

ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

WP	54-82-06	DIST	6
HWY	401	STR SITE	24-682

Highway 401 Westbound Collector Transfer Ramp
to Ramp E-N/S

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GEOCRE 30M12-223

DATE DEC 05 1994

FOUNDATION INVESTIGATION REPORT

For

Highway 401 Westbound Collector Transfer Ramp to Ramp E-N/S

W.P. 54-82-06, Site 24-682

Highway 401, District 6, Toronto

Introduction

This report summarizes the results of a foundation investigation conducted at the Highway 401 Westbound Collector transfer ramp structure and adjacent retaining walls. The investigation was carried out at the request of Central Region Structural Section. This report applies to the proposed structure and its approaches as well as for retaining walls in the immediate vicinity of the structure.

Site Description

The site is located on the north side of Highway 401, approximately 500 m east of the Highway 10 underpass structure, in the City of Mississauga. The surrounding area is predominantly used industrial and commercial.

Physiographically, the site is located in the region known as the "Peel Plain". This region is characterized by a level to undulating "till or boulder clay" plain underlain by shale or limestone bedrock.

Investigation Procedures

i) Field

The subsurface investigation for this alignment of the proposed Highway 401 westbound collector lanes was carried out between 94 06 23 and 94 06 30. It consisted of nine sampled boreholes - E-1, P-1, P-2, P-3, P-4, R-1, R-2, W-1. All borings were advanced using a 5.2(i) track-mounted auger machine. Two boreholes were advanced by means of hollow stem auger, and the remainder by solid stem augers.

Samples were recovered by means of a 50 mm I.D. split spoon sampler. BQ rock cores were retrieved from boreholes E-1 and W-2.

A subsurface investigation was also conducted at this site in August 1983. It was carried out by Morton & Partners Ltd. who were retained by the MTO. Information from two of the boreholes was updated and is used in this report.

ii) Laboratory

Laboratory testing was carried out on representative samples to identify and determine the physical properties of the overburden and weathered shale including:

Natural Moisture Content
Atterburg Limits
Grain Size Distribution
Bulk Unit Weight

The results of the laboratory tests are plotted on the Record of Borehole sheets and on Figures 1 through 4.

Subsurface Conditions

General

The borings carried out at the site, (1,4 E-1, P-1, P-2, P-3, P-4, R-1, R-2, R-3, W-1) reveal a fill area to the west end of the site composed of shale bedrock fragments excavated from the Highway 401/403/410 interchange. It ranges from 5.4 m to 6.7 m thick at the borehole locations. Elsewhere, relatively shallow overburden, composed of a heterogeneous mixture of clayey silt to silty clay, with some gravel, and some sand is present. The deposit is a cohesive glacial till and varies in thickness from 2.1 m to 3.0 m from the ground surface.

Weathered shale bedrock of the Queenston Formation was identified in all the borings. The glacial till/weathered bedrock interface ranges in elevation from 189.7 to 191.4 across the site.

Groundwater was encountered in the overburden between El. 191.4. and 193.8, but is more typically at El 192.0+/-.

The subsurface conditions across the area are shown on the Record of Borehole Sheets. The locations and elevations of the borings, together with the stratigraphical sections inferred from the borehole data are shown on Drawing No. 548206-A. Detailed subsurface descriptions follow.

Weathered Shale Fragments (Fill Material)

A fill composed largely of weathered shale bedrock, is present at the west end of the site in boreholes P-1, R-1 and W-1. The fill was placed during excavations carried out at the Highway 401/403/410 interchange. It rises above the prevailing ground surface by as much as 6.7 m+/- . Sampling revealed that the material is well graded, containing very fine grained sediments to

cobble and boulder size fragments. The variability of the material is evident from the range of N-values obtained, 8 to 88 blows per 30 cm. The fill is cohesive and its consistency ranges from firm to hard. The following properties were identified from laboratory testing carried out on representative samples:

	Range (%)
Natural Moisture Content (w)	7 - 12
Plastic Limit (w_p)	27 - 35
Liquid Limit (w_L)	17 - 19
Unit Weight (γ)	22.5

Refer to Figure 1 for the grain size distribution curves typical for this deposit. The Plasticity Chart for this material is provided in Figure 2.

In borehole R-1, clayey silt fill material was encountered below the shale fill between El. 192.9 and 194.1. The cohesive deposit contains trace to some gravel and some sand. N-values of 10 and 11 obtained from sampling revealed a material that is stiff in consistency.

Clayey Silt to Silty Clay (Glacial Till)

A surficial deposit of clayey silt to silty clay was encountered across the remainder of the site except at the extreme easterly borehole, R-3. It is cohesive and contains trace to some gravel and some sand, with occasional zones of sandy silt. Its heterogeneous nature implies that it is glacial in origin and may contain cobbles and boulders. This stratum was encountered beneath the shale fill area between El 191.9 and 193.0. The glacial deposit measures 1.6 to 3.3 m in thickness at the borehole locations and directly overlies bedrock. Laboratory tests carried out on representative samples of this material revealed the following properties:

	Range (%)	Average (%)
Natural Moisture Content (w)	2 - 22	15
Plastic Limit (w_p)	14 - 20	17
Liquid Limit (w_L)	22 - 42	32

Refer to Figure 3 for the grain size distribution envelope for this deposit. The Plasticity Chart for this material is provided in Figure 4.

Silty Sand to Sand

An isolated surficial deposit of silty sand to sand overlying bedrock was encountered in borehole R-3, the most easterly borehole at the site. It is non-cohesive and contains trace to some gravel. A zone of cohesive glacial till was encountered at approximate El. 192.0. The thickness of the stratum measured 3.0 m at the borehole location and it directly overlies the shale bedrock. The N-values obtained vary from 21 to 88, reflecting a deposit with a relative density ranging from compact to very dense.

Bedrock

Shale bedrock was encountered at depths ranging from 2.1 m to 8.7 m at the shale fill embankment, i.e. between El. 189.7 and 191.4. It was recovered by means of split spoon sampling and rock coring. The bedrock samples and cores were examined by D.A. Williams, Petrographer with the Soils and Aggregates Section. The bedrock is described as Queenston shale, red in colour and highly to slightly weathered.

Detailed Rock Core Descriptions may be referred to in the Appendix of this report.

<i>Borehole</i>	<i>Depth to Bedrock</i>	<i>Bedrock Elevation</i>
1	2.9	189.8
4	2.3	190.6
E-1	2.1	190.4
P-1	8.7	189.7
P-2	2.7	189.8
P-3	2.7	189.8
P-4	2.6	189.9
R-1	8.0	191.3
R-2	2.7	191.4
W-1	8.5	190.1

Groundwater Conditions

Groundwater levels, established by measuring in the open boreholes, varied from El. 191.4 to 193.8. The groundwater elevations recorded at the time of the investigation are tabled below and are plotted on the Record of Borehole sheets and stratigraphical profile. In most cases, the water table is perched above the bedrock and when boring advanced into the bedrock, the water in the boreholes dissipated through the weathered shale.

<i>Borehole</i>	<i>Groundwater Elevation</i>
1	192.3
4	191.4
E-1	192.2
P-1	191.8
P-2	192.1
P-3	192.3
P-4	192.1
R-1	dry
R-2	191.9
R-3	192.0
W-1	193.8

Discussion

It is proposed to construct a three span (38 m, 55 m, 38 m) voided post-tensioned structure. Retaining walls, N/E and S/W, are required to accommodate the grade differences between the westbound collector lanes and the westbound transfer ramp that intersect at a skew of approximately 18°. The westbound collector, the westbound transfer ramp and separating structure will be constructed at or above existing ground elevation.

