

**FOUNDATION INVESTIGATION AND DESIGN REPORT
FOR
RETAINING WALL
HIGHWAY 6 (NEW)
FROM HIGHWAY 403 SOUTHERLY
TO EXISTING HIGHWAY 6
CITY OF HAMILTON, ONTARIO
G.W.P. 9-91-00 & 21-91-00**

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PML Ref: 00HF108
Geocres No. Not Assigned

December, 2001

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FOUNDATION INVESTIGATION REPORT
For
Retaining Wall
Highway 6 (New)
From Highway 403 Southerly to Existing Highway 6
City of Hamilton, Ontario
G.W.P. 9-91-00 & 21-91-00

INTRODUCTION

This report summarizes the results of the foundation investigation carried out for the proposed retaining wall between chainage 22+675 and 22+750 along the proposed Highway 6 (New) alignment in the former Town of Ancaster, now in the City of Hamilton, Ontario. The investigation was conducted for Delcan Corporation on behalf of the Ontario Ministry of Transportation.

The proposed retaining wall will retain the east wall of a proposed 5 to 10 m deep cut to be excavated for the Highway 6 (New) alignment. The proposed road grade in front of the wall (based on the Pre-Design Report profile) will rise to the north from elevation 233.0 to 234.5.

SITE DESCRIPTION

The site is situated in a rural agricultural setting southwest of the south end of Lake Ontario. It is situated in the Norfolk Sand Plain. A steep, south-facing slope exists immediately north of Book Road.

The overburden primarily consists of glaciolacustrine-deltaic sand north of a depositional scarp adjacent to the north side of Book Road. The overburden thickness generally ranges from 30 to 40 m above the scarp at Book Road.

INVESTIGATION PROCEDURES

The fieldwork was carried out on April 5 and 6, 2001 and comprised three boreholes drilled to depths of 15.7 to 36.0 m below grade at the locations shown on Drawing 1. Boreholes 1 and 3 were terminated upon auger refusal on probable bedrock.

The boreholes were advanced using continuous flight solid and hollow stem augers, powered by truck and track-mounted CME-75 drillrigs, supplied and operated by specialist drilling contractors, working under the full-time supervision of members of our engineering staff.

Representative samples of the overburden 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.

The groundwater conditions in the boreholes were closely monitored during the course of the fieldwork. A piezometer was installed in borehole 2 for subsequent water level measurements. Details of the installation and subsequent water level readings are recorded on the Record of Borehole sheets.

All of the recovered samples were returned to our laboratory for detailed visual examination, classification and routine moisture content determinations. Atterberg Limits test and grain size distribution analyses were conducted on selected samples. The results of the grain size distribution analyses are presented on the Record of Borehole sheets and Figure 1 attached.

The locations of the boreholes were established in the field by Peto MacCallum Ltd. relative to highway centreline stakes positioned by J.D. Barnes Limited. The ground surface elevations were interpolated from contours shown on the digital base plans titled "The Kings Highway 6 New", dated May and June 2000 provided by Delcan Corporation.

SUMMARIZED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, soil boundary elevations, standard penetration test "N" values, groundwater observations and the results of laboratory moisture content determinations.

The results of particle size distribution analyses conducted on selected samples recovered during drilling are presented on Figure 1.

The subsurface stratigraphy encountered at the retaining wall location generally comprised a surficial topsoil layer overlying discontinuous clayey silt and/or sand layers underlain by a major silt deposit. Localized units of clay were encountered within and beneath the silt at one borehole location.

Topsoil

A 180 and 200 mm thick surficial layer of topsoil was encountered in boreholes 1 and 2 located below the crest of the scarp. The topsoil comprised dark brown clayey silt.

Clayey Silt

A unit of cohesive clayey silt to non-cohesive silt with some clay was encountered beneath the surficial topsoil layer in borehole 2 and surficially in borehole 3. The clayey silt layer was 0.9 and 1.0 m thick and was penetrated at depths of 0.9 to 1.2 m (elevation 242.6 to 243.9).

Sand

A non-cohesive sand layer was encountered in boreholes 2 and 3 beneath the silt layer. The sand was very loose, with 'N' values of 2 and 3, and had moisture contents of 7 and 13%. The sand was penetrated at depths of 2.4 and 2.6 m (elevation 241.4 and 242.2).

Silt

A major deposit of non-cohesive compact to very dense silt, with 'N' values typically ranging from 12 to 60, was encountered in all of the boreholes beneath the surficial topsoil and/or clayey silt/sand. The silt was contacted at depths of 0.2 to 2.6 m (elevation 238.1 to 242.2). The moisture content of the silt ranged from 12 to 27%, typically 16 to 20%. The results of particle size distribution analyses conducted on selected samples of the silt recovered during drilling are presented on Figure 1. Atterberg Limits testing was conducted on a selected sample of silt, and was determined to be non-plastic. The silt was penetrated in borehole 1 at a depth of 26.0 m (elevation 212.3), and in borehole 3 upon refusal to auger on probable bedrock at a depth of 36.0 m (elevation 208.8). Drilling was terminated within the silt in borehole 2 at a depth of 15.7 m.

