Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION INVESTIGATION AND DESIGN REPORT

for

WILKIN MUNICIPAL DRAIN CULVERT C-8 EXTENSION
SITE NO. 35-504C
REHABILITATION OF HIGHWAY 23
G.W.P. 58-00-00
PALMERSTON TO HARRISTON
TOWN OF MINTO, ONTARIO

PETO MacCALLUM LTD.
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PML Ref.: 04KF132B
Index No.: 049FIR and 050FDR
Geocres No.: 40P15-34
October 11, 2005

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for

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FOUNDATION INVESTIGATION REPORT
for
Wilkin Municipal Drain Culvert C-8 Extension
Site No. 35-504C
Rehabilitation of Highway 23
G.W.P. 58-00-00
Palmerston to Harriston
Town of Minto, Ontario

1. INTRODUCTION

Rehabilitation of the approximate 9 km long section of Highway 23 that extends from Palmerston northerly to the Harriston west limits in the Town of Minto, Ontario is planned. This report was prepared for Stantec Consulting Ltd. on behalf of the Ministry of Transportation of Ontario.

Rehabilitation of Highway 23 will involve the extension of a culvert where the Wilkin municipal drain crosses the highway at approximate Station 15+278, Highway 23 chainage. The culvert designated as C-8 is a concrete rigid frame box structure with a size of 3.0 m wide by 1.8 m high and 31.0 m long. Extension of the culvert by 1.5 m at the east end is envisaged.

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

2. SITE DESCRIPTION AND GEOLOGY

Highway 23 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 and residential development.

The project area lies in the physiographic region known as the Teeswater Drumlin Field characterised by a complex of low, broad hills with gentle slopes. The principal soil along the study corridor is represented by the Harriston Loam, a medium textured sandy silt to silt till with good drainage. Some of the low lying areas between drumlins are swampy with poor drainage (L.J.Chapman & D.F.Putnam, *The Physiography of Southern Ontario*, 3rd Edition, Ontario Research Foundation, 1984).

The frost penetration depth for design purposes as outlined in the Pavement Design and Rehabilitation Manual is 1.6 m. The average annual freezing index in the area is in the order of 800 degree·days Celsius.

3. INVESTIGATION PROCEDURES

The field work for this study was carried out on May 17 and 18, 2005 and comprised two boreholes advanced to depths of 7.9 and 10.8 m below existing grade. The approximate locations of the boreholes put down on the east (right) shoulder of the highway and at the east end of the proposed culvert extension along with a stratigraphic cross-section are shown on Drawing 1, appended.

The borehole numbers are provided with the prefix code C8 to reflect the MTO specific culvert number for ease of reference.

The borehole layout was established in accordance with the requirements noted in the Request for Proposal. Peto MacCallum Ltd. selected the borehole locations in the field. The ground surface elevations at the boreholes were provided by the surveying company AGM.

The boreholes were advanced using continuous flight hollow 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.

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 moisture content determinations as well as an Atterberg limits test and four grain size distribution analyses was carried out on selected samples. The results of the laboratory Atterberg limits testing and grain size distribution analyses are presented in Figures PC-1 and GS-1 to GS-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 borehole logs.

The borehole locations and 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 locations. Between boreholes, the boundaries are assumed and may vary.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprises a surficial topsoil layer or the road embankment made up of granular, silty/sandy/gravelly fill and probable culvert trench gravel backfill underlain by deposits of clayey silt till and sandy silt till. Groundwater was measured in one borehole at 2.7 m, elevation 383.1. The strata encountered are summarised below.

4.1 Topsoil

Surficial topsoil is present in borehole C8-2 advanced at the east end of the culvert extension. Represented by low organic sandy silt, the topsoil has a thickness of 200 mm and was penetrated at elevation 383.2.

4.2 Fill

Granular material over silty/sandy/gravelly fill is present surficially in borehole C8-1 put down on the east shoulder of the highway. These units make up the road embankment with a total thickness of 3.7 m and were penetrated at elevation 382.1. The materials have a moisture content of about 12%.

4.3 Gravel

Directly beneath the embankment fill in borehole C8-1 is a 1.5 m thick layer of gravel with sand trace to some silt that probably comprises the culvert trench backfill material. The relative density of this layer decreases with depth from dense to compact ('N' values of 31 and 16). The gravel was penetrated at a depth of 5.2 m (elevation 380.6).

The results of a grain size distribution analysis performed on this material are presented in Figure GS-1.

4.4 Clayey Silt Till

Underlying the gravel in borehole C8-1 and topsoil in borehole C8-2 is clayey silt till. The thickness of this deposit varies between 0.6 and 2.5 m. The clayey silt till is very stiff to firm in consistency ('N' values of 19, 11 and 7) and has a moisture content of 11 to 13%. The deposit was penetrated at respective depths of 5.8 and 2.7 m (elevation 380.0 and 380.7).

The results of an Atterberg limits test and grain size distribution analysis conducted on a representative sample of the cohesive material are presented in Figures PC-1 and GS-2 respectively. The liquid limit of the clayey silt was 17 and its plastic limit 11, with a corresponding plasticity index of 6.

