



**THURBER** ENGINEERING LTD.

**PRELIMINARY  
FOUNDATION INVESTIGATION REPORT  
HIGHWAY 17 TWINNING, RENFREW AREA  
CPR WBL STRUCTURAL CULVERT SITE NO. 29X-0194/B1  
WP 4068-09-00 / ASSIGNMENT NO. 4018-E-0009**

Geocres No.: 31F-240

Report to:

**Ministry of Transportation Ontario**

Latitude: 45.476925°  
Longitude: -76.632043°

December 2022  
Thurber File No.: 24726



## TABLE OF CONTENTS

### PART 1. FACTUAL INFORMATION

1	INTRODUCTION.....	1
2	SITE DESCRIPTION .....	2
2.1	Site Geology.....	2
3	SITE INVESTIGATION AND FIELD TESTING .....	2
4	LABORATORY TESTING .....	3
5	GENERAL DESCRIPTION OF SUBSURFACE CONDITIONS .....	4
5.1	Topsoil/Organics .....	4
5.2	Clayey Silt (CL to CL-ML).....	4
5.3	Till: Silty Sand to Clayey Sand to Sandy Silt (SM, SC-SM, SC, ML).....	6
5.4	Bedrock .....	7
5.5	Surface and Groundwater .....	7
5.6	Analytical Testing .....	8
6	MISCELLANEOUS .....	10

### APPENDICES

Appendix A.	Borehole Location Plan and Stratigraphic Drawings
Appendix B.	Record of Borehole Sheets
Appendix C.	Laboratory Testing
Appendix D.	Site Photographs
Appendix E.	MASW Report



**PRELIMINARY  
FOUNDATION INVESTIGATION REPORT  
HIGHWAY 17 TWINNING, RENFREW AREA  
CPR WBL STRUCTURAL CULVERT SITE NO. 29X-0194/B1  
WP 4068-09-00 / ASSIGNMENT NO. 4018-E-0009**

**Geocres No.: 31F-240**

**PART 1. FACTUAL INFORMATION**

**1 INTRODUCTION**

Thurber Engineering Ltd. (Thurber) has been engaged by the Ministry of Transportation Ontario (MTO) under Assignment No. 4018-E-0009 to carry out Foundation Investigations to support the design of the Highway 17 Twinning Project which extends from Scheel Drive westerly to 3 km west of Bruce Street in the Renfrew area.

This report addresses the proposed Highway 17 westbound lanes (WBL) crossing of the now abandoned Canadian Pacific Railway (CPR) line (currently known as Algonquin Trail) east of Renfrew, Ontario. The existing Highway 17 alignment will become the future Highway 17 westbound lanes (WBL). Details of the foundation investigations associated with the proposed structure to carry future eastbound traffic over the trail are reported under separate cover.

This section of the report presents the factual findings obtained from a desktop study carried out based on historical information as well as pertinent information collected at nearby sites as part of the overall project and included:

- Memorandum prepared by Department of Highways Ontario titled, “*Foundation Investigation Report for The Overhead Structure at the Crossing of Proposed Hwy. 17 ‘New’ WBL and Canadian Pacific Railway, Twp. Of Horton – Co. of Renfrew, District No. 9 (Ottawa), W.O. 71-11085, W.P. 5-76-01*”, dated December 17, 1971 (Geocres No. 31F00-053); and,
- Report prepared by Thurber titled, “*Preliminary Foundation Investigation and Design Report, Highway 17 Twinning, Renfrew Area, CPR EBL Structural Culvert Site No. 29X-0194/B2, WP 4068-09-00 / Assignment No. 4018-E-0009*”, dated December 2022 (Geocres No. 31F-241).

The purpose of this study was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions.

It should be noted that the use of and reliance on Part 1 of the Report is governed by and limited to the terms and conditions set out in the Report and a reliance letter. The Preferred Proponent remains responsible to assess the need for additional investigations and to complete that work.



## 2 SITE DESCRIPTION

The site is located on Highway 17 approximately 1.2 km east of O'Brien Road (Highway 60). Highway 17 is generally oriented east to west and the trail at the site is oriented roughly northeast to southwest. For project purposes, the highway and trail are herein described as oriented east-west and north-south, respectively.

The land adjacent to the site typically consists of forests, wetlands, and agricultural fields. The terrain is relatively flat apart from the existing highway embankment and drainage ditches adjacent to the trail. Highway 17 in this area consists of a two-lane undivided highway with paved shoulders. The existing embankment side slopes did not show any visible signs of distress at the time of the investigation and were sloped at approximately 2.0H:1V to 2.3H:1V.