Recommendations

Structure Foundations

Abutments

The abutments to the structure should be founded in bedrock. At this site, shallow foundations or caissons could be considered.

Shallow Foundations

The West Abutment footing may be founded at or below elevation 189.8. The East Abutment footing may be founded at or below elevation 190.3. The recommended design values for spread footings on the weathered shale bedrock, as per OHBDC 3rd Ed., are as follows:

Factored Bearing Resistance at ULS	1 500 kPa
Bearing Resistance at SLS	will not govern

Caisson Foundations

As an alternative to spread footings, caissons may be considered. This would reduce the amount of excavation required at the West Abutment for a footing on bedrock. The following recommendations apply for caissons socketed into the weathered shale:

	<u>West Abutment</u>	<u>East Abutment</u>
Est. Base of Caisson Elev.	188.8	189.3
Factored Resistance @ U.L.S.	2 200 kPa	2 200 kPa
Axial Resistance @ S.L.S.	will not govern	will not govern

The depth of socketing should be equal to twice the caisson diameter.

It is expected that the caissons can be installed without liners and that any water encountered can be removed from the excavated caisson by pumping prior to the placement of concrete.

West Pier and East Pier

Similar recommendations may be applied at the pier locations.

Shallow Foundations

Spread footings may be founded at or below the following elevations:

West Pier	El. 189.7 m
East Pier	El. 189.8 m

The recommended design values for spread footings on the weathered shale bedrock as per OHBDC 3rd Ed. are as follows:

Factored Bearing Resistance at ULS	1 500 kPa
Bearing Resistance at SLS	will not govern

Caisson Foundations

Again, to reduce the amount of excavation of the existing shale fill, short caissons may be considered.

The following recommendations apply for caissons socketed into the weathered shale:

	<u>West Pier</u>	<u>East Pier</u>
Est. Base of Caisson Elev.	188.7	188.8
Factored Resistance @ U.L.S.	2 200 kPa	2 200 kPa
Axial Resistance @ S.L.S.	will not govern	will not govern

The depth of socketing should be equal to twice the caisson diameter.

It is expected that the caissons can be installed without liners and that any water encountered can be removed from the excavated caisson by pumping prior to the placement of concrete.

Retaining Walls

Retaining Wall S/W

Retaining Wall S/W is approximately 55 m long and decreases in height with an increasing grade to the west. Hence, a stepped footing arrangement should be considered. Its foundation will be located within or above the weathered shale fill.

Retaining Wall N/E

Retaining Wall N/E is approximately 95 m in length. The retaining wall footing will be founded on or above glacial till and will also require stepping.

Conventional Retaining Walls

For footings within the weathered shale fill, on the clayey silt glacial till, or in a fill, it is recommended that a granular pad with minimum thickness of 0.5 m be placed a minimum of 1.2 m below the final ground elevation.

Where fill is required, the surficial material containing organics should be removed for the area of the footing and replaced with compacted granular to the base of the footing elevation. For footings on a granular pad the following design values are recommended:

Factored Bearing Resistance at ULS	375 kPa
Bearing Resistance at SLS	250 kPa

Granular fill should be compacted to a minimum 95% SPDD.

For calculation of resistance to sliding, an unfactored friction coefficient of $\phi = 30^\circ$ may be assumed between concrete and granular fill.

Retained Soil System Walls

Proprietary walls may be considered for all three retaining walls. If retained soil systems are used, the proposal should be forwarded to the MTO RSS Committee c/o George Al-Bazi, Structural Office.

Design considerations for construction excavations and dewatering are the responsibility of the proprietary RSS company and shall be in accordance with the requirements of the Occupational Health and Safety Act. Fully detailed proposals should be submitted to the Foundation Design Section for review a minimum of 10 working days prior to construction.

General Recommendations for Spread Footings

No dewatering concerns are anticipated for the footing excavations. It is expected that any seepage into the excavation can be relieved by sump pumping techniques.

Due to the rapid disintegration of shale bedrock when exposed, it is recommended that a 150 mm thick working slab of concrete be poured within 8 hours of the completion of footing excavation. In addition, shale bedrock exposed on the sides of excavations should be protected with tarpaulins.

A 1.2 m earth cover is required for all footings. It is preferable to provide a minimum of 1.2 m of earth cover for the footings founded on shale bedrock because of the friable nature of the weathered shale.

The sliding resistance between the base of the footing and the weathered shale may be computed using an unfactored friction coefficient of $\tan 22^\circ$.

Lateral Earth Pressure

Backfill to the abutments should consist of granular material in accordance with MTO Standard Special Provision 109F03. Computation of earth pressures should be carried out as per Section 6-7.4.5 of the OHBDC, 3rd Ed.. Design parameters of the acceptable granular backfill are as follows.

	<u>Granular "A"</u>	<u>Granular "B"</u>
Angle of Internal Friction (ϕ)	35°	30°
Unit Weight (kN/m ³)	22.8	21.2

An active condition may be assumed provided that soil movement behind the wall is permitted.

Construction Considerations

A NSSP for caisson installation, developed by the Foundation Design Section, should be incorporated into the contract package.

Temporary excavations within the weathered shale fill and overburden may be carried out at 1.5H:1V slopes or flatter. Temporary excavations in the shale bedrock may be as steep as 1H:3V to a maximum depth of 6.0 m before incorporating a 2.0m wide mid-height berm. Sides of excavations exposing shale bedrock should be protected with a tarpaulin to minimize disintegration of the shale.

Across the site, cohesive glacial till overlies shale bedrock. The Contractor should be made aware that cobbles/boulders may be encountered during excavation and during placement of foundations. In addition, it is likely that cobble and boulder sized fragments of weathered shale or siltstone will be encountered during excavations within the weathered shale fill.

Slope Stability

The proposed slopes will be stable at 2H:1V. Where embankments exceed 6.0 m in height, a 2.0 m wide mid-height bench should be incorporated.

Miscellaneous

The fieldwork for this investigation was carried out by L. O'Malley, Engineering Student, under the supervision of B. Bennett, Foundation Engineer, utilizing drilling equipment owned and operated by Canadian Soil Drilling Inc..

The report was prepared by B. Bennett and reviewed and approved by D. Dundas, Sr. Foundation Engineer.



