO 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 two Atterberg limits tests and two grain size distribution analyses was carried out on selected samples. The results of the Atterberg limits testing and grain size distribution analyses are presented in Figures PC-1, PC-2 and GS-1, GS-2 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 and penetrometer test data, ground water observations and moisture content determinations. The results of laboratory Atterberg limits testing and grain size distribution analyses are also shown on the record of borehole R-1.

The new and previous borehole locations as well as a stratigraphic cross-section prepared from the borehole data are shown on Drawing 1. The boundaries between soil strata have been established only at the borehole location. Between boreholes, the boundaries are assumed and may vary.



The subsurface stratigraphy revealed in the boreholes drilled at the site comprised a surficial topsoil and/or fill underlain by cohesive clayey silt till. Ground water was measured in the newly drilled borehole and two piezometers previously installed in borehole 4 to be at elevation 350.1 to 353.3. The strata encountered are summarised below.

4.1 Topsoil

Surficial topsoil was present in boreholes 1 and 4 advanced near the south and north ends of the proposed culvert, respectively. The topsoil had a thickness of 200 mm in the former borehole and 350 mm in the latter.

4.2 Fill

Fill composed of sand and/or low plasticity clayey silt was present surficially in boreholes 2, 3, R-1 and directly beneath the topsoil in boreholes 1 and 4. The surficial layer of sand fill pavement structure in boreholes 2 and 3 put down on the shoulders of the highway was 0.7 and 1.1 m thick respectively, extending to elevations 357.4 and 357.8. The 5.5 to 5.8 m deep fill in boreholes 2 and 3 comprises the highway embankment fill, while the 2.2 to 3.2 m deep fill in boreholes 4 and R-1 comprises the embankment fill of the adjacent access road. The fill units had a total thickness of 0.9 to 5.8 m and were penetrated at depths of 1.1 to 5.8 m (elevations 352.4 to 353.4). The standard penetration test N-values in the clayey silt zone of the fill were in a range of 3 to 17, typically 5 to 10. It is noted that the existing asphalt road pavement was not penetrated during the investigation.

The results of an Atterberg limits test and grain size distribution analysis conducted on the clayey silt fill are presented in Figures PC-1 and GS-1 respectively. The liquid limit of the clayey silt fill was 30 and the plastic limit 20, with a corresponding plasticity index of 10. The moisture content of the clayey silty fill in borehole R-1 varied between 11 and 24%.

4.3 Clayey Silt Till

Underlying the fill in all the boreholes was cohesive clayey silt till of low plasticity. This deposit was at least 2.6 to 4.3 m thick in boreholes 1 to 4 which terminated at depths of 3.7 to 9.8 m and



had a minimum thickness of 7.4 m in borehole R-1 terminated within the clayey silt till at 9.6 m depth (elevation 346.0). The deposit was typically very stiff to hard, with the upper 1 m thick zone in borehole R-1 exhibiting firm to stiff consistency. The results of penetrometer testing performed on the clayey samples retrieved from borehole R-1 indicate a shear strength in a range of 75 to over 225 kPa.

The results of an Atterberg limits test and grain size distribution analysis conducted on the clayey material are presented in Figures PC-2 and GS-2 respectively. The liquid limit of the clayey silt till was 29 and the plastic limit 16, with a corresponding plasticity index of 13. The moisture content of the clayey silt till in borehole R-1 varied between 11 and 19%.

4.4 Ground Water

Water was observed in borehole R-1 during drilling at 2.1 m depth (elevation 353.5). Upon completion of augering, ground water was measured at a depth of 5.5 m (elevation 350.1). Two piezometers were previously installed in borehole 4. The readings taken during this study showed water levels to be at elevation 350.3 in the deep piezometer and 353.3 in the shallow one.

It is noted that flowing artesian conditions were encountered at the Dahmer culvert site located some 800 m westerly at Sta. 25+389. (Refer to GWP 335-97-00, Site 25-318-C, Geocres No. 40P7-52 for details.) The aquifer was confined in a sandy gravel layer encountered at 15.8 m depth (elevation 334.9). The estimated flow was about 50 litres per minute and the estimated piezometric head was 1.5 m above ground surface.

The roadside ditches and the municipal culvert were dry or carry a low volume of water at the time of the investigation. The ground was locally saturated with about 0.1 m deep standing water.

Based on the observations during this investigation, the perched water level is anticipated at elevation 353.5 and the stabilized ground water level at elevation 350.3. The observed ground water levels are subject to seasonal fluctuations and precipitation patterns.



5. CLOSURE

The field work was carried out under the supervision of Mr. F. Portela, Senior Technician, and direction of Mr. G. Degil, P.Eng., Senior Foundation Engineer. The equipment was supplied by Geo-Environmental Drilling Inc. The laboratory testing was performed in the PML Toronto laboratory.

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

Yours very truly

Peto MacCallum Ltd.

A handwritten signature in black ink, appearing to read "Grigory O. Degil".

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

A handwritten signature in black ink, appearing to read "Carlos M.P. Nascimento".

