



FOUNDATION INVESTIGATION AND DESIGN REPORT

for

**HOLMESVILLE CREEK CULVERT REPLACEMENT/EXTENSION
REHABILITATION OF HIGHWAY 8, GODERICH TO CLINTON
WP 189-89-04
TOWNSHIP OF GODERICH, ONTARIO**

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PML Ref.: 05KF129B
Index No.: 086FIR & 087FDR
Geocres No.: 40P12-11
November 3, 2006



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for

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FOUNDATION INVESTIGATION REPORT
for
Holmesville Creek Culvert Replacement/Extension
Rehabilitation of Highway 8, Goderich to Clinton
WP 189-89-04
Township of Goderich, Ontario

1. INTRODUCTION

Planned under this project is the rehabilitation of Highway 8 from the Goderich east limits easterly for 16.8 km to the Clinton west limits in the Township of Goderich, Ontario. Part of this project involves the possible replacement (or extension) of the culvert located about 1 km north of the Hamlet of Holmesville (Holmesville Creek Culvert). This report was prepared for McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation of Ontario.

The Holmesville Creek Culvert is designated as C-114 (Site No. 12-391-C) and is located at the Holmesville Creek crossing of Highway 8. The culvert is located at approximate Station 24+780, Highway 8 chainage.

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

2. SITE DESCRIPTION AND GEOLOGY

Highway 8 within the project limits is primarily situated in a rural setting with rolling terrain containing streams and swampy streaks in depressions. Land use along the study corridor is mainly agricultural with some forested/swamp areas and local residential development.

The project area lies in the physiographic region known as the Huron Slope characterised by an undulating till plain, with the till often coming to the surface and resting on stratified clay. The principal surficial soil along the study corridor is clayey silt till interbedded with silt, sand and gravel (L.J.Chapman & D.F.Putnam, *The Physiography of Southern Ontario*, 3rd Edition, Ontario Research Foundation, 1984). Between Goderich and Clinton there are deposits of gravel and sand that are actively explored commercially as sources of aggregate. The Holmesville Creek Culvert lies within this sand and gravel deposit zone.



The bedrock underlying the site is at an approximate depth of 63 m and comprises limestone of the Dundee Formation, based on the Ontario Geological Survey map of Bedrock Resources, ARIM 177-2C for Huron County.

The frost penetration depth for design purposes as shown on the OPSD 3400-011 is 1.3 m.

3. INVESTIGATION PROCEDURES

The field work for this study was carried out in the period of April 18 to June 6, 2006 and comprised three boreholes and two dynamic cone penetration tests drilled to depths of 4.6 to 9.8 m at the locations shown on Drawing 1.

The borehole layout was established by Peto MacCallum Ltd. (PML) in accordance with the requirements noted in the Request for Proposal. It was considered that the site conditions were relatively uniform at the three borehole locations drilled for culvert replacement and an additional borehole for culvert extension on both sides was not needed at this site. The locations of and ground surface elevations at the boreholes were also determined by PML. All elevations in this report are expressed in metres.

The boreholes and dynamic cone penetration tests were advanced using a track-mounted drill rig and a motorized tripod setup where access restrictions required. The equipment was 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 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 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 9 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 by visual and tactile examination. The results of laboratory Atterberg limits testing and grain size distribution analyses are presented in Figures PC-1, PC-2 and GS-1 to GS-4 respectively.

4. SUMMARISED SUBSURFACE CONDITIONS

4.1 General

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 pocket penetrometer test data, groundwater observations and moisture content determinations. The results of the dynamic cone penetration tests are also included on the Record of Borehole sheets. 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 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 a surficial fill, including the pavement and embankment of the Highway 8 shoulder, over topsoil underlain by organic clayey silt alluvium and sand with gravel containing cobbles and boulders. At deeper levels, the sand with gravel was underlain by a glacial deposit of silt till. No natural gas



emissions were noted from the boreholes during drilling. Groundwater measured in the boreholes was at 0.3 to 2.7 m depths, elevations 251.6 to 252.1.

4.2 Fill

Surficial fill was present in all the boreholes. The fill under the shoulder of Highway 8 (borehole 2) was 2.2 m thick and composed of sand and gravel. The sand and gravel fill comprised both the highway pavement and the existing embankment platform.

At the western and eastern ends of the culvert, the fill was made up of clayey or sandy silt and had a thickness of 600 to 800 mm, respectively.

The fill was penetrated at elevation 251.6 at each of the ends of the culvert and at elevation 252.1 under the road embankment. The fill was typically loose with standard penetration test N-values ranging from 5 to 9.

The moisture content ranged widely from 4 to 25% in the fill samples. The results of grain size distribution analysis performed on the sand with gravel fill are presented in Figure GS-1.

4.3 Topsoil

Directly beneath the fill was a continuous topsoil layer made up of silt or clayey silt with organics. The topsoil was 500 to 800 mm in thickness and had a moisture content of about 41%. The topsoil was penetrated at depths of 1.1 to 3.0 m (elevations 251.0 to 251.3).

4.4 Organic Clayey Silt Alluvium

Underlying the topsoil in all the boreholes was organic clayey silt alluvium. This deposit was 0.4 to 1.0 m thick and firm to stiff in consistency, with the penetrometer test results indicating shear strength values of 75 and 90 kPa. The organic clayey silt alluvium was penetrated at depths of 1.6 to 3.4 m (elevations 250.0 and 250.9).



The results of Atterberg limits testing and grain size distribution analysis conducted on a representative sample of this material are presented in respective Figures PC-1 and GS-2. The liquid and plastic limits of the organic clayey silt alluvium was 26 and 14 respectively, thus giving the plasticity index of 12. Water content determinations in this unit were 8 and 10%.

4.5 Sand with Gravel

Overlain by the organic clayey silt alluvium was a cohesionless sand with gravel unit. This unit was typically compact in relative density (N-values ranging from 7 to over 50 blows but typically between 12 and 26) and contained cobbles and boulders. Having a thickness of 5.3 m in borehole 2, the sand was penetrated at 8.7 m depth (elevation 245.6). Augering was terminated within the sand and gravel at a depth of 4.6 m (elevation 247.8) in borehole 1 and 1.8 m depth (elevation 250.4) in borehole 3 from where a dynamic cone penetration test was advanced in the same inferred material to the 5.5 m termination depth (elevation 246.7) of the borehole.

The results of grain size distribution analysis performed on the sand are presented in Figure GS-3. The moisture content of the sand with gravel unit ranged from 7 to 15%.

4.6 Silt Till

Silt till was contacted below the sand with gravel deposit at a depth of 8.7 m (elevation 245.6) in borehole 2. This silt till deposit was at least 1.1 m thick and compact (N-value of 23). Cobbles and boulders were encountered within the silt till during drilling. The deposit was not penetrated upon termination of drilling at 9.8 m depth (elevation 244.5).