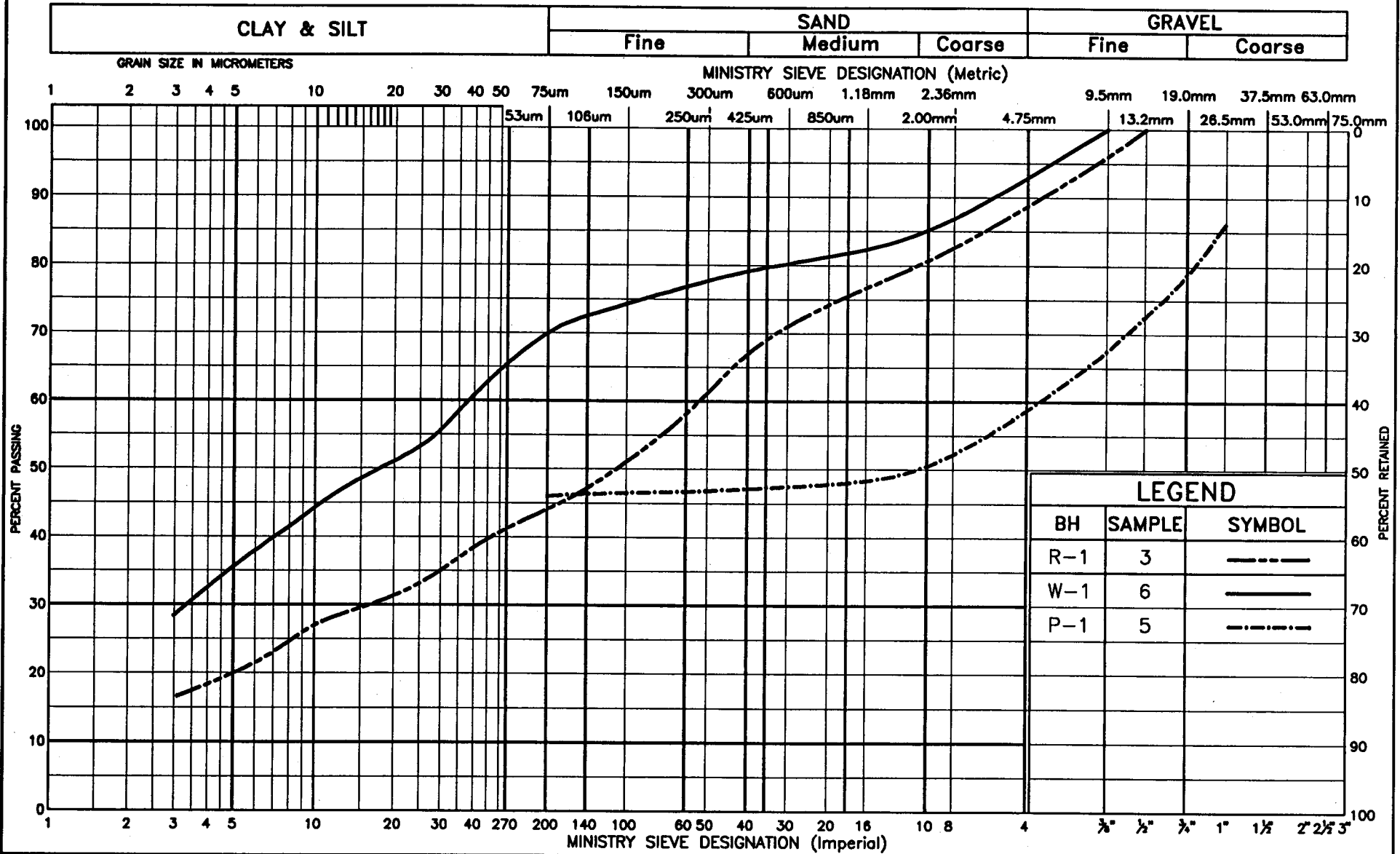
B. Bennett
Betty Bennett, P.Eng.
Foundation Engineer