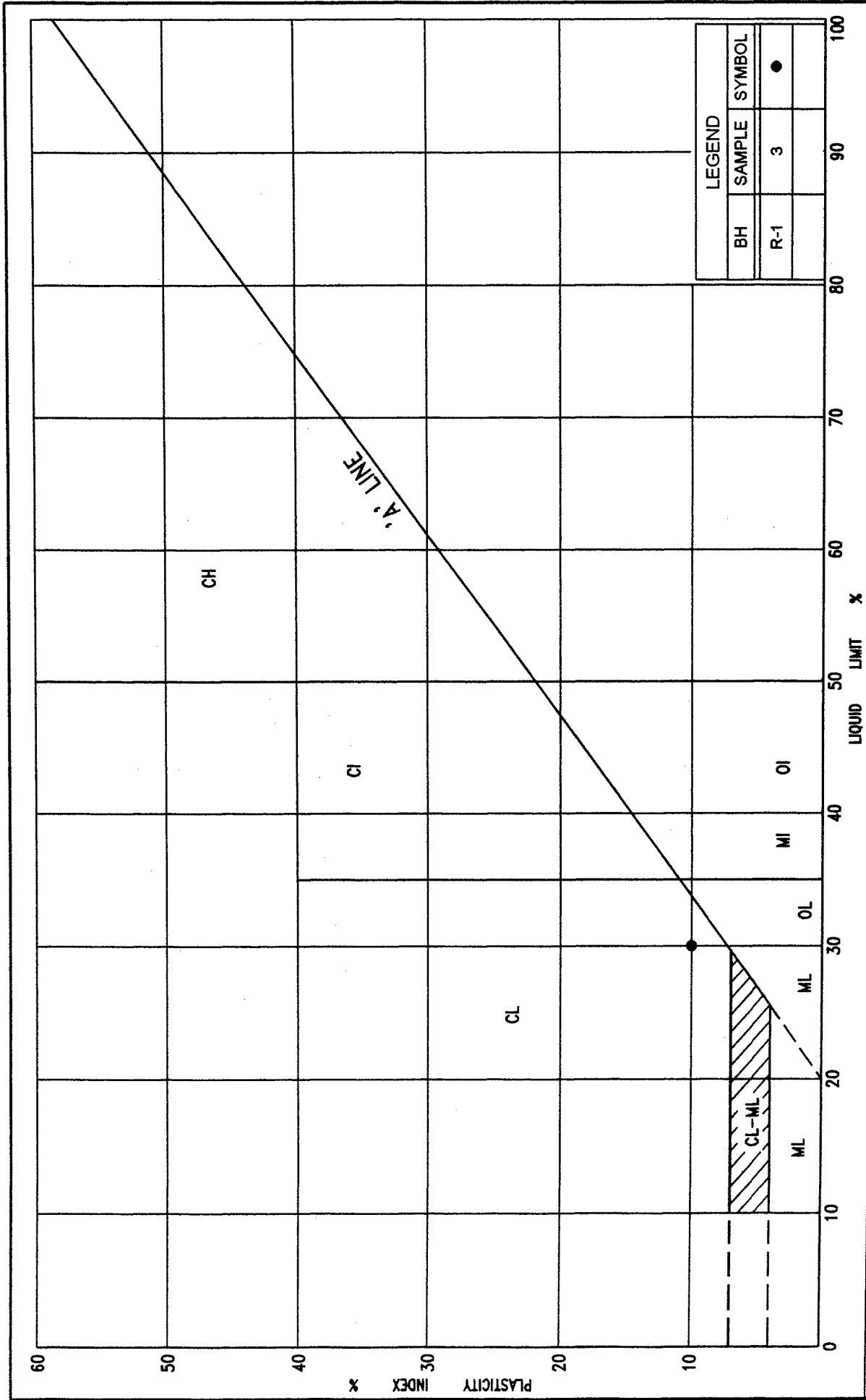
Carlos M.P. Nascimento, P.Eng.
Project Manager