Clay

A localized layer of cohesive stiff silty clay, with an 'N' value of 12, was encountered within the major silt deposit in borehole 1 at a depth of 8.5 m (elevation 229.8). The layer was 1.5 m thick and had a moisture content of 12%.

A deposit of cohesive very stiff silty clay, with an 'N' value of 29, was contacted beneath the major silt layer in borehole 1 at a depth of 26.0 m (elevation 212.3). The clay had a moisture content of 22%. The clay was penetrated upon refusal to auger on bedrock at a depth of 29.7 m (elevation 208.6).

Bedrock

Drilling was terminated upon refusal to auger on probable bedrock in boreholes 1 and 3 at the following depths:

Borehole No.	Depth to Probable Bedrock (m)	Probable Bedrock Elevation
1	29.7	208.6
3	36.0	208.8

Bedrock was contacted below the silt overburden in the six deep boreholes drilled during the foundation investigation carried out for the Book Road structure located some 60 m to the southwest at depths of 22.6 to 23.2 m (elevation 208.3 to 208.4). The bedrock consisted of dolostone of fair to good quality. It is noteworthy that a 75 mm thick void was detected in the rock in one borehole during the previous investigation, at a depth of 23.1 m, 600 mm below the bedrock surface.

Groundwater

Upon completion of drilling, water was observed in borehole 3 at a depth of 9.1 m, (elevation 235.7). Details concerning water levels measured in the piezometer installed in borehole 2 are as follows:

Date	Depth to Water (m)	Elevation
9 April 2001	6.2	237.6
3 May 2001	5.9	237.9
26 June 2001	6.2	237.6

Observed groundwater levels are subject to seasonal fluctuations and precipitation patterns.

CLOSURE

The fieldwork was carried out under the supervision of Mr. M. Rapsey and Mr. P. Cullen. The equipment was supplied by Malone's Soil Sampling and Elite Drilling.

The report was prepared by Mr. P. Cullen, B.Eng. and Mr. M.R. Anderson, P.Eng., Senior Project Engineer, and reviewed by Mr. D.W. Kerr, P.Eng., Manager of Geotechnical and Geo-Environmental Services, Hamilton. Mr. B.R. Gray, P.Eng. carried out an independent review of the report.

Yours very truly

Peto MacCallum Ltd.



A handwritten signature in black ink, appearing to read "D. W. Kerr", written over a horizontal line.

Dennis W. Kerr, M.Eng., P.Eng.
Manager Geotechnical and
Geo-Environmental Services
Hamilton



A handwritten signature in black ink, appearing to read "Brian R. Gray", written over a horizontal line.