D. Dundas
D.H. Dundas, P.Eng.
Sr. Foundation Engineer

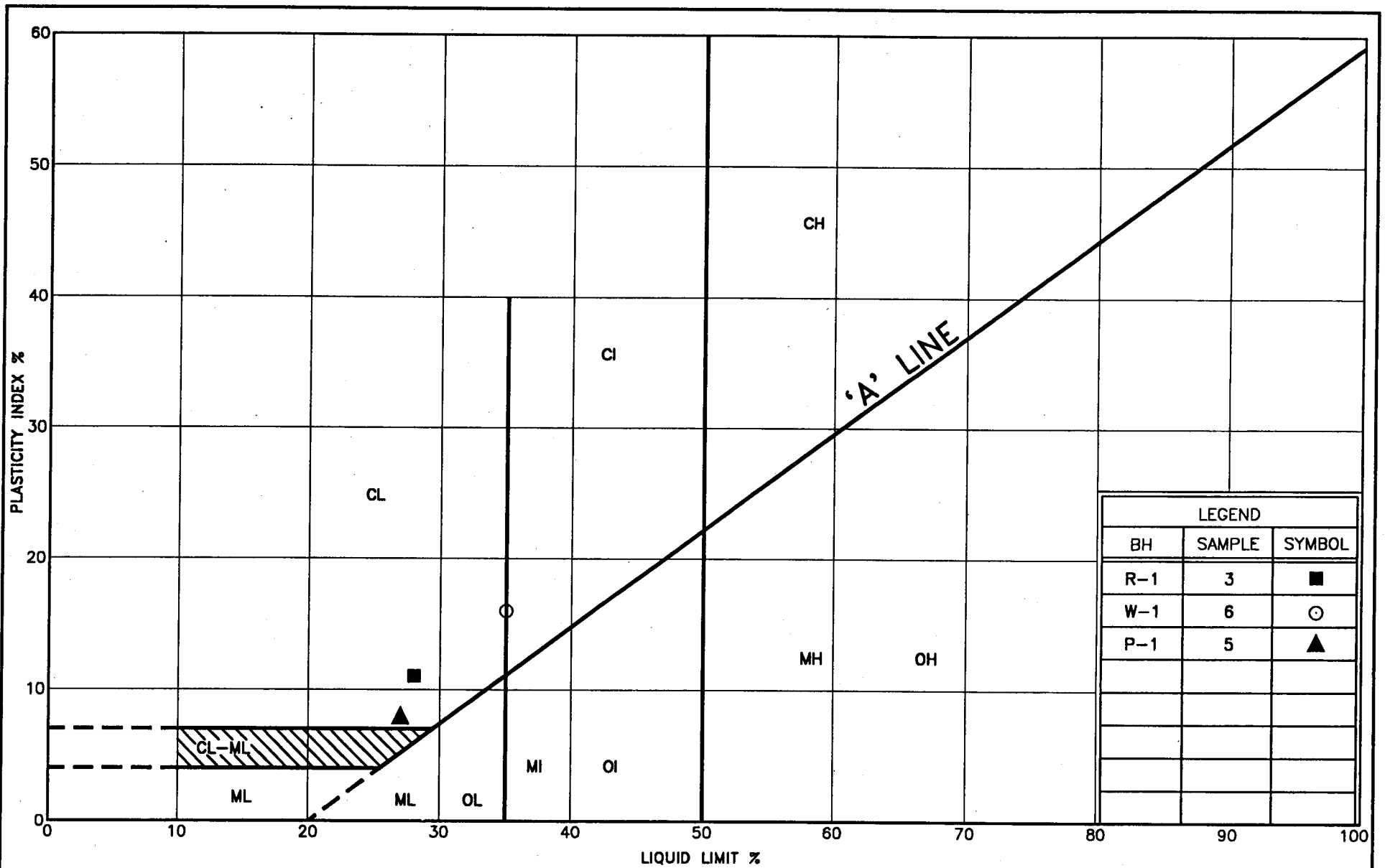
APPENDIX

UNIFIED SOIL CLASSIFICATION SYSTEM

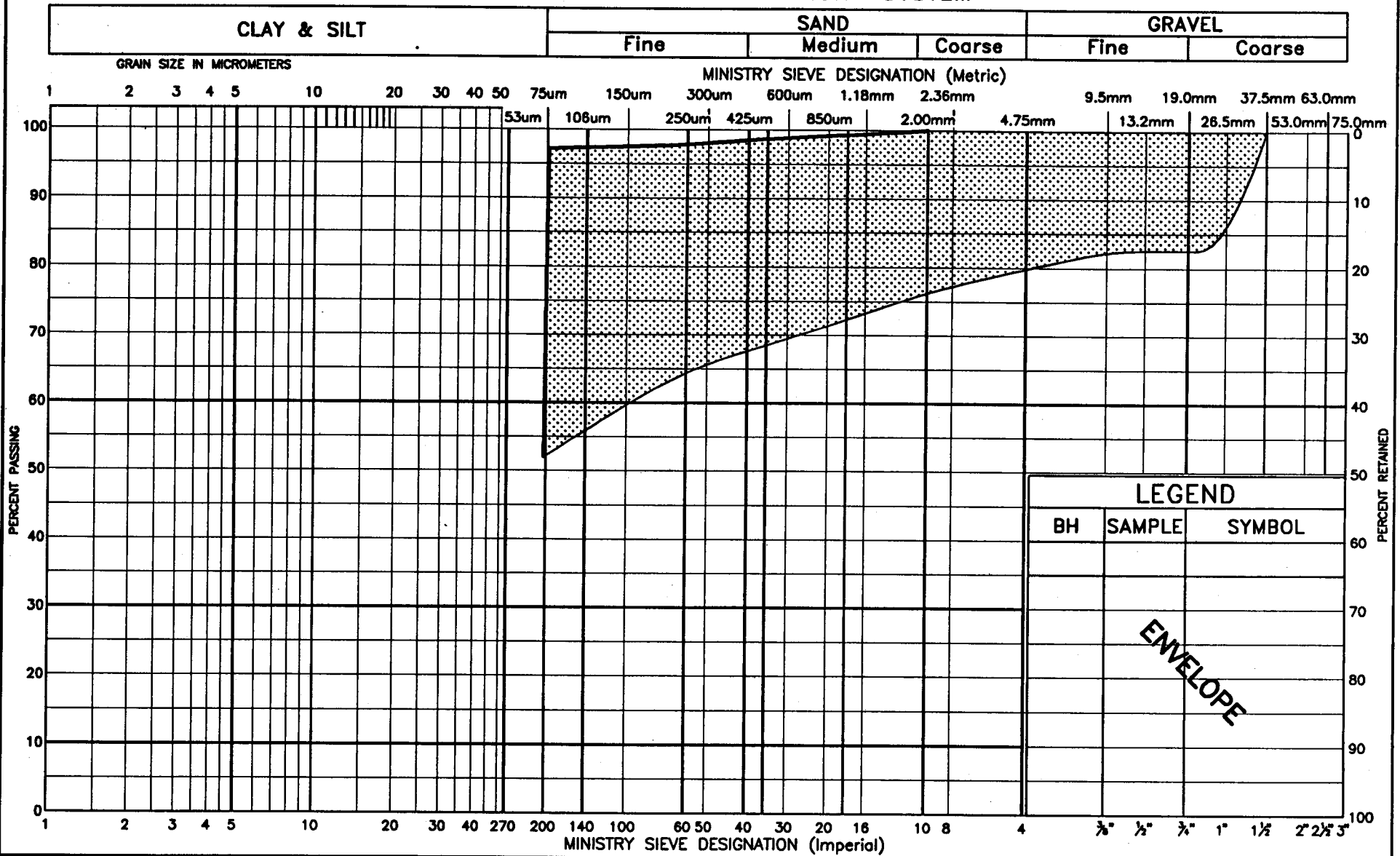


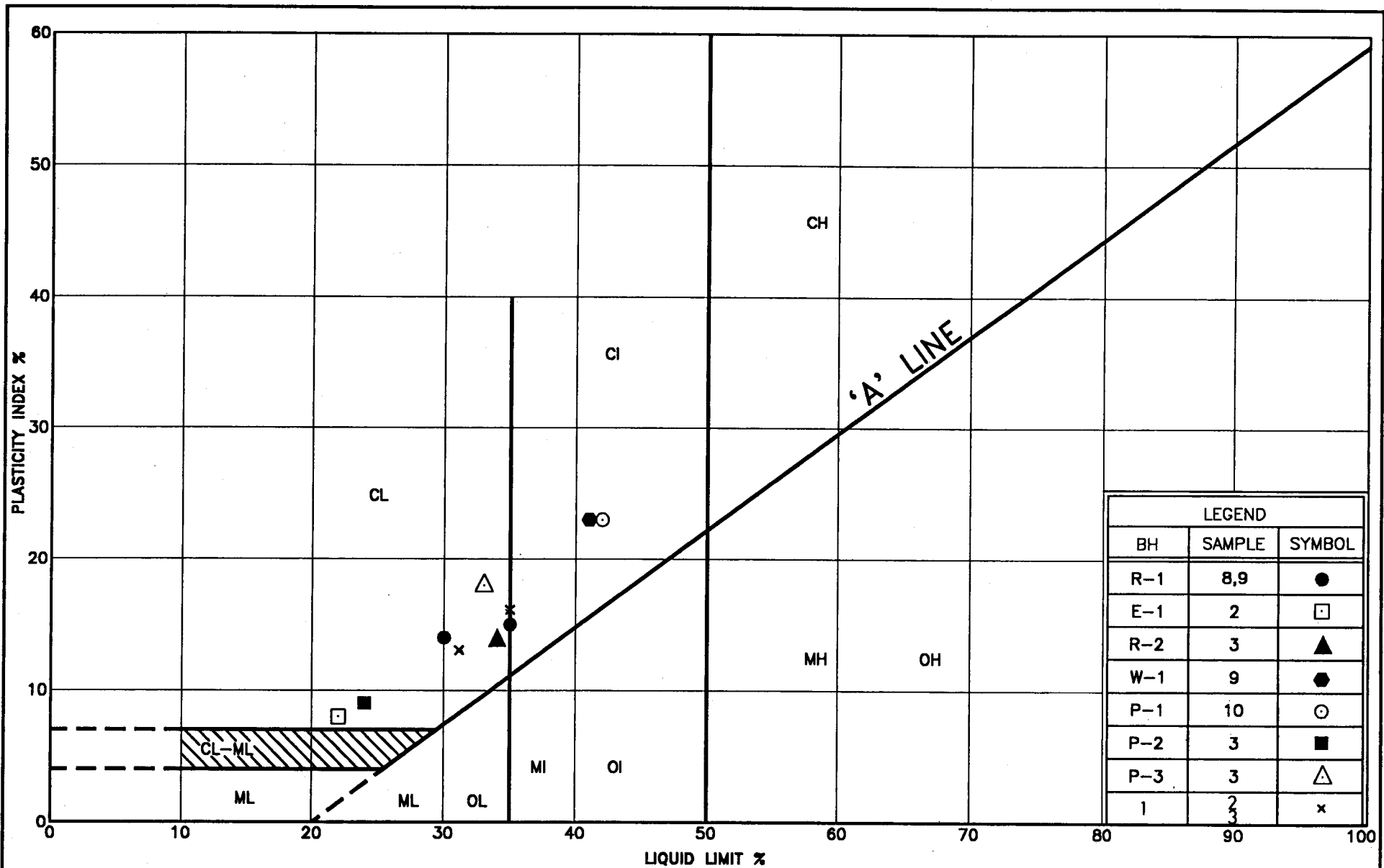
GRAIN SIZE DISTRIBUTION
WEATHERED SHALE FRAGMENTS (FILL MATERIAL)