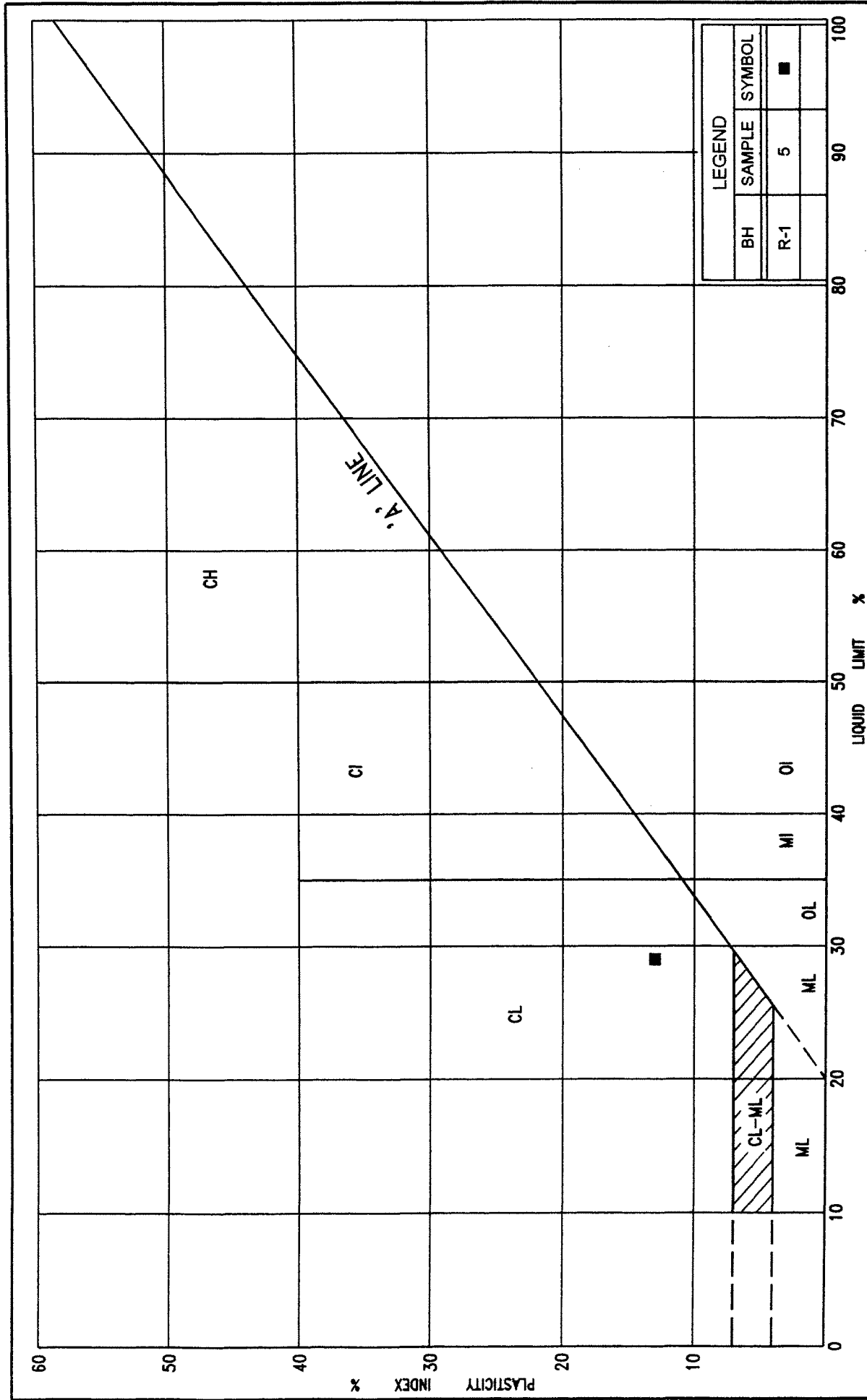
A handwritten signature in black ink, appearing to read "Brian R. Gray".

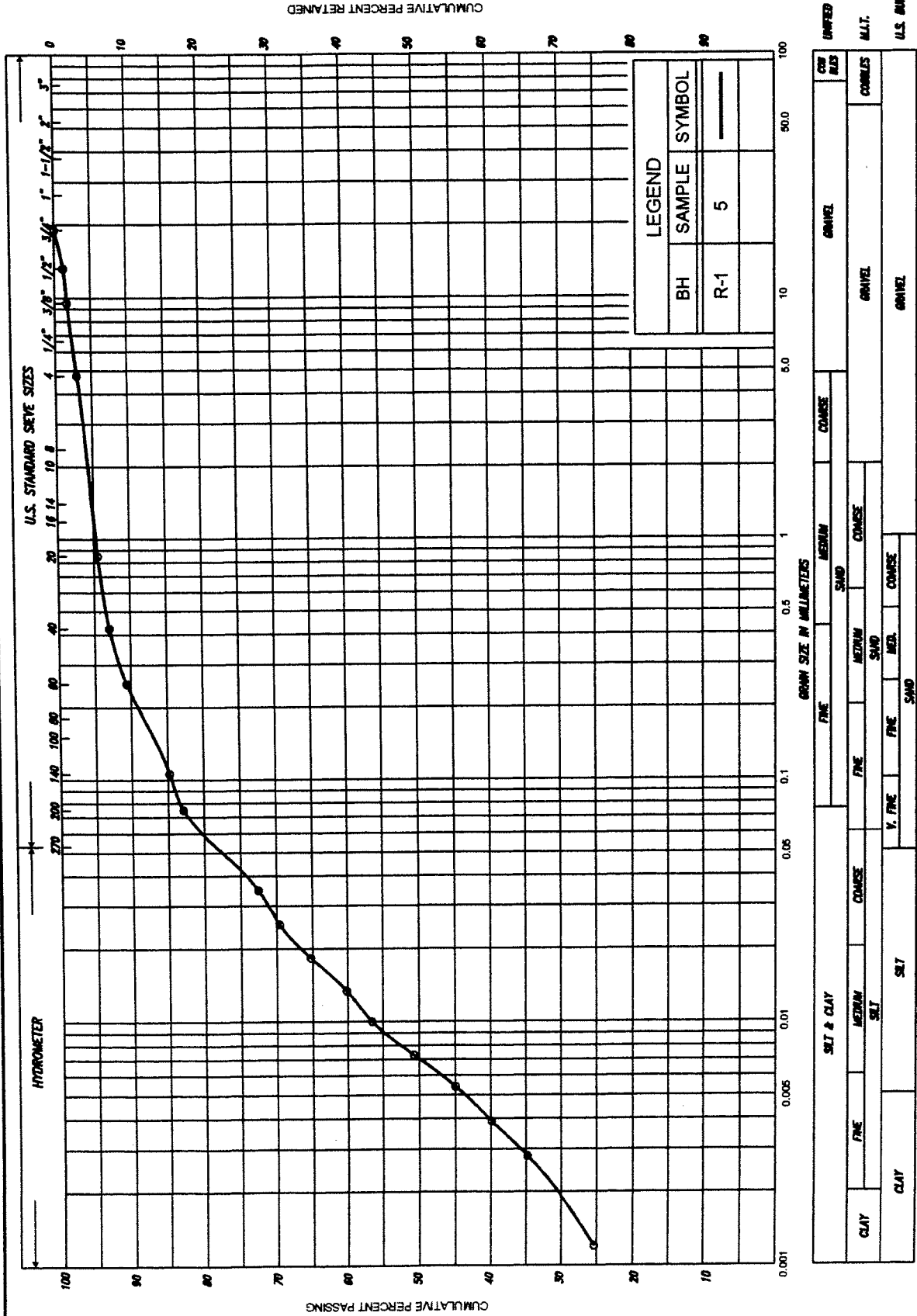
Brian R. Gray, MEng, P.Eng.
MTO Designated Contact