The results of Atterberg limits testing and grain size distribution analysis conducted on a representative sample of this material are presented in respective Figures PC-2 and GS-4. The liquid and plastic limits of the silt till was 16 and 13 respectively, giving the plasticity index of 3. The moisture content of the deposit was about 12%.



4.7 Groundwater

Water was observed in all the boreholes in the course of the field work at depths of 0.3 to 2.3 m (elevations 251.7 to 252.1). Upon completion of drilling, groundwater was measured at depths of 0.3 to 2.7 m (elevations 251.6 to 252.1). The water found at western end of the culvert was about 350 mm deep (about elevation 251.8) on April 18, 2006.

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 and direction of Mr. C.M.P. Nascimento, P.Eng., Senior Project Engineer. The soil drilling equipment was supplied by Geo-Environmental Drilling Inc.

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. 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 "C. Nascimento", is written over the printed name.

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

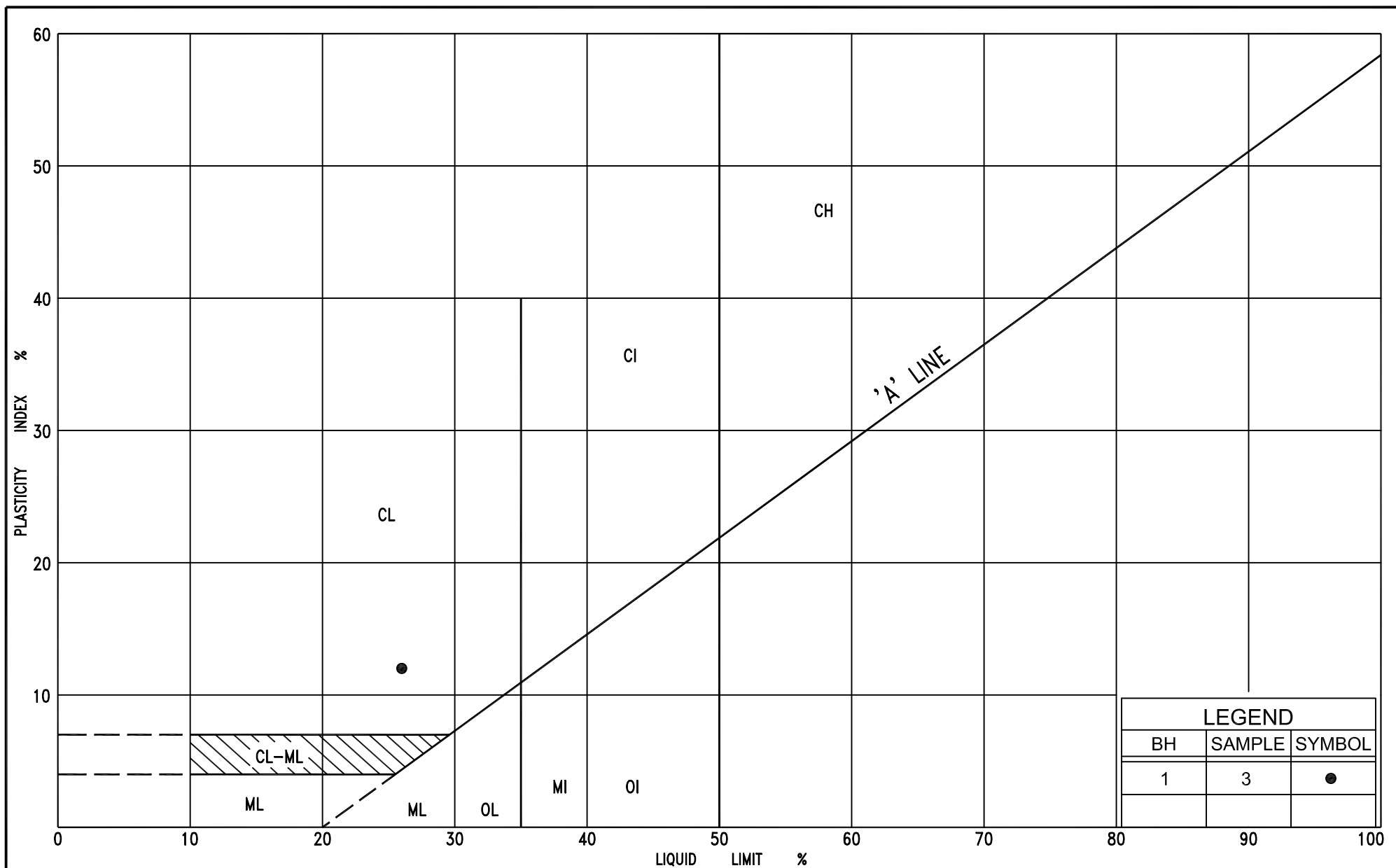


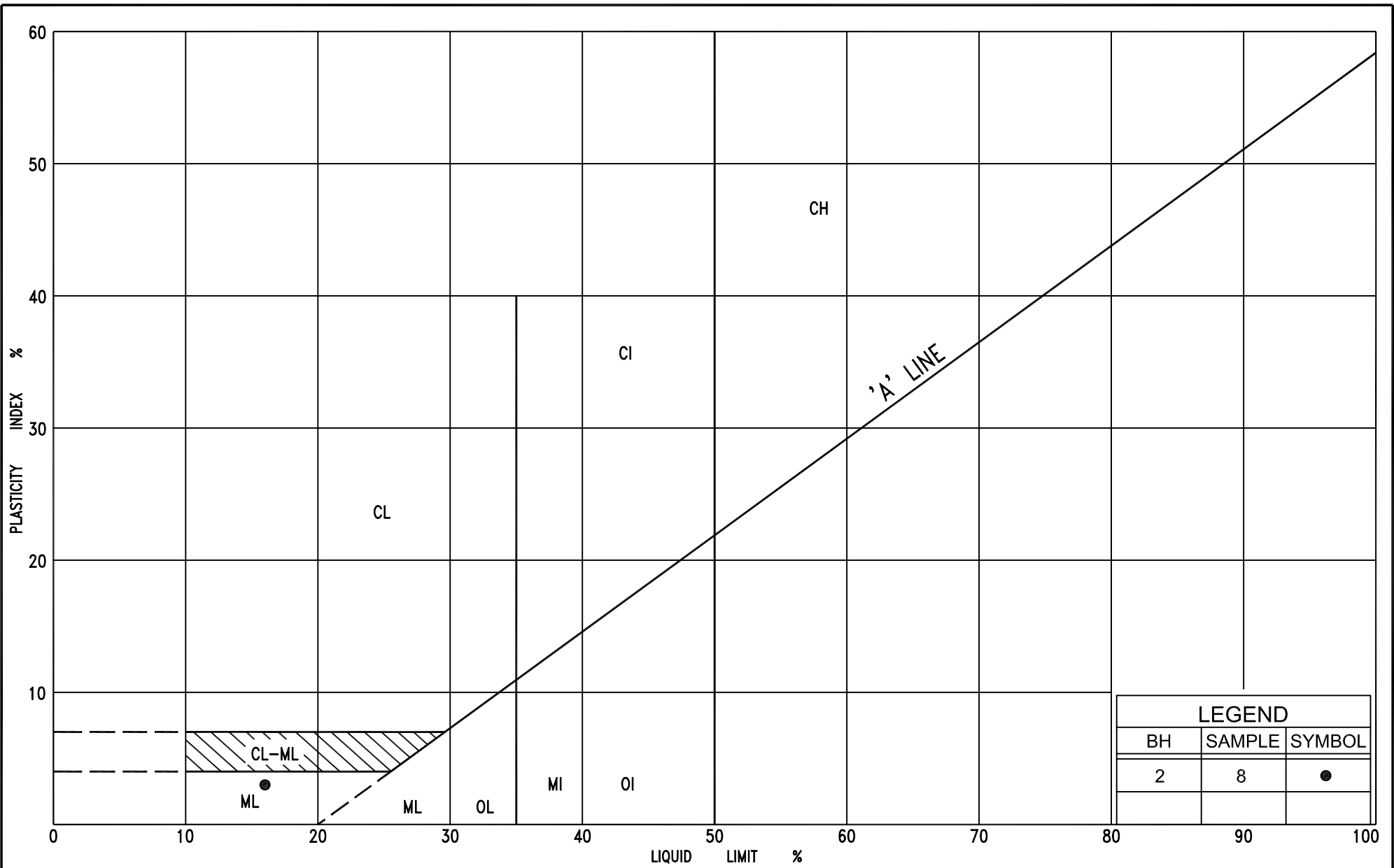
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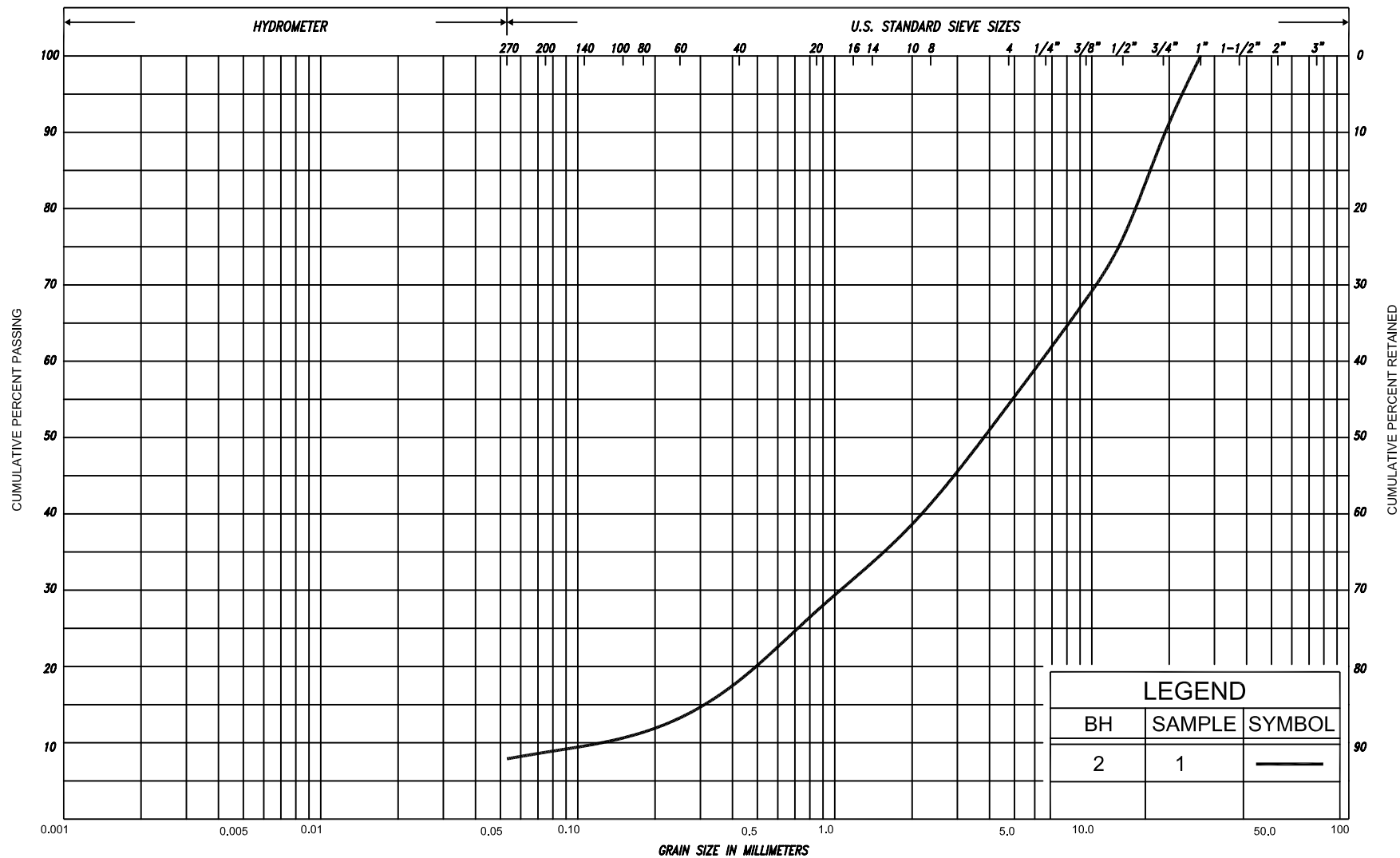
Brian R. Gray, MEng, P.Eng.
MTO Designated Contact