FIG No 1
WP 54-82-06



UNIFIED SOIL CLASSIFICATION SYSTEM





RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.P. 54-82-06 LOCATION N 4 832 504, E 290 684 ORIGINATED BY _____
 DIST 6 HWY 401 BOREHOLE TYPE Hollow Stem Auger, NXL Core COMPILED BY _____
 DATUM Geodetic DATE 83 08 26-29 CHECKED BY JDM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT 7 KN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa 20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL * LAB VANE 20 40 60 80 100					WATER CONTENT (%) 10 20 30				
192.8	Ground Surface																
0.0	CLAYEY SILT to SILTY CLAY Some Sand Trace to Some Gravel Occ. Sandy silt zones Trace Organics Stiff to Hard (Glacial Till)		1	AS													
			2	SS	10										19.8	0 8 65 27	
			3	SS	44										20.0	0 18 50 32	
189.8			4	SS	70										22.2	11 31 38 20	
2.9			5	SS	100	/0cm									22.4		
	BEDROCK Queenston Shale Highly Weathered		6	SS	110	/17cm											
186.9			7	NX	78 % rec												
5.8	End of Borehole																

RECORD OF BOREHOLE No 4

1 OF 1

METRIC

W.P. 54-82-06 LOCATION N 4 832 550, E 290 780 ORIGINATED BY _____
 DIST 6 HWY 401 BOREHOLE TYPE Hollow Stem Auger COMPILED BY JDM
 DATUM Geodetic DATE 83 08 26-30 CHECKED BY JDM

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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
192.9	Ground Surface																
0.0	Trace Organics		1	AS													
	CLAYEY SILT to SILTY CLAY																
	Some Sand		2	SS	26											20.4	
	Trace to Some Gravel																
	Occ. sandy silt zones																
	Stiff to Hard		3	SS	44											21.4	
190.6	(Glacial Till)																
2.3	BEDROCK		4	SS	73											21.1	
	Queenston Shale																
	Highly Weathered		5	SS	100	/2cm											
188.2																	
4.7	End of Borehole		6	SS	100	/1cm											

RECORD OF BOREHOLE No E-1

1 OF 1

METRIC

W.P. 54-82-06 LOCATION Coords.: N 4 832 535, E 290 793 ORIGINATED BY L.O.
DIST 6 HWY 401 BOREHOLE TYPE Solid Stem Auger, BW Casing, BQ Rock Core COMPILED BY L.O.
DATUM Geodetic DATE 1994 06 28 CHECKED BY B.B.

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			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100									
192.5	Ground Surface																
0.0	CLAYEY SILT TO SILTY CLAY Trace to Some Gravel Some Sand Stiff to Very Stiff (Glacial Till) Brown Red		1	SS	11		192										
190.4			2	SS	21											17 31 (52)	
2.1	BEDROCK Queenston Shale Highly Weathered Slightly Weathered		3	SS	102	/18cm	190										
			4	SS	85	/13cm											
			5	SS	85	/13cm											
188.2			6	RC	REC 79%		188									ROD 0%	
6.3	End of Borehole																

RECORD OF BOREHOLE No P-1

1 OF 1

METRIC

W.P. 54-82-06 LOCATION Coords.: N 4 832 527, E 290 697 ORIGINATED BY L.O.
DIST 6 HWY 401 BOREHOLE TYPE Hollow Stem Auger COMPILED BY L.O.
DATUM Geodetic DATE 1994 06 29 CHECKED BY B.B.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100					WATER CONTENT (%) W _p W W _L 10 20 30				
198.4	Ground Surface																
0.0																	
	WEATHERED SHALE FRAGMENTS Fine Grained to Cobble / Boulder Size Gray Stiff to Hard (Fill Material)		1	SS	11												
			2	SS	12												
			3	SS	19												
			4	SS	46												
			5	SS	10												
			6	SS	13												
193.0																	
5.4	CLAYEY SILT TO SILTY CLAY Some Sand Trace to Some Gravel Stiff to Hard (Glacial Till)		7	SS	8												
			8	SS	11												
			9	SS	17												
			10	SS	16												
	Brown Red																
189.7			11	SS	106												
8.7	BEDROCK Queenston Shale																
189.0	Highly Weathered		12	SS	85												
9.4	End of Borehole																

RECORD OF BOREHOLE No P-2

1 OF 1

METRIC

W.P. 54-82-06 LOCATION Coords.: N 4 832 508, E 290 701 ORIGINATED BY L.O.
 DIST 6 HWY 401 BOREHOLE TYPE Solid Stem Auger, BW Casing, BQ Rock Core COMPILED BY L.O.
 DATUM Geodetic DATE 1994 06 27 CHECKED BY B.B.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					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	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
192.5	Ground Surface													
0.0	CLAYEY SILT TO SILTY CLAY Trace to Some Gravel Some Sand Trace Organics Occ. Silty Sand Zones Stiff to Hard (Glacial Till)		1	SS	9		192							
189.8			2	SS	22									
2.7			3	SS	55		190							20 23 (57)
			4	SS	100	/13cm								
	BEDROCK Queenston Shale Highly Weathered Slightly Weathered		5	RC	REC 59%		188							RQD 0%
			6	RC	REC 95%		186							RQD 13%
185.2														
7.3	End of Borehole													

RECORD OF BOREHOLE No P-3

1 OF 1

METRIC

W.P. 54-82-06 LOCATION Coords.: N 4 832 541, E 290 757 ORIGINATED BY L.O.
 DIST 6 HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY L.O.
 DATUM Geodetic DATE 1994 06 23 CHECKED BY B.B.

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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
192.5	Ground Surface																
0.0	CLAYEY SILT TO SILTY CLAY Trace to Some Gravel Some Sand Stiff to Hard (Glacial Till)		1	SS	12		192										
			2	SS	20		191										
189.8	Brown Red		3	SS	100	/29cm	190										1 10 (89)
2.7	BEDROCK Queenston Shale Highly Weathered		4	SS	105	/12cm	189										
			5	SS	97	/6cm	189										
			6	SS	85	/6cm	188										
187.1			7	SS	89	/8cm											
5.4	End of Borehole																

RECORD OF BOREHOLE No P-4

1 OF 1

METRIC

W.P. 54-82-06 LOCATION Coords.: N 4 832 527, E 290 761 ORIGINATED BY L.O.
 DIST 6 HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY L.O.
 DATUM Geodetic DATE 1994 06 24 CHECKED BY B.B.

