



**FOUNDATION INVESTIGATION AND DESIGN REPORT
for
JOSHUA'S CREEK ARCH CULVERT EXTENSION
SITE NO. 10-140/C, QUEEN ELIZABETH WAY AND HIGHWAY 403
TOWN OF OAKVILLE
REGIONAL MUNICIPALITY OF HALTON, ONTARIO
G.W.P. 2163-10-00**

PETO MacCALLUM LTD.
165 CARTWRIGHT AVENUE
TORONTO, ONTARIO
M6A 1V5
Phone: (416) 785-5110
Fax: (416) 785-5120
Email: toronto@petomaccallum.com

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PML Ref.: 14TF005
Index No.: 037FIR and 038FDR
GEOCRES No.: 30M5-314
June 19, 2015



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for
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SITE NO. 10-140/C, QUEEN ELIZABETH WAY AND HIGHWAY 403
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TABLE OF CONTENTS

1. INTRODUCTION	1
2. SITE DESCRIPTION AND GEOLOGY	1
3. INVESTIGATION PROCEDURES	2
4. SUMMARIZED SUBSURFACE CONDITIONS.....	4
4.1 Topsoil	5
4.2 Fill.....	5
4.3 Clayey Silt to Silty Clay Till	6
4.4 Bedrock.....	6
4.5 Groundwater	7
5. CLOSURE	8

Table A – Rock Core Description

Explanation of Terms Used in Report

Record of Borehole Sheets

Drawing JC-1 – Borehole Locations

Drawing JC-2 – Soil Strata

Figure JC-GS-1 – Grain Size Distribution for Silty Clay Fill

Figure JC-GS-2 – Grain Size Distribution for Clayey Silt to Silty Clay Till

Figure JC-PC-1 – Plasticity Chart for Silty Clay Fill

Figure JC-PC-2 – Plasticity Chart for Clayey Silt to Silty Clay Till

Appendix FIR-A – Relevant GEOCRETS Data

Appendix FIR-B – Site Photographs

Appendix FIR-C – Rock Core Photographs

FOUNDATION INVESTIGATION REPORT

for

Joshua's Creek Arch Culvert Extension
Site No. 10-140/C, Queen Elizabeth Way and Highway 403
Town of Oakville
Regional Municipality of Halton, Ontario
GWP 2163-10-00

1. INTRODUCTION

This report summarizes the results of the foundation investigation required for the detail design of the Joshua's Creek Arch culvert extension and associated retaining walls. The study was carried out by Peto MacCallum Ltd. (PML) for Stantec Consulting Ltd. (Stantec) on behalf of the Ministry of Transportation of Ontario (MTO).

The existing Joshua's Creek Arch culvert is located on the Queen Elizabeth Way (QEW) at Station 23+223 in the Town of Oakville, Regional Municipality of Halton. This report provides subsurface information encountered at the existing culvert site.

Existing foundation/geotechnical information relevant to Joshua's Creek has been obtained from the MTO GEOCRES library. The report and drawings from MTO GEOCRES No. 30M5-112 were reviewed for pertinent information pertaining to the project site. The Foundation Investigation portion of the previous report is appended for reference in Appendix FIR-A.

All elevations in this report are expressed in meters.

2. SITE DESCRIPTION AND GEOLOGY

The Joshua's Creek culvert is located approximately 160 m south of the Ford Drive underpass of the Queen Elizabeth Way. The site is about 2 km southwest of Peel Regional Road 19, otherwise known as Winston Churchill Boulevard, the border between the City of Mississauga and the Town of Oakville. Site photographs are included in Appendix FIR-B.



The project area lies within the physiographic region known as the South Slope. The South Slope is bounded by the Peel Plain to the north and the Iroquois Plain to the south. The physiographic region extends from the Niagara escarpment to the Trent River and covers approximately 2,435 square kilometers. The South Slope is characterized by glacial till deposits overlying shale bedrock of the Queenston and Dundas Formations. (L.J. Chapman and D.F. Putnam, *The Physiography of Southern Ontario*, 3rd Edition, 1984). Locally, the Queenston Formation shale interbedded with limestone bands is encountered at relatively shallow depths underlain by clayey silt till deposits.

Within the QEW/Highway 403 corridor near the project site, land use comprises vacant land required and consumed by the QEW and Highway 403 right of ways. Outside of the highway right of ways, the land use is comprised primarily of commercial and light industrial buildings and businesses. The Ford Motor Company occupies the majority of the land to the south of the QEW/Highway 403.

Joshua's Creek flows in a west to east direction at the culvert location, eventually discharging into Lake Ontario.

3. INVESTIGATION PROCEDURES

The field work for this study was carried out during the period of January 12 to January 19, 2015 and comprised 5 boreholes drilled to depths ranging from 0.9 m to 8.7 m at the locations shown on Drawing JC-1, appended.

The target termination criterion of 100 blows per 0.3 m penetration or refusal on bedrock was met for all five of the boreholes located near the proposed culvert extension and proposed retaining walls, with two boreholes cored into bedrock to give information pertaining to the underlying bedrock.



Further details are summarized in the following table:

LOCATION	BOREHOLE No.	DEPTH (m)		
		AUGER	ROCK CORE	TOTAL
Proposed Culvert Extension	C-1	1.5	3.1	4.6
Proposed Culvert Extension	C-2	4.8	3.9	8.7
North Retaining Wall	RW-6	2.5	--	2.5
South Retaining Wall	RW-7	6.3	--	6.3
North Retaining Wall	RW-8	0.9	--	0.9

The locations of the boreholes were selected by PML allowing for drill rig accessibility. The ground surface elevations for all five boreholes were established by Callon Dietz Incorporated.

All five boreholes were advanced using continuous flight hollow stem augers through the soil cover. Boreholes C-1, RW-6 and RW-8 were completed with a track-mounted D-120 drill rig while boreholes C-2 and RW-7 were drilled using a truck-mounted D-120 drill rig. All equipment was supplied and operated by a specialist drilling contractor, working under the full-time supervision of a PML field supervisor. Boreholes C-1 and C-2 were extended 3.1 and 3.9 m into bedrock respectively, using HQ diamond rock coring equipment supplemented by wash boring techniques.

Representative soil samples were recovered at 0.75 and 1.5 m depth intervals using the standard penetration test method. Standard penetration tests were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata. Soils were identified in accordance with the MTO soil classification manual procedures. Observations of auger grinding were recorded and included larger particle sizes such as cobbles, boulders and/or bedrock fragments.

The recovered soil samples were returned to the PML laboratory in Toronto for detailed visual examination, laboratory testing and classification. The laboratory testing program for Joshua's Creek foundation investigation included the following tests:

- Natural moisture content determinations (12)
- Atterberg Limits (4)
- Grain size distribution analyses (4)



The groundwater conditions in the boreholes were assessed during drilling by visual examination of the soil, the sampler and drill rods as the samples were retrieved and, where encountered, by measuring the groundwater level in the open boreholes. However, groundwater observations were minimal due to the frozen winter conditions present during the investigation.

The boreholes were backfilled in accordance with the MTO guideline and MOE Reg. 903 for borehole abandonment.

The laboratory grain size distribution envelopes for the investigation for the fill material and native till are presented in Figure JC-GS-1 and Figure JC-GS-2 respectively. The results of the Atterberg Limits tests for the fill material and native till are presented in Figure JC-PC-1 and Figure JC-PC-2 respectively. All of the test results are summarized on the Record of Borehole sheets.

Two rock core specimens were taken from boreholes C-1 and C-2 and the results are summarized in section 4.4 of this report and shown on the Record of Borehole sheets.

4. SUMMARIZED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole sheets for details of the subsurface conditions including soil classifications, bedrock descriptions, inferred stratigraphy, boundary elevations, standard penetration test data and groundwater observations. The results of laboratory Atterberg limits testing, grain size distribution analyses and moisture content determinations are also shown on the Record of Borehole sheets.

The borehole locations, stratigraphic profile and cross-sections prepared from the borehole data are shown on Drawings JC-1 and JC-2. The boundaries between soil strata have been established at the borehole locations only. Between and beyond the boreholes, the soil boundaries are assumed and may vary.

The subsurface stratigraphy revealed in the boreholes generally comprised of topsoil underlain by mixed fill layers over the native clayey silt to silty clay glacial till. Cobbles were encountered within



the fill material while weathered bedrock (shale) fragments were encountered in the clayey silt to silty clay glacial till deposit. The glacial till was underlain by relatively flat lying soft to medium strength shale bedrock with interbedded limestone layers. Groundwater was only observed in one borehole due to the frozen winter conditions.

The strata encountered are summarised below.

4.1 Topsoil

A 100 to 300 mm thick topsoil unit was encountered surficially in all five boreholes and extended to elevation 120.2, 123.5, 122.3, 125.1 and 121.8 in boreholes C-1, C-2, RW-6, RW-7 and RW-8 respectively.

4.2 Fill

Organic inclusions were encountered throughout the cohesive and non cohesive fill material in all five boreholes drilled for the Joshua's Creek culvert extension.

Borehole RW-7 encountered a 0.9 m thick non cohesive silty sand fill that extended from 0.2 to 1.1 m, (elevation 124.2) underlying the topsoil deposit. Below the non cohesive fill, a 0.3 m cohesive clayey silt fill was contacted. The total fill height encountered in borehole RW-7 was 1.2 m, which extends to elevation 123.9.

Underlying the topsoil deposits in boreholes C-1, C-2, RW-6 and RW-8, cohesive fill material was encountered. The thickness of the clayey silt to silty clay fill deposit varied widely from 0.4 to 2.8 m and extended to 0.7, 3.0, 2.5 and 0.9 m (elevation 119.8, 120.7, 119.9 and 121.1) in boreholes C-1, C-2, RW-6 and RW-8 respectively.

N values of the cohesive fill typically ranged from 7 to 15 blows, indicating firm to stiff consistency. A random high N value of 29 reflected the presence of weathered shale fragments within the fill in borehole RW-7. Similarly, cobbles were encountered in the cohesive fill in borehole C-2.

The results of the grain size distribution analyses for the one sample tested of the clayey silt to silty clay with sand with gravel fill is included in Figure JC-GS-1. The Atterberg plasticity chart for



the fill material is presented in Figure JC-PC-1. The liquid and plastic limits of the clayey silt to silty clay fill sample were 39 and 23, respectively, with the corresponding plasticity index 16 for soil sample 2 of borehole RW-6. Within the clayey silt to silty clay fill of all five boreholes, the moisture content determinations ranged from 10 to 33%, corresponding to a moist soil condition.

The fill material extended to bedrock at 2.5 and 0.9 m in boreholes RW-6 and RW-8 (elevation 119.9 and 121.1) respectively.

4.3 Clayey Silt to Silty Clay Till

A 0.8 to 4.9 m thick hard clayey silt to silty clay glacial till deposit was contacted below the cohesive fill at 0.7, 3.0 and 1.4 m (elevation 119.8, 120.7 and 123.9) and terminated on shale bedrock at 1.5, 4.8 and 6.3 m (elevation 119.0, 118.9 and 119.0) in boreholes C-1, C-2 and RW-7 respectively. Weathered shale fragments were encountered throughout the till deposit.

N values of the till material ranged from 35 to 50 blows per 5 cm penetration indicating hard consistency. The results of Atterberg limits testing and grain size distribution analyses conducted on three samples of the till deposit are presented in respective Figures JC-PC-2 and JC-GS-2. The clayey silt to silty clay till had a liquid limit that ranged between 31 and 40, a plastic limit that ranged between 20 and 23 and a corresponding plasticity index ranging between 11 and 17. The moisture content of the glacial till was determined to range between 10 to 15%, well below the plastic limit indicating a heavily over consolidated cohesive deposit of low to medium plasticity.

4.4 Bedrock

Bedrock was contacted in all five boreholes C-1, C-2, RW-6, RW-7 and RW-8 at 1.5, 4.8, 2.5, 6.3 and 0.9 m (elevation 119.0, 118.9, 119.9, 119.0 and 121.1), respectively. The slight to highly weathered bedrock comprises a grey to dark grey soft to medium strength shale bedrock with interbedded limestone.

The measured core recovery varied between 22 and 100%. The RQD determined from the rock cores ranged between 0 to 70%, thus indicating very poor to fair quality rock. The upper 1.6 m



core sample in borehole C-2 had very poor rock quality (RQD ranged from 0 to 33%) and a measured core recovery between 22 and 100%.

Weathered bedrock was exposed within the creek bed of Joshua's Creek. Detailed descriptions of the rock cores retrieved from boreholes C-1 and C-2 is given in Table A, appended. Photographs of the rock cores are shown in Appendix FIR-C.

4.5 Groundwater

In the process of augering, water was detected in borehole RW-6 at 2.2 m (elevation 120.2). The groundwater was flowing on top of the bedrock which was encountered in borehole RW-6 at 2.5 m (elevation 119.9).

Upon completion of drilling, groundwater was not measurable in borehole RW-6. No water was observed in boreholes C-1, C-2, RW-7 and RW-8 during or upon completion of drilling. The absence of groundwater in the remaining four boreholes can be attributed to the frozen winter conditions present on site during the investigation.

The groundwater level at the site is governed by the water level in Joshua's Creek. The water level of Joshua's Creek was taken as the top of the ice surface relative to borehole C-1 at elevation 120.2 m on January 19, 2015. The groundwater levels are subject to seasonal fluctuations and precipitation patterns.



5. CLOSURE

The field work was carried out under the supervision of Mr. S. Aziz and direction of Mr. K. R. Daly, B.Eng., EIT. The equipment was supplied by Altech Ltd Drilling and Investigative Services. The laboratory testing of the selected samples was carried out in the PML laboratory in Toronto.

This Foundation Investigation Report was prepared by Mr. K. R. Daly, B.Eng, EIT and reviewed by Mr. B. R. Gray, MEng, P. Eng., Principal Consultant and Mr. D. Dundas, P. Eng., Senior Geotechnical Engineer. Mr. C. M. P. Nascimento, P.Eng., Project Manager and MTO Designated Principal Contact conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

A handwritten signature in blue ink, reading "Kyle Daly".

Kyle R. Daly, B.Eng, EIT
Project Supervisor, Geotechnical Services



David H. Dundas, P. Eng.
Senior Engineer, Geotechnical Services



Carlos M.P. Nascimento, P.Eng.
Project Manager and
MTO Designated Principal Contact

KD/CN/BRG:kd-jk



TABLE A – ROCK CORE DESCRIPTIONS

CORE RECOVERY					CORE DESCRIPTION	
HOLE NO.	CORE NO.	DEPTH (m)	RECOVERY (%)	RQD (%)	DEPTH (m)	DESCRIPTION
BH C-1	1	1.5 ⁽¹⁾ – 2.1	67	38	1.5 – 4.6	SHALE WITH INTERBEDDED LIMESTONE: Grey, fine grained, occasional interbedded grey limestone (effervesces freely in dilute (5%) hydrochloric acid), soft to medium strength, bedding in shale horizontal, laminated and fissile, slightly weathered to highly weathered, close spaced flat partings, smooth planar, tight, poor to fair quality.
	2	2.1 – 3.0	100	50		
	3	3.0 – 4.6	97	70		
BH C-2	1	4.8 ⁽²⁾ – 5.0	58	0	4.8 – 8.7	SHALE WITH INTERBEDDED LIMESTONE: Grey to dark grey, fine grained, with quartz vein and occasional interbedded grey limestone (effervesces freely in dilute (5%) hydrochloric acid), soft to medium strength, bedding in shale horizontal, laminated and fissile, slightly to moderately weathered, close spaced flat partings, smooth planar, tight, very poor to poor quality.
	2	5.0 – 5.5	22	0		
	3	5.5 – 5.8	33	0		
	4	5.8 – 6.1	93	33		
	5	6.1 – 6.4	100	0		
	6	6.4 – 7.0	88	29		
	7	7.0 – 7.3	92	0		
	8	7.3 – 8.1	93	50		
	9	8.1 – 8.7	83	50		

Notes:

Drilled: January 12 to January 19, 2015

Logged: January , 2015

RQD = Rock Quality Designation

1.5⁽¹⁾, 4.8⁽²⁾: Bedrock starts at 1.5 m at BH C-1 and 4.8 m at BH C-2

Originated: JO/SAT
 Compiled: SA
 Checked: MA

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.