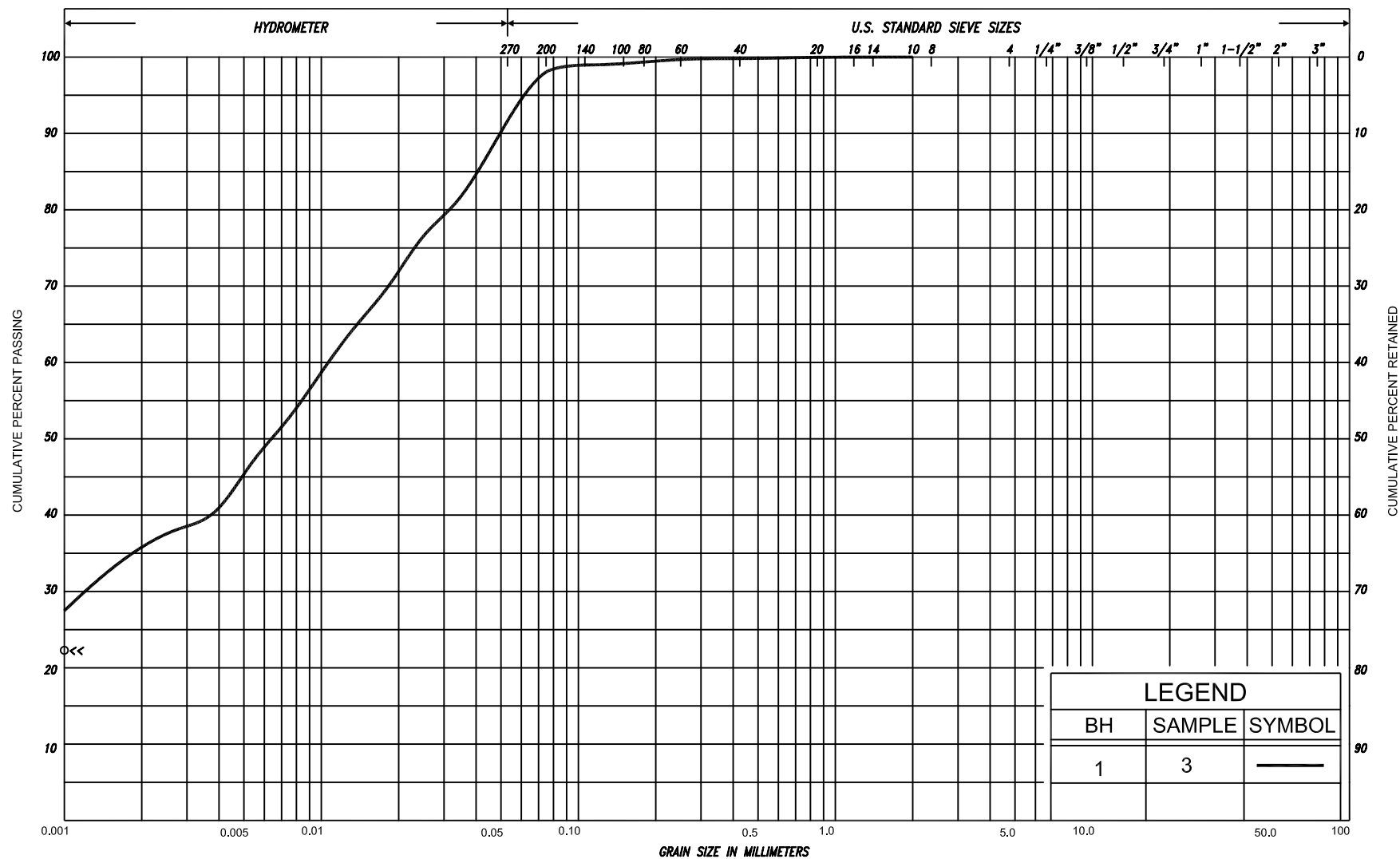
GD/CN:mi





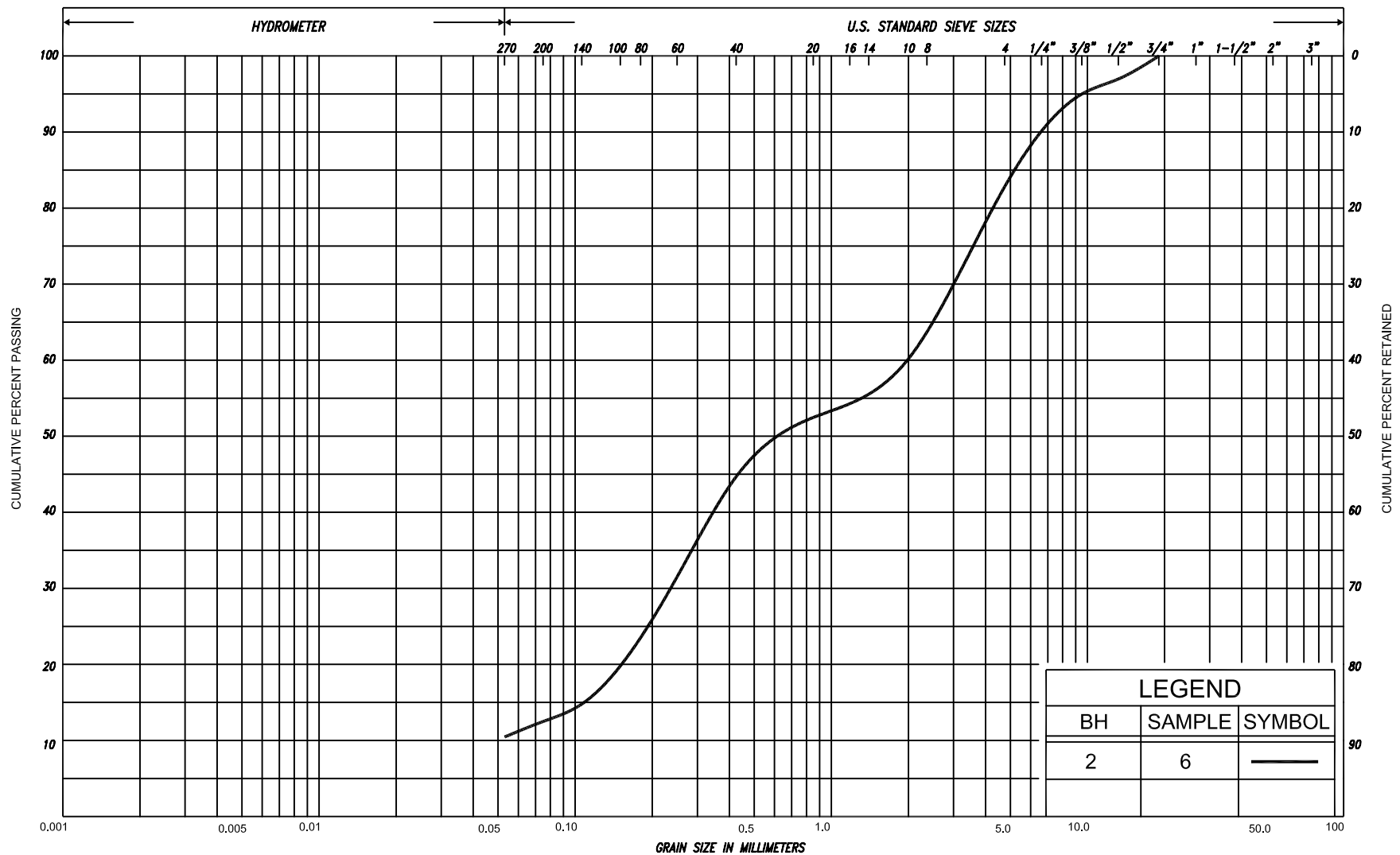


SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL			COBBLES	UNIFIED	
				SAND										
CLAY	FINE	MEDIUM	COARSE	FINE		MEDIUM		COARSE		GRAVEL			COBBLES	M.I.T.
	SILT													
CLAY		SILT		V. FINE	FINE	MED.	COARSE	GRAVEL						U.S. BUREAU
				SAND										