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 (%)		
								SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL * LAB VANE 20 40 60 80 100										10 20 30		
192.5	Ground Surface																			
0.0	CLAYEY SILT TO SILTY CLAY Trace Sand Trace Gravel Occ. Silty Sand Zones Firm to Hard (Glacial Till)						192													
			1	SS	6															
			2	SS	20															
189.9	Some Sand		3	SS	57		190													
2.8			4	SS	90		/15cm													
	BEDROCK Queenston Shale Highly Weathered		5	SS	90		/13cm													
		6	SS	88	/15cm	188														
187.1		7	SS	100	/10cm															
5.4	End of Borehole																			

RECORD OF BOREHOLE No R-1

1 OF 1

METRIC

W.P. 54-82-08 LOCATION Coords.: N 4 832 487, E 290 815 ORIGINATED BY L.O.
 DIST 6 HWY 401 BOREHOLE TYPE Hollow Stem Auger COMPILED BY L.O.
 DATUM Geodetic DATE 1994 06 30 CHECKED BY B.B.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa 20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL * LAB VANE					WATER CONTENT (%) 10 20 30				
199.3	Ground Surface																
0.0						DRY *											
			1	SS	13												
			2	SS	19												
	WEATHERED SHALE FRAGMENTS Fine Grained to Cobble / Boulder Size Grey Stiff to Hard (Fill Material)		3	SS	9											11 44 29 16	
			4	SS	55												
			5	SS	37												
			6	SS	8												
	CLAYEY SILT Trace to Some Gravel Some Sand (Fill Material)		7	SS	10												
192.9			8	SS	11											6 22 (72)	
6.4	Trace Organics		9	SS	42											5 27 (68)	
	CLAYEY SILT TO SILTY CLAY Some Sand Trace to Some Gravel Stiff to Hard (Glacial Till)		10	SS	86												
191.3			11	SS	100	/27cm											
8.0	BEDROCK Queenston Shale Highly Weathered		12	SS	95	/23cm											
189.5																	
9.8	End of Borehole																

RECORD OF BOREHOLE No R-2

1 OF 1

METRIC

W.P. 54-82-06 LOCATION Coords.: N 4 832 566, E 290 836 ORIGINATED BY L.O.
 DIST 6 HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY L.O.
 DATUM Geodetic DATE 1994 06 23 CHECKED BY B.B.

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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100	W _p	W	W _L		
194.1	Ground Surface																
0.0	CLAYEY SILT TO SILTY CLAY Some Sand Trace to Some Gravel Red Trace Organics Very Stiff to Hard (Glacial Till)		1	SS	25												
			2	SS	50												
191.4			3	SS	98												
2.7			4	SS	100	/15cm											
			5	SS	100	/9cm											
	BEDROCK Queenston Shale Highly Weathered		6	SS	100	/15cm											
			7	SS	100	/8cm											
			8	SS	110	/14cm											
187.1			9	SS	105	/13cm											
7.0	End of Borehole																

RECORD OF BOREHOLE No R-3

1 OF 1

METRIC

W.P. 54-82-06 LOCATION Coords.: N 4 832 583, E 290 897 ORIGINATED BY L.O.
 DIST 6 HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY L.O.
 DATUM Geodetic DATE 1994 06 23 CHECKED BY B.B.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT 7 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	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
194.4	Ground Surface													
0.0														
	Trace Organics		1	SS	21		194							
	SILTY SAND TO SAND													
	Trace to Some Gravel		2	SS	42									
	Brown													
	Compact to Very Dense													
	Glacial Till Zone		3	SS	86		192							
191.4														
3.0			4	SS	76									
	BEDROCK		5	SS	112	/23cm								
	Queenston Shale													
	Highly Weathered		6	SS	112	/25cm	190							
			7	SS	110	/8cm								
			8	SS	110	/11cm								
187.5			9	SS	102	/8cm	188							
6.9	End of Borehole													

RECORD OF BOREHOLE No W-1

1 OF 1

METRIC

W.P. 54-82-06 LOCATION Coords.: N 4 832 515, E 290 665 ORIGINATED BY L.O.
 DIST 6 HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY L.O.
 DATUM Geodetic DATE 1994 06 27 CHECKED BY B.B.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)				
198.6	Ground Surface					20 40 60 80 100											
0.0	WEATHERED SHALE FRAGMENTS Fine Grained to Cobble / Boulder Size Grey Stiff to Hard (Fill Material)		1	SS	10												
			2	SS	14												
			3	SS	9												
			4	SS	19												
			5	SS	53												
			6	SS	19												
			7	SS	88												
			8	SS	16												
191.9	CLAYEY SILT TO SILTY CLAY Some Sand Trace to Some Gravel Very Stiff to Hard (Glacial Till) Brown Red		9	SS	19												
6.7			10	SS	44												
190.1	BEDROCK Queenston Shale Highly Weathered Slightly Weathered		11	SS	104	/25cm											
8.5			12	SS	85	/9cm											
			13	SS	80	/13cm											
			14	RC	REC 70%												
187.1	End of Borehole																
11.5																	

ROCK CORE DESCRIPTION
WP 54-82-06

CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
P-2 (N)	5	4.14-5.74	59	0	4.14-7.34	SHALE, greyish red, with interbedded greenish grey SILTSTONE (17%); very fine grained; very weak to weak; unweathered to slightly weathered; fractures extremely close to close spaced, flat to near vertical, planar to undulating, smooth.
	6	5.74-7.34	95	13		
W-1 (N)	14	9.91-11.51	70	0	9.91-11.51	SHALE, greyish red, with interbedded greenish grey SILTSTONE (5%); very fine grained; very weak to weak; unweathered to slightly weathered; fractures extremely close to close spaced, flat to near vertical, planar to undulating, smooth.
E-1 (N)	6	4.70-6.30	79	0	4.70-6.30	SHALE, greyish red, with interbedded greenish grey SILTSTONE (15%); very fine grained; very weak to weak; unweathered to slightly weathered; fractures extremely close to close spaced, flat to near vertical, planar to undulating, smooth.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

Note: Depths are approximated where core recovery is less than 100%
Logged by: DAW, Soils and Aggregates Section

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 (RQD), 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

MECHANICAL PROPERTIES OF SOIL

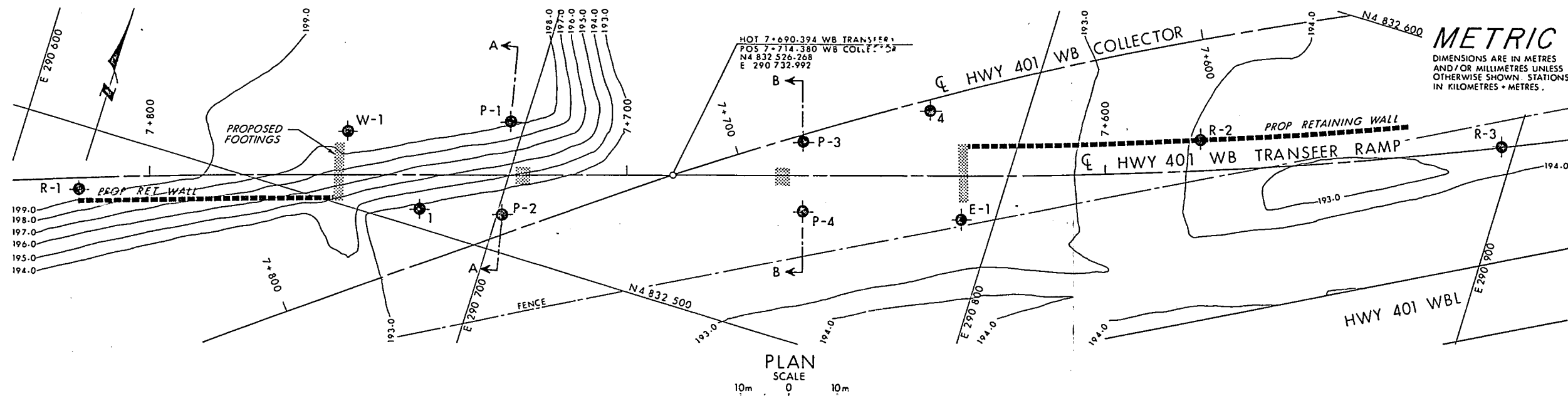
m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_a	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
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 = $\frac{c_u}{\tau_r}$