COMPOSITION: SECONDARY SOIL COMPONENTS ARE DESCRIBED ON THE BASIS OF PERCENTAGE BY MASS OF THE WHOLE SAMPLE AS FOLLOWS:

PERCENT BY MASS	0 - 10	10 - 20	20 - 30	30 - 40	> 40
	TRACE	SOME	WITH	ADJECTIVE (SILTY)	AND (AND SILT)

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

R Q D (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S SPLIT SPOON	T P THINWALL PISTON
W S WASH SAMPLE	O S OSTERBERG SAMPLE
S T SLOTTED TUBE SAMPLE	R C ROCK CORE
B S BLOCK SAMPLE	P H T W ADVANCED HYDRAULICALLY
C S CHUNK SAMPLE	P M T W ADVANCED MANUALLY
T W THINWALL OPEN	F S FOIL SAMPLE
F V FIELD VANE	

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
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_i	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

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

RECORD OF BOREHOLE No C-1

1 of 1

METRIC

G.W.P. 2163-10-00 **LOCATION** Coords: 4 817 049.5 N; 290 723.3 E **ORIGINATED BY** S.A.
DIST Central **HWY** QEW / 403 **BOREHOLE TYPE** C.F.H.S.A. and HQ Diamond Coring **COMPILED BY** K.D.
DATUM Geodetic **DATE** January 19, 2015 **CHECKED BY** B.R.G.

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			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE										○		
								● QUICK TRIAXIAL × LAB VANE												
120.5	Ground Surface																			
0.0 120.2	Topsoil																			
0.3 119.8	Clayey silt organic inclusions		1	SS	2		120													
0.7	Soft Grey/ Moist brown (FILL)		2	SS	50/10cm															
119.0 1.5	Clayey silt, with sand, with gravel weathered shale fragments		3	RC HQ	REC 67%		119													
	Hard Grey/ Moist brown (TILL)																			
	Shale bedrock with embedded limestone		4	RC HQ	REC 100%		118													
	Soft to medium strength																			
	Slightly to highly weathered																			
	Poor to fair quality clay seams		5	RC HQ	REC 97%		117													
115.9 4.6	End of borehole						116													
	Sample 2: Sampler bouncing																			

RECORD OF BOREHOLE No C-2

1 of 1

METRIC

G.W.P. 2163-10-00 **LOCATION** Coords: 4 817 030.7 N; 290 733.2 E **ORIGINATED BY** S.A.
DIST Central **HWY** QEW / 403 **BOREHOLE TYPE** C.F.H.S.A. and HQ Diamond Coring **COMPILED BY** K.D.
DATUM Geodetic **DATE** January 12, 2015 **CHECKED BY** B.R.G.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE LIQUID 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					WATER CONTENT (%)				
								20 40 60 80 100					W _p W W _L				
123.7	Ground Surface																
123.5	Topsoil																
0.2	Clayey silt organic and sand fill inclusions		1	SS	10												
	Stiff Reddish Moist brown/grey cobbles		2	SS	15												
			3	SS	17												
	firm dark brown/black		4	SS	7												
120.7	(FILL)																
3.0	Silty clay trace sand, trace gravel, weathered shale fragments		5	SS	47												
	Hard Grey/Moist brown (TILL)																
118.9			6	SS	50/5cm												
4.8	Shale bedrock with embedded limestone		7	RC HQ	REC 58%												
	Soft to medium strength		8	RC HQ	REC 22%												
	Slightly to moderately weathered		9	RC HQ	REC 33%												
	Very poor to poor quality clay seams		10	RC HQ	REC 93%												
			11	RC HQ	REC 100%												
			12	RC HQ	REC 88%												
			13	RC HQ	REC 92%												
			14	RC HQ	REC 93%												
			15	RC HQ	REC 83%												
115.0	End of borehole																
8.7																	
	* Borehole charged with drilling water																

RECORD OF BOREHOLE No RW-6

1 of 1

METRIC

G.W.P. 2163-10-00 **LOCATION** Coords: 4 817 072.1 N; 290 723.3 E **ORIGINATED BY** S.A.
DIST Central **HWY** QEW / 403 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** K.D.
DATUM Geodetic **DATE** January 19, 2015 **CHECKED BY** B.R.G.

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										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
122.4	Ground Surface						20	40	60	80	100									
122.3 0.1	Topsoil		1	SS	5															
	Silty clay with sand, with gravel organic inclusions																			
	Stiff Reddish Moist brown		2	SS	13															
	(FILL)																			
			3	SS	12															
	hard wet																			
119.9 2.5	End of borehole		4	SS	50/3cm															
	Refusal on probable bedrock																			
	Sample 4: Sampler bouncing																			
	* 2015 01 19																			
	Water level observed during drilling																			
	Borehole caved in at 1.8m																			

RECORD OF BOREHOLE No RW-7

1 of 1

METRIC

G.W.P. 2163-10-00 **LOCATION** Coords: 4 817 028.5 N; 290 714.6 E **ORIGINATED BY** S.A.
DIST Central **HWY** QEW / 403 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** K.D.
DATUM Geodetic **DATE** January 12, 2015 **CHECKED BY** B.R.G.

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/m³	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 (%)									
125.3	Ground Surface						20	40	60	80	100	20	40	60			
125.1	Topsoil																
0.2	Silty sand some gravel, trace clay organics, rootlets		1	SS	15		125						○				
	Compact Reddish Moist brown		2	SS	29								○				
123.9	Clayey silt, some sand weathered shale fragments organic inclusions						124										
1.4	Very stiff Reddish Moist brown (FILL)		3	SS	35								○				
	Clayey silt some sand, trace gravel weathered shale fragments		4	SS	62		123						○	├─┐		5 17 50 28	
	Hard Reddish Moist brown/ Grey (TILL)		5	SS	50/10cm		122										
			6	SS	50/5cm												
			7	SS	50/8cm		121										
							120										
119.0			8	SS	50/15cm		119										
6.3	End of borehole Refusal on probable bedrock Sample 8: Sampler bouncing * Borehole dry																

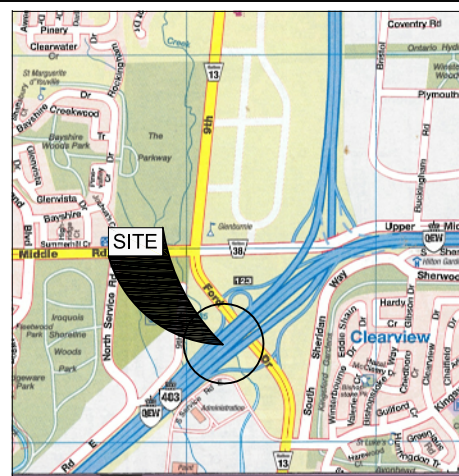
RECORD OF BOREHOLE No RW-8

1 of 1

METRIC

G.W.P. 2163-10-00 **LOCATION** Coords: 4 817 060.9 N; 290 718.9 E **ORIGINATED BY** S.A.
DIST Central **HWY** QEW / 403 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** K.D.
DATUM Geodetic **DATE** January 19, 2015 **CHECKED BY** B.R.G.

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 (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
122.0	Ground Surface							20	40	60	80	100								
121.8	Topsoil																			
0.2	Clayey silt, some sand organics, rootlets		1	SS	14															
121.1	Stiff to Reddish Moist hard brown		2	SS	50/3cm															
0.9	(FILL) weathered shale fragments																			
	End of borehole																			
	Refusal on probable bedrock																			
	Sample 2: Sampler bouncing																			



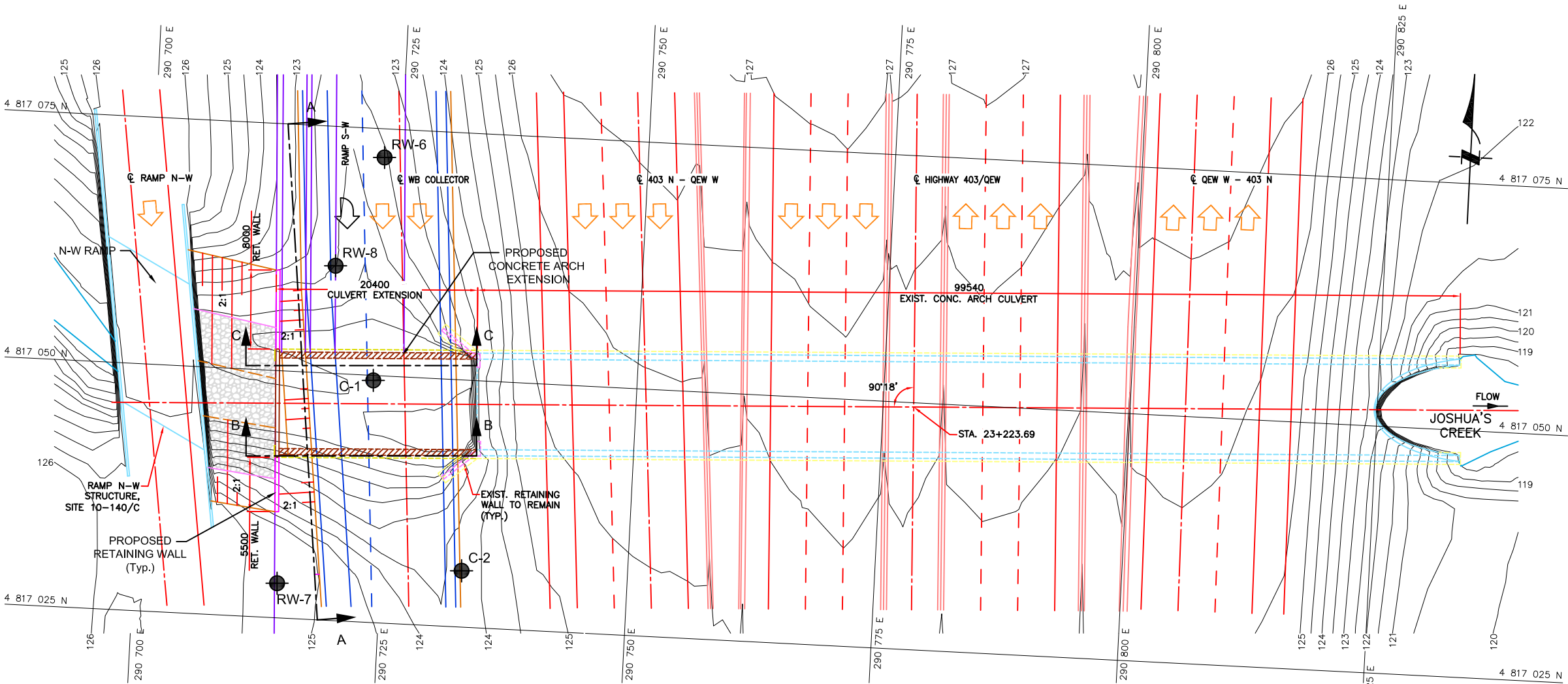
KEY PLAN
200m 0 200m 400m 600m 800m 1km

LEGEND			
	Borehole		
	Cone		
	Borehole and 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 Jan. 2015		
*	Water level not established		
	Head		
	ARTESIAN WATER		
	Encountered		
	PIEZOMETER		
BH No	ELEVATION	NORTHINGS	EASTINGS
C-1	120.5	4 817 049.5	290 723.3
C-2	123.7	4 817 030.7	290 733.2
RW-6	122.4	4 817 072.1	290 723.3
RW-7	125.3	4 817 028.5	290 714.6
RW-8	122.0	4 817 060.9	290 718.9

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. 30M5-314			
HWY No	QEW/403	DIST CENTRAL	
SUBM'D	NA	CHECKED KD	DATE JUNE 19, 2015
DRAWN	NL	CHECKED DD	APPROVED CN
SITE 10-140/C		DWG JC-1	



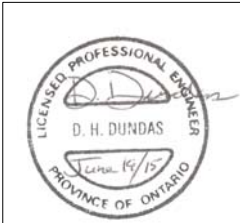
PLAN

SCALE



NOTES:

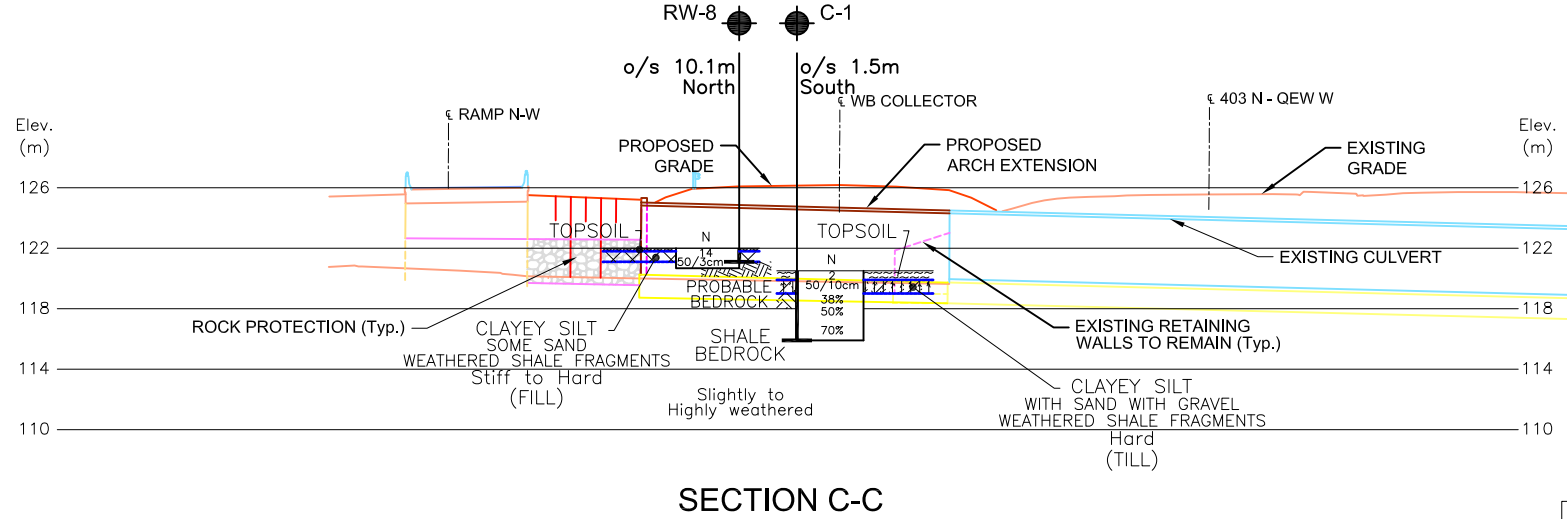
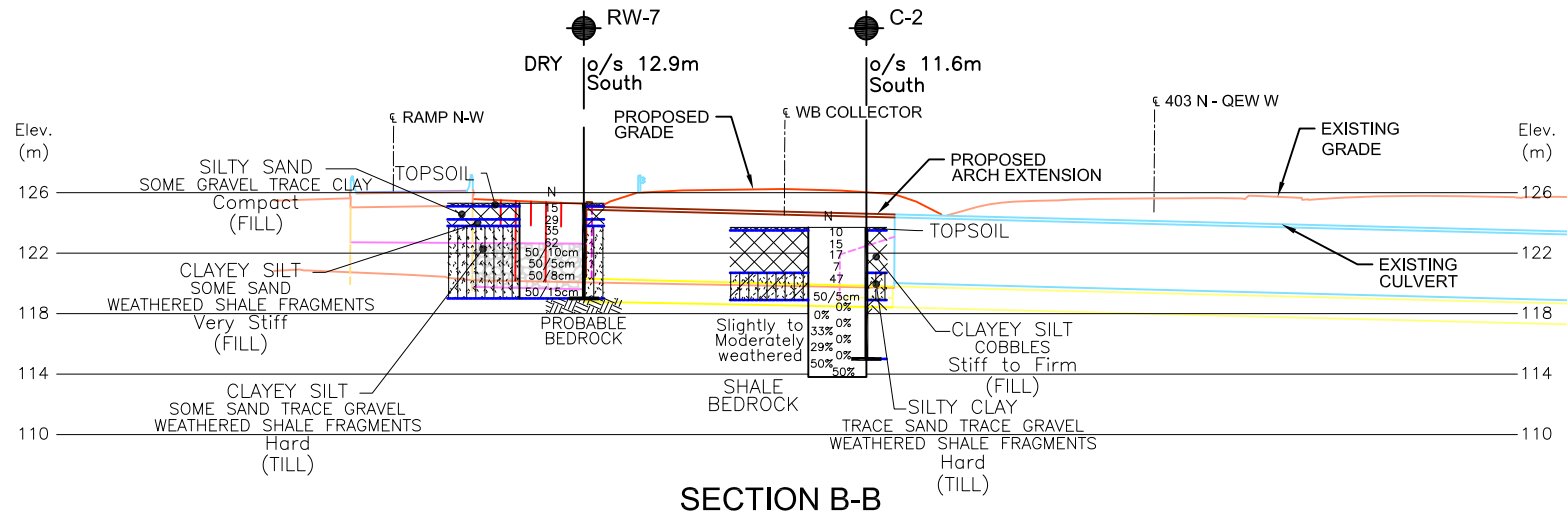
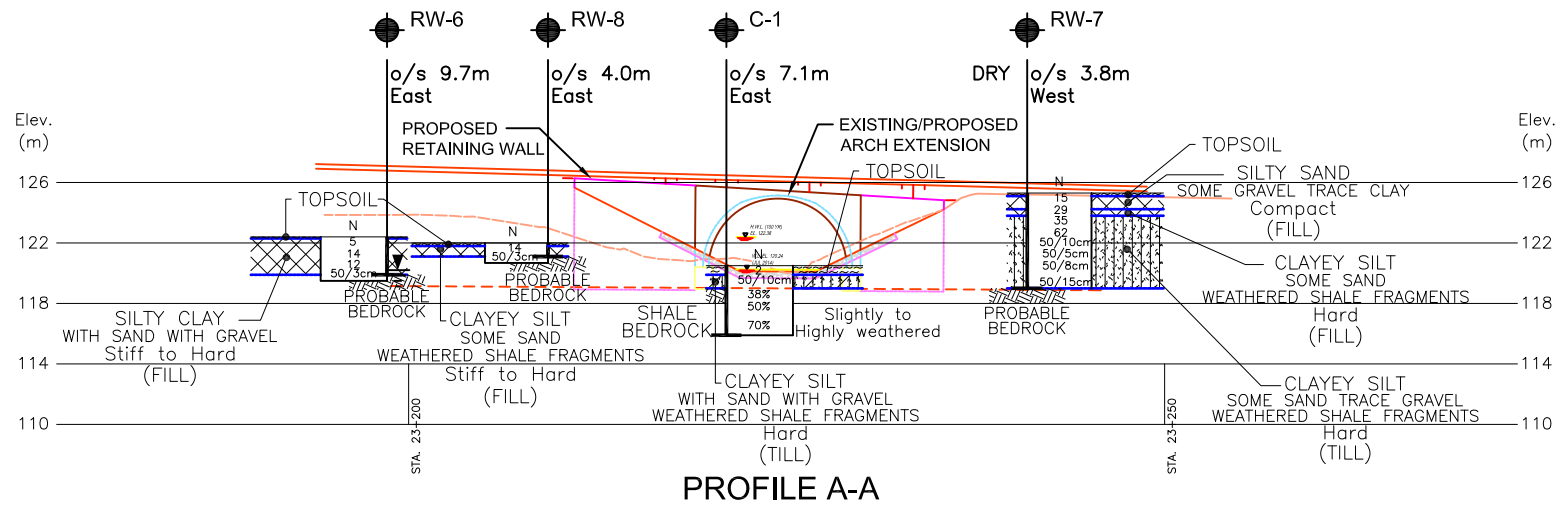
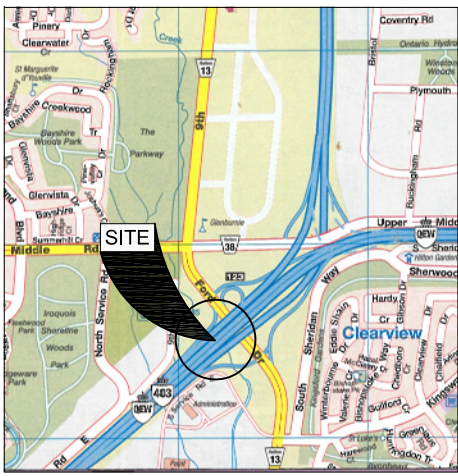
- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
- THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
- FOR PROFILE A-A, AND SECTIONS B-B AND C-C, REFER TO DRAWING JC-2.
- DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.



REF Stantec Drawing:
165000893_joshuas_cr_culv_r3_p1.dwg dated Feb. 2015

CONT No XXXX-XXX
GWP No 2163-10-00

JOSHUA'S CREEK ARCH CULVERT EXTENSION
QEWS/HIGHWAY 403 ONTARIO
SOIL STRATA



LEGEND			
	Borehole		
	Cone		
	Borehole and 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 Jan. 2015		
*	Water level not established		
	Head		
	ARTESIAN WATER		
	Encountered		
	PIEZOMETER		

BH No	ELEVATION	NORTHINGS	EASTINGS
FOR DETAILS REFER TO DRAWING JC-1			

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

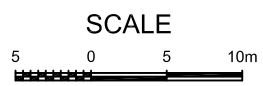
REVISIONS	DATE	BY	DESCRIPTION

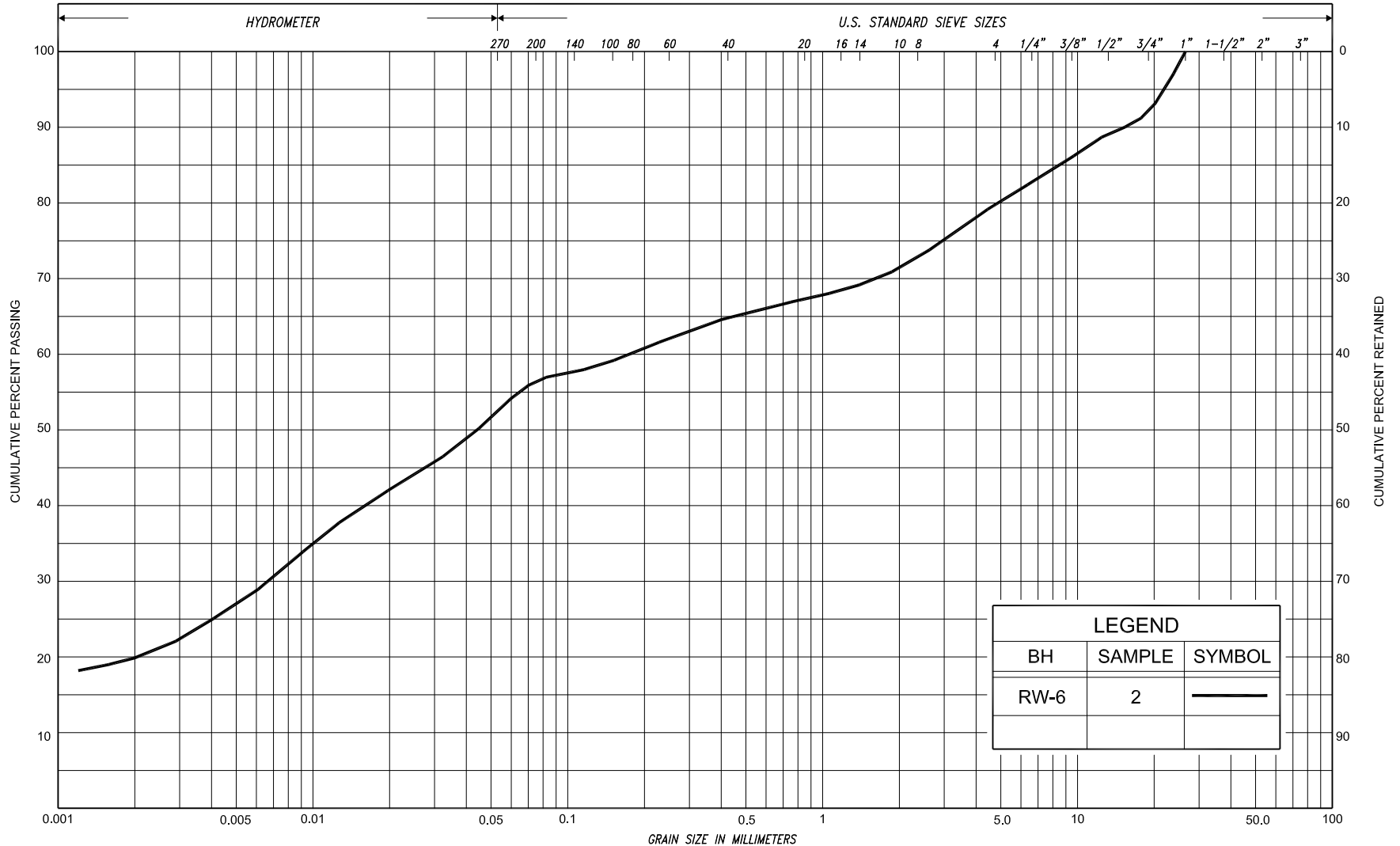
Geocres No. 30M5-314			
HWY No	QEWS/403	DIST CENTRAL	
SUBM'D	NA	CHECKED	KD
DRAWN	NL	CHECKED	DD
DATE		JUNE 19, 2015	SITE 10-140/C
APPROVED		CN	DWG JC-2



REF Stantec Drawing:
165000893_joshuas_cr_culv_r3_p1.dwg dated Feb. 2015

- NOTES:
- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
 - THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
 - FOR BOREHOLE LOCATIONS REFER TO DRAWING JC-1.
 - DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.



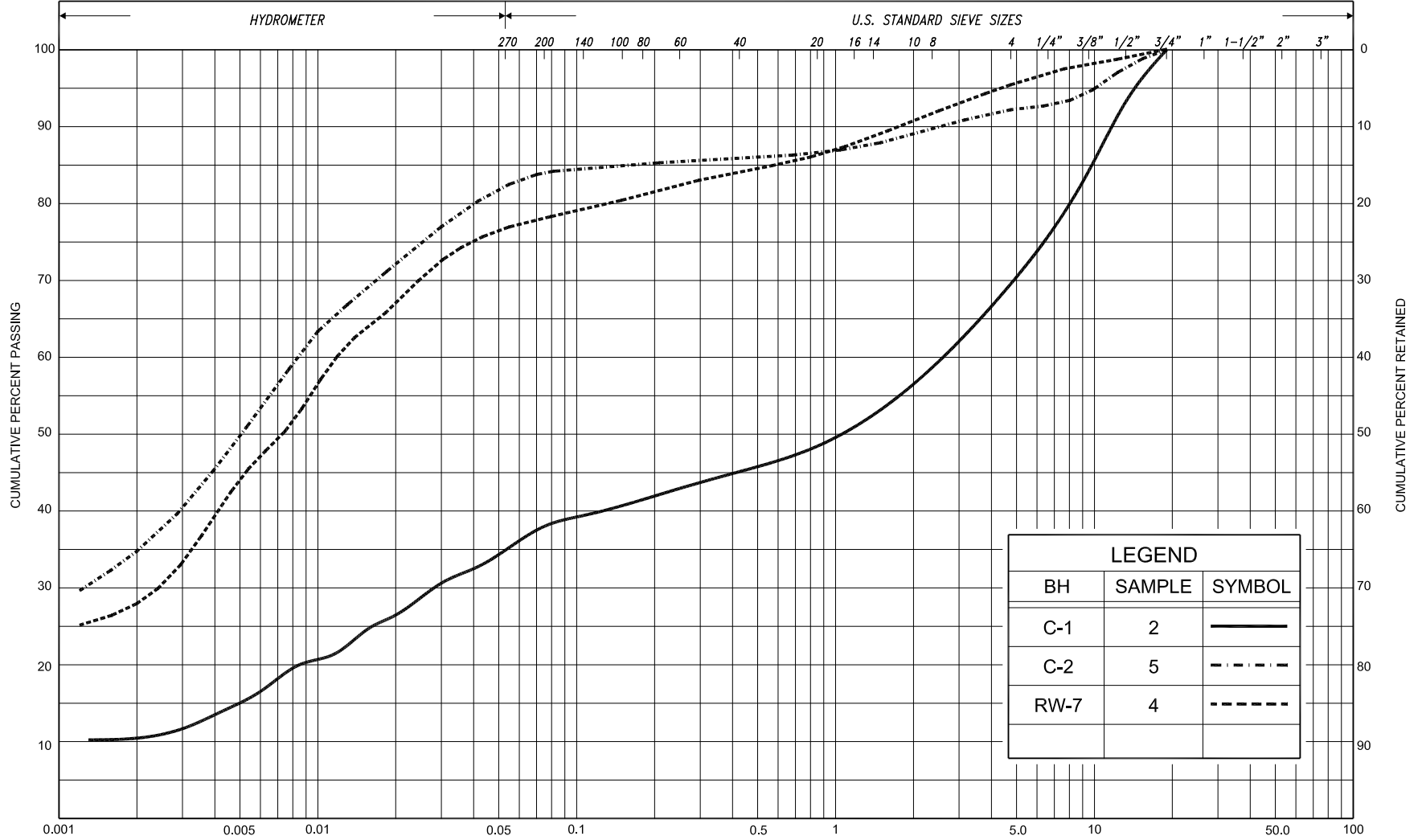


SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL			COBBLES	UNIFIED	
				SAND										
CLAY	FINE	MEDIUM	COARSE	FINE		MEDIUM	COARSE		GRAVEL			COBBLES	M.I.T.	
	SILT			SAND										
CLAY		SILT		V. FINE	FINE	MED.	COARSE	GRAVEL						U.S. BUREAU
				SAND										