Brian R. Gray, M.Eng., P.Eng.
President

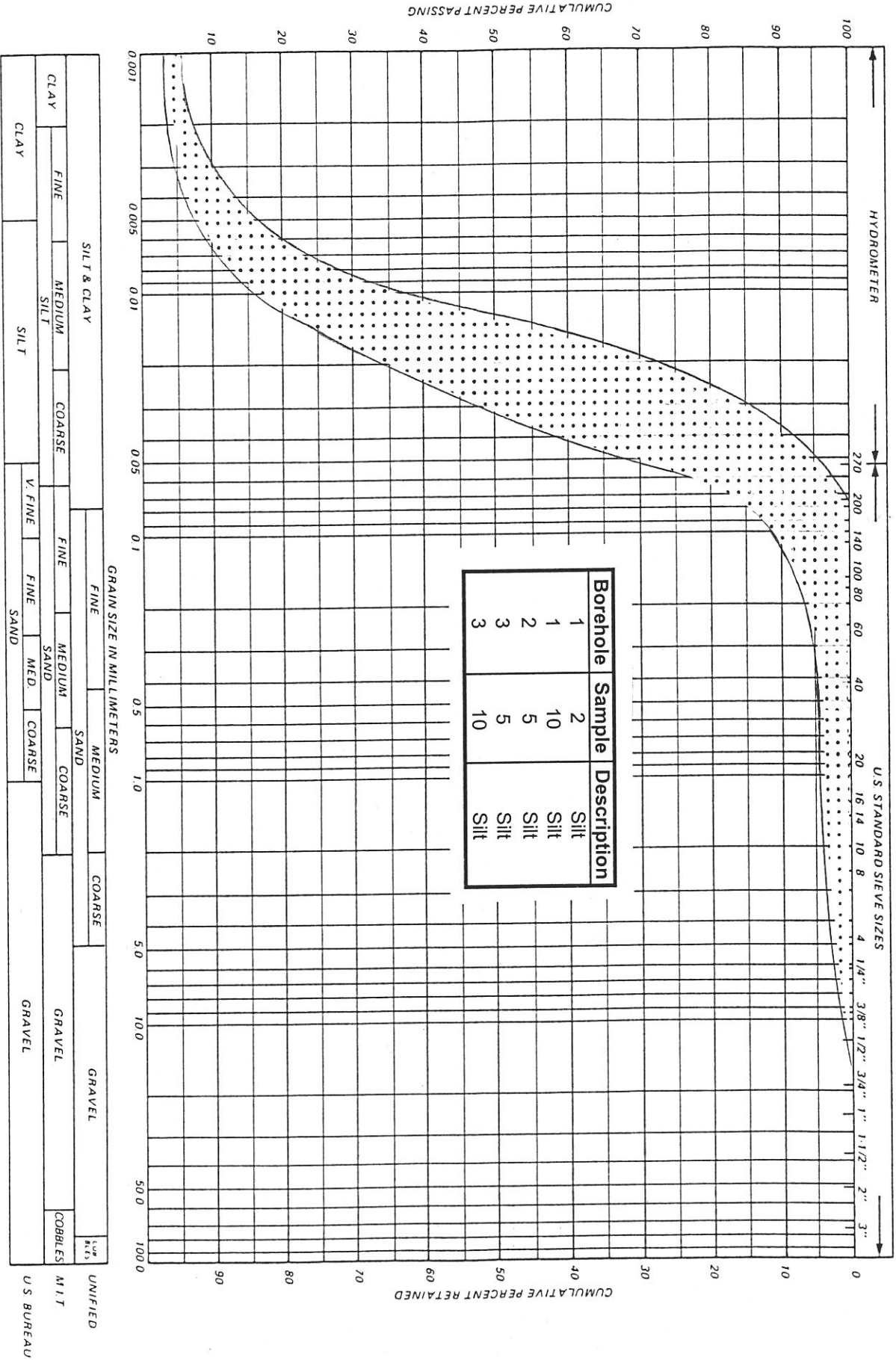
PC:vg

APPENDIX A

FIGURE 1

PARTICLE SIZE DISTRIBUTION CHART

PML REF. 00HF108
REPORT NO. -
FIGURE 1



REMARKS

APPENDIX B

RECORD OF BOREHOLE LOGS

LIST OF ABBREVIATIONS

PENETRATION RESISTANCE

STANDARD PENETRATION RESISTANCE 'N', - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 0.3m INTO THE SUBSOIL. DRIVEN BY MEANS OF A 63.5kg HAMMER FALLING FREELY A DISTANCE OF 0.76m.

DYNAMIC PENETRATION RESISTANCE : - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A 51mm, 60 DEGREE CONE, FITTED TO THE END OF DRILL RODS. 0.3m INTO THE SUBSOIL. THE DRIVING ENERGY BEING 475 J PER BLOW.

DESCRIPTION OF SOIL

THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE DENSITY OR DENSENESS OF COHESIONLESS SOILS ARE DESCRIBED IN THE FOLLOWING TERMS :-

<u>CONSISTENCY</u>	<u>'N' BLOWS/0.3 m</u>	<u>c kPa</u>	<u>DENSENESS</u>	<u>'N' BLOWS/0.3 m</u>	
VERY SOFT	0 - 2	0 - 12	VERY LOOSE	0 - 4	
SOFT	2 - 4	12 - 25	LOOSE	4 - 10	
FIRM	4 - 8	25 - 50	COMPACT	10 - 30	
STIFF	8 - 15	50 - 100	DENSE	30 - 50	
VERY STIFF	15 - 30	100 - 200	VERY DENSE	> 50	
HARD	> 30	> 200			
W.T.P.L.	WETTER THAN PLASTIC LIMIT		D.T.P.L.	DRIER THAN PLASTIC LIMIT	
	A.P.L.		ABOUT PLASTIC LIMIT		

TYPE OF SAMPLE

S.S.	SPLIT SPOON	T.W.	THINWALL OPEN
W.S.	WASHED SAMPLE	T.P.	THINWALL PISTON
S.B.	SCRAPER BUCKET SAMPLE	O.S.	OESTERBERG SAMPLE
A.S.	AUGER SAMPLE	F.S.	FOIL SAMPLE
C.S.	CHUNK SAMPLE	R.C.	ROCK CORE
S.T.	SLOTTED TUBE SAMPLE		
	P.H.	SAMPLE ADVANCED HYDRAULICALLY	
	P.M.	SAMPLE ADVANCED MANUALLY	

SOIL TESTS

Q _u	UNCONFINED COMPRESSION	L.V.	LABORATORY VANE
Q	UNDRAINED TRIAXIAL	F.V.	FIELD VANE
Q _{cu}	CONSOLIDATED UNDRAINED TRIAXIAL	C	CONSOLIDATION
Q _d	DRAINED TRIAXIAL		

▲, Δ - Undisturbed and remoulded shear strength determined from in situ vane test.

■ - Undrained shear strength determined from pocket penetrometer test.