4.5 Sandy Silt Till

Cohesionless sandy silt till is encountered below the clayey silt till in both boreholes. This unit is compact in the upper 1 m thick zone ('N' values of 25, 26) and dense to very dense below (60 to 153 blows of hammer per 150 mm penetration). The moisture content varies between 6 and 12%. The minimum thickness of the sandy silt till was 5.0 m in borehole C8-1 and 5.2 m in borehole C8-2. Augering was terminated within the soil unit at respective depths of 10.8 and 7.9 m (elevation 375.0 and 375.5).

The results of grain size distribution analyses performed on two samples of the cohesionless material are presented in Figure GS-3.

4.6 Groundwater

Water was observed in one borehole in the course of the field work. Upon completion of drilling, groundwater was measured in borehole C8-1 at 2.7 m depth (elevation 383.1). Observed groundwater levels are subject to seasonal fluctuations and precipitation patterns.

5. CLOSURE

The field work was carried out under the supervision of Mr. M. Rapsey and direction of Mr. P. Cullen, P.Eng., Project Engineer. The equipment was supplied by Marathon Drilling Co. Ltd.

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 Foundation Engineer. 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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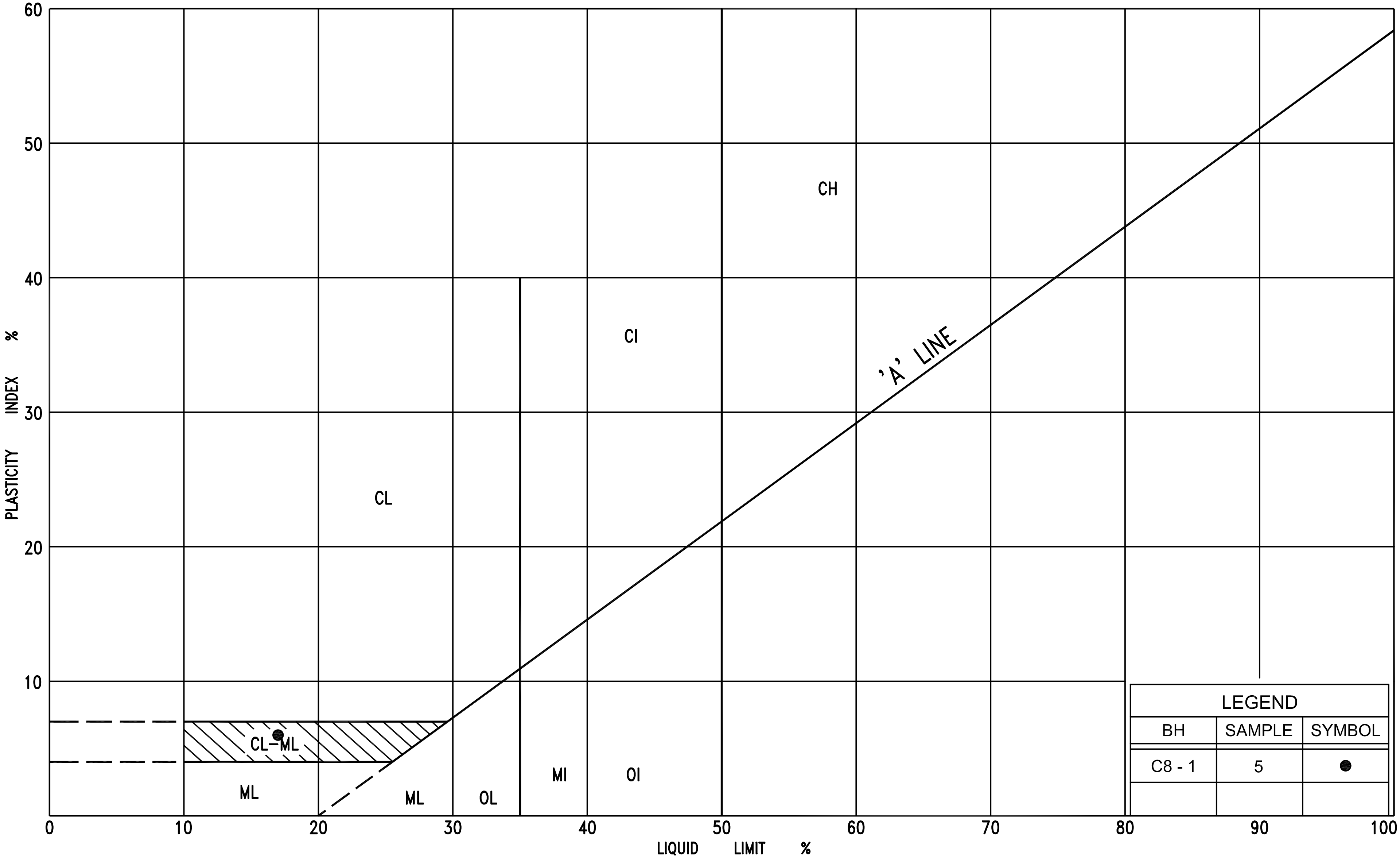
GD/CN/BRG:mi