LEGEND		
BH	SAMPLE	SYMBOL
1	3	—

SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL			COBBLES	UNIFIED
CLAY	FINE		MEDIUM	COARSE	FINE		MEDIUM	COARSE	GRAVEL			COBBLES	M.I.T.
	SILT				V. FINE	FINE	MED.	COARSE	GRAVEL				U.S. BUREAU



LEGEND		
BH	SAMPLE	SYMBOL
2	6	—

SILT & CLAY				GRAIN SIZE IN MILLIMETERS			GRAVEL		COB BLES	UNIFIED
				FINE	MEDIUM	COARSE				
				SAND						
CLAY	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	GRAVEL		COBBLES	M.I.T.
				SAND						
CLAY	SILT			V. FINE	FINE	MED.	COARSE	GRAVEL		U.S. BUREAU



SILT & CLAY					FINE		MEDIUM		COARSE		GRAVEL			COB BLES	UNIFIED	
CLAY	FINE		MEDIUM		COARSE	FINE		MEDIUM		COARSE		GRAVEL			COBBLES	M.I.T.
	SILT							SAND								U.S. BUREAU
CLAY		SILT			V. FINE	FINE	MED.	COARSE		GRAVEL						
					SAND											

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
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	n	1, %	POROSITY	e_{max}	1, %	VOID RATIO IN LOOSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	w	1, %	WATER CONTENT	e_{min}	1, %	VOID RATIO IN DENSEST STATE
ρ_w	kg/m^3	DENSITY OF WATER	S_r	%	DEGREE OF SATURATION	I_D	1	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	1	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	1	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	1	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	1	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	1, %	VOID RATIO						

1 of 1


METRIC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT w_p w w_L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE			"N" VALUES	20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%)	
								20 40 60 80 100				20 40 60	
252.4	Ground Surface										GR SA SI CL ML OL		

[illegible]

* 2006 06 06

▽ Water Level observed during drilling

 Water Level measured
after drilling

- Penetrometer test

RECORD OF BOREHOLE No 2


1 of 1

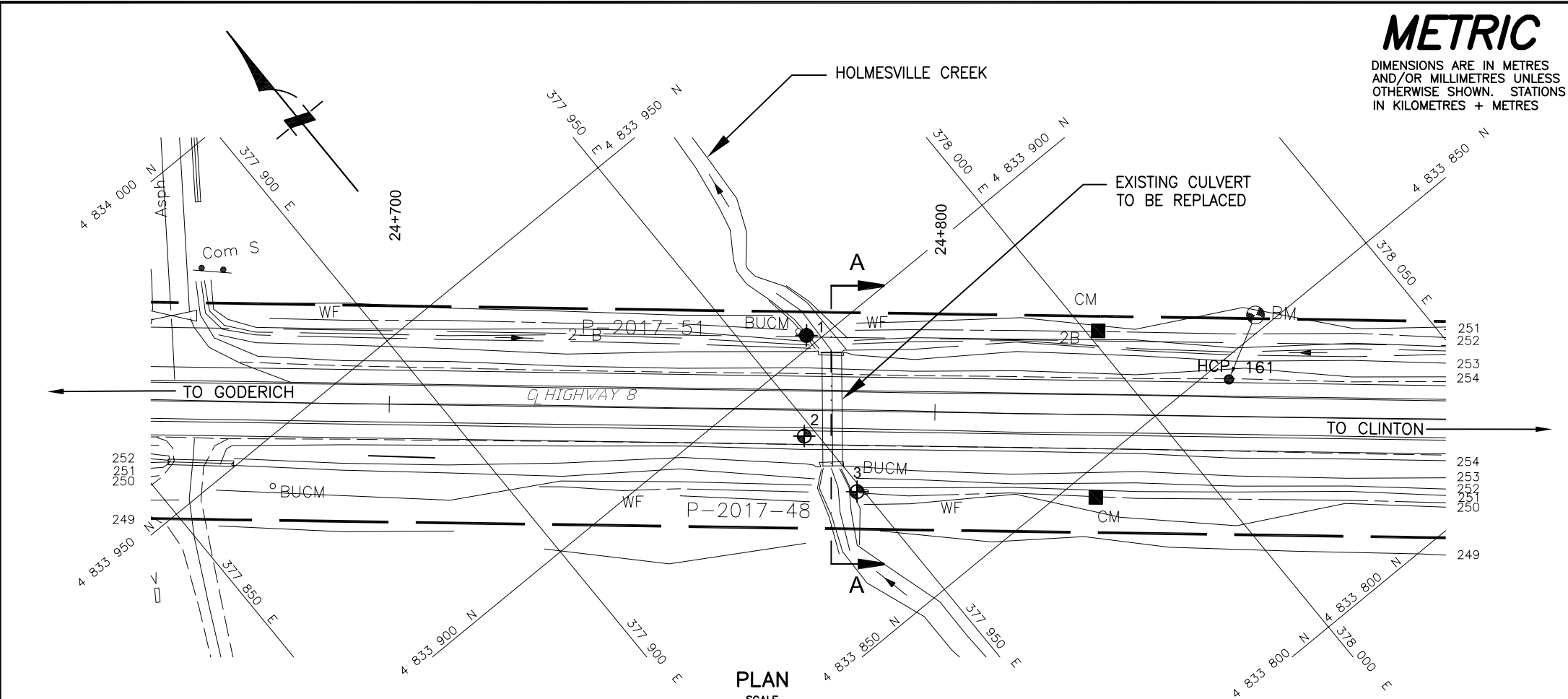
METRIC

G.W.P. 189-89-04 LOCATION Co-ords: 4 833 888 N; 377 948 E ORIGINATED BY G.I.
DIST O.Sound HWY 8 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D
DATUM Geodetic DATE April 18, 2006 CHECKED BY C.N.