RECORD OF BOREHOLE No 1										1 of 2		METRIC	
G W P 9-91-00 & 21-91-00			LOCATION			RETAINING WALL - Sta. 22+675 20m Rt HWY 6 (NEW)			ORIGINATED BY M.R.				
DIST CR HWY 6 (NEW)			BOREHOLE TYPE			Continuous Flight Hollow Stem Augers			COMPILED BY P.C.				
DATUM Geodetic			DATE			April 5, 2001			CHECKED BY M.R.A.				
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT Y kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV. DEPTH	DESCRIPTION	NUMBER	TYPE			VALUES	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)				
238.25	Ground Surface												
238.05	Topsoil				238								
0.20	Silt, trace of gravel, fine sand and clay												
	Compact to dense	1	SS	45	237								
	Brown				236								
		2	SS	37	235							2 2 89 7	
	Grey				234								
		3	SS	19	233								
					232								
		4	SS	36	231								
					230								
		5	SS	29	229								
229.75	Silty Clay, trace of sand, with lenses of brown silt	6	SS	12	228								
8.50	Stiff Grey				227								
228.25	Silt, trace of clay and fine sand	7	SS	25	226								
10.00	Compact Grey to dense	8	SS	45	225								
					224								

Continued on Page 2 of 2

RECORD OF BOREHOLE No 1

2 of 2

METRIC

G W P 9-91-00 & 21-91-00

LOCATION

RETAINING WALL - Sta. 22+675 20m Rt HWY 6 (NEW)

ORIGINATED BY M.R.

DIST CR

HWY 6 (NEW)

BOREHOLE TYPE

Continuous Flight Hollow Stem Augers

COMPILED BY P.C.

DATUM

Geodetic

DATE

April 5, 2001

CHECKED BY M.R.A.

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 (%) GR SA SI CL					
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100										WATER CONTENT (%) 20 40 60				
								SHEAR STRENGTH (kPa)														
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X LAB VANE														
223.25	Ground Surface		9	SS	26		223															
15.00	Continued from Page 1 of 2						222															
	Silt and fine sand, with occasional lenses of grey silty clay																					
	Compact Grey Saturated																					
221.50							221															
16.75	Silt, trace of gravel and fine sand, trace clay																					
	Very Grey dense		10	SS	62		220									1 2 91 6						
							219															
							218															
							217															
			11	SS	55		216															
							215															
							214															
			12	SS	60		213															
							212															
212.25							211															
26.00	Silty Clay, trace of sand, with numerous thin lenses of brown silt						210															
	Very Grey stiff		13	SS	29		209															
208.55																						
29.70	End of borehole Auger refusal on probable bedrock																					

* WATER LEVEL NOT DETERMINED

+7, x5: Numbers refer to
Sensitivity

20
15-5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 2

1 of 2

METRIC

G W P 9-91-00 & 21-91-00

LOCATION

RETAINING WALL - Sta. 22+715 19m Rt HWY 6 (NEW)

ORIGINATED BY M.R.

DIST CR HWY 6 (NEW)

BOREHOLE TYPE

Continuous Flight Hollow Stem Augers

COMPILED BY P.C.

DATUM Geodetic

DATE _____

April 6, 2001

CHECKED BY M.R.A.

[illegible]

RECORD OF BOREHOLE No 2										2 of 2		METRIC									
G W P 9-91-00 & 21-91-00				LOCATION RETAINING WALL - Sta. 22+715 19m Rt HWY 6 (NEW)				ORIGINATED BY M.R.													
DIST CR HWY 6 (NEW)				BOREHOLE TYPE Continuous Flight Hollow Stem Augers				COMPILED BY P.C.													
DATUM Geodetic				DATE April 6, 2001				CHECKED BY M.R.A.													
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 Y kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)								
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20						40	60	80	100	WATER CONTENT (%)			
228.75	Ground Surface																				
15.00	Continued from Page 1 of 2		9	SS	31																
228.05	Silt, trace of clay and sand																				
15.70	End of borehole																				
<p>* GROUNDWATER CONDITIONS</p> <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th>DATE</th> <th>GROUNDWATER ELEVATION (m)</th> </tr> </thead> <tbody> <tr> <td>Apr. 9, 2001</td> <td>237.6</td> </tr> <tr> <td>May 3, 2001</td> <td>237.9</td> </tr> <tr> <td>June 26, 2001</td> <td>237.6</td> </tr> </tbody> </table>														DATE	GROUNDWATER ELEVATION (m)	Apr. 9, 2001	237.6	May 3, 2001	237.9	June 26, 2001	237.6
DATE	GROUNDWATER ELEVATION (m)																				
Apr. 9, 2001	237.6																				
May 3, 2001	237.9																				
June 26, 2001	237.6																				



Foundation Design

1 of 2

METRIC

G W P 9-91-00 & 21-91-00

LOCATION

Co-ords. 4 782 984 N; 267 043 E
RETAINING WALL - Sta. 22+738 18m Rt HWY 6 (NEW)

ORIGINATED BY P.C.

DIST CR HWY 6 (NEW)

BOREHOLE TYPE

Continuous Flight Solid Stem Augers

COMPILED BY P.C.

DATUM _____ Geodetic _____

DATE _____

April 5, 2001

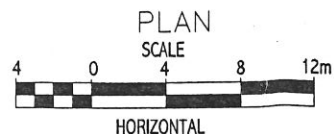
CHECKED BY M.R.A.