LEGEND		
BH	SAMPLE	SYMBOL
C8 - 1	5	●

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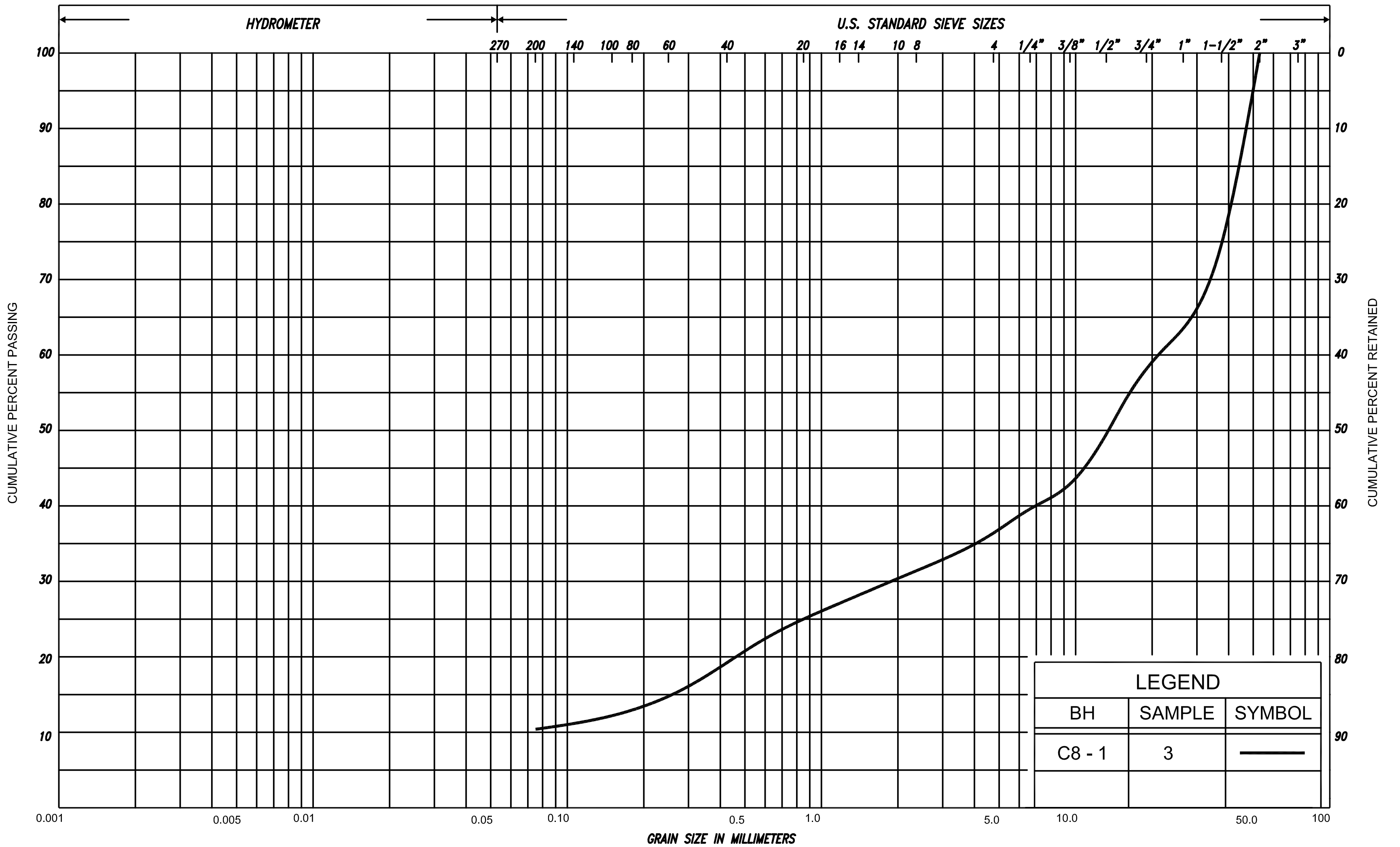
PLASTICITY CHART

CLAYEY SILT, with sand, trace gravel (TILL) (CL–ML)