GD:mi









GRAIN SIZE DISTRIBUTION CLAYEY SILT, some sand, trace gravel (TILL)

FIG No. GS-2

HWY 7 & 8

G.W.P. No. 335-97-00



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:

R Q D (%)	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
σ_u	l	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	l	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	l	COMPRESSION INDEX
C_s	l	SWELLING INDEX
C_α	l	RATE OF SECONDARY CONSOLIDATION
c_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	l	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	l	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

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

METRIC

ORIGINATED BY F.P.

COMPILED BY G.D.

CHECKED BY *GD*

20
15 — 5 (%) STRAIN AT FAILURE
10

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

CONT No
WP No 335-97-00
HIGHWAY 7 & 8
ROTH MUNICIPAL DRAIN CULVERT
BOREHOLE LOCATIONS & SOIL STRATA



SHEET

PML Peto MacCallum Ltd
CONSULTING ENGINEERS

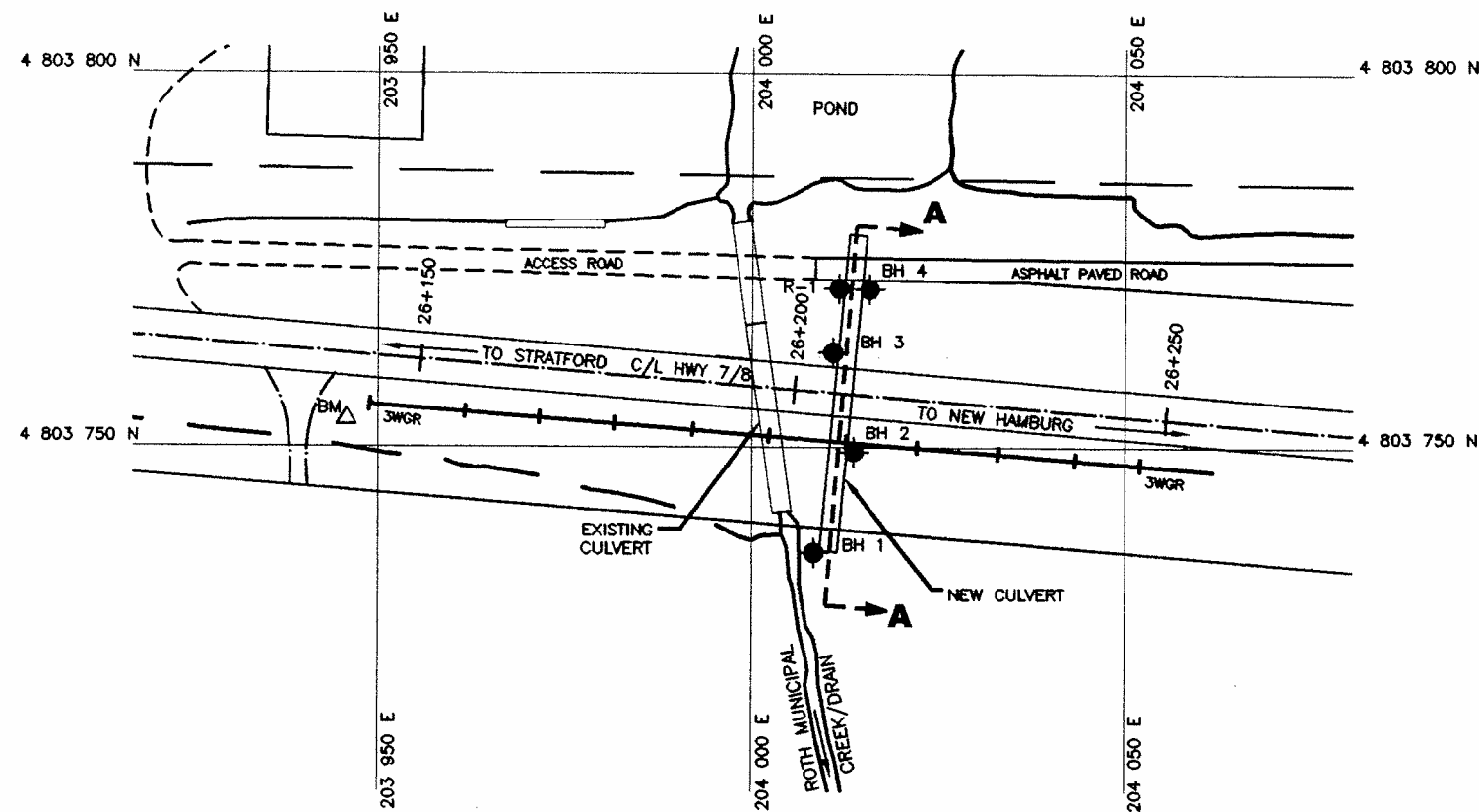


KEY PLAN
SCALE
0 2 4 6 8 km