+7, x⁵: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 3										2 of 2		METRIC				
G W P 9-91-00 & 21-91-00			LOCATION			Co-ords. 4 782 964 N; 267 043 E			RETAINING WALL - Sta. 22+738 18m Rt HWY 6 (NEW)			ORIGINATED BY P.C.				
DIST CR HWY 6 (NEW)			BOREHOLE TYPE			Continuous Flight Solid Stem Augers			COMPILED BY P.C.							
DATUM Geodetic			DATE			April 5, 2001			CHECKED BY M.R.A.							
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 (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20	40	60	80	100	W _p	W		
229.75	Ground Surface															
15.00	Continued from Page 1 of 2 Silt, some fine sand, trace clay		9	SS	12											
						228										
						227										
			10	SS	33											
						226										0 15 78 7
						225										
						224										
			11	SS	49											
						223										
						222										
222.95	End of Sampled Borehole. Augered to Refusal					221										
21.80						209										
						208										
208.75	End of borehole Auger refusal on probable bedrock															
36.00	* 2001 04 05 WATER MEASURED DURING DRILLING															

APPENDIX C

DRAWINGS 1 AND 1A



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

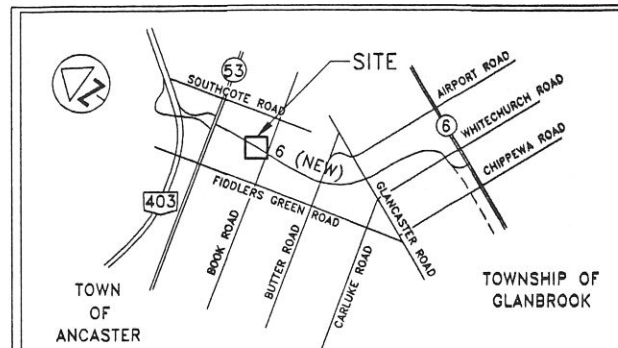
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GWP No. & 21-91-00



SHEET

HWY 6 (NEW)
Proposed Retaining Wall at
Station 22+675 to 22+750
BOREHOLE LOCATIONS

Peto MacCallum Ltd.
CONSULTING ENGINEERS



KEY PLAN
N.T.S.

LEGEND



Borehole

No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
1	238.25	4 782 902	267 038
2	243.75	4 782 942	267 041
3	244.75	4 782 964	267 043

NOTE

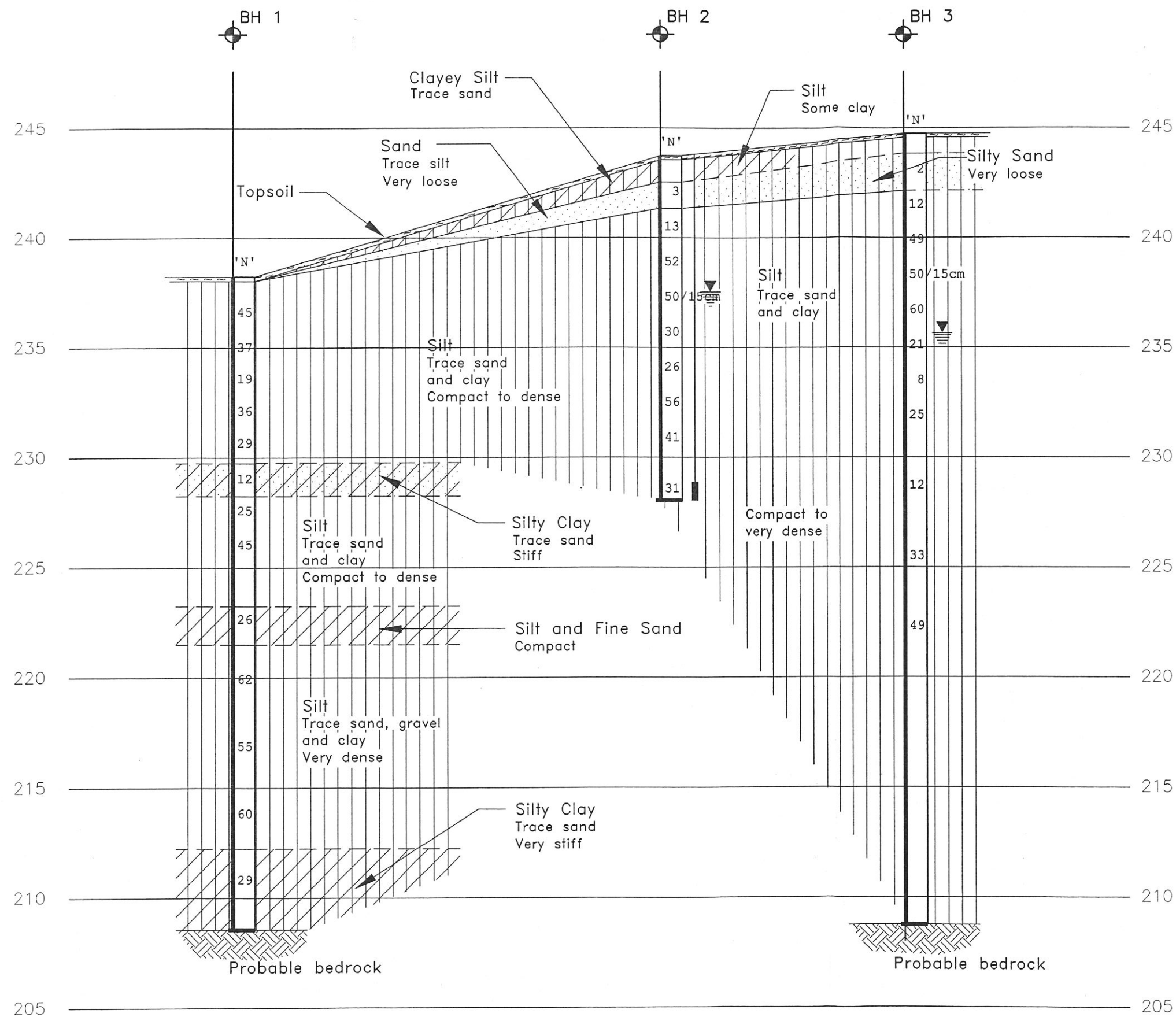
Refer to Drawing 1A for soil Profile A-A