The existing bridge is a three-span, pile supported structure. The trail crosses under the highway at a 45 degree skew, the trail is an unpaved pathway at approximate elevation 131.0 m to 131.5 m. A drainage ditch runs along the eastern edge of the trail and crosses beneath the bridge through a culvert in front of the existing east abutment. The area east of the trail and south of the existing embankment is dominated by wet ground and standing water. West of the trail are agricultural fields and areas overgrown with brush.

Photographs showing the existing conditions at the site at the time of the field investigation are included in Appendix D for reference.

### 2.1 Site Geology

Based on published geological information in *The Physiography of Southern Ontario* by Chapman and Putnam (1984), the site lies within the physiographic region known as the Ottawa Valley Clay Plains. The Ottawa Valley Clay Plains are characterized primarily by clay plains deposited by the Champlain Sea (Leda Clay) interrupted by ridges of rock or sand.

Base mapping by the Ontario Geological Survey indicates the bedrock in the area is carbonate metasedimentary rocks, marble, calc-silicate rocks, skarn, tectonic breccias of the Grenville Supergroup and Flinton Group.

## 3 SITE INVESTIGATION AND FIELD TESTING

The original site investigation for the existing Highway 17 bridge (future WBL) was carried out between September 7 and October 22, 1971. The field investigation consisted of advancing eight boreholes, identified as BH 1 to BH 8. A recent field investigation was carried out along the proposed new EBL alignment to the south and included a geophysical investigation using Multichannel Analysis of Surface Waves (MASW), completed on June 3, 2020. Details of the MASW testing equipment and methodology are provided in Appendix E.

The 1971 borehole locations were surveyed for elevation and plan location relative to chainage and offset from the then-proposed Highway 17 alignment. The plan coordinates of the boreholes were estimated relative to current base plans. The approximated northing and easting of the



boreholes are shown on the Borehole Location and Soil Strata Drawings in Appendix A and in Table 3-1 below. The drilled location is with reference to the existing bridge structure. The elevation of the boreholes have been converted to a metric geodetic benchmark and are shown on the Borehole Location and Soil Strata Drawings in Appendix A, the individual Record of Borehole sheets in Appendix B, and in Table 3-1 below. The site is located within MTM Zone 9.

**Table 3-1: Borehole Summary**

<b>Borehole No.</b>	<b>Drilled Location</b>	<b>Northing* (Latitude)</b>	<b>Easting* (Longitude)</b>	<b>Ground Surface Elevation** (m)</b>	<b>Termination Depth (m)</b>
BH 1	West Abutment	5037467 (45.477052)	294443 (-76.632473)	129.7	16.5
BH 2	West Abutment	5037469 (45.47707)	294459 (-76.632268)	129.6	17.6
BH 3	West Pier	5037457 (45.476962)	294457 (-76.632294)	129.8	20.2
BH 4	West Pier	5037459 (45.476981)	294472 (-76.632102)	129.8	21.9
BH 5	East Pier	5037444 (45.476846)	294474 (-76.632076)	130.0	19.8
BH 6	East Abutment	5037435 (45.476765)	294503 (-76.631705)	129.7	19.8
BH 7	West Approach	5037485 (45.477214)	294429 (-76.632652)	129.7	4.7
BH 8	East Approach	5037416 (45.476594)	294518 (-76.631513)	129.7	9.4

\* The plan locations of the boreholes were estimated relative to available CAD base plan and area approximate only.

\*\* The ground surface elevation may be significantly different now compared to that of 1971.

Soil samples were obtained at selected intervals using split spoon samplers in conjunction with Standard Penetration Testing (SPT) during the investigation. In-situ vane shear testing was carried out in cohesive soils. Shelby tube samples of the cohesive deposit were collected during the field investigation. In Boreholes BH 1 to BH 6, the bedrock was cored for lengths ranging from about 3.6 to 7.6 m to collect BX sized core samples. Groundwater levels were observed in the open boreholes during the field investigation.

## 4 LABORATORY TESTING

Geotechnical laboratory testing consisted of natural moisture content determination, grain size distribution testing, Atterberg Limit determination, bulk density, and lab shear vane carried out on selected samples. Consolidation testing was also carried out on two samples of the cohesive deposit.

The results of the geotechnical tests are summarized on the Record of Borehole sheets included in Appendix B and are presented on the figures included in Appendix C.