GRAIN SIZE DISTRIBUTION **SILTY CLAY, with sand, with gravel (CI)** **(FILL)**

FIG No.	JC-GS-1
HWY:	403 / QEW
G.W.P. No.	2163-10-00



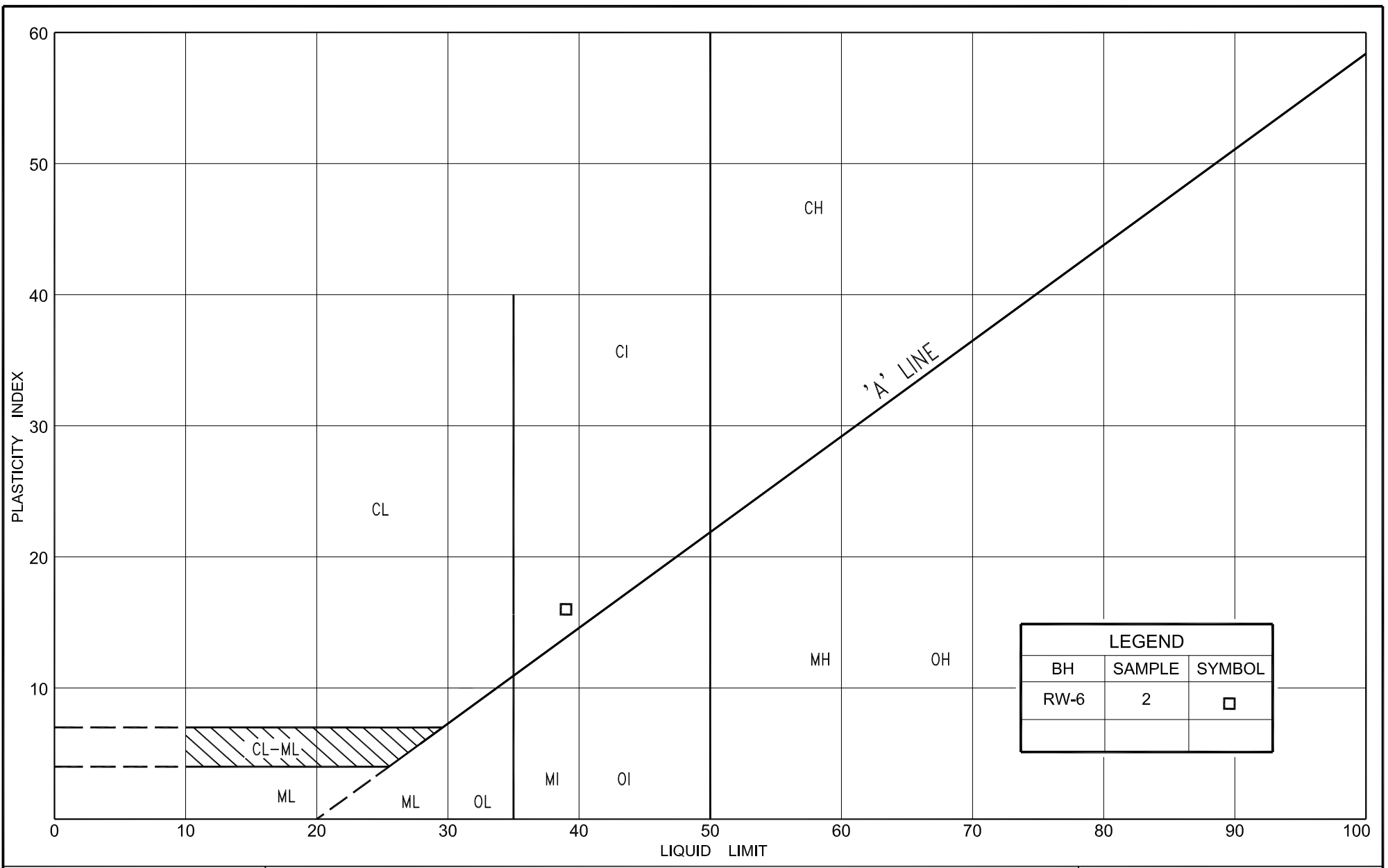
SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL		COBBLES	UNIFIED
				SAND								
CLAY	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	GRAVEL				COBBLES	M.I.T.
	SILT			SAND								
CLAY		SILT		V. FINE	FINE	MED.	COARSE	GRAVEL				U.S. BUREAU
				SAND								



GRAIN SIZE DISTRIBUTION

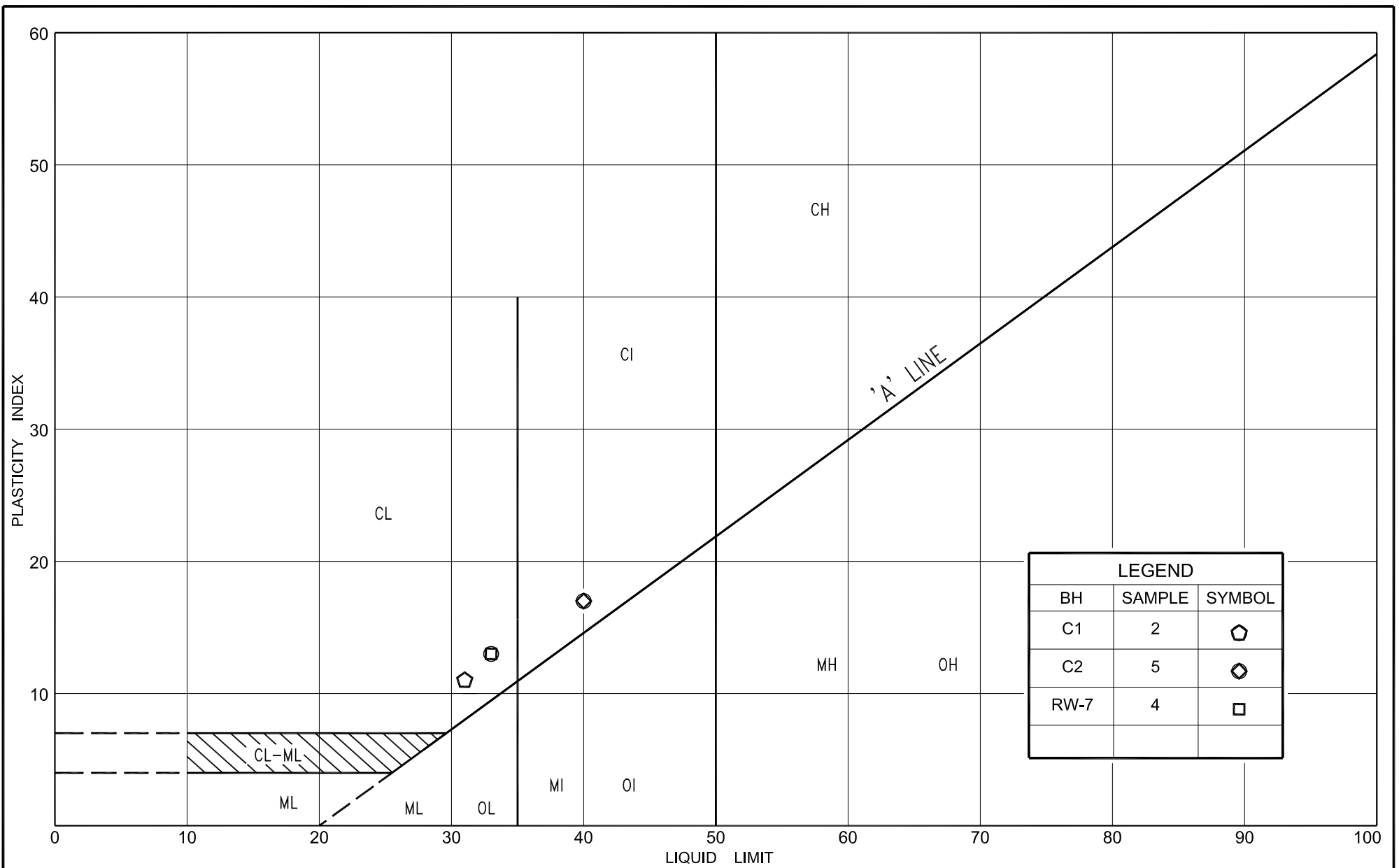
CLAYEY SILT TO SILTY CLAY, with sand, trace to with gravel (CL-CI)
(TILL)

FIG No. JC-GS-2
HWY: 403 / QEW
G.W.P. No. 2163-10-00



PLASTICITY CHART
 SILTY CLAY, with sand, with gravel (CI)
 (FILL)

FIG No.	JC-PC-1
HWY:	403 / QEW
G.W.P. No.	2163-10-00



PLASTICITY CHART
 CLAYEY SILT TO SILTY CLAY, with sand, trace to with gravel (CL-CI)
 (TILL)

FIG No. JC-PC-2
 HWY: 403 / QEW
 G.W.P. No. 2163-10-00



APPENDIX FIR-A

Relevant GEOCREs Data

ENGINEERING MATERIALS OFFICE
SOIL MECHANICS SECTION

WP ~~159-75-05~~

DIST 4

125-66-20

HWY 403

STR SITE 10-140A

Extension to Joshuas Creek Arch Structure
and Proposed Stream Realignment

DISTRIBUTION

G.C.E. Burkhardt (3)
R.D. Gunter
M.R. Ernesaks
D.E. Thrasher (2)

C. Grebski
G.A. Wrong
B.J. Giroux
R.S. Pillar

R. Hore

R. Fitzgibbon)
J. Anderson) cover only
G. Sloan)

Files ✓

FOUNDATION INVESTIGATION REPORT

For

Extension to Joshuas Creek Arch Structure
and Proposed Stream Realignment
QEW/403/Ford Drive Interchange
W.P. ~~159-75-05~~, Site 10-140A
District 4, Hamilton

125-65-20

INTRODUCTION

This report contains the results of a foundation investigation performed by the Soil Mechanics Section at the site of the above mentioned project. Fieldwork was carried out during June 17 to June 21, 1977, using 3¼" hollow stem, continuous flight augers and BXL coring techniques to advance 4 boreholes to depths ranging from 10 to 17 feet below ground surface.

SITE DESCRIPTION AND GEOLOGY

The site is immediately west of QEW, about ¼ mile south of the Ford Drive underpass, in the Regional Municipality of Halton, Town of Oakville.

Runoff from QEW drains into Joshuas Creek through catch-basins and grass covered ditches. In this area the creek meanders southeasterly in a steep-sided valley (slopes about 1:1), 15 to 25 feet deep, and appears to have eroded at least 10 feet into the bedrock, as evidenced by outcrops on the north valley sides. The sides of the creek in the vicinity of QEW are protected from erosion with gabion walls. The surrounding land is wooded; with a house, stable and kennel located at the top of the south valley embankment.

The creek bed is strewn with gravel and cobbles. Water flow through the creek during the fieldwork was estimated to be less than one cubic foot per minute.

SUBSURFACE CONDITIONS

General

Borings were put down adjacent to the existing Joshuas Creek within the Ministry's property limits because of property restrictions as discussed in the Appendix. The locations of the borings are shown in Dwg. No. 1597505-A. In the area investigated, shale bedrock was found to exist under a layer of cobbles and gravels of variable thickness, up to 4 feet thick at certain locations. The shale bedrock was investigated to a maximum depth of $16\frac{1}{2}$ feet. In the vicinity of the existing structure, an isolated pocket of silty clay about 2 feet thick was found sandwiched between the cobble layer and the shale bedrock at a depth of 2 feet below the ground surface. A description of the soil types and bedrock is given below:

Cobbles and Gravel

Some of this material appears to have been transported to the site by Joshuas Creek and some derived from erosion of the valley sides. The thickness of this material is extremely variable, ranging from a few scattered cobbles up to 4 feet thick in places. While gravel was found in the waterway as well as on the flood plains on either side of the creek, cobbles were found mainly in the creekbed.

Silty Clay

This material was encountered in one isolated location in the vicinity of the existing structure. It has a thickness of up to 2 feet and is sandwiched between the cobble-gravel layer and shale bedrock, at a depth of 2 feet below ground surface.

Shale Bedrock

Bedrock is a shale with frequent horizontal limestone beds. The shale layers are more predominant and they constitute up to 85% of the bedrock. The shale is soft and fissile, with a fine texture and closely spaced horizontal bedding. The limestone layers are randomly spaced and are generally 2 to 8 inches thick, and pitted with calcite vugs. The upper 2 feet of the shale is badly weathered.

Rock Quality Designation (RQD) is used to judge the engineering quality of the bedrock. According to the low values of RQD recorded here, which generally vary from 20% to 50%, the quality of the shale bedrock is considered to be generally poor.

A detailed description of the bedrock given by Mr. B. Glassford, Geologist for M.T.C., is enclosed in the Appendix.

GROUNDWATER CONDITIONS

Groundwater level is controlled by the creek water level. For construction purposes, the groundwater level can be assumed equal to the prevailing water level in the creek.

125-66-20

RECORD OF BOREHOLE No 17

W P 159-75-05 LOCATION Co-ords. N 15,803,222; E 953,842 ORIGINATED BY JRW
 DIST 4 HWY 403 BOREHOLE TYPE Hollow Stem Augering - EXL Core COMPILED BY JRW
 DATUM Geodetic DATE June 17, 1977 CHECKED BY RS

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					
393.7	Creek Bottom																
391.7	Cobbles and gravel																
389.7	Silty clay some sand		1	AS			390										
4.0	Bedrock		2	AS													
80%	Shale-Soft & weathered		3	SS	109												
	Frequent laminations of limestone		4	RC	Rec 60%												RQD 50%
	Up to 8" thick		5	RC	Rec 75%		380										RQD 20%
376.8			6	RC	Rec 80%												RQD 20%
16.9	End of Borehole																

+³, x⁵: Numbers refer to Sensitivity

20
15-5 (%) STRAIN AT FAILURE
10

125-66-2a

RECORD OF BOREHOLE No 18

W P 459-75-05 LOCATION Co-ords. N 15,803,247; E 953,804 ORIGINATED BY JRW
 DIST 4 HWY 403 BOREHOLE TYPE Hollow Stem Augering - BX Coring COMPILED BY JRW
 DATUM Geodetic DATE June 17 & 20, 1977 CHECKED BY JRS

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					
395.2	Creek Bottom																GR SA SI CL
393.4	Cobbles & gravel																
1.8	Bedrock		1	RC	60%		390										RQD 50%
	85% Shale-Soft & weathered Frequent laminations of lime-stone up to 8" thick		2	RC	50%												RQD 35%
385.3			3	RC	Rec 95%												RQD 80%
9.9	End of Borehole																

+³, x⁵: Numbers refer to
Sensitivity

20
15-20.5 (%) STRAIN AT FAILURE
10

125-66-20

RECORD OF BOREHOLE No 19

W P 159-75-05 LOCATION Co-ords. N 15,803,500; E 953,533 ORIGINATED BY JRW
 DIST 4 HWY 403 BOREHOLE TYPE Solid Stem & Hollow Stem Augering COMPILED BY JRW
 DATUM Geodetic DATE June 21, 1977 CHECKED BY KS

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					
399.0	Creek Bottom															
397.5	Cobbles & gravel															
1.5	Bedrock Soft weathered shale with Frequent Limestone laminations		No sampling													
389.2						390										
9.8	End of Borehole Note: Stratigraphy inferred from augering.															