FIG No.	PC-1
HWY	23
G.W.P. No.	58-00-00



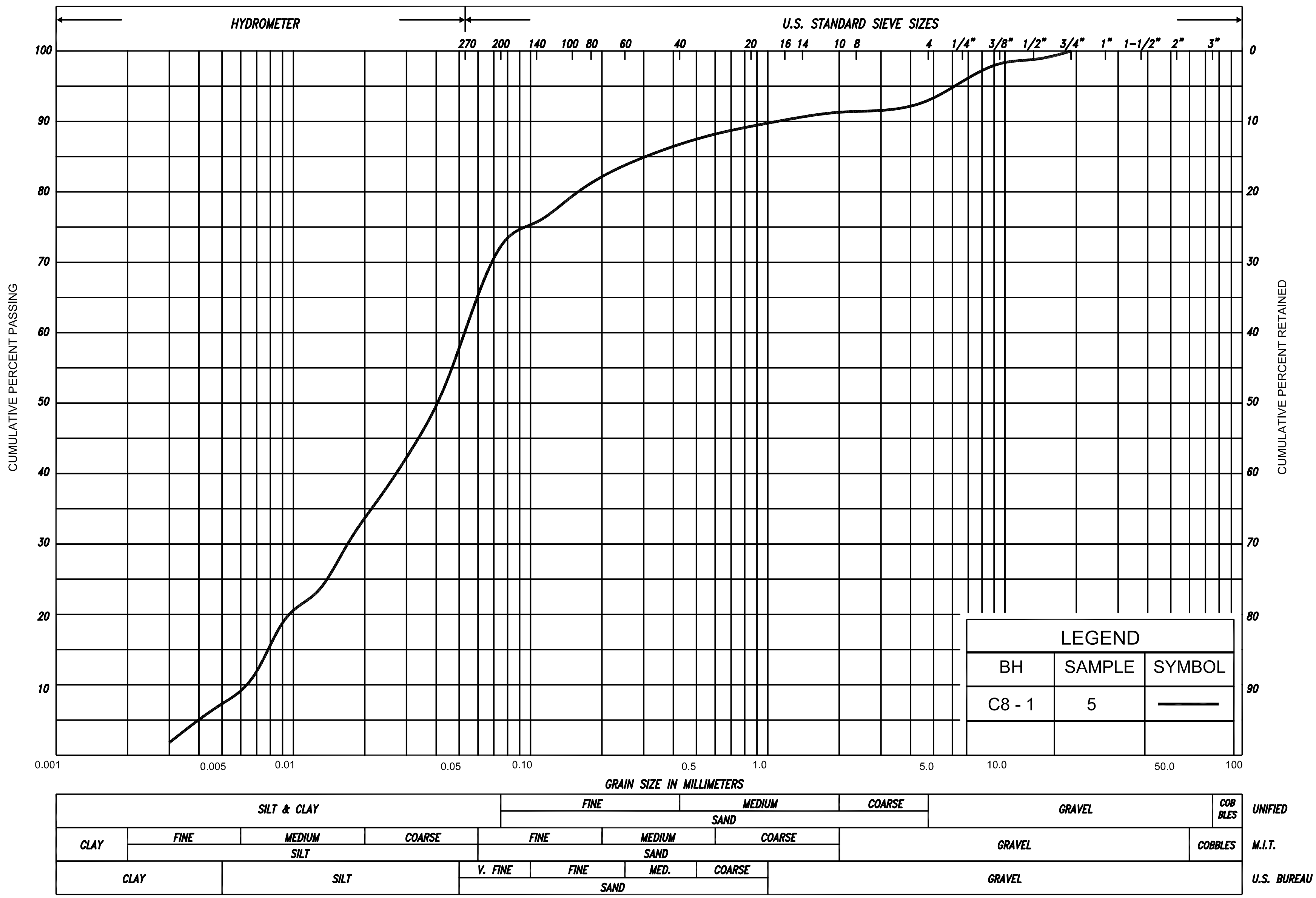
SILT & CLAY				FINE SAND	MEDIUM SAND	COARSE SAND	GRAVEL	COBBLES	UNIFIED
CLAY	FINE SILT	MEDIUM SILT	COARSE SILT	FINE SAND	MEDIUM SAND	COARSE SAND	GRAVEL	COBBLES	M.I.T.
CLAY	SILT		V. FINE SAND	FINE SAND	MED. SAND	COARSE SAND	GRAVEL		U.S. BUREAU

Ministry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

GRAVEL, with sand, trace to some silt
(PROBABLE FILL)

FIG No.	GS-1
HWY	23
G.W.P. No.	58-00-00



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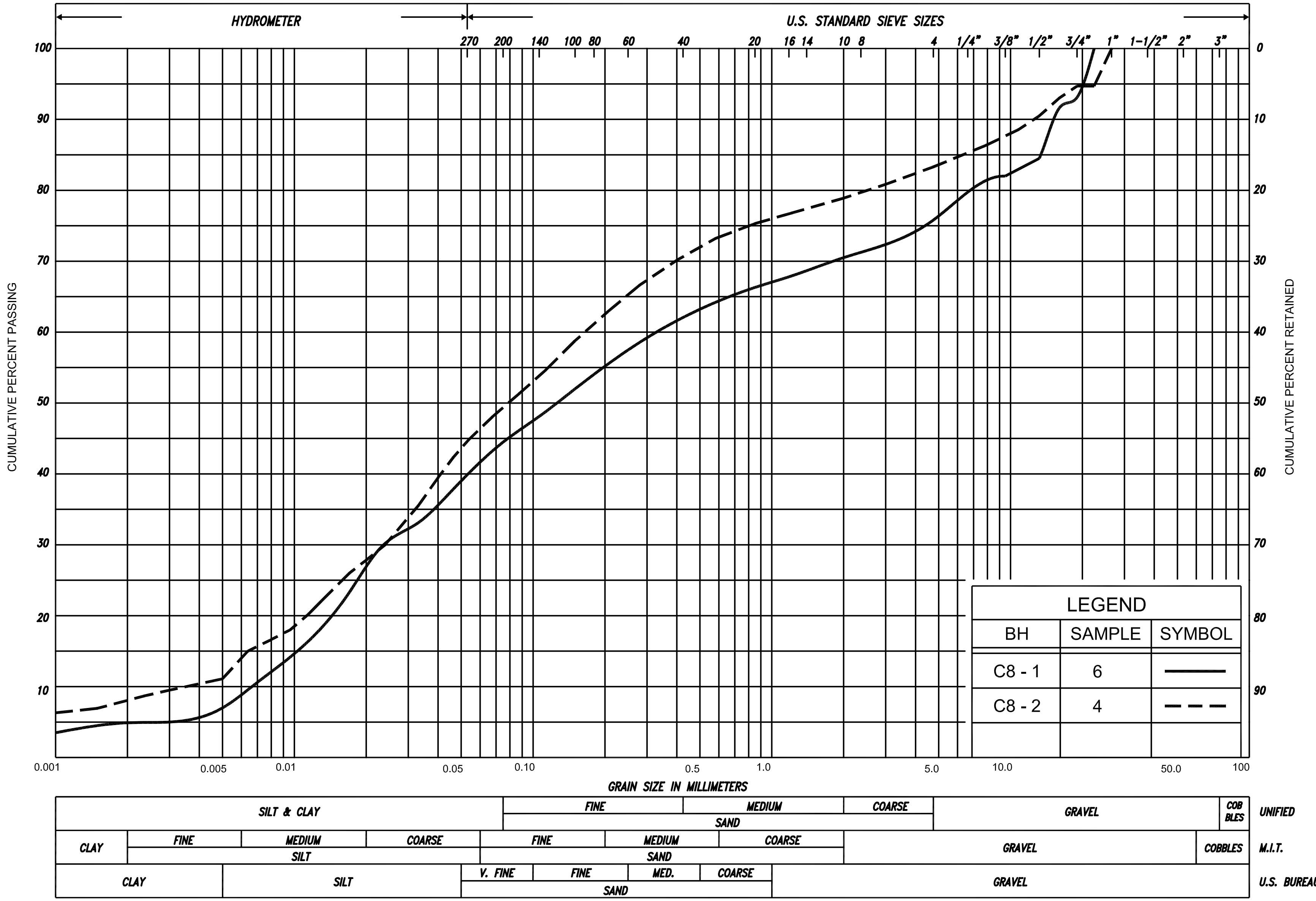
GRAIN SIZE DISTRIBUTION