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 Sept. 2005		
	Head		
	ARTESIAN WATER Encountered		
	PIEZOMETER		
BH No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
R-1	355.6	4 803 771	204 012
BH 1	354.1	4 803 736	204 008
BH 2	358.5	4 803 749	204 014
BH 3	358.5	4 803 763	204 011
BH 4	355.6	4 803 771	204 016

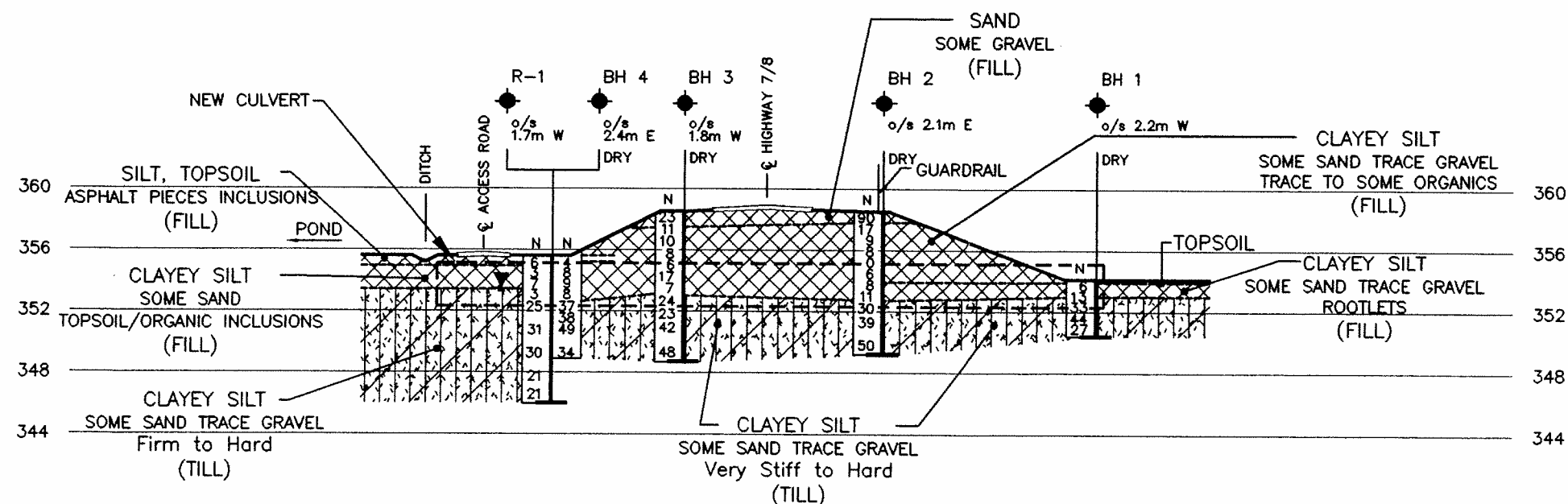
NOTE
The boundaries between soil strata have been established
only at Borehole locations. Between Boreholes the
boundaries are assumed from geological evidence.

REVISIONS	DATE	BY	DESCRIPTION
Geocore No. 40P7-53			
HWY No	7 & 8	DATE	FEB. 28, 2006
DRAWN	NA	CHECKED	CH
APPROVED	BRG	DATE	1



PLAN

SCALE
0 5 10 20m



A-A
SECTION

SCALE
0 2 4 8m

NOTES:

- SECTIONS ARE PROVIDED SOLELY FOR ILLUSTRATIVE PURPOSES. REFER TO RECORD OF BOREHOLES FOR DETAILED DESCRIPTION OF SUBSURFACE CONDITIONS, IN-SITU TEST DATA AND LABORATORY TEST RESULTS.
- STRATIGRAPHY SHOWN FOR BOREHOLES 1 TO 4 IS BASED ON RECORD OF BOREHOLES PREPARED BY JACQUES WHITFORD ENVIRONMENTAL LIMITED, JOB No. ONT10907. GROUND SURFACE ELEVATIONS FOR BOREHOLES 1 TO 4 WERE ESTIMATED.