Centreline and wall alignment are based on information in
Pre-Design Report (WP 9-91-00) and are considered
approximate.

REV.	DATE	BY

Geocres No.

HWY No. 6 (NEW)	DIST	CR
SUBM'D P.C.	CHECKED P.C.	DATE NOV. 2001
DRAWN C.B.	CHECKED M.R.A.	APPROVED D.W.K.
	DWG	1



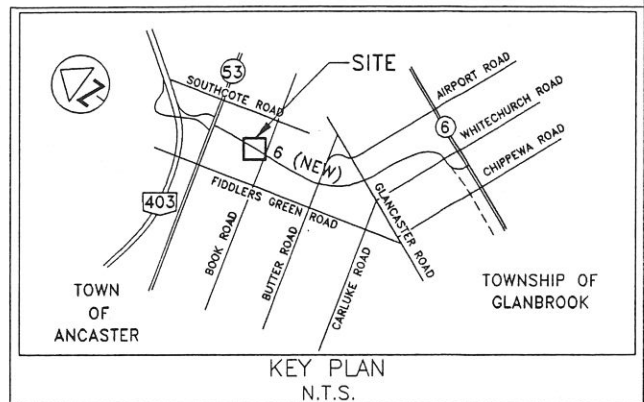
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES - METRES






CONT No.	9-91-00
GWP No. &	21-91-00

HWY 6 (NEW)
Proposed Retaining Wall at
Station 22+675 to 22+750
SOIL STRATA

SHEET

Peto MacCallum Ltd.
CONSULTING ENGINEERS



LEGEND			
	Borehole		
	N		
	Blows/0.3m (Std. Pen Test, 475 J / blow)		
	W L at time of investigation or in piezometer		
	Piezometer		

No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
1	238.25	4 782 902	267 038
2	243.75	4 782 942	267 041
3	244.75	4 782 964	267 043

= NOTE =

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

REV.			
	DATE	BY	

Geocres No.

HWY No. 6 (NEW)			DIST	CR
SUBM'D P.C.	CHECKED P.C.	DATE NOV. 2001	SITE	
DRAWN C.B.	CHECKED M.R.A	APPROVED D.W.K.	DWG	1A

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December, 2001

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FOUNDATION DESIGN REPORT

For
Retaining Wall
Highway 6 (New)
From Highway 403 Southerly to Existing Highway 6
City of Hamilton, Ontario
G.W.P. 9-91-00 & 21-91-00

INTRODUCTION

This report provides geotechnical comments and recommendations regarding design and construction of the proposed retaining wall to be located 60 m north of Book Road along the proposed Highway 6 (New) alignment in the former Town of Ancaster, now in the City of Hamilton, Ontario. The investigation was conducted for Delcan Corporation on behalf of the Ontario Ministry of Transportation.

The proposed retaining wall will be located from approximate chainage 22+675 to 22+750 and will retain the east wall of a proposed 5 to 10 m deep cut to be excavated for the Highway 6 (New) alignment. The proposed road grade in front of the wall (based on the Pre-Design Report profile) will rise to the north from elevation 233.0 to 234.5.

The subsurface stratigraphy encountered at the wall location generally comprised a surficial topsoil layer overlying discontinuous clayey silt and/or sand layers underlain by a major silt deposit. Localized units of clay were encountered within and beneath the silt at one borehole location. Water was measured in a piezometer installed along the wall alignment at depths of 5.9 to 6.2 m (elevation 237.6 to 237.9).

FOUNDATIONS

Spread Footings

Details regarding the proposed founding level for the retaining wall were not established. It is assumed the design founding level will be some 2.0 m below the proposed road grade, near elevation 231.0 to 232.5.

The foundation subgrade at the inferred level is expected to comprise compact to dense silt. Based on the borehole information, it is considered that the retaining wall may be supported on native undisturbed soil at the assumed depth. The following bearing resistances are recommended for a minimum 2.5 m wide footing:

Founding Material	Factored Bearing Resistance at ULS (kPa)	Bearing Resistance at SLS (kPa)
Compact to Dense Silt	400	275

A footing embedment depth of 1.2 m was assumed for computation of the ULS resistance.