CLAYEY SILT, with sand, trace gravel (TILL)
(CL–ML)

FIG No.	GS-2
HWY	23
G.W.P. No.	58-00-00



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GRAIN SIZE DISTRIBUTION

SANDY SILT, some to with gravel, trace clay (TILL)

FIG No.	GS-3
HWY	23
G.W.P. No.	58-00-00

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 C8-1

METRIC

G.W.P. 58-00-00 | LOCATION Co-ords: 4 860 803 N; 193 979 E HWY. 23 Sta. 15+281 o/s 5.1m Rt. | ORIGINATED BY MR

DIST 33 HWY 23 | BOREHOLE TYPE Continuous Flight Hollow Stem Augers | COMPILED BY GD

DATUM Geodetic | DATE May 17, 2005 | CHECKED BY

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Ground Surface								
	Granular 'A' over Sand and silt, some gravel, trace clay inclusions of topsoil. Brown Damp (FILL)					385			
		1	SS	32		384	o		
	Gravel, with sand, trace silt. Brown Damp (FILL)				▼*	383			
		2	SS	17					
	Gravel, with sand, trace to some silt. Dense to compact Brown Wet (PROBABLE FILL)	3	SS	31		382			
		4	SS	16		381			
	Clayey silt, with sand, trace gravel. Very stiff Brown Wet (TILL)	5	SS	19			o—H		
	Sandy silt, with gravel, trace clay. Compact to very dense Brown to brownish grey Wet to dry (TILL)					380			
		6	SS	25			o		
						379			
		7	SS	63/ 15cm			o		
		8	SS	74/ 15cm		378	o		
						377			
		9	SS	130/ 15cm			o		
						376			
		10	SS	153/ 15cm		375			
	End of borehole								

* 2005 05 17

▼ Water level measured after drilling

DYNAMIC CONE PENETRATION RESISTANCE PLOT; SHEAR STRENGTH kPa: ○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L

+ × Numbers refer to Sensitivity

Ministry of Transportation Ontario

Peto MacCallum Ltd. Foundation Design

RECORD OF BOREHOLE No C8-2

METRIC

G.W.P. 58-00-00 LOCATION Co-ords: 4 860 798 N; 193 996 E HWY. 23 Sta. 15+273.4 o/s 21.8m Rt. ORIGINATED BY MR

DIST 33 HWY 23 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY GD

DATUM Geodetic DATE May 18, 2005 CHECKED BY

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR SA SI CL
383.4	Ground Surface						
0.0	Topsoil						
0.2	Clayey silt, with sand, with gravel. Stiff to firm, Brown to grey, Wet (TILL)				383		
					382		
		1	SS	11		o	
		2	SS	7	381		
380.7 / 2.7	Sandy silt, some gravel, trace clay. Compact to very dense, Brown, Wet / Grey, Dry (TILL)						
		3	SS	26	380	o	
		4	SS	98/ 23cm		o	17 34 41 8
		5	SS	50/ 8cm	379	o	
					378		
		6	SS	60/ 15cm	377	o	
					376		
375.5		7	SS	50/ 8cm		o	
7.9	End of borehole						

* Borehole dry on completion of drilling

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE, 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%)