APPENDIX A

Previous Record of Borehole Sheets

(Source: Investigation carried out by Jacques Whitford Ltd.
and reported under Job No. ONT10907)

RECORD OF BOREHOLE No BH1										1 OF 1		METRIC	
W.P. <u>WP 135-98-00</u>			LOCATION <u>REGIONAL MUNICIPALITY OF WATERLOO</u>				ORIGINATED BY <u>MW</u>						
DIST <u>HWY Highway 7&8</u>			BOREHOLE TYPE <u>100 mm Dia. Solid Stem Power Auger</u>				COMPILED BY _____						
DATUM <u>Local</u>			DATE <u>05.01.20 - 05.01.20</u>				CHECKED BY _____						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELFV DEPTH	DESCRIPTION	SIRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED × FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)
0.0	Grass												
0.2	200mm Topsoil												
-0.2	Brown, firm, Clayey SILT (FILL), some sand and rootlets, trace gravel, wet	F	1	SS	6								
-1.1	Brown, very stiff to hard, Clayey SILT (TALL), some sand, trace gravel, moist	T	2	SS	13								
-1.7	- gmy		3	SS	33								
-3.7	- auger grinding		4	SS	44								
-3.7	END OF BOREHOLE AT A DEPTH OF 3.7m		5	SS	27								
-3.7	Borehole caved to a depth of 2.9m												
-3.7	Borehole dry on the completion of drilling												

Numbers refer to
Sensitivity

3% STRAIN AT FAILURE

ONTARIO M/01 1/2007 JACK AND BORE GPI ONTARIO MGT G01 0503201

<div style="display: flex; justify-content: space-between;"> 535 47-00 RECORD OF BOREHOLE No BH2 1 OF 1 METRIC </div>																	
W.P. <u>WP 135-98-00</u>		LOCATION <u>REGIONAL MUNICIPALITY OF WATERLOO</u>				ORIGINATED BY <u>MW</u>											
DIST <u>HWY Highway 7&8</u>		BOREHOLE TYPE <u>100 mm Dia. Solid Stem Power Auger</u>				COMPILED BY _____											
DATUM <u>Local</u>		DATE <u>05.01.20 - 05.01.20</u>				CHECKED BY _____											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV. DEPTH	DESCRIPTION	STRAT PILOT	NUMBER	TYPE			N° VALUES	SHEAR STRENGTH kPa ○ UNCONFINED × FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%) w _p w w _L				
0.0	Gravel Brown, very dense, SAND (FILL), some gravel, damp	T	1	SS	90												
-0.7	Brown, very stiff, Clayey SILT (FILL), some sand, trace to some organics, trace gravel, damp to moist	F	2	SS	17												
	- stiff	T	3	SS	9												
	- firm	T	4	SS	8												
		T	5	SS	5												
		T	6	SS	6												
	- very stiff	T	7	SS	8												
-5.8	Brown, hard, Clayey SILT (TILL), some sand, trace gravel, moist	F	8	SS	11												
-7.6	- grey	T	9	SS	30												
-9.3	END OF BOREHOLE AT A DEPTH OF 9.3m Borehole caved to a depth of 8.8m Borehole dry on the completion of drilling	T	10	SS	39												
-9.3		T	11	SS	50												

$\times^3 \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH3

1 OF 1

METRIC

W.P. WP 135-AR-03 LOCATION REGIONAL MUNICIPALITY OF WATERLOO ORIGINATED BY MW
 DIST HWY Highway 758 BOREHOLE TYPE 100 mm Dia. Solid Stem Power Auger COMPILED BY _____
 DATUM Local DATE 05.01.20 - 05.01.21 CHECKED BY _____

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
FLEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
0.0	Gravel Brown, compact, SAND (FILL), some gravel, moist	1	SS	23													
-1.1	- trace asphalt	2	SS	11													
1.1	Brown, firm to stiff, Clayey SILT (FILL), some sand, gravel and organics, damp	3	SS	10													
	- trace organics	4	SS	8													
	- wet	5	SS	6													
		6	SS	17													
-4.6	- grey	7	SS	7													
4.6	- some sand, trace quartz	8	SS	24													
-5.5	Brown, very stiff, Clayey SILT (FILL), some sand, trace gravel, moist	9	SS	23													
		10	SS	42													
-7.9	- grey	11	SS	48													
7.9																	
-9.8	END OF BOREHOLE AT A DEPTH OF 9.8m																
9.8	Borehole open and dry on completion of drilling																

Numbers refer to
Sensitivity

STRAIN AT FAILURE

1 OF 1

METRIC

LOCATION REGIONAL MUNICIPALITY OF WATERLOO

ORIGINATED BY MW

BOREHOLE TYPE 200 mm Dia. Hollow Stem Power Auger

COMPILED BY

DATUM Local

DATE 05.01.21 - 05.01.21

CHECKED BY...

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



FOUNDATION DESIGN REPORT

for

**ROTH MUNICIPAL DRAIN CULVERT REPLACEMENT
RESURFACING 9.0 KM OF HIGHWAY 7 & 8 FROM
1.68 KM WEST OF WATERLOO REGIONAL ROAD 1,
EASTERLY TO 0.88 KM WEST OF WATERLOO REGIONAL ROAD 51
G.W.P. 335-97-00
TOWNSHIP OF PERTH EAST, ONTARIO**

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Table 1 - List of Standard Specifications Referenced in Report

Peto MacCallum Ltd.