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 (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL						× LAB VANE		
254.3	Ground Surface						20	40	60	80	100	20	40	60	GR SA SI CL			
0.0	Sand and gravel trace silt																	
	Compact Brown Damp to loose (PAVEMENT AND EMBANKMENT FILL)		1	SS	9										46 46 (8)			
252.1	Topsoil		2	SS	2													
2.2																		
251.3	Organic clayey silt trace sand, rootlets		3	SS	19													
3.0	Firm Grey Wet to stiff (Alluvium)		4	SS	7													
250.9	Sand, some gravel trace to some silt with layers of sand and gravel		5	SS	17													
3.4	Compact Brown Moist to wet		6	SS	12										17 70 (13)			
			7	SS	13													
245.6	Silt, some sand some clay, trace gravel cobbles and boulders		8	SS	23										5 19 63 13			
8.7	Compact Grey Moist (TILL)																	
244.5	End of borehole																	
9.8																		
	* 2006 04 18																	
	▽ Water Level observed during drilling																	
	▼ Water Level measured after drilling																	
	■ Penetrometer test																	
	Sample 4: 'N' value lowered by hydraulic disturbance																	

METRIC

 Water Level measured after drilling



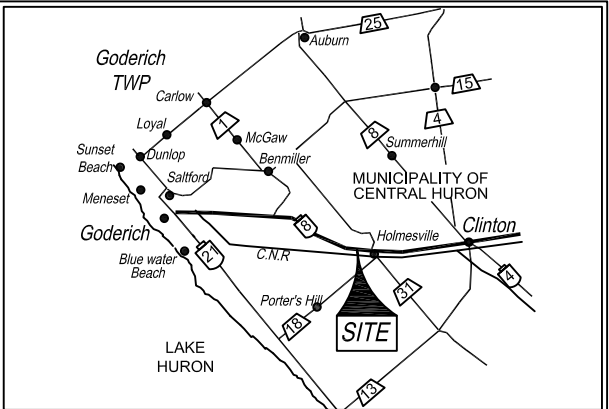
CONT No
WP No 189-89-04

HOLMESVILLE CREEK CULVERT
REPLACEMENT AT STA. 24+780
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET

PMI 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 the time of investigation April-May 2006
- Head
- ARTESIAN WATER Encountered

BH No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
1	252.4	4 833 902	377 960
2	254.3	4 833 888	377 948
3	252.2	4 833 874	377 949

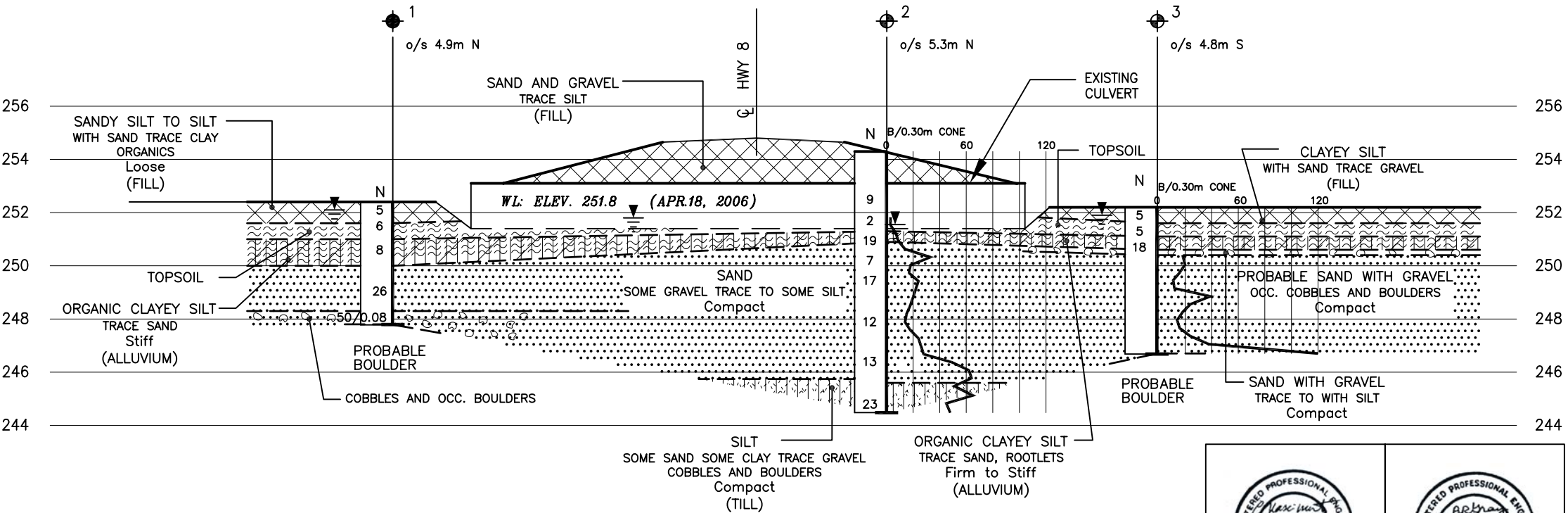
NOTE

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: 40P12-11

HWY No. 8	DIST Owen Sound
SUBM'D GD	CHECKED GD
DATE SEPT. 05, 2006	SITE 12-391-C
DRAWN GI/NA	CHECKED CN
APPROVED BRG	DWG 1



A-A
SECTION

SCALE

2 1 0 2 4m



REF No: 008god-8a.dwg; April 29, 2005



FOUNDATION DESIGN REPORT

for

**HOLMESVILLE CREEK CULVERT REPLACEMENT/EXTENSION
REHABILITATION OF HIGHWAY 8, GODERICH TO CLINTON
WP 189-89-04
TOWNSHIP OF GODERICH, ONTARIO**

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TABLE 1 – List of Standard Specifications Referenced in Report

FOUNDATION DESIGN REPORT
for
Holmesville Creek Culvert Replacement/Extension
Rehabilitation of Highway 8, Goderich to Clinton
WP 189-89-04
Township of Goderich, Ontario

1. INTRODUCTION

This report provides foundation engineering comments and recommendations for the possible replacement (or extension) of the Holmesville Creek Culvert that is included in the rehabilitation works of a 16.8 km long section of Highway 8 between Goderich east limits and Clinton west limits. This report was prepared for McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation of Ontario (MTO).

The Holmesville Creek Culvert is designated as C-114 (Site No. 12-391-C) and located at the Holmesville Creek crossing that is at approximate Station 24+780, Highway 8 chainage. The Holmesville Creek Culvert is a 20 m long concrete, rigid frame open footing, 3.6 by 1.5 m in opening size.

MRC has indicated that the Holmesville Creek culvert may be extended (both sides) instead of being replaced. This report pertains to design and construction of the possible culvert replacement or extension and associated backfill zones.