+7, ×5 : Numbers refer to Sensitivity

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

METRIC

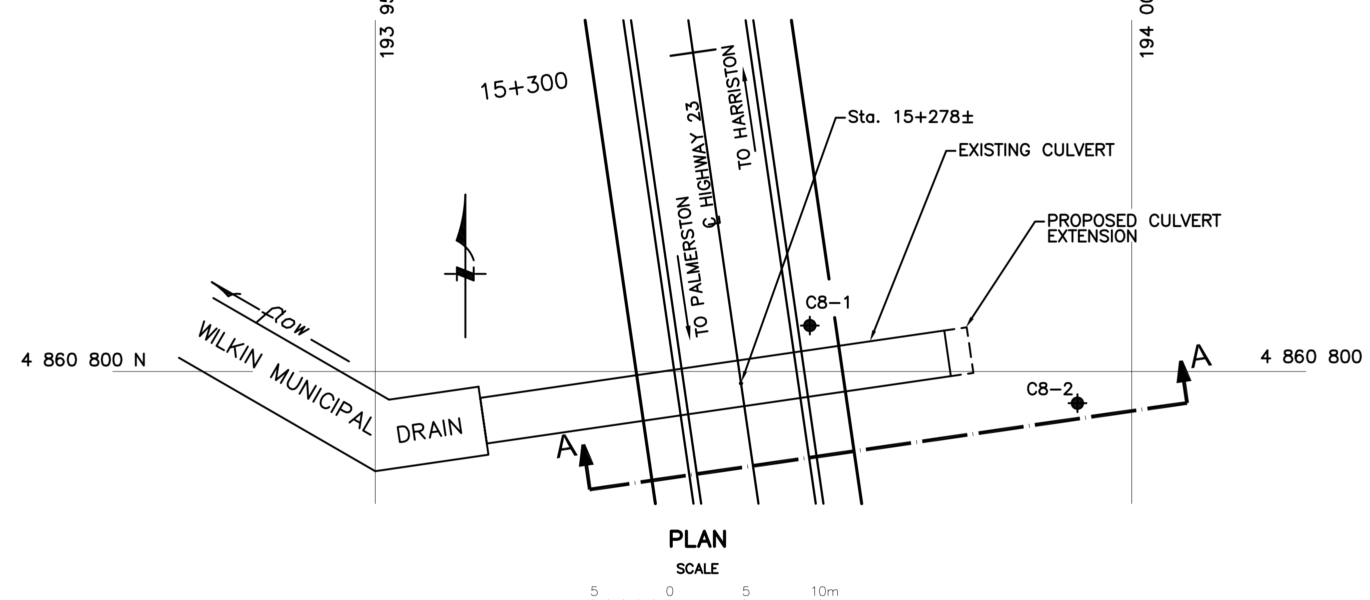
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES

CONT No
GWP No 58-00-00

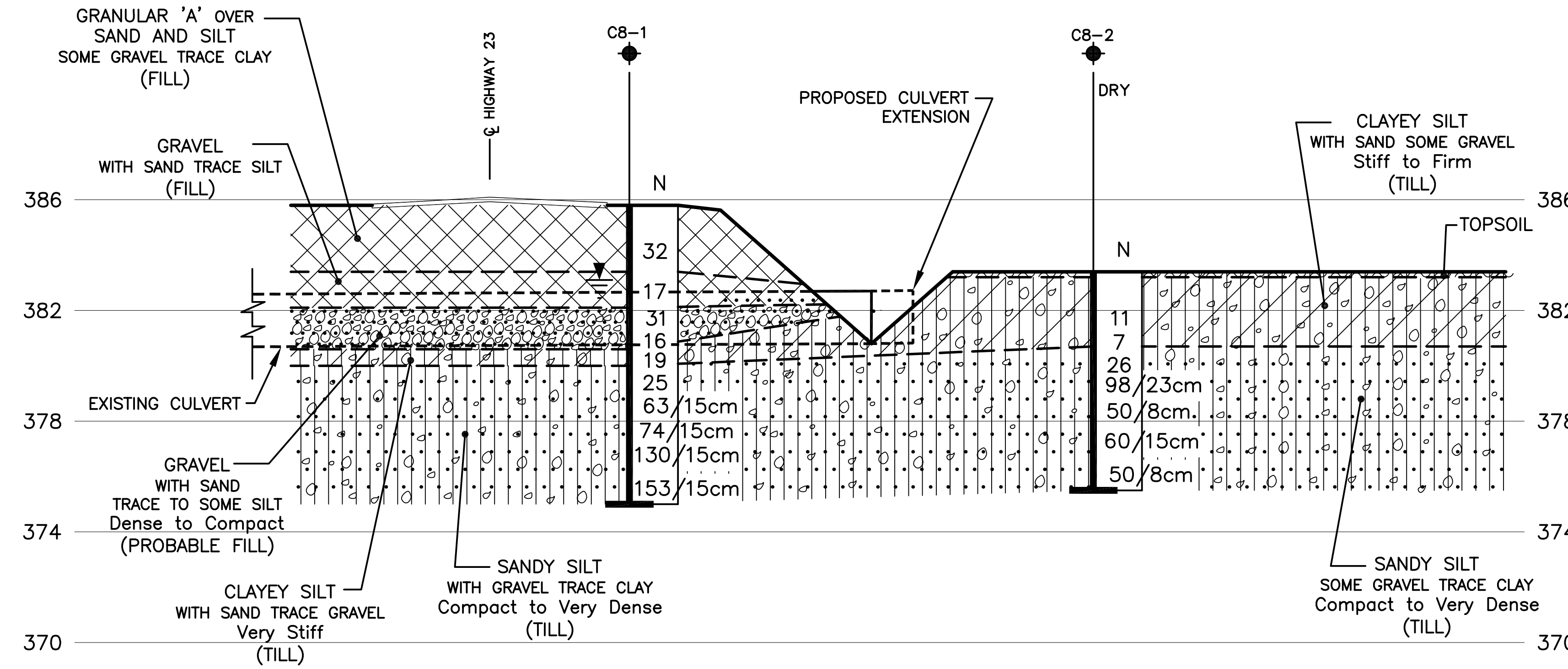
HIGHWAY 23
CULVERT C-8
WILKIN MUNICIPAL DRAIN
BOREHOLE LOCATIONS & SOIL STRATA

SHEET

PML Peto MacCallum Ltd.
CONSULTING ENGINEERS



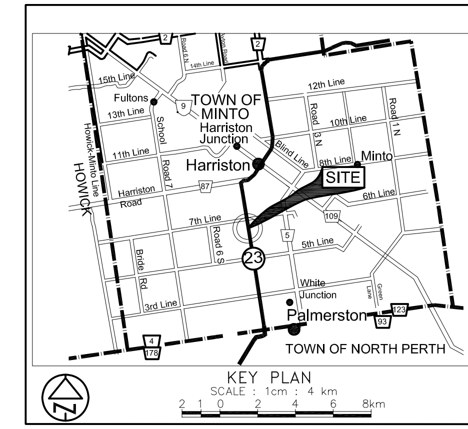
PLAN
SCALE
5 0 5 10m



A-A
SECTION
SCALE
2.5m 0 1 2 3 4 5m

NOTE:

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.



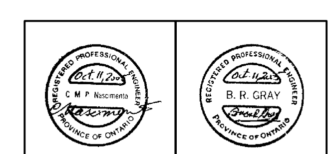
KEY PLAN
SCALE : 1cm : 4 km
2 1 0 2 4 6 8km

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 May 2005
▽	Head ARTESIAN WATER Encountered
ǀ	PIEZOMETER

BH No	ELEVATION	CO-ORDINATES NORTH	EAST
C8-1	385.8	4 860 803	193 979
C8-2	383.4	4 860 798	193 996

- 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 - 34

HWY No 23		DIST 33
SUBM'D GD	CHECKED GD	DATE OCT. 11, 2005	SITE 35-504C
DRAWN NA	CHECKED CN	APPROVED BRG	DWG 1

REF No xbse_160210427_design.dwg DT. June 2005

FOUNDATION DESIGN REPORT

for

WILKIN MUNICIPAL DRAIN CULVERT C-8 EXTENSION
SITE NO. 35-504C
REHABILITATION OF HIGHWAY 23
G.W.P. 58-00-00
PALMERSTON TO HARRISTON
TOWN OF MINTO, ONTARIO

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CONSULTING ENGINEERS

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for
Wilkin Municipal Drain Culvert C-8 Extension
Site No. 35-504C
Rehabilitation of Highway 23
G.W.P. 58-00-00
Palmerston to Harriston
Town of Minto, Ontario

1. INTRODUCTION

This report provides foundation engineering comments and recommendations for the proposed extension of one culvert while rehabilitating the approximately 9 km long section of Highway 23 that extends from Palmerston northerly to the Harriston west limits in the Town of Minto, Ontario. This report was prepared for Stantec Consulting Ltd. on behalf of the Ministry of Transportation of Ontario (MTO).

Rehabilitation of Highway 23 will involve extension of a culvert where the Wilkin municipal drain crosses the highway at approximate Station 15+278, Highway 23 chainage. The culvert designated as C-8 is a concrete rigid frame box structure with a size of 3.0 m wide by 1.8 m high and 31.0 m long. Extension of the culvert by 1.5 m at the east end is envisaged.

This report pertains to the design and construction of the proposed culvert extension and associated bedding/backfill zones.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprises a surficial topsoil layer or the road embankment made up of granular, silty/sandy/gravelly fill and probable culvert trench gravel backfill underlain by deposits of clayey silt till and sandy silt till. The groundwater level measured during the field investigation conducted in May 2005 was at elevation 383.1.

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2. FOUNDATIONS

The invert of the existing culvert is indicated to be near elevation 380.9 (ref.: Plate 180-89/14-0 of 'Highway 23 Reconstruction. Culvert Recommendations' drawings prepared by Stantec Consulting Ltd.). The design subgrade level of the granular bedding is interpreted to be near elevation 380.4.

The subgrade material below this level revealed in boreholes C8-1 and C8-2 comprised very stiff clayey silt till and compact sandy silt till respectively. The high groundwater level within the pipe trench backfill at the time of the field investigation was at elevation 383.1, at least 2.5 m above the subgrade level of the culvert.

Based on the road grade (elevation 385.9) and ground surface elevation at the toe of slope (elevation 383.4) , the embankment fill height at the existing culvert location is assessed to be 2.5 m.