C O N S U L T I N G E N G I N E E R S

FOUNDATION DESIGN REPORT

for

Roth Municipal Drain Culvert Replacement
Resurfacing 9.0 km of Highway 7 & 8
from 1.68 km West of Waterloo Regional Road 1,
Easterly to 0.88 km West of Waterloo Regional Road 51
G.W.P. 335-97-00
Township of Perth East, Ontario

1. INTRODUCTION

This report provides foundation engineering comments and recommendations for the proposed replacement of the Roth municipal drain culvert while resurfacing a 9 km long section of Highway 7 & 8 that extends approximately from 1.7 km west of Waterloo Regional Road 1 easterly to 0.9 km west of Waterloo Regional Road 51 in the Township of Perth East, Ontario. This report was prepared for McCormick Rankin Corporation on behalf of the Ministry of Transportation of Ontario (MTO).

Resurfacing of Highway 7 & 8 will involve replacement of a culvert where the Roth municipal drain crosses the highway at approximate Station 26+195, Highway 7 & 8 chainage. The existing culvert is a cast-in-place concrete rigid frame box structure with a size of 1.83 m wide by 1.52 m high and 25.3 m long. Construction of an approximately 2.4 m diameter concrete pipe culvert some 13 m to the east of the existing culvert is envisaged.

The replacement culvert is intended to be installed utilising a jack-and-bore technique. The existing culvert will be abandoned and the open ditch drain realigned to the new culvert location.

This report pertains to the design and construction of the proposed new culvert and associated bedding/backfill zones, where required.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised a surficial topsoil and/or fill underlain by cohesive clayey silt till. The ground water level measured in the newly drilled borehole and two piezometers previously installed in borehole 4 was at elevation 350.1 to 353.3.

Construction of the culvert by the jacking and boring method is considered to be feasible through the highway embankment section. The contractor should be aware of the potential presence of

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an aquifer with flowing artesian conditions that was encountered at the Dahmer culvert site located some 800 m westerly at Sta. 25+389. (Refer to GWP 335-97-00, Site 25-318-C, Geocres No. 40P7-52 for details.) The structures for temporary road protection and for the jacking and exit pits should not be installed below the levels investigated for this report.

A list of MTO documents used in subsequent sections of the report is given in Table 1 for ease of reference. All elevations in this report are expressed in meters.

2. CULVERT CONSTRUCTION

2.1 General

The invert of the existing culvert is indicated to be near elevation 352.5 (ref.: Plate 166-788/38-0 of 'Highway 7 & 8. Preliminary Design' drawings). The new culvert is assumed to be constructed at the same invert level. The subgrade material below this level revealed in boreholes 1 to 4 and R-1 comprised very stiff clayey silt till.

Based on the road surface grade (elevation 358.6) and the estimated ground surface elevation at the toe of slope, the embankment fill height at the location of the replacement culvert is assessed to be about 4.0 m.

It is considered that the very stiff clayey silt till exposed in the boreholes at and below the design subgrade is capable of supporting the stress imposed by the embankment and the new 2.4 m diameter pipe culvert.

The obvert of the 2.4 m diameter pipe is anticipated at about elevation 354.9. This obvert level is about 2.5 to 2.9 m below the level of the sand and gravel zone of the road embankment fill where the tunnel section of the culvert is feasible. The culvert pipe obvert is 0.7 m below grade north of the embankment and 0.8 m above grade south of the embankment and it is considered that these soil cover thicknesses will not provide sufficient vertical restriction for the tunnelling procedure. Consequently, the culvert sections located beyond the limits of the highway platform embankment should be installed by the cut and cover method.



2.2 Tunnelling Considerations

The tunnel for the new pipe culvert is expected to be advanced mostly through the clayey silt fill zone with the base on the very stiff clayey silt till.

Tunnelling construction through the road embankment at the proposed grades utilising such methods as a jack-and-bore technique are considered to be feasible at this site, subject to the comments and recommendations provided in the following paragraphs.

For the jack-and-bore technique the general construction specification for pipeline and utility installation by jacking and boring, OPSS 416 should be followed. For this site, a steel liner should be advanced together with a shield through the clayey silt fill to prevent excessive cave-in at the face of the tunnel and minimise the road settlements over the tunnel.

Temporary entry (jacking pit) and exit shafts will be necessary for the tunnelling operations. At the level of the entry / exit shafts and tunnel, the soils are mainly represented by the clayey silt fill of firm to stiff consistency. The coefficient of horizontal subgrade reaction, k_s (kN/m^3), for the clayey silt fill present at the site should be computed using the following equation:

$$k_s = \frac{67c_u}{b}$$

where c_u = undrained shear strength of the clayey silt fill
= 50 kPa

b = thrust block width, m

If the fill does not provide adequate support for the jacking of the tunnel liner, the reaction system should extend below the invert level into the major very stiff to hard clayey silt till deposit. The coefficient of horizontal subgrade reaction for the very stiff clayey silt till should be computed using the above formula in which an undrained shear strength of 100 kPa is considered to be appropriate.