+³, x⁵: Numbers refer to
Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

125-62-20

RECORD OF BOREHOLE No 20

W P 159-75-05 LOCATION Co-ords. N 15,803,245; E 953,727 ORIGINATED BY JKW
 DIST 4 HWY 403 BOREHOLE TYPE Hollow Stem Augering COMPILED BY JRW
 DATUM Geodetic DATE June 21, 1977 CHECKED BY JS

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 [%] GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
395.6	Creek Bottom																
0.0 392.1	Cobbles & gravel																
3.5	Bedrock		No sampling				390										
386.1	Soft weathered shale with frequent limestone laminations																
9.5	End of Borehole																
	Note: Stratigraphy inferred from augering																

+³, x⁵: Numbers refer to
Sensitivity

20
15-5 (%) STRAIN AT FAILURE
10



Ministry of
Transportation and
Communications

Ontario

DIAMOND DRILL RECORD

HOLE NO. _____ SHEET NO. _____

DIP

PROPERTY W.P. 159-75-05
LOCATION QEW and Ford Drive
Joshuas Creek
LATITUDE _____
DEPARTURE _____
BEARING _____

90°

TOTAL FOOTAGE _____

ELEV. COLLAR _____
DATUM _____
DATE STARTED _____
DATE COMPLETED _____
DRILLED BY _____
LOGGED BY _____

FOOTAGE		FORMATION	SAMPLE NUMBER	%		REMARKS
FROM	TO					
		HOLE #17				
5'0"	5'6"	Shale, soft, dark grey, fine texture, fissile.		80%		RQD 5%
5'6"	6'2"	Limestone, soft, light grey, fine texture.				RQD 90%
6'2"	16'8"	Shale and limestone beds, broken and missing core				RQD 5%
		8" limestone at 13' pitted with calcite vugs				
		6" limestone at 12' pitted with calcite vugs				
		4" limestone at 15'6" pitted with calcite vugs				
		HOLE #18				
1'8"	9'7"	Shale, soft, dark grey, fine texture, fissile, broken and ground core throughout entire length of core.		85%		RQD 10%
		5" limestone at 2'6" pitted with calcite vugs				
		2" limestone at 3'0"				
		3" limestone at 5'0"				
		3" limestone at 5'8"				
		8" limestone at 8'10"				

DATE OF EXAMINATION June 28, 1977

B. K. Glassford

ABBREVIATIONS & SYMBOLS USED IN THIS REPORT

PENETRATION RESISTANCE

'N'-STANDARD PENETRATION RESISTANCE : - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES INTO THE SUBSOIL, DRIVEN BY MEANS OF A 140 POUND HAMMER FALLING FREELY A DISTANCE OF 30 INCHES.

DYNAMIC PENETRATION RESISTANCE : - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A 2 INCH, 60 DEGREE CONE, FITTED TO THE END OF DRILL PODS, 12 INCHES INTO THE SUBSOIL. THE DRIVING ENERGY BEING 350 FOOT POUNDS 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>c LB./SQ FT</u>	<u>DENSENESS</u>	<u>'N' BLOWS / FT.</u>
VERY SOFT	0 - 250	VERY LOOSE	0 - 4
SOFT	250 - 500	LOOSE	4 - 10
FIRM	500 - 1000	COMPACT	10 - 30
STIFF	1000 - 2000	DENSE	30 - 50
VERY STIFF	2000 - 4000	VERY DENSE	> 50
HARD	> 4000		

TERMS TO BE USED IN DESCRIBING SOILS:-

TRACE < 10% , SOME 10-25% , WITH 25-40% , > 40% SILTY, SANDY, GRAVELLY, CLAYEY ETC.

TYPE OF SAMPLE

S.S	SPLIT SPOON	T.W	THINWALL OPEN
W.S	WASHED SAMPLE	T.P	THINWALL PISTON
S.T	SLOTTED TUBE SAMPLE	O.S	OESTERBERG SAMPLE
A.S	AUGER SAMPLE	F.S	FOIL SAMPLE
C.S	CHUNK SAMPLE	R.C	ROCK CORE

P.H SAMPLE ADVANCED HYDRAULICALLY

P.M SAMPLE ADVANCED MANUALLY

SOIL TESTS

U	UNCONFINED COMPRESSION	L.V	LABORATORY VANE
UU	UNCONSOLIDATED UNDRAINED TRIAXIAL	F.V	FIELD VANE
CU	CONSOLIDATED ISOTROPIC UNDRAINED TRIAXIAL	C	CONSOLIDATION
CD	" " DRAINED "	S	SENSITIVITY
CAU	" ANISOTROPIC UNDRAINED "		
CAD	" " DRAINED "		

ABBREVIATIONS & SYMBOLS USED IN THIS REPORT

SOIL PROPERTIES

GENERAL

γ	UNIT WEIGHT OF SOIL (BULK DENSITY)
γ_s	UNIT WEIGHT OF SOLID PARTICLES
γ_w	UNIT WEIGHT OF WATER
γ_d	UNIT DRY WEIGHT OF SOIL (DRY DENSITY)
γ'	UNIT WEIGHT OF SUBMERGED SOIL
G	SPECIFIC GRAVITY OF SOLID PARTICLES $G = \frac{\gamma_s}{\gamma_w}$
e	VOID RATIO
n	POROSITY
w	WATER CONTENT
S _r	DEGREE OF SATURATION
w _L	LIQUID LIMIT
w _P	PLASTIC LIMIT
I _P	PLASTICITY INDEX
w _S	SHRINKAGE LIMIT
I _L	LIQUIDITY INDEX = $\frac{w - w_P}{I_P}$
I _C	CONSISTENCY INDEX = $\frac{w_L - w}{I_P}$
e _{max}	VOID RATIO IN LOOSEST STATE
e _{min}	VOID RATIO IN DENSEST STATE
I _D	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
	RELATIVE DENSITY D _r IS ALSO USED
h	HYDRAULIC HEAD OR POTENTIAL
q	RATE OF DISCHARGE
v	VELOCITY OF FLOW
i	HYDRAULIC GRADIENT
k	COEFFICIENT OF PERMEABILITY
j	SEEPAGE FORCE PER UNIT VOLUME
m _v	COEFFICIENT OF VOLUME CHANGE = $\frac{-\Delta e}{(1+e)\Delta\sigma}$
c _v	COEFFICIENT OF CONSOLIDATION
C _c	COMPRESSION INDEX = $\frac{\Delta e}{\Delta \log_{10} \sigma}$
T _v	TIME FACTOR = $\frac{c_v t}{d^2}$ (d, DRAINAGE PATH)
U	DEGREE OF CONSOLIDATION
τ_f	SHEAR STRENGTH
c'	EFFECTIVE COHESION
ϕ'	EFFECTIVE ANGLE OF SHEARING RESISTANCE, OR FRICTION
c _u	APPARENT COHESION
ϕ_u	APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION
μ	COEFFICIENT OF FRICTION
S _t	SENSITIVITY

π	= 3.1416
e	BASE OF NATURAL LOGARITHMS 2.7183
$\log_e a$ OR $\ln a$	NATURAL LOGARITHM OF a
$\log_{10} a$ OR $\log a$	LOGARITHM OF a TO BASE 10
t	TIME
g	ACCELERATION DUE TO GRAVITY
V	VOLUME
W	WEIGHT
M	MOMENT
F	FACTOR OF SAFETY

STRESS AND STRAIN

u	PORE PRESSURE
σ	NORMAL STRESS
$\bar{\sigma}$	NORMAL EFFECTIVE STRESS ($\bar{\sigma}$ IS ALSO USED)
τ	SHEAR STRESS
ϵ	LINEAR STRAIN
γ	SHEAR STRAIN
ν	POISSON'S RATIO (μ IS ALSO USED)
E	MODULUS OF LINEAR DEFORMATION (YOUNG'S MODULUS)
G	MODULUS OF SHEAR DEFORMATION
K	MODULUS OF COMPRESSIBILITY
η	COEFFICIENT OF VISCOSITY

EARTH PRESSURE

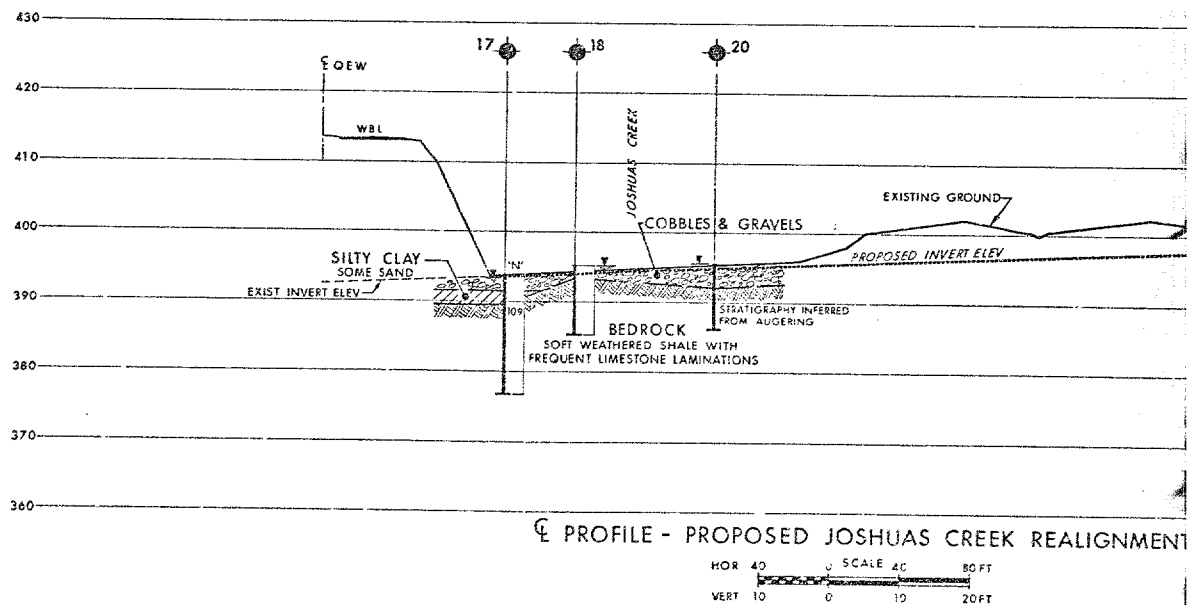
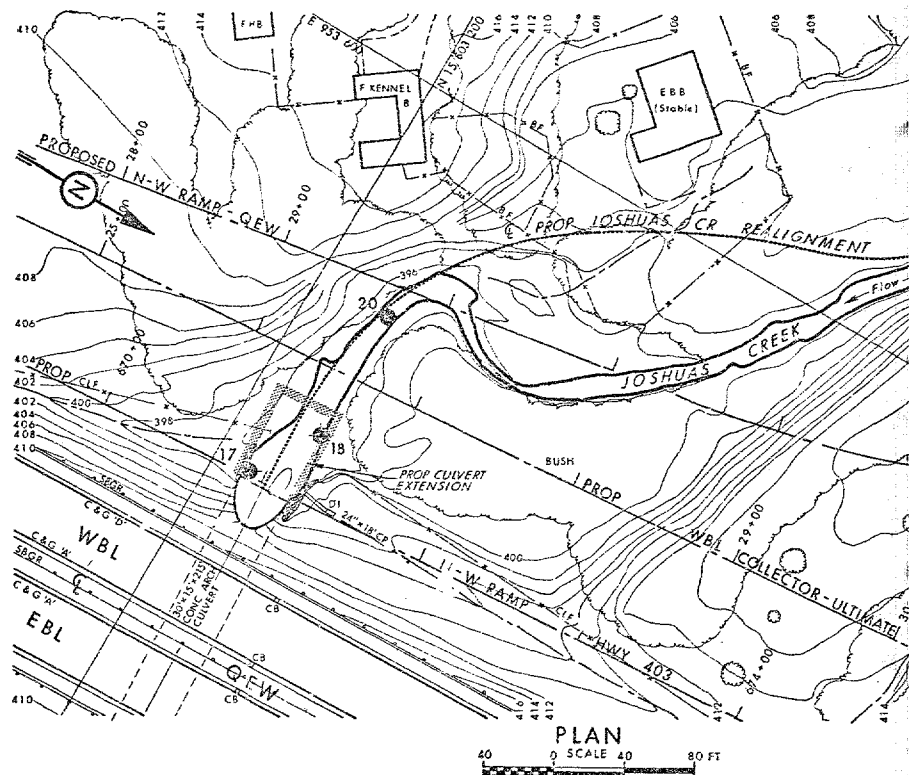
$\bar{\sigma}$	DISTANCE FROM TOP OF WALL TO POINT OF APPLICATION OF PRESSURE
δ	ANGLE OF WALL FRICTION
K	DIMENSIONLESS COEFFICIENT TO BE USED WITH VARIOUS SUFFIXES IN EXPRESSIONS REFERRING TO NORMAL STRESS ON WALLS
K ₀	COEFFICIENT OF EARTH PRESSURE AT REST

FOUNDATIONS

B	BREADTH OF FOUNDATION
L	LENGTH OF FOUNDATION
D	DEPTH OF FOUNDATION BENEATH GROUND
N	DIMENSIONLESS COEFFICIENT USED WITH A SUFFIX APPLYING TO SPECIFIC GRAVITY, DEPTH AND COHESION ETC IN THE FORMULA FOR BEARING CAPACITY
k _s	MODULUS OF SUBGRADE REACTION

SLOPES

H	VERTICAL HEIGHT OF SLOPE
D	DEPTH BELOW TOE OF SLOPE TO HARD STRATUM
β	ANGLE OF SLOPE TO HORIZONTAL

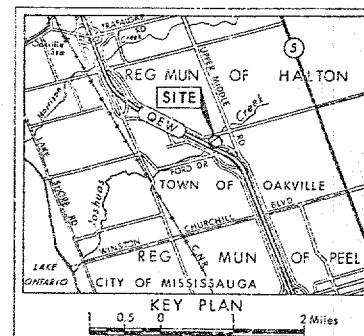


CONT No 125-66-10
WP No 159-75-05

PROP CULVERT EXTENSION
& JOSHUAS CR REALIGNMENT
BORE HOLE LOCATIONS & SOIL STRATA



SHEET



LEGEND

- Bore Hole
- Dynamic Cone Penetration Test (Cone)
- Bore Hole & Cone
- 'N' Blows/ft (Std Pen Test 350 ft lbs energy)
- CONE Blows/ft (60" Cone, 350 ft lbs energy)
- W.L. at time of investigation June 1977

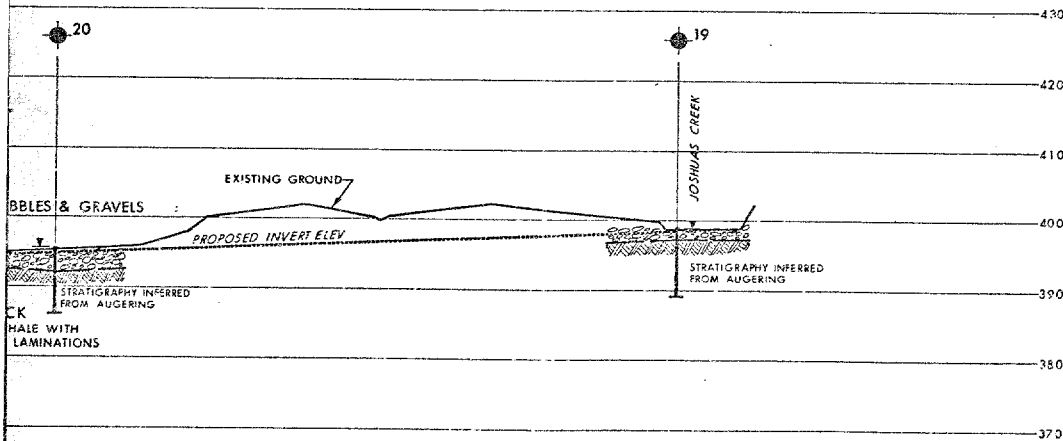
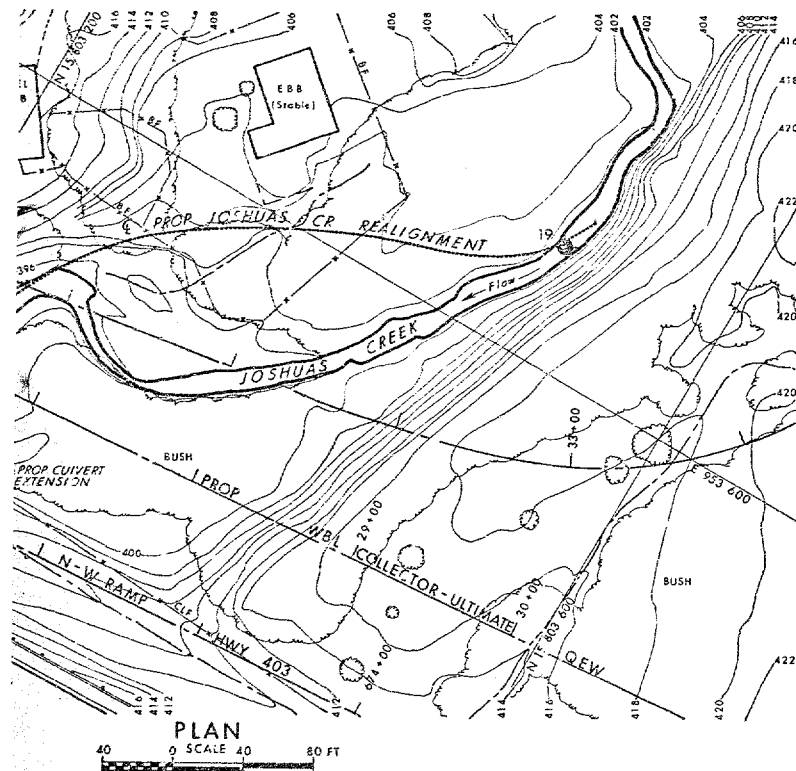
No	ELEVATION	CO ORDINATES	
		NORTH	EAST
17	393.7	15 803 222	953 842
18	395.2	15 803 247	953 804
19	399.0	15 803 500	953 533
20	395.6	15 803 245	953 727