The subsurface stratigraphy revealed in the boreholes drilled at the site was relatively uniform and generally comprised loose surficial fill including the pavement and embankment platform of the Highway 8 shoulder over consecutive layers of topsoil and firm to stiff organic clayey silt alluvium. These materials overlay a typically compact sand with gravel unit containing cobbles and boulders and a compact silt till deposit at depth. Groundwater measured in the boreholes was at levels ranging from 0.3 to 2.7 m depths, elevations 251.6 to 252.1.

The site conditions indicated that the proposed replacement culvert or culvert extensions may be designed to match the open footing design of the existing culvert. Extending the culvert using box culvert sections is not recommended due to potential problems caused by differential frost action



between the two types of foundations. The alternative replacement with a precast or cast-in place concrete box culvert is also feasible. A discussion of alternatives is presented in this report. Subgrade preparation and erosion protection should be carried out as outlined in this report.

It is understood that construction and traffic staging at this site will be accomplished by limiting traffic to one lane for the duration of the replacement culvert construction. Temporary widening of the existing embankment during construction is not being considered. Temporary road protection will be required along the centreline of the highway as a minimum. In view of the presence of cohesionless sand and gravel fill at the subgrade level it is anticipated that the road protection will need to comprise of sheetpiling.

In view of the relatively pervious nature of the cohesionless native soils, it is anticipated that the construction of the replacement culvert or culvert extensions will require the use of a dewatering system such as well points. Where dewatering is required it should be designed to prevent affecting existing water wells.

It is noted that no responsibility or liability is assumed by the consultant for alerting the contractor and to “red-flag” 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

2.1 General

The invert of the existing open footing culvert is inferred to be near elevation 251.4. The existing subgrade founding level of the spread footings is inferred to be at or about elevation 250.5 based on the footing depth of 0.9 m indicated on Drawing 1 of the Contract No. 20004-3404 for Concrete Culvert Rehabilitation ETR 171-8/27-0 dated December 2003.



The subgrade material revealed in the boreholes just below the founding level comprises cohesionless compact sand with gravel. The high groundwater level at the time of the field investigation was at elevations 251.6 to 252.1, some 1.1 to 1.6 m above the inferred subgrade level.

Based on ground surface elevations at the borehole locations and the road grade (approximate elevation 254.8), the embankment fill at the location of the culvert is assessed to be about 2.5 m high.

The possible culvert extensions should be designed as open footing culverts to match the existing open footing design and prevent potential differential frost heave problems between the existing and new sections of culvert.

The replacement culvert may be designed as an open footing culvert or as a precast or cast-in-place concrete box culvert. For the box culvert replacement alternative, the base of the new culvert may be founded at about elevation 250.6 allowing for the granular bedding to be placed above the founding level of the existing footings (elevation 250.5) and the invert of the crossing established on fill placed inside the culvert. Alternatively, the box culvert may be placed 0.4 m higher at about elevation 251.0, that is about 0.4 m below the design invert level using engineered fill, mass concrete or unshrinkable fill to backfill the excavation carried out to remove the existing footings and fill potentially present between and beyond the footings. It is considered that the span of the culvert will be adequate for cast-in-place or precast concrete construction.

A discussion of the advantages and disadvantages of the foundation alternatives outlined above is provided in Section 7 of this report.

Preparation of the subgrade for construction of the culvert 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 granular fill or, if required, mass concrete fill.



The topsoil, organic clayey silt alluvium and other deleterious soils revealed at and below the subgrade should be excavated. Under the foundations of the open footing culvert, any grade differences should be made up with mass concrete fill.

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 and OPSS 422. A frost penetration depth of 1.3 m should be employed for the design.

2.2 Open Footing Culvert Replacement or Extensions

The new footings for culvert replacement or culvert extensions should be founded at elevation 250.1 to provide adequate frost protection. Construction of the foundations for the culvert replacement on spread footings bearing on the compact sandy soils found in the boreholes within the zone of influence of the new foundations is considered to be feasible, provided that groundwater control measures are implemented. The removal of the existing footings where required for the culvert replacement should be carefully planned and executed to prevent disturbance to the existing and proposed subgrade soils.

The culvert foundations constructed on the compact sand / sand and gravel should be designed using the following geotechnical resistances at ultimate and serviceability limit states (ULS and SLS) for the minimum 0.5 m wide footing:

$$\begin{aligned}\text{Factored Geotechnical Resistance at ULS} &= 300 \text{ kPa} \\ \text{Geotechnical Resistance at SLS} &= 200 \text{ kPa}\end{aligned}$$

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



2.3 Box Culvert Replacement

As indicated previously, the possible culvert extensions should be designed as open footing sections (and not as box culverts) to match the existing design type and avoid possible erosion and foundation problems.

As alternatives for the open footing type culvert foundation, the replacement box culvert may be founded at elevation 250.6, about 150 mm above the level of the existing footings, estimated at about elevation 250.5 or at about elevation 251.0 that is about 0.4 m below the inferred invert level for the replacement culvert. Since a bedding layer is not considered to be required for cast-in-place concrete box culverts, this culvert type may be founded at about elevation 251.1.

The box culvert founded at the deeper elevation 250.6 will be placed on the compact sand with gravel deposit. The following geotechnical resistances at ultimate and serviceability limit states (ULS and SLS) should be used for design.

Factored Geotechnical Resistance at ULS	=	300 kPa
Geotechnical Resistance at SLS	=	200 kPa

For the box culvert replacement option at the shallower level (elevation 251.0 or 251.1) the existing footings and the fill between and outside of the footings should be removed to allow placement of engineered fill, unshrinkable fill or mass concrete.

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 laterally outward 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.

It is considered that both cast-in-place or precast concrete design and construction are feasible at the Holmesville Creek crossing site. 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 and OPSS 422. The bedding for a precast box culvert should comprise a minimum 150 mm thick layer of Granular A material.

The box culvert foundations constructed on engineered fill should be designed using the geotechnical resistance at ultimate and serviceability limit states (ULS and SLS) provided previously in this section since the thickness of the engineered fill will be less than 1.0 m.

Settlement considerations for the box culvert replacement are the same as those provided previously in the report for the open footing type culvert.

It is noted that the depth of excavation for the new possible extension foundations will be about 3 m beyond the toe of the existing embankment and up to 5 m within the existing embankment fill. Where the excavation extends into the existing embankment and longitudinal earth/fill support will be required for stage construction, road protection will require further bracing to support the cut slopes. Refer to Section 5 of this report for comments.

It is considered that conventional sump pumping techniques will not be sufficient to control seepage of groundwater into the excavation. More positive groundwater control measures should be implemented. Further comments in this regard are provided in Section 5 of this report.