Care should be taken during tunnelling to maintain the pipe grades, since the base of the tunnel will be installed into harder clayey silt till material than the remainder of the liner.



2.3 Cut and Cover Considerations

North and south of the embankment where culvert sections will be installed utilising the cut and cover method, the topsoil and/or fill revealed at the borehole locations should be excavated to expose the founding subgrade. Any other deleterious soils encountered below the subgrade level should be excavated prior to placement of the granular base below these culvert sections and replaced with engineered fill.

Preparation of the subgrade 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 engineered fill, if required.

Engineered fill placed under the culvert 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 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 culvert should be carried out in accordance with OPSD 803.010, 803.031 and OPSS 422. The bedding material should comprise a minimum 150 mm thick layer of Granular A.

A frost penetration depth of 1.6 m should be employed.

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

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) restricted to minimise the potential for movement and/or damage of the culvert due to the lateral earth pressure induced by compaction.



The 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 imposed 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), CAN/CSA-S6-00, March 2001, 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/m³)

γ' = unit weight of submerged backfill material below design water level (kN/m³)
 $= \gamma - \gamma_w$

γ_w = unit weight of water
 $= 9.8 \text{ kN/m}^3$

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

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



If a headwall and wing walls are utilised, a weeping tile system and/or weep holes should be installed behind the wall to minimise the build-up of hydrostatic pressure. 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 drain pipe should be placed on a positive grade and lead to a frost free outlet.

3. EXCAVATION AND GROUND WATER CONTROL

The ground water level measured at the culvert location was 1 m above the anticipated base of excavation for the entry / exit shafts. Cognisant of the permeability characteristics of the clayey soils present at the site, conventional sump pumping techniques should be sufficient to control seepage of ground water into the excavations at both ends of the culvert and during the tunnelling operation.

It is noted that the maximum depth of excavation will be about 3 m at the north end of the replacement culvert and 2 m at the south end. Excavation is expected to extend 0.5 to 1.0 m below the highest ground water level through the topsoil, clayey silt fill and clayey silt till. Subject to adequate ground water control, excavation of the soils should be feasible using conventional equipment. According to Occupational Health and Safety Act criteria, the in situ materials are classified as Type 3 soils above the ground water table necessitating temporary cut slopes to be inclined at 1H:1V (horizontal to vertical). Below the ground water table, the materials are classified as Type 4 soils requiring 3H:1V slopes.

It is anticipated that a suitable roadway protection scheme in accordance with SP 105S19 will be required to support the walls of the excavation and adjacent traffic lanes during construction. Several protection scheme alternatives such as sheet piling, sheeting supported by rakers or bracing, cantilever soldier piles and lagging may be considered. The schemes should be designed for performance level 2 provided that ground water control is in place. Otherwise, a performance level 1a system such as soldier piles and lagging with anchored tiebacks is recommended to prevent movement of the existing embankment. The contractor is responsible for preparing a detailed design for the road protection system.



Since the open ditch drain will be realigned to the new culvert location after construction is complete, no measures to control water flow in the stream need to be implemented. Observed water 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 ground water 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 (Ontario Regulation 213/91) and with local/MTO regulations.

4. 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. The cut-off walls should extend 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 bedding material as well as extend laterally to protect the granular material. The requirements of CHBDC clauses 1.10.5.6 and 1.10.11.6.5 should be applied.

Inlet protection in accordance with OPSS 511 and 1004 is recommended to prevent erosion adjacent to the culvert as well as scour that could undermine the culvert and/or embankment. The actual design requirements (length and width of the aprons at the inlet 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 embankment slopes and retained soils behind the head walls 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:

<u>SOIL TYPE</u>	<u>K FACTOR</u>
Clayey Silt Till	0.5

5. CLOSURE

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., Project Manager. Mr. B.R. Gray, MEng, P.Eng., MTO Designated Contact, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

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GD:mi





TABLE 1
LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT

TITLE	DOCUMENT	DATE
Construction Specification for Pipeline and Utility Installation by Jacking and Boring	OPSS 416	November 2003
Construction Specification for Precast Reinforced Concrete Box Culverts and Box Culverts in Open Cut	OPSS 422	April 2004
Construction Specification for Compacting	OPSS 501	November 2005
Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting	OPSS 511	November 2004
Construction Specification for Topsoil	OPSS 570	August 1990
Construction Specification for Sodding	OPSS 571	November 2001
Construction Specification for Seed and Cover	OPSS 572	November 2003
Excavation and Backfilling of Structures	OPSS 902	December 1983
Material Specification for Aggregates - Miscellaneous	OPSS 1004	November 2005
Material Specification for Geotextiles	OPSS 1860	November 2004
Construction Specification for Compaction	SP 105S10	November 2004
Construction Specification for Protection Systems	SP 105S19	March 2005
Excavation and Backfilling of Structures	SP 902S01	September 2003
Backfill and Cover for Concrete Culverts	OPSD 803.010	November 1999
Frost Treatment - Pipe Culverts: Frost Penetration Line between Top of Pipe and Bedding Grade	OPSD 803.031	November 2005
Minimum Granular Backfill Requirements - Retaining Walls	OPSD 3121.150	November 2005