-NOTE-

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

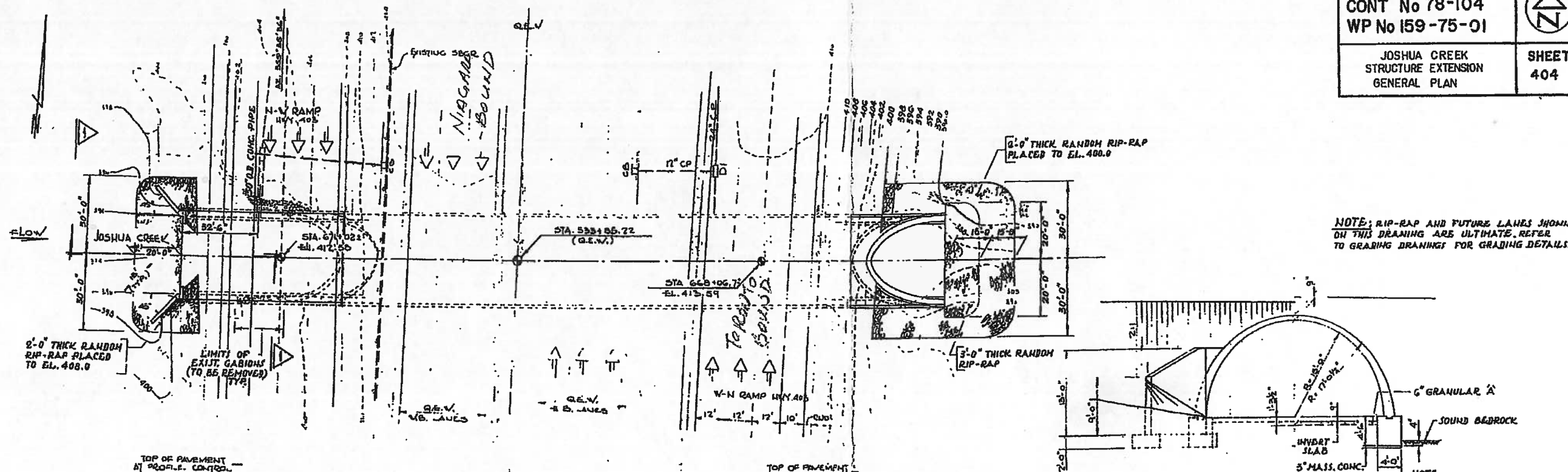
REVISIONS	DATE	BY	DESCRIPTION

MAY 1979
CHECKED BY DATE JULY 15, 1977
DRAWN BY CHECKED BY DATE



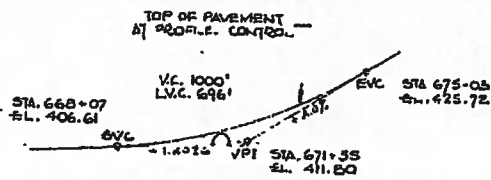
PROPOSED JOSHUAS CREEK REALIGNMENT

HOR 40 0 SCALE 40 80 FT
VERT 10 0 10 20 FT

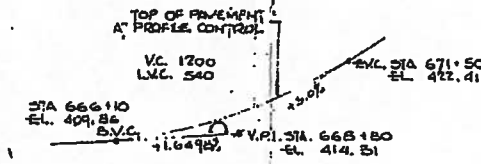


NOTE: RIP-RAP AND FUTURE LANES SHOWN ON THIS DRAWING ARE ULTIMATE. REFER TO GRADING DRAWINGS FOR GRADING DETAILS.

NOTE: ALL FOOTINGS TO BE CAST AGAINST SOUND BEDROCK AS DIRECTED BY ENGINEER.



PROFILE OF N-W RAMP



PROFILE OF V-N RAMP

CONCRETE QUANTITIES

CONCRETE QUANTITIES ARE LISTED BELOW FOR THE APPROPRIATE CONCRETE LUMP SUM TENDER ITEM:

1. CONCRETE IN STRUCTURE (4000 R.S.I.) - 217 cu.yd. AND RET. WALLS (3000 R.S.I.) - 21 cu.yd.
2. CONCRETE IN INVERT SLAB - 74 cu.yd.

GENERAL NOTES:

CLASS OF CONCRETE
ARCH - 4000 R.S.I.
FOOTINGS, RET. WALLS, INVERT SLAB - 3000 R.S.I.

CLEAR COVER TO REINF. STEEL
FOOTINGS & RET. WALLS - 3"
ARCH EXTRADOS - 3"
ARCH INTRADOS - 2"

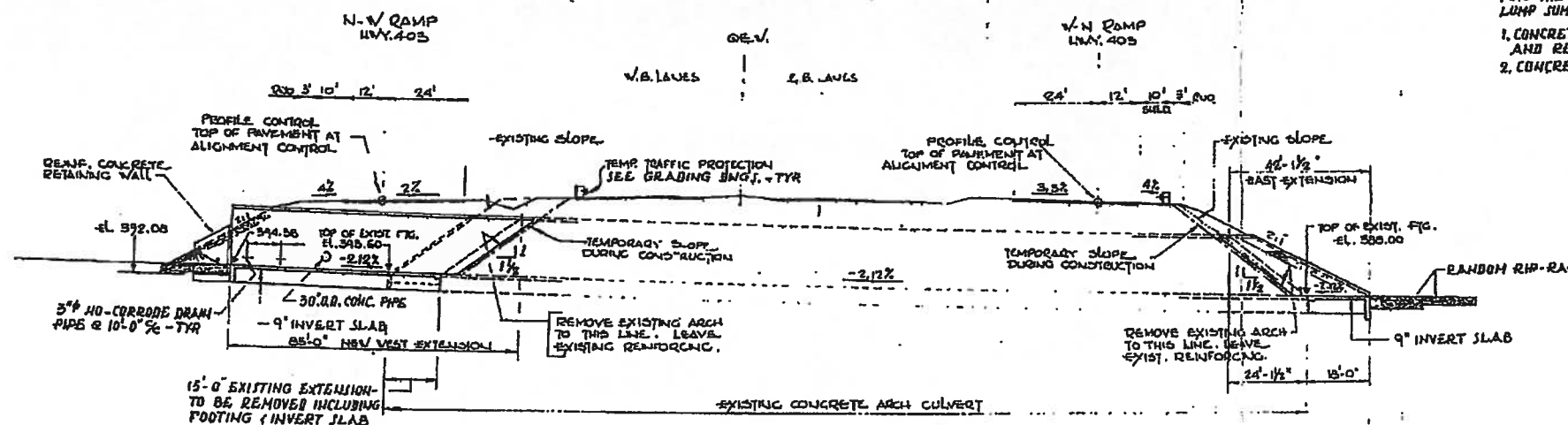
REINF. STEEL SHALL BE C.S.A. G30 SERIES GRADE 60.

CONSTRUCTION NOTES

BACKFILL OPERATIONS SHALL PROGRESS SIMULTANEOUSLY ON BOTH SIDES OF THE ARCH AXIS. THE DIFFERENCE IN WORKING LEVELS OF BACKFILL BETWEEN EITHER SIDE SHALL AT NO TIME EXCEED 1'-0".

LIST OF DRAWINGS

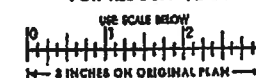
DWG. 1 GENERAL PLAN
2 BORE HOLE LOCATIONS & SOIL STRATA
3 WEST EXTENSION
4 EAST EXTENSION
DWG. 5 STANDARD DETAILS



SECTION ALONG OF STRUCTURE



FOR REDUCED PLAN

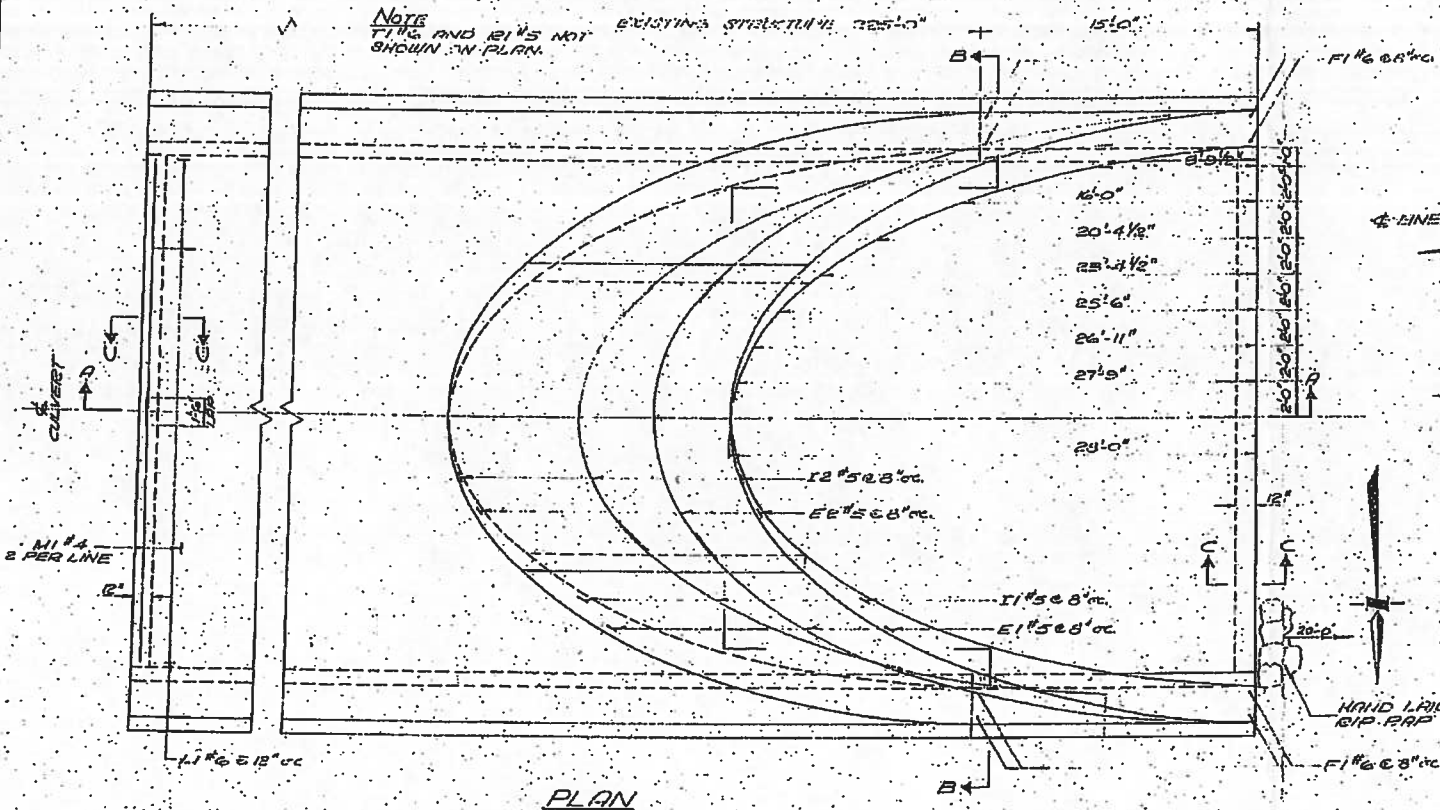


REVISION	DATE	BY	DESCRIPTION
1			DESIGN V.V. CHECK P.K. LOADING 11520-44 DATE MAR/20
2			DRAWING V.V. CHECK P.K. SITE No 10-140A DWG. 1

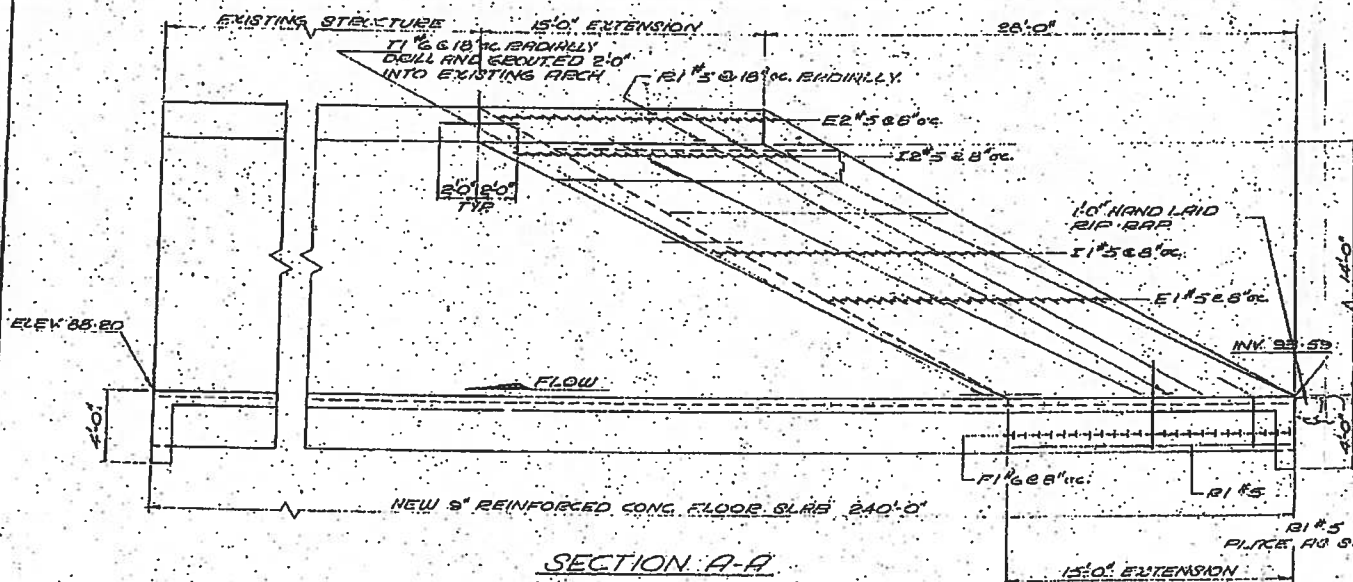
No. 6 STR. 28+30

NOTE
F.T.G. AND B.T.S. NOT
SHOWN IN PLAN.