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

PHYSICAL PROPERTIES OF SOIL

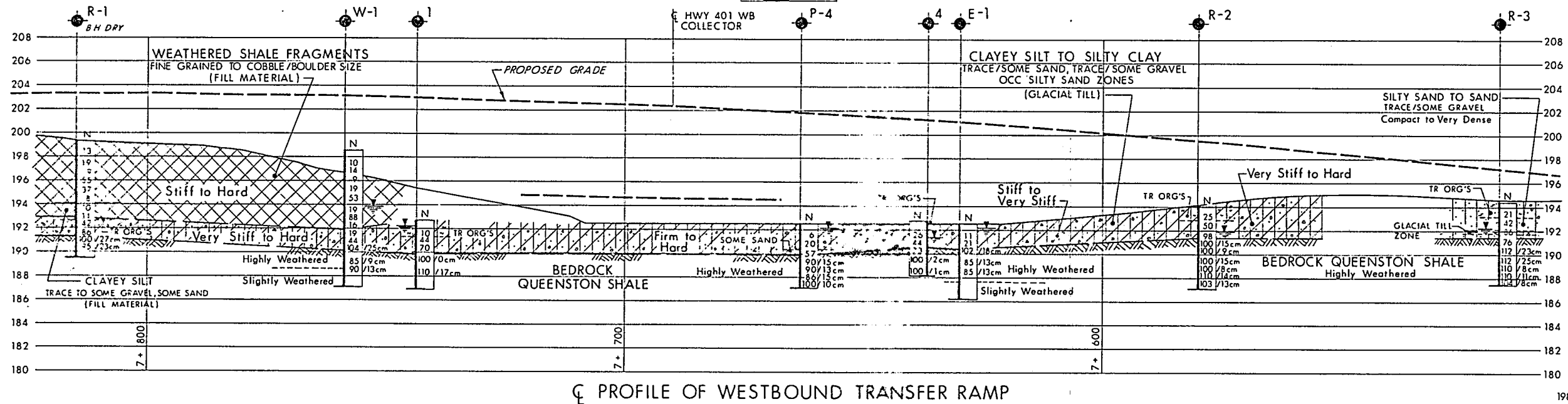
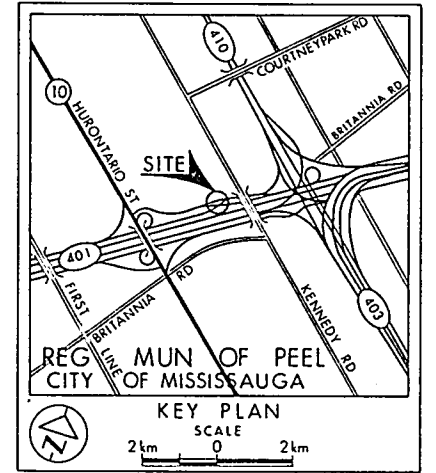
ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{\min}	1, %	VOID RATIO IN DENSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$
ρ_w	kg/m^3	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m^3	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m^3	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	e_{\max}	1, %	VOID RATIO IN LOOSEST STATE	j	kn/m^3	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						



CONT No
WP No 54-82-06

HWY 401 WB COLLECTORS & WB
TRANSFER RAMP TO RAMP E-N/S

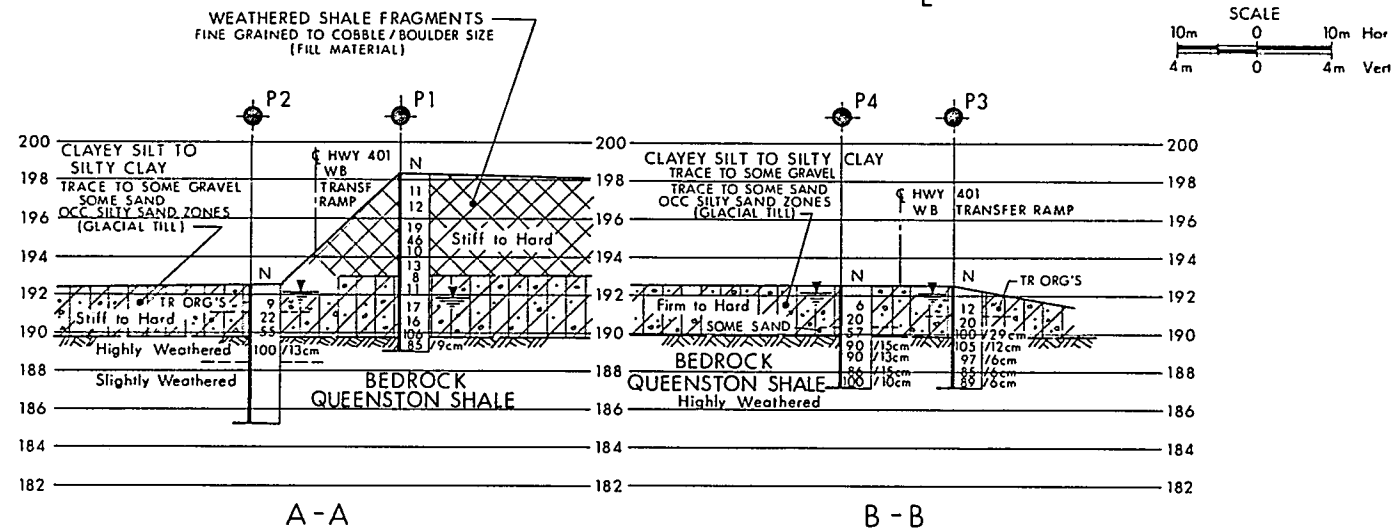
BORE HOLE LOCATIONS & SOIL STRATA



LEGEND

- Bore Hole
- Dynamic Cone Penetration Test (Cone)
- Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- WL at time of investigation 1983 08 and 1994 06

No	ELEVATION	CO-ORDINATES NORTH	EAST
1	192.8	4 832 504	290 684
4	192.9	4 832 550	290 780
E-1	192.5	4 832 535	290 793
P-1	198.4	4 832 527	290 697
P-2	192.5	4 832 508	290 701
P-3	192.5	4 832 541	290 757
P-4	192.5	4 832 527	290 761
R-1	199.3	4 832 487	290 615
R-2	194.1	4 832 566	290 836
R-3	194.4	4 832 583	290 897
W-1	198.6	4 832 515	290 665



NOTE: The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen Cond.

REV.	DATE	BY	DESCRIPTION
1			

Geocres No 30M12-223

HWY No 401	SUBMD BB	CHECKED	DATE 1994 10 13	DIST 6
DRAWN DT	CHECKED	APPROVED		SITE 24-682
				DWG 548206-A



MEMORANDUM



To: V. Boehnke, P.Eng.
Head, Structural Section
Central Region

Date: June 15, 1994

Attn: N. Potak, P.Eng
Sr. Structural Engineer

From: Foundation Design Section Tel: (416) 235-3731
Room 315, Central Bldg. Fax: (416) 235-5240

Re: Preliminary Foundation Recommendations for
Hwy 401 WB Collector/Transfer to Ramp E-NS
Hwy 401 Widening betw'n Hwys 401/403 and First Line West
W.P. 54-82-06, Site 24-682, District 6

A foundation investigation has been completed at the above-mentioned location. This memo outlines the general subsurface conditions encountered at the site and the preliminary foundation recommendations for the proposed transfer ramp structure and adjoining retaining walls.