It is considered that the very stiff clayey silt till and compact to very dense sandy silt till exposed in the boreholes at and below the design subgrade are capable of supporting the stress imposed by the embankment and culvert foundations.

The culvert foundations constructed on the very stiff clayey silt till or compact sandy silt till should be designed using the following geotechnical resistance at ultimate and serviceability limit states (ULS and SLS) for the 3 m span box culvert:

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

The resistance at SLS allows for 25 mm of settlement of the founding medium. The total and differential settlements along the culvert length are expected to be negligible in view of the low net bearing pressure under the culvert extension foundation. Therefore, provision for camber is not considered necessary for the culvert extension.

The topsoil revealed at ground surface (borehole C8-2) will 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 the culvert and replaced with engineered fill.

Preparation of the subgrade for construction of the culvert extension 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.

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 base and down to the subgrade at 45° to the horizontal and be established by a site specific survey.

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 material for a precast box culvert extension, if utilised, should comprise a minimum 150 mm thick layer of Granular A.

A frost penetration depth of 1.6 m should be employed.

It is noted that the depth of excavation will be about 3 m beyond the toe of the existing embankment and 5 m within the existing embankment fill.

In addition, the excavation will be nearly 3 m below the groundwater level encountered within the embankment fill and extend into the existing embankment. A positive groundwater control system will be needed and bracing required to support the cut slopes. Further comments in this regard are provided in subsequent sections of this report.

3. CULVERT BACKFILL

Backfill adjacent to the culvert should be placed in accordance with the Ontario Provincial Standard specifications and drawings (OPSD 803.010, OPSD 3504.000 and OPSS 422).

Backfill should be brought up simultaneously on each side of the culvert extension 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. Refer to OPSD 808.010 for additional requirements for operation of heavy equipment near the culvert.

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/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	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 design should consider both the maximum water level in the stream and the stabilised groundwater level condition. The groundwater level measured at the culvert location was at elevation 383.1. 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. The horizontal force imposed on the walls of the box culvert will be resisted by the base slab.

A weeping tile system and/or weep holes should be installed at the wing walls 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.

4. EXCAVATION AND GROUNDWATER CONTROL

The groundwater level measured in the existing culvert trench backfill encountered in one of the boreholes at the time of the field investigation was nearly 3 m above the anticipated depth of excavation. Since the sandy silt till at the site is relatively pervious, conventional sump pumping techniques to control groundwater inflow may not be sufficient and wells or well points may be required prior to excavation to provide a stable excavation base.

The dewatering system should be installed by a specialist dewatering contractor. The design of the dewatering 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.

Excavation to the anticipated founding level of the culvert is expected to extend about 3 m below the highest groundwater level through the pavement structure, fill, topsoil and deposits of gravel, clayey silt till and sandy silt till culvert. Subject to adequate groundwater control, excavation of the soil 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 groundwater table necessitating temporary cut slopes to be inclined at 1H:1V (horizontal to vertical). Below the groundwater table, the materials are classified as Type 4 soils requiring 3H:1V slopes.

It is anticipated that a suitable roadway protection scheme following SP 539S01 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 groundwater control is in place. Otherwise, a performance level 1 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 scheme.

It will be necessary to implement measures to control water flow in the stream. Conventional procedures such as draining and/or diversion of the stream should be sufficient. 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 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 (Ontario Regulation 213/91) and with local/MTO regulations.

5. EMBANKMENT FILL

The embankment height at the culvert location does not exceed 3 m.

The anticipated subgrade for the embankment comprises compact to dense gravel and typically stiff clayey silt till. Topsoil was encountered in the borehole drilled beyond the toe of the existing embankment. The topsoil and other excessively loose, soft, organic or otherwise deleterious materials encountered in the ditch beyond the culvert inlet within the limits of the embankment fill should be subexcavated prior to fill placement.

The embankment side slopes 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.

It is considered that the subgrade soil is capable of supporting the embankment. Settlement of the embankment material is assessed to be in the order of 25 mm. The settlement is expected to occur as the fill is placed and be essentially complete within one month following fill placement.

6. EROSION CONTROL

The protective measures noted in the OPSD 800 series (particularly OPSD 803.030 and 803.020 for open and box culverts) 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 foundation. 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 newly constructed embankment slopes and retained soils behind the 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
Gravel	0.1
Sandy Silt Till	0.3
Clayey Silt Till	0.5

7. 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 Foundation Engineer. Mr. B.R. Gray, MEng, P.Eng., MTO Designated Contact, conducted an independent review of the report.

Yours very truly

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TABLE 1

LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT

TITLE	DOCUMENT	DATE
Construction Specification for Precast Reinforced Concrete Box Culverts and Box Culverts in Open Cut	OPSS 422	April 2004
Construction Specification for Compacting	OPSS 501	February 1996
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 2004
Material Specification for Geotextiles	OPSS 1860	November 2004
Construction Specification for Compaction	SP 105S10	November 2004
Construction Specification for Protection Schemes	SP 539S01	April 2004
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 Below Bedding Grade	OPSD 803.030	September 15, 1996
Pipe Protection against Heavy Construction Equipment	OPSD 808.010	September 15, 1996
Minimum Granular Backfill Requirements - Retaining Walls	OPSD 3504.000	April 1999