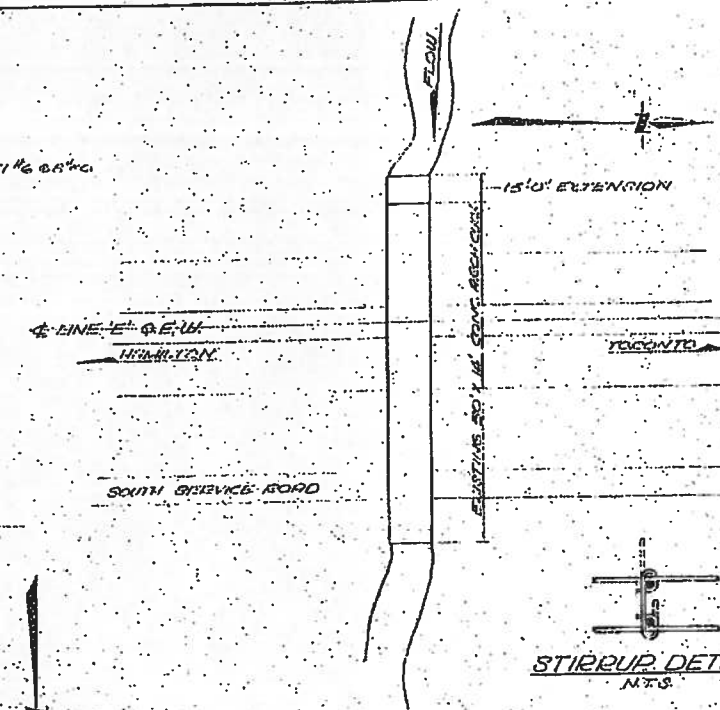
EXISTING STRUCTURE 225'-0"



PLAN

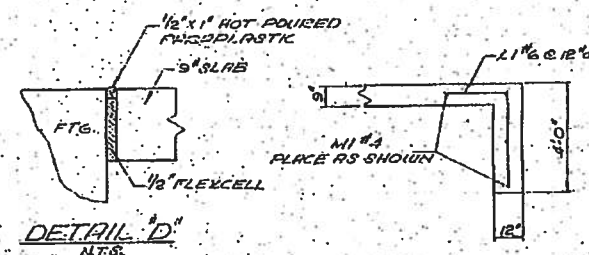


SECTION A-A



SITE PLAN
SCALE 1" = 50'-0"

STIRRUP DETAIL
M.T.S.

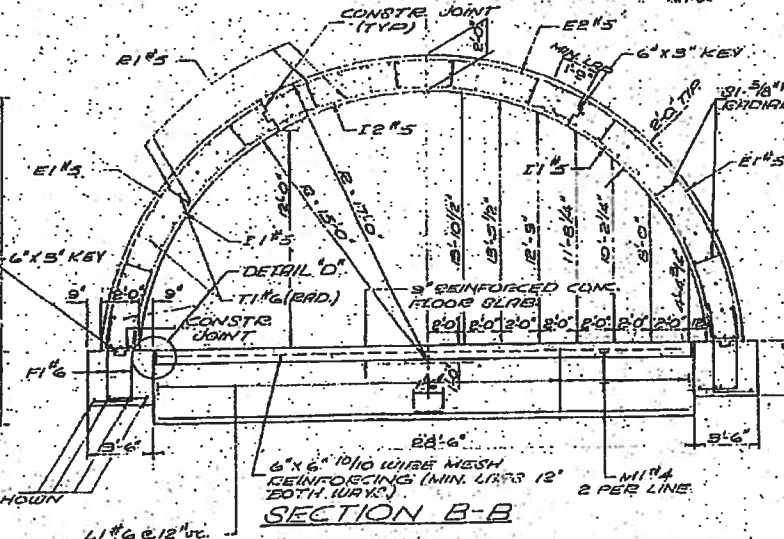


DETAIL D-D
M.T.S.

NOTES

- TO CONTRACTOR: CONTRACTOR WORK ON THIS STRUCTURE MUST NOT BE COMMENCED UNTIL MEASUREMENTS TO ALL CONTROL POINTS HAVE BEEN EFFECTED AND CHECKED BY THE ENGINEER.
- TO CONTRACTOR: STRUCTURE TO BE BUILT IN ACCORDANCE WITH FORMS AND THE SPECIAL PROVISIONS LISTED HEREIN WHICH MAY BE OBTAINED FROM THE ENGINEER.
- CONCRETE MIX: 5000 P.S.I. AT 28 DAYS. APPROVED ADMIXTURE SUPPLIED BY THE CONTRACTOR WILL BE ADDED TO ALL CONCRETE AS SPECIFIED BY THE ENGINEER.
- CLERK COVER ON REINFORCING STEEL: 3" EXCEPT AS NOTED.
- CONSTRUCTION NOTES: ALL EXPOSED REBARS TO BE CHAMFERED 1"x1" EXCEPT AS NOTED. ALL CONSTRUCTION JOINTS MUST BE APPROVED BY THE ENGINEER.

SECTION C-C
SCALE 3/8" = 1'-0"



SECTION B-B

PRINT RECORD
No. FOR DATE
3 25.11.1964

REVISION
DATE BY DESCRIPTION

DEPARTMENT OF HIGHWAYS ONTARIO			
BRIDGE DIVISION			
TRAFALGAR TWP ARCH CULVERT EXTENSION			
KING'S HIGHWAY NO. 6 E. W.	STR. 28+30	EST. NO. 6	
CO. HALTON	101.15	CONTRACT NO.	
TWP. TRAFALGAR	101.15	CONTRACT NO.	
GENERAL PLAN			
APPROVED: [Signature]	DATE: [Date]	BY: [Name]	
DESIGN: [Name]	CHECK: [Name]	CONTRACT: [Name]	
DRAWING: [Name]	CHECK: [Name]	CONTRACT: [Name]	
DATE: [Date]	LOADING: [Name]	DRAWING: [Name]	

Twp 82-140-1-D 10-140 1103



APPENDIX FIR-B

Site Photographs



Photograph 1: Taken near borehole C-2, facing northeast (January 12, 2015).



Photograph 2: Taken near borehole C-1, facing east (January 19, 2015).



Photograph 3: Taken near borehole C-1, facing east (January 19, 2015).



Photograph 4: Taken near borehole RW-7, facing northeast (January 12, 2015).



APPENDIX FIR-C

Rock Core Photographs



Photograph 1: Cores retrieved from borehole C-1. Rock cores 1 to 3 from 1.5 to 4.6 m. RQD values ranged from 38 to 70%, indicating poor to fair rock quality.



Photograph 2: Cores retrieved from borehole C-2. Rock cores 1 to 9 from 4.8 to 8.7 m. RQD values ranged from 0% to 50%, indicating very poor to poor rock quality.



**FOUNDATION DESIGN REPORT
for
JOSHUA'S CREEK ARCH CULVERT EXTENSION
SITE NO. 10-140/C, QUEEN ELIZABETH WAY AND HIGHWAY 403
TOWN OF OAKVILLE
REGIONAL MUNICIPALITY OF HALTON, ONTARIO
G.W.P. 2163-10-00**

PETO MacCALLUM LTD.
165 CARTWRIGHT AVENUE
TORONTO, ONTARIO
M6A 1V5
Phone: (416) 785-5110
Fax: (416) 785-5120
Email: toronto@petomaccallum.com

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GEOCRES No.: 30M5-314
June 19, 2015



TABLE OF CONTENTS

1. INTRODUCTION	1
1.1 Background.....	1
1.2 Discussion.....	2
2. FOUNDATIONS.....	3
2.1 Geotechnical Bearing Resistances	3
2.2 General Recommendations.....	4
2.2.1 Subgrade Preparation.....	4
2.2.2 Sliding Resistance	5
2.2.3 Seismic Site Coefficient	5
2.2.4 Foundation Frost Depth	6
3. CONSTRUCTION CONSIDERATIONS.....	7
3.1 Roadway Protection System	7
3.2 Embankment Widening	8
3.3 Excavation	8
3.4 Groundwater Control	9
4. CULVERT BACKFILL.....	10
5. HEADWALLS AND WINGWALLS.....	12
6. EROSION CONTROL	12
7. CLOSURE	14

Appendix FDR-A – OPSS's and NSSP's

FOUNDATION DESIGN REPORT

for

Joshua's Creek Arch Culvert Extension
Site No. 10-140/C, Queen Elizabeth Way and Highway 403
Town of Oakville
Regional Municipality of Halton, Ontario
GWP 2163-10-00

1. INTRODUCTION

The proposed extension of the Joshua's Creek Arch culvert is planned as part of the rehabilitation of the Queen Elizabeth Way and Highway 403 structures near Ford Drive in Oakville Ontario. This report was prepared for Stantec Consulting Ltd. (Stantec) on behalf of the Ministry of Transportation of Ontario (MTO).

This foundation design report for Detailed Design purposes provides foundation engineering comments and recommendations for the design and construction of the proposed concrete arch extension of the Joshua's Creek culvert.

A list of the standard specifications referenced in this report and related Non Standard Special Provisions are compiled in Appendix FDR-A. All elevations in this report are expressed in meters.

1.1 Background

The existing Joshua's Creek arch culvert is located on the Queen Elizabeth Way and Highway 403 at Station 23+223 in the Town of Oakville, Regional Municipality of Halton. The length and span of the existing culvert are approximately 100 and 10.4 m, respectively. The Joshua's Creek culvert has an existing invert slab approximately 230 mm thick.

The new 20.4 m long concrete arch culvert extension is to be constructed at the same invert levels as the existing culvert. The culvert will be extended at the inlet, which is on the west side of the structure. It is proposed that the new culvert extension be a cast-in-place concrete arch culvert. Alternatively, a precast concrete arch culvert extension may be considered.

In summary, the subsurface stratigraphy at the culvert inlet generally consisted of up to 0.3 m thick topsoil underlain by mainly cohesive firm to stiff fill deposit underlain by hard clayey silt to silty clay glacial till. The till material is underlain by soft to medium strength shale bedrock with interbedded limestone. Cobbles were encountered within the fill deposit. Weathered bedrock fragments were encountered in the glacial till material overlying the bedrock.



Due to frozen winter conditions, the groundwater level during the investigation was taken as the top of the ice surface in Joshua's Creek. The corresponding elevation of 120.2 m and was taken on January 19, 2015. The groundwater level at the site is ultimately governed by the water level in Joshua's Creek.

1.2 Discussion

From a foundation perspective, the proposed installation of a precast or a cast-in-place concrete arch culvert extension is feasible at the culvert location. It is assumed that the culvert extension will be similar in type and configuration to the existing culvert.

The construction of the culvert extension should consider groundwater control measures for construction under wet or dry conditions. Site specific groundwater control measures are required because of the shallow overburden overlying bedrock at the culvert site. Also, possible high water levels at the site during construction could be due to seasonal creek water level fluctuations.

The shale bedrock encountered at Joshua's Creek is classified as slightly to highly weathered. Should excavation of the shale be required to reach the founding elevations of the open footings, the digability of the weathered shale should be possible using a large hydraulic hoe equipped with a rock bucket. A hoe ram and/or road header may be required to penetrate relatively harder zones (limestone bands) within the shale. Progressively more difficult conditions should be anticipated with increasing depth of excavation into the shale.

The weathered shale in the excavation is expected to deteriorate rapidly upon exposure. A concrete skin slab with minimum thickness 100 mm should be placed immediately following the excavation to protect the rock face and subgrade from further deterioration. The existing invert slab should also be incorporated in the design to preserve the integrity of the Queenston shale bedrock against weathering and erosion.

Refer to the related Non Standard Special Provisions for dewatering, bedrock excavation and concrete working slab requirements in Appendix FDR-A.

A temporary roadway protection system may need to be employed during the construction of the extension of the Joshua's Creek concrete arch culvert. Recommendations for a roadway protection system are included in this report.



The "red flag" issues outlined in the preceding paragraphs and the recommended methods of overcoming these issues noted in the following sections of the report are intended to alert and aid the designer and the Contractor. It is noted that no responsibility or liability is assumed by the consultants or the MTO for alerting the Contractor to all critical issues. The requirement to deliver acceptable construction quality remains the responsibility of the Contractor.

2. FOUNDATIONS

In order to match the existing arch culvert foundation, open spread footings will have to be employed to provide foundation support to the new culvert extension and the new retaining walls.

From a foundation perspective open spread footings founded on shallow weathered shale bedrock matching the existing footings of the existing culvert is the preferred alternative and is considered feasible at the project site.

The following recommendations apply to both precast and cast-in-place concrete culvert extension options, except for the sliding resistance in Section 2.2.2 where different parameters are tabulated for the two options concerning precast and cast-in-place concrete footings.

2.1 Geotechnical Bearing Resistances

The existing culvert was designed to be founded on weathered shale bedrock. Open spread footings for the culvert extension and associated retaining walls must also be founded on the shallow weathered shale bedrock at the site to provide adequate bearing support and to control differential settlement between the existing culvert and the new construction. The shallow weathered shale bedrock is considered capable of adequately supporting the stress imposed by the concrete arch culvert extension and the associated retaining walls.

It is assumed that the invert level of the proposed arch culvert extension will be specified to match the existing culvert invert level.

It is estimated that 0.9 to 6.3 m of excavation will be required to achieve the anticipated culvert extension founding elevation on the shale bedrock at the inlet location. The shallow shale bedrock is moderately to highly weathered at the surface and becomes less weathered as the shale is penetrated.



The target founding elevations and recommended factored geotechnical bearing resistances at ultimate limit states (ULS) and the geotechnical reaction at serviceability limit states (SLS) for the proposed concrete arch culvert extension and retaining walls constructed on the native slightly or highly weathered shale bedrock are as follows:

SUBGRADE SOIL TYPE	TARGET ELEVATION (m)	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL REACTION AT SLS (kPa)
Highly Weathered Shale Bedrock	119.0	800	600
Slightly Weathered Shale Bedrock	117.4	1000	>1000

For footings founded on highly weathered shale bedrock the geotechnical reaction at SLS was recommended to allow for a maximum 10 mm to 20 mm compression of the founding medium. For footings founded on slightly weathered shale bedrock the geotechnical reaction at SLS was recommended to allow for a maximum 10 mm compression of the founding medium.

It is noted that consideration should be given at the design engineer's discretion, to introduce joints in the culvert to accommodate the differential settlements between the existing culvert and the extension section.

The recommended bearing resistances are applicable for the existing footing widths. The new footing widths for the concrete arch culvert extension will match the existing footing widths of the existing culvert.

2.2 General Recommendations

2.2.1 Subgrade Preparation

Preparation of the subgrade for construction of the culvert extension should be performed and monitored in accordance with OPSS 902. To prevent further weathering of the shale at the base of the excavation, a concrete skin slab with a minimum thickness of 100 mm should be placed within 4 hours following excavation.

If mass concrete construction is required to build up from uneven bedrock, it should be in accordance with OPSS.PROV 904.



Comments concerning excavation of bedrock to enable construction of the footings are provided in Section 3.3 of this report.

In addition, within the culvert bed, the concrete invert slab should be designed to match the existing invert slab at the existing culvert. The design of the concrete invert slab should be provided by the structural engineer.

2.2.2 Sliding Resistance

The following unfactored parameters should be used in the computation of sliding resistance of precast and cast-in-place concrete foundations.