General Site and Subsurface Conditions

The fieldwork was carried out to the north of the present westbound lanes of Highway 401, approximately 500 m east of the Highway 10 underpass structure. The site is located in the City of Mississauga. Physiographically, it is located in the Peel Plain that is characterized by glacial overburden overlying bedrock.

The borings carried out revealed a fill area to the west end of the site composed of shale bedrock fragments excavated from the Highway 401/403/410 interchange. It ranges in thickness from 5.4 m to 6.7 m at the borehole locations. Elsewhere, relatively shallow overburden composed of clayey silt to silty clay glacial till was encountered, varying in thickness from 2.1 m to 3.0 m from the ground surface. Weathered shale bedrock of the Queenston Formation was identified in all the borings. The glacial till/weathered bedrock interface ranges in elevation from 189.7 to 191.4 across the site.

Discussion and Recommendations

It is proposed to construct a three span (38 m, 55 m, 38 m) voided post-tensioned structure. Retaining walls, N/E and S/W, are required to accomodate the grade differences between the westbound collector lanes and the westbound transfer ramp that intersect at a skew of approximately 18°. The westbound collector, the westbound transfer ramp and separating structure will be constructed at or above existing ground elevation.

Structure Foundations

Abutments

The abutments to the structure should be founded in bedrock. At this site, shallow foundations or caissons could be considered.

Shallow Foundations

The West Abutment footing may be founded at or below elevation 189.8. The East Abutment footing may be founded at or below elevation 190.3. The recommended design values for spread footings on the weathered shale bedrock, as per OHBDC 3rd Ed., are as follows:

Factored Bearing Resistance at ULS	1 500 kPa
Bearing Resistance at SLS	will not govern

Caisson Foundations

As an alternative to spread footings, caissons may be considered. This would reduce the amount of excavation required at the West Abutment for a footing on bedrock. The following recommendations apply for caissons socketed into the weathered shale:

	<u>West Abutment</u>	<u>East Abutment</u>
Est. Base of Caisson Elev.	188.8	189.3
Factored Resistance @ U.L.S.	2 200 kPa	2 200 kPa
Axial Resistance @ S.L.S.	will not govern	will not govern

The depth of socketing should be equal to twice the caisson diameter.

It is expected that the caissons can be installed without liners and that any water encountered can be removed from the excavated caisson by pumping prior to the placement of concrete.

West Pier and East Pier

Similar recommendations may be applied at the pier locations.

Shallow Foundations

Spread footings may be founded at or below the following elevations:

West Pier	El. 189.7 m
East Pier	El. 189.8 m

The recommended design values for spread footings on the weathered shale bedrock as per OHBDC 3rd Ed. are as follows:

Factored Bearing Resistance at ULS	1 500 kPa
Bearing Resistance at SLS	will not govern

Caisson Foundations

Again, to reduce the amount of excavation of the existing shale fill, short caissons may be considered.

The following recommendations apply for caissons socketed into the weathered shale:

	<u>West Pier</u>	<u>East Pier</u>
Est. Base of Caisson Elev.	188.7	188.8
Factored Resistance @ U.L.S.	2 200 kPa	2 200 kPa
Axial Resistance @ S.L.S.	will not govern	will not govern

The depth of socketing should be equal to twice the caisson diameter.

It is expected that the caissons can be installed without liners and that any water encountered can be removed from the excavated caisson by pumping prior to the placement of concrete.

Retaining Walls

Retaining Wall S/W

Retaining Wall S/W is approximately 55 m long and decreases in height with an increasing grade to the west. Hence, a stepped footing arrangement should be considered. Its foundation will be located within or above the weathered shale fill.

Retaining Wall N/E

Retaining Wall N/E is approximately 95 m in length. The retaining wall footing will be founded on or above glacial till and will also require stepping.

Conventional Retaining Walls

For footings within the weathered shale fill, on the clayey silt glacial till, or in a fill, it is recommended that a granular pad with minimum thickness of 0.5 m be placed a minimum of 1.2 m below the final ground elevation.

Where fill is required, the surficial material containing organics should be removed for the area of the footing and replaced with compacted granular to the base of the footing elevation. For footings on a granular pad the following design values are recommended:

Factored Bearing Resistance at ULS	375 kPa
Bearing Resistance at SLS	250 kPa

Granular fill should be compacted to a minimum 95% SPDD.

For calculation of resistance to sliding, an unfactored friction coefficient of $\phi = 30^\circ$ may be assumed between concrete and granular fill

Retained Soil System Walls

Proprietary walls may be considered for all three retaining walls. If retained soil systems are used, the proposal should be forwarded to the MTO RSS Committee c/o George Al-Bazi, Structural Office.

Design considerations for construction excavations and dewatering are the responsibility of the proprietary RSS company and shall be in accordance with the requirements of the Occupational Health and Safety Act. Fully detailed proposals should be submitted to the Foundation Design Section for review a minimum of 10 working days prior to construction.

General Recommendations for Spread Footings

No dewatering concerns are anticipated for the footing excavations. It is expected that any seepage into the excavation can be relieved by sump pumping techniques.

Due to the rapid disintegration of shale bedrock when exposed, it is recommended that a 150 mm thick working slab of concrete be poured within 8 hours of the completion of footing excavation. In addition, shale bedrock exposed on the sides of excavations should be protected with tarpaulins.

A 1.2 m earth cover is required for all footings. It is preferable to provide a minimum of 1.2 m of earth cover for the footings founded on shale bedrock because of the friable nature of the weathered shale.

The sliding resistance between the base of the footing and the weathered shale may be computed using an unfactored friction coefficient of $\tan 22^\circ$.

Lateral Earth Pressure

Backfill to the abutments should consist of granular material in accordance with MTO Standard Special Provision 109F03. Computation of earth pressures should be carried out as per Section 6-7.4.5 of the OHBDC, 3rd Ed.. Design parameters of the acceptable granular backfill are as follows.

	<u>Granular "A"</u>	<u>Granular "B"</u>
Angle of Internal Friction (ϕ)	35°	30°
Unit Weight (kN/m^3)	22.8	21.2

An active condition may be assumed provided that soil movement behind the wall is permitted.

Construction Considerations

A NSSP for caisson installation, developed by the Foundation Design Section, should be incorporated into the contract package.

Temporary excavations within the weathered shale fill and overburden may be carried out at 1.5H:1V slopes or flatter. Temporary excavations in the shale bedrock may be as steep as 1H:3V to a maximum depth of 6.0 m before incorporating a 2.0m wide mid-height berm. Sides of


excavations exposing shale bedrock should be protected with a tarpaulin to minimize disintegration of the shale.

Across the site, cohesive glacial till overlies shale bedrock. The Contractor should be made aware that cobbles/boulders may be encountered during excavation and during placement of foundations. In addition, it is likely that cobble and boulder sized fragments of weathered shale or siltstone will be encountered during excavations within the weathered shale fill.

Slope Stability

The proposed slopes will be stable at 2H:1V. Where embankments exceed 6.0 m in height, a 2.0 m wide mid-height bench should be incorporated.

If there any questions or comments regarding these recommendations, please advise. The complete report will be distributed once laboratory testing and drafting is completed.



Betty Bennett, P.Eng.
Sr. Foundation Eng.
(Acting)