The recommended resistance at serviceability limit states allows for 25 mm of total settlement; differential settlement is expected to be less than 75% of this value.

Prior to placement of structural concrete, all foundation excavations should be examined by geotechnical personnel to verify the competency of the founding surface.

All footings subject to frost action should be provided with the normal 1.2 m of earth cover or equivalent thermal insulation. A 25 mm thick layer of polystyrene insulation is thermally equivalent to 600 mm of soil cover.

The horizontal force on the wall will be resisted in part by the friction force developed between the underside of the retaining wall footing and the founding soils. An unfactored friction factor of 0.30 is recommended for footings on the native compact to dense silt.

Piles

Supporting vertical and horizontal loads imposed by the wall base using steel H-piles is considered feasible. The piles should be driven to refusal on bedrock anticipated at depths of 29.7 to 36.0 m (elevation 208.6 to 208.8). Recommended values for factored axial resistance at ULS for two pile sections are presented below:

H-Pile Section	Factored Resistance at ULS (kN)
HP 310 x 79	1450
HP 310 x 110	2000

The resistance at serviceability limit states normally allows for 25 mm of compression of the pile and founding medium. Considering the bedrock to be non-yielding and the pile length required, the design is not expected to be governed by settlement since the loading required to produce deformation of the pile will be much larger than the factored resistance at ULS.

The type of equipment required to drive the piles will be somewhat dictated by the design capacity. In general, the piles should be driven to practical refusal using a hammer which transfers at least 40 KJ of energy to the pile. Since the piles will set on hard rock, a specific set for this project is not provided.

The installation operations should be inspected on a full-time basis by qualified geotechnical personnel to confirm the founding elevation, alignment, plumbness, uniformity of set, and quality of splices.

Driving shoes should be provided (OPSD 3301) to minimize the potential for damage when driving through dense zones and setting into bedrock.

Pile caps should be provided with at least 1.2 m of earth cover or equivalent thermal insulation as protection against frost action. A 25 mm thick layer of polystyrene insulation is thermally equivalent to 600 mm of soil cover.

The soil adjacent to the piles is expected to comprise compact to dense silt with isolated zones of stiff clay. The coefficient of horizontal subgrade reaction, k_s , for the silt may be computed using the following equation to evaluate the point of contraflexure:

$$k_s = n_h z/b$$

where z = depth (m)
 b = pile width (m)

The recommended value of n_h for compact to dense silt is 8,000 kN/m³.

Resistance to lateral loads may be provided in part by mobilization of passive resistance along the pile. The lateral resistance recommended for two pile sections is:

	<u>HP 310 x 79</u>	<u>HP 310 x 110</u>
Factored Lateral Resistance at ULS =	110 kN	170 kN
Lateral Resistance at SLS =	40 kN	60 kN

If additional lateral resistance is required, batter piles driven to rock should be employed.

Caissons

Supporting the structure on caissons socketed into bedrock a length equal to half the caisson diameter may be considered. It is noteworthy that the presence of voids were detected in boreholes drilled during the foundation investigation at the Book Road underpass structure. The caissons should be designed using a conservative value for factored end-bearing resistance at ULS of 5500 kPa and a factored bond stress at ULS of 750 kPa. The factored axial resistance of caissons with the following diameter, socketed a half-diameter into rock, is:

Caisson Diameter (m)	Factored Axial Resistance at ULS (kN)
0.76	3100
0.91	4500
1.07	6200
1.22	8100

Considering the bedrock to be non-yielding, the design is not expected to be governed by settlement since the loading required to produce deformation will be much larger than the factored resistance at ULS.

The caissons should be installed and inspected in accordance with the requirements of Special Provision No. 903S01 (April 2000).

It is anticipated that augering will be feasible to advance the caissons through the overburden. Groundwater may present some problems during installation of the caissons; the caisson liner should be sufficient to eliminate groundwater inflow in the overburden. Some inflow of groundwater through the bedrock is likely to occur, placement of concrete by tremie method will probably be necessary.

The unfactored lateral resistance (p) of a single caisson may be estimated by computing the passive earth pressure developed over an equivalent wall area with a depth of six times the caisson diameter and width of three times the caisson diameter provided the spacing between caissons is greater than 5 caisson diameters using the following equation:

$$p = K (\gamma_1 h_1 + \gamma_2 h_2 + q) + \gamma_w h_2$$

$$K = \text{lateral earth pressure coefficient} = 3.0$$

where $\gamma_1 = \text{unit weight of soil above the water table (kN/m}^3\text{)}$
 $= 20.0 \text{ kN/m}^3$

$$h_1 = \text{depth to water table (m)}$$

$$\gamma_2 = \text{unit weight of soil below the water table (kN/m}^3\text{)}$$
$$= 10.2 \text{ kN/m}^3$$

$$h_2 = \text{depth below water table (m)}$$

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

$$q = \text{surcharge load (kPa), if present}$$

The groundwater level measured during the field investigation was at elevation 237.5.