SOIL TYPE	EQUIVALENT FOUNDATION FRICTION ANGLE (Degrees)		SATURATED UNIT WEIGHT (kN/m ³)
	CAST-IN-PLACE	PRECAST	
Granular A or Granular B Type II	35	32	22.8
Clayey Silt to Silty Clay Till	28	26	20.0
Weathered Shale Bedrock	26	24	20.0

Sliding design should be in conformance with Section 6.7.5 of the CHBDC.

2.2.3 Seismic Site Coefficient

The seismic site coefficient for the conditions at the Joshua's Creek culvert site is 1.0 -Type I soil profile as per clause 4.4.6 of the Canadian Highway Bridge Design Code (CHBDC) 2006 Edition – for the anticipated foundation conditions.

The following seismic parameters will be used for design accordance with the CHBDC for a design earthquake with 475-year return period:

- Velocity Related Seismic Zone 0
- Zonal Velocity Ratio 0.05
- Acceleration Related Seismic Zone 1
- Zonal Acceleration Ratio 0.05
- PEAK Ground Acceleration 0.04 g



The soil profile type at this site has been classified as Type I. Therefore, according to Clause 4.4.6.1 of CHBDC, a site Coefficient "S" (ground motion amplification factor) of 1.0 will be used in seismic design.

In accordance with Clause 4.6.4 of CHBDC, retaining structures will be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. For the design of retaining walls, the coefficients of lateral earth pressure in the following table will be used.

Seismic Earth Pressure Coefficients

Loading Condition	Granular A Or Granular B Type II		Granular B, Type I	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Coefficient of Active Earth Pressure, K_{AE}	0.29	0.42	0.32	0.51
Coefficient of Earth Pressure At Rest, K_{OE}	0.46	-	0.51	-
Coefficient of Passive Earth Pressure, K_{PE} (*)	3.5	-	3.25	-

(*) Not recommended at this site.

Given the compact to very dense compactness of native soils the potential for liquefaction of the foundation soils is negligible.

2.2.4 Foundation Frost Depth

Since shale is frost susceptible, the underside of the footings must have a minimum of 1.2 m earth cover or equivalent insulation for frost protection purposes.



3. CONSTRUCTION CONSIDERATIONS

Potential construction concerns include, but are not limited to:

- 1) A lean concrete skin slab should be placed on bearing surfaces of exposed shale within 4 hours after the bedrock surface has been properly prepared and is free of loose debris, to prevent further weathering, softening and deterioration.
- 2) Excavation across the width of the creek to remove loose debris and prepare the subgrade could require creek diversion during construction. This may be accomplished by utilizing a cofferdam around the work area, coupled with a dewatering scheme. Either a flume pipe or a pumping system could be utilized to achieve creek diversion.
- 3) Excavation must not undermine the existing footings and/or invert slab of the existing Joshua's Creek culvert.

A list of the Ontario Provincial Standard documents relevant to this report is provided in Appendix FDR-A along with Non Standard Special Provisions (NSSP's).

3.1 Roadway Protection System

It is anticipated that a suitable roadway protection system following OPSS.PROV 539 will be necessary to support the walls of excavation and adjacent traffic lanes during construction of the Joshua's Creek arch culvert extension.

A roadway protection system should be designed according to OPSS.PROV 539. It is recommended that a minimum performance level 2 be implemented to prevent excessive lateral movement of the adjacent existing embankment during construction. The Contractor should be responsible for the selection, detailed design and performance of the roadway protection scheme.

Alternative roadway protection schemes such as sheet piling or anchored soldier piles and lagging could be considered. Soldier piles and lagging are generally considered suitable for applications above groundwater table in cohesive materials and is the preferred option if roadway protection is required at Joshua's Creek.



3.2 Embankment Widening

It is recommended that existing topsoil and fill materials containing organics should be excavated down to native hard clayey silt to silty clay till soils or shale bedrock along the required widened area. The excavated material should be replaced with suitable fill.

Embankment fill should be placed and compacted in accordance with OPSS.PROV 206 and OPSS.PROV 501. New embankment fill against existing embankment slopes or on a sloping ground surface should be benched into the existing slope in accordance with OPSD 208.010.

It is estimated that the post construction settlement of the new embankment constructed as recommended in this report will be in the order of 30 mm. About 5 to 20 mm of this post construction settlement is expected to take place immediately after completion of construction and the remaining settlement is anticipated to occur over a period of 3 months after construction.

The settlements of the shale bedrock under the maximum 6.0 m height of embankment widening will be negligible.

The post construction settlement of the widened portion of the embankment can be minimized by preloading for a period of 2 months. If there is a requirement to minimize differential settlement between the existing and widened embankment areas due to self settlement of the fill in a shorter time period, the use of granular fill is preferred since the majority of their settlements will occur during construction. Granular B Type II material should be used to fill over wet subgrade areas, in particular those adjacent to the creek.

These potential settlements will adequately satisfy the MTO guidelines for transverse differential settlements as outlined in the MTO "Embankment Settlement Criteria Guidelines" dated March 2, 2010, and a preloading provision is not required before paving.

3.3 Excavation

Excavation to the anticipated subgrade level of the open footings for the new Joshua's Creek arch culvert extension is expected to extend through the topsoil and surficial fill (near the culvert inlet) and through the hard clayey silt to silty clay till into the weathered shale bedrock present at the site.

The shale bedrock encountered at Joshua's Creek is classified as slight to highly weathered. Subject to adequate groundwater control, should excavation of the shale be required to reach the



founding elevations of the open footings for the culvert extension or to reach the founding elevations for the retaining walls, the weathered shale should be digable using a large hydraulic hoe equipped with a rock bucket. A hoe ram, jack hammer and/or roadheader may be required to penetrate relatively harder zones (limestone bands) within the shale. Progressively more difficult conditions should be anticipated with increasing depth of excavation into the shale.

Refer to the related NSSP for rock excavation in Appendix FDR-A.

All excavations should be conducted in accordance with OPSS 902. Weathered shale fragments found in the native till material similar in size to cobbles and boulders may be encountered in the native till soil during excavation.

The first stage of the excavation should include the fill above and then beside the existing culvert to avoid sliding or instability concerns. It is recommended that the excavation of the fill be carried out simultaneously on both sides of the culvert to avoid instability. Since the new culvert extension will be installed at the same invert level as the existing culvert, the backfill material should be placed and compacted as recommended in Section 4 of this report.

According to the Occupational Health and Safety Act (Ontario Regulation 213/91) criteria, bedrock is considered Type 1 soils, the in-situ very stiff to hard cohesive soils are considered as Type 2 soils necessitating temporary cut slopes to be inclined no steeper than 1H:1V above a level 1.2 m from the bottom of the excavation. The stiff soils and existing fill are classified as Type 3 soils which necessitate cut slopes to be inclined no steeper than 1H:1V from the bottom of the excavations. Below the water table, cut slopes should be shaped at 3H:1V or flatter. Where composite soil types exist, the excavation slopes should be cut to the requirements of the soil type with the highest number that is present in the slope according to OHSA.

All construction work should be carried out in accordance with the Occupational Health and Safety Act and with local/MTO regulations.

3.4 Groundwater Control

The extent of groundwater control will depend on the depth of excavation below the ground water level at the time of construction and on the Contractor's construction techniques. Groundwater control refers to both surface water management during and after construction and to dewatering during construction. This aspect is the responsibility of the Contractor as temporary works, but for



construction in the dry, the prevailing groundwater level should be lowered a minimum of 0.5 m below excavations.

Reference is made to OPSS 517 and OPSS 518 which pertain to construction dewatering. Refer to the related NSSP for dewatering in Appendix FDR-A.

It will be likely necessary to implement measures to control seasonal ponded or surface water flow at the culvert location. Conventional procedures such as dam and pump and/or diversion of the any overland flow streams should be sufficient. Nevertheless, it should be considered that groundwater levels are subject to seasonal fluctuations and precipitation patterns and where the groundwater table is well above the proposed subgrade level at the time of construction, cofferdams may be required for the installation of the culvert extension. The Contractor is responsible for the selection, detailed design and performance of the cofferdams.

It is also recommended that the work be carried out during the usually dry months of June to September to minimize the amount of groundwater inflow to be handled and the volume of surface water, if any, to be diverted from the construction area.

It should be considered that a permit to take water (PTTW) is required by the Ministry of the Environment for water taking over 50,000 litres per day. From a geotechnical standpoint the requirement for a PTTW will depend on the volume of water to be piped over the anticipated temporary dam and diversion of the flow of Joshua's Creek to permit construction of the culvert extension.

4. CULVERT BACKFILL

Backfill adjacent to the culvert extension and the retaining walls (head walls and/or wing walls) should be placed in accordance with OPSS 401, OPSS.PROV 501 and OPSS 902. Backfill material specifications should conform to OPSS.PROV 1010.

Backfill should be brought up simultaneously on each side of the culvert and operation of heavy equipment within 0.5 times the height of the culvert (each side) should be restricted to minimize the potential for movement and/or damage of the culvert due to the lateral earth pressure induced by compaction.



The proposed culvert must be designed to support the stress imposed by the overlying fill as well as to resist the unbalanced lateral earth pressure and compaction pressure exerted by the backfill adjacent to the culvert walls.

The lateral earth and water pressure, p (kPa), should be computed using the equivalent fluid pressures presented in Section 6.9 of the Canadian Highway Bridge Design Code (CHBDC) or employing the following equation assuming a triangular pressure distribution.

$$p = K (\gamma h_1 + \gamma' h_2 + q) + \gamma_w h_2 + C_p + C_s$$

where p = lateral earth pressure (kPa)

K = lateral earth pressure coefficient

γ = unit weight of backfill material above design water level (kN/m³)

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

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

h_1 = depth below final grade (m), above design water level

h_2 = depth below design water level (m)

q = any surcharge load (kPa)

C_p = compaction pressure (refer to clause 6.9.3 of CHBDC)

C_s = earth pressure induced by seismic events, kPa (refer to clause 4.6.4 of CHBDC)

where ϕ = angle of internal friction of retained soil (35° for Granular A or B Type II)

δ = angle of friction between soil and wall (23.5° for Granular A or B Type II)

The following parameters are recommended for design:

PARAMETER	GRANULAR A OR GRANULAR B TYPE II	SUITABLE FILL
Angle of Internal Friction, degrees	35	30
Unit Weight, kN/m ³	22.8	21.0
Coefficient of Active Earth Pressure (K_a)	0.29	0.29
Coefficient of Earth Pressure At Rest (K_o)	0.46	0.45
Coefficient of Passive Earth Pressure (K_p)	3.50	3.45

The design should consider both the maximum water level in the creek and the stabilized groundwater level condition. The maximum creek water level will be dictated by flood flow conditions and should be defined by the project hydrological engineer.

Head walls integral with the culvert are considered to be unyielding walls. The coefficient of earth pressure at rest should be employed to design unyielding walls. Head walls that are not integral



with the culvert are considered to be yielding walls, in which case the active coefficient of earth pressure applies.

The seismic site coefficient for the conditions at this site was provided in Section 2.2.3.

5. HEADWALLS AND WINGWALLS

The previous recommendations and geotechnical parameters for culvert foundations and backfill should be utilized for the design of the foundations for headwalls and wingwalls, if required. Where the walls are designed integral with the culvert structure, the wall founding levels should match those of the culvert. For walls designed separately from the culvert structure, the founding levels should be established to provide 1.2 m of earth cover for adequate foundation frost protection.

The design of the walls should be checked for sliding resistance using the geotechnical parameters provided for sliding in Section 2 for precast and cast-in-place concrete foundations and the values for earth pressure design provided in Section 4.

A weeping tile system and/or weep holes should be installed to minimize the build-up of hydrostatic pressure behind the headwalls and wingwalls. 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 outlet drainage pipes should be placed on a positive grade.

6. EROSION CONTROL

The protective measures noted in the OPSD 800 series to deal with erosion (inlet/outlet treatment, headwalls, cut-off walls etc.) are considered to be appropriate. The backfill to walls should consist of OPSS Granular A or Granular B Type II. The cut-off walls should extend laterally and vertically to protect the granular backfill material and to a depth at least equal to the fluctuation of the water level at the culvert location to prevent flow below the culvert.

Inlet protection in accordance with OPSS 511 and OPSS.PROV 1004 is recommended to prevent erosion adjacent to the culvert as well as scour that could undermine the culvert foundation. The actual design requirements concerning the length and width of aprons at the inlet of the culvert as well as the rock size, apron thickness, height of erosion protection on the embankment slope and type of material will be dictated by stream hydraulics, stream configuration and the water level in the



stream and should be established by the project hydrologist. Alternatively, a head wall can be designed to protect the embankment and direct water to the culvert inlet.

Any newly constructed embankment slopes and retained soils behind the headwalls and wingwalls should be covered with topsoil or suitable excess earth material and seeded in accordance with OPSS 802 and OPSS.PROV 804, 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. Additional appropriate erosion control measures for the project should be assessed using the following erodibility K factor.

SOIL TYPE	K FACTOR
Silty Sand	0.30
Clayey Silt to Silty Clay	0.45



7. CLOSURE

This Foundation Design Report was prepared by Mr. K. R. Daly BEng, EIT, and reviewed by Mr. B. R. Gray, MEng, P.Eng., Principal Consultant and Mr. D. Dundas, P. Eng., Senior Geotechnical Engineer. Mr. C. M. P. Nascimento, P. Eng., Project Manager and MTO Designated Principal Contact conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

A handwritten signature in blue ink, reading "Kyle R. Daly".

Kyle R. Daly, BEng, EIT
Project Supervisor, Geotechnical Services



David H. Dundas, P. Eng.
Senior Engineer, Geotechnical Services



Carlos M.P. Nascimento, P.Eng.
Project Manager and
MTO Designated Principal Contact

KD/CN/BRG:kd-mi-jk



APPENDIX FDR-A

OPSS's and NSSP's



SPECIFICATIONS RELEVANT TO THE REPORT

DOCUMENT	TITLE
OPSS.PROV 206	Construction Specification for Grading
OPSS 401	Construction Specification for Trenching, Backfilling and Compacting
OPSS.PROV 501	Construction Specification for Compacting
OPSS 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 518	Construction Specification for Control of Water From Dewatering Operations
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS 802	Construction Specification for Topsoil
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling of Structures
OPSS.PROV 904	Construction Specification for Concrete Structures
OPSS.PROV 1004	Material Specification for Aggregates – Miscellaneous
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSS 1860	Material Specification for Geotextiles
OPSD 208.010	Benching of Earth Slopes



NSSP for Rock Excavation - Addition to OPSS 902

The Contractor shall be advised that the equipment required and method of excavation within the bedrock will be dependent upon the geometry of the excavation and the depth of excavation into the bedrock. Although the method of excavation should remain the responsibility of the Contractor, the shale bedrock is slight to highly weathered and subject to adequate groundwater control, excavations of the upper highly weathered shale should be possible with conventional excavation techniques for shale bedrock. A hoe ram or jack hammer may be required to penetrate relatively harder zones (limestone bands) within the shale. Progressively more difficult conditions should be anticipated with increasing depth of excavation.

NSSP for Dewatering - Addition to OPSS 902

The Contractor shall take measures to lower the prevailing groundwater level a minimum of 0.5 m below the base of excavations or foundation bases for construction in-the-dry.

NSSP for Concrete Working Slab Requirements - Addition to OPSS 902 & OPSS.PROV 904

The shale bedrock is prone to weathering when exposed to the elements. To prevent further weathering of the shale at the founding levels, a lean concrete skin slab with a minimum thickness of 100 mm should be placed on all bearing surfaces as soon as possible but within 4 hours after the bearing surfaces have been exposed to prevent further weathering, softening and deterioration.