2.4 Sliding Resistance

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	COMPACT SAND / GRAVEL
Friction Angle, degrees	35	30
Cohesion, kPa	0	0
Unit Weight, kN/m ³	22.8	20.5



3. CULVERT BACKFILL

Backfill adjacent to the culverts should be placed in accordance with OPSD 803.010, OPSD 3121.150 and OPSS 422. The compaction of earth backfill against the culvert should follow the OPSS 501 and SP 105S10.

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), 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 kN/m³

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

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 some 1.5 m above the inferred existing footing subgrade level of the culvert. The highest 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.

4. HEADWALL AND/OR WING WALLS

If headwalls and wing walls are utilised, the previous recommendations and geotechnical parameters for culvert foundations and backfill should be utilised for design of the foundations. The wall founding levels should match those of the respective culverts where the walls are designed integral with the culvert structure. For walls designed separately from the culvert structure, the founding levels should be established 1.3 m below the culvert invert level for adequate frost protection. Where the ground surface behind the walls is sloped, we refer to Section 6.9.1 of the CHBDC and respective commentary for structural computations using the medium dense soil type.

The design of the walls should be checked for sliding resistance using the geotechnical parameters provided in Section 2.4 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 wall. 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.

5. EXCAVATION AND GROUNDWATER CONTROL

Excavation to the anticipated founding level of the culvert replacement is expected to extend through the fill, topsoil and organic clayey silt alluvium into the native deposit of sand / sand and gravel. Provision for excavation of cobbles and boulders at the site should be allowed for. 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 fills, organic soils and cohesionless sand with gravel materials are typically classified as Type 3 soils necessitating an inclination of temporary cut slopes at 1H:1V (horizontal to vertical). 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 be considered. The full depth of the existing fill soils which may extend to the founding level of the existing footings should be supported.

It is anticipated that a suitable roadway protection scheme following SP 105S19 will be required to support the walls of the excavation and adjacent traffic lanes during construction. In view of the cohesionless native soils at this site, protection scheme alternatives such as sheet piling or sheeting supported by rakers or bracing should be considered. The schemes should be designed for performance level 1b provided that groundwater control is in place. Otherwise, a performance level 1a system is recommended to prevent movement of the existing embankment. The contractor is responsible for the selection, preparation and performance of a detailed design for the road protection scheme.

The groundwater level observed in the boreholes at the time of the field investigation was 2 m above the anticipated level of excavation. Cognisant of the pervious sand / sand and gravel present at the culvert location, it is considered that dewatering by means of conventional sump



pumps will not be sufficient to control seepage of groundwater into the excavation. Therefore, more elaborate groundwater control measures such as well points should be implemented. Dewatering should follow the current OPSS 517. Where dewatering is carried out it should be designed to prevent affecting existing water wells. The contract documents should have a specific item to clearly state that the selection, design and implementation of dewatering of excavations is the contractor's responsibility.

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 stream and 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. 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 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 cut-off walls where required for the box culvert options should also protect the engineered fill if the option to install a replacement box culvert is selected. 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 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:

<u>SOIL TYPE</u>	<u>K FACTOR</u>
Sand with Gravel	0.2
Clayey silt	0.5

7. DISCUSSION OR FOUNDATION ALTERNATIVES

7.1 Advantages and Disadvantages of Foundation Alternatives

The following table summarizes the advantages and disadvantages and inferred risks/consequences of each of the foundation alternatives for the possible replacement or extension of the culvert at the Holmesville Creek site.



ADVANTAGES AND DISADVANTAGES - HOLMESVILLE CREEK CULVERT

OPEN FOOTING (*)		BOX CULVERT WITH BASE AT ELEV. 250.6 (**)		BOX CULVERT WITH BASE AT ELEV. 251.0 (**)	
ADVANTAGES	DISADVANTAGES	ADVANTAGES	DISADVANTAGES	ADVANTAGES	DISADVANTAGES
Design matches existing culvert type.	Erosion control of soil between the footings is required.	Precast concrete culvert alternative is feasible.	Requires fill placement inside culvert to make up grade to design invert level.	Precast concrete culvert alternative is feasible.	Subgrade level needs to be adjusted using engineered fill.
Requires relatively narrow excavation to install foundations.	Relatively high user cost due to long construction schedule.	Concrete base provides erosion protection.	Only partial frost protection is incorporated - frost tapers required.	Concrete base provides erosion protection at invert level.	Cut-off walls should extend below engineered fill level (minimum).
Cut-off walls not required between footings.		Excavation for installation is narrower than for box culvert at Elev. 251.0.		Precast culvert expedites construction, minimizing user costs.	Requires wider excavation and adequate site conditions (dewatering) for engineered fill construction.
Design incorporates full frost protection.		Precast culvert expedites construction, minimizing user costs.			Only partial frost protection is incorporated - frost tapers required.

Notes: Culvert base and invert elevations were inferred for the purpose of this report.

(*) Applicable to possible culvert extension or replacement option.

(**) Applicable to culvert replacement.

For the replacement culvert construction, the precast concrete culvert option founded at about elevation 250.6 is considered to be less costly at this site, since the construction will be expedited without the forming and the setting time required for cast-in-place concrete construction and placement of engineered fill below the granular base of the culvert is not required.

For the construction of the culvert extensions, the open footing design is the recommended alternative in view of technical considerations.



It is considered that the costs related to sheetpiling required for road protection will be similarly applicable to all of the all alternative foundation schemes.

7.2 Preferred Foundation Option Considerations

The preferred foundation scheme for the possible culvert extensions is the open footing type to prevent potential frost heave problems.

From the foundation perspective, either of the three foundation schemes for a possible replacement culvert is feasible, however the box culverts provide a more effective erosion protection. The box culvert at the lower level (about elevation 250.6) is considered the preferred option in view of the estimated lower cost of construction and user cost.

It is noted that the selected foundation alternative also depends on other considerations, such as potential fish habitat protection, which are being evaluated separately by MRC.

8. 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., 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.

A handwritten signature in black ink, appearing to read "C. M. P. Nascimento", is written over the printed name.

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



A handwritten signature in black ink, appearing to read "Brian R. Gray", is written over the printed name.

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



GD/CN:mi



TABLE 1
LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT

DOCUMENT	TITLE	DATE
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 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation	November 2005
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 2005
OPSS 1860	Material Specification for Geotextiles	November 2004
SP 105S10	Construction Specification for Compaction	November 2004
SP 105S19	Construction Specification for Protection Systems	March 2005
SP 902S01	Excavation and Backfilling of Structures	September 2003
OPSD 803.010	Backfill and Cover for Concrete Culverts	November 1999
OPSD 3121.150	Minimum Granular Backfill Requirements – Retaining Walls	November 2005