LATERAL EARTH PRESSURES

The retaining wall should be designed to resist the unbalanced horizontal earth pressure imposed by the backfill/soil adjacent to the wall. The lateral earth pressure, p , may be computed using the equivalent fluid pressures presented in Section 6-7.4 of the Ontario Bridge Design Code (OHBDC, 3rd Edition, 1991) for a wall height of less than 10 m, or employing the following equation, assuming a triangular pressure distribution; provided the backslope of the retained soil is level.

$$p = K (\gamma h + q)$$

where

K = lateral earth pressure coefficient

γ = unit weight of free-draining granular material (kN/m^3)

h = depth below final grade (m)

q = surcharge load (kPa), if present

The lateral earth pressure using the above equation is calculated provided the backslope of the retained soil is level. This value will increase if the retained soil exceeds 10° to the horizontal.

Free draining granular material should be used as backfill behind the wall. The following parameters are recommended for design. The parameters for the native silt should be employed if the inclination of an imaginary line, extended upward from a point 600 mm below the base of the footing at an inclination of 60° to the horizontal, intersects the inclination of the cut slope at a point below the mid point of the cut face.

	Granular "A"	Granular "B"	Native Silt
Angle of Internal Friction (degrees)	35	32	30
Unit weight (kN/m^3)	22.8	21.2	20.0
Active Earth Pressure Coefficient (K_a)	0.27	0.31	0.33
At Rest Earth Pressure Coefficient (K_o)	0.43	0.47	0.50
Passive Earth Pressure Coefficient (K_p)	3.69	3.25	3.00

The coefficient of earth pressure at-rest should be used for design of a rigid and unyielding wall, the active earth pressure coefficient for unrestrained structures.

The earth pressure coefficients should be reviewed if the slope of the backfill exceeds 10° to the horizontal. Alternately, the material above the level of the top of the abutment wall could be treated as a surcharge load (q in the preceding equation).

A weeping tile system and/or weep holes should be installed to minimize the build-up of hydrostatic pressure behind the wall. The weeping tiles should be surrounded by a properly designed granular filter or geotextile 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.

A retained soil system could also be employed. The founding material is expected to comprise granular engineered fill or silt overburden. The following parameters should be employed for design of the system foundation:

	<u>Granular "A"</u>	<u>Native Overburden</u>
Friction Angle (degrees)	35	30
Cohesion (kPa)	0	0
Unit weight (kN/m ³)	22.8	20.0

The bearing resistances recommended previously for spread footings constructed on the native overburden should be employed for design of the RSS wall.

A factor of safety of 2.3 was calculated for lateral displacements due to vertical loads imposed by the retained soil.

The supplier of the retained soil system should be responsible for design of the structure (backfill, reinforcement, internal and external stability) and provide drawings to show pertinent information such as location, length, height, elevations, performance level, appearance, etc.

Anchors

Soil anchors, if employed, should be designed to develop resistance in the compact to dense native silt behind a wedge of soil extending upwards from the toe of the wall at an inclination of 60° from the horizontal. The fixed anchors should be positioned at least 5 m below the grade behind the wall.

The unfactored pull-out resistance (R) of anchors grouted in the compact to dense silt can be estimated using the following equation:

$$R = K_f \sigma'_z L_s A_s$$

where

K_f = anchorage coefficient
= 0.5 for compact to dense silt

σ'_z = effective vertical stress at midpoint of anchor,
= $\gamma' z$

γ' = effective unit weight of overburden soil
= 20 kN/ m³ above groundwater level
(elevation 237.6 for design purposes)
= 10.2 kN/ m³ below groundwater level

z = depth to midpoint of anchor (m)

L_s = anchor length (m)

A_s = unit surface area of anchor (m²/m)

EXCAVATION AND GROUNDWATER CONTROL

Excavation of the overburden for wall construction should be relatively straightforward using conventional equipment. The in situ materials are classified as Type 3 soils according to Occupation Health and Safety Act criteria. Temporary cut slopes inclined at 1 horizontal to 1 vertical should generally be stable.

Flatter sideslopes may be required if soft/wet materials or concentrated seepage zones are encountered. In this regard, the potential for seasonally perched water in the sand deposits overlying the less permeable silt should be considered.

Cognizant of the water levels measured during the investigation (typically 6.2 m below grade), and subject to seasonal precipitation patterns, it is expected that seepage or surface water which enters the excavation can be readily handled by conventional sump pumping techniques. Temporary sump pits or diversion ditches may be required to handle any concentrated/larger volumes of seepage from the cut wall.

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.

CLOSURE

This report was prepared by Mr. P. Cullen, B.Eng. and Mr. M.R. Anderson, P.Eng., Senior Project Engineer, and reviewed by Mr. D.W. Kerr, P.Eng., Manager of Geotechnical and Geo-Environmental Services, Hamilton. Mr. B.R. Gray, P.Eng. carried out an independent review of the report.



Yours very truly

Peto MacCallum Ltd.

A handwritten signature in black ink, appearing to read "D. W. Kerr", written over a horizontal line.

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A handwritten signature in black ink, appearing to read "Brian R. Gray", written over a horizontal line.

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