## **5 GENERAL DESCRIPTION OF SUBSURFACE CONDITIONS**

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Location and Soil Strata Drawings included in Appendix A. The MASW data collected as part of the 2021 investigation is provided in Appendix E, for reference. A general description of the stratigraphy based on the conditions encountered in the boreholes is given in the following sections. However, the factual data presented on the Borehole Records takes precedence over the Soil Strata Drawings and the general description. It must be recognized that the soil and groundwater conditions may vary between and beyond borehole locations. Soil classification terminology from the historic borehole information may vary from current practice.

In general terms, the site was found to have a surficial layer topsoil, and/or organics overlying a native clayey silt deposit, which is underlain by a deposit of silty sand glacial till over dolomite bedrock.

The sections below describe subsurface conditions encountered at the time the boreholes were advanced in 1971. Since the boreholes were put down prior to the construction of the existing bridge, it should be noted that surficial deposits within the vicinity of the proposed WBL culvert likely differ from that described below. The surficial deposits would likely have been disturbed, altered, or completely removed during the construction of the existing bridge.

### **5.1 Topsoil/Organics**

Topsoil, organic silt and peat were encountered at the ground surface at all borehole locations. The 1971 investigation report described it as “loose, sandy topsoil intermixed with organic silt.” Boreholes BH 5 and BH 6 indicated that it contained peat. Moisture content testing on one sample of organic silt yielded a value of 45%. Atterberg Limit testing on the same sample indicated a liquid limit of 44% and a plasticity index of 15. This material can be classified as an organic silt of intermediate plasticity. The thickness of the surficial topsoil/organic deposit ranged from about 150 to 600 mm at the time of the investigation. The organic thickness may vary between or beyond the borehole locations and has been assumed to have been subsequently removed within the footprint of the existing bridge approach embankments and foundation elements and, therefore, the thicknesses provided above should not be used for estimating purposes at the site.

### **5.2 Clayey Silt (CL to CL-ML)**

A native, cohesive deposit of clayey silt was encountered below the topsoil or organics in all boreholes. This layer ranged in thickness from 3.2 m to 4.3 m with an underside elevation ranging from 126.5 m to 125.3 m. Occasional sand seams up to about 75 mm thick were reported within this deposit at all borehole locations.

SPTs conducted within this layer gave N-values ranging from 2 to 27. In-situ shear vane tests indicated undrained shear strengths of 62 kPa to greater than 96 kPa, but generally indicated a stiff to very stiff consistency. Sensitivity ranged from 4 to 11.

The moisture content of the samples tested ranged from about 19 to 37%. The results of Atterberg Limits testing carried out on 11 samples of this material are summarized below and are illustrated on Figure C1 in Appendix C. The laboratory results indicate that the material is generally a clayey silt of low plasticity (CL to CL-ML).

**Summary of Atterberg Limit Testing – Clayey Silt**

Parameter	Value
Liquid Limit	20 – 32
Plastic Limit	14 – 18
Plasticity Index	6 – 15

The results of three grain size analysis tests conducted on samples of this material are summarized below and are illustrated on Figure C2 Appendix C.

**Summary of Grain Size Distribution Testing – Clay to Clayey Silt**

Soil Particle	Percentage (%)
Gravel	0 – 5
Sand	10 – 37
Silt	47 – 68
Clay	11 – 22

The results of laboratory oedometer (one-dimensional consolidation) tests carried out on two relatively undisturbed clay samples obtained with thin-walled tube samples are presented on Figure C5 in Appendix C and summarized below. The results for the nearby Borehole CPR19-6, drilled and tested as part of the nearby 2021 investigation, are also summarized in the table below.

**Table 5-1: Consolidation Test Results – Clayey Silt**

Parameter	Results		
Borehole	BH 4	BH 7	CPR19-6
Sample	TW 4	TW 4	ST3
Sample Depth, (m)	3.2	3.4	1.8
Sample Elevation, (m)	126.6	126.3	128.6
Approx. Existing Effective Stress, $P_0$ , (kPa)	32.3	34.3	25
Moisture Content, (%)	31	19	23
Liquid Limit, (%)	26	24	32
Plastic Limit, (%)	15	13	16
Liquidity Index	1.5	0.5	0.44
Unit Weight, $\gamma$ (kN/m <sup>3</sup> )	19.9*	19.9*	19.9
Specific Gravity, $G_s$	-	-	2.730
Initial Void Ratio $e_0$	1.023	0.606	0.653
Pre-consolidation Pressure, $P_c'$ , (kPa)	254	380	270
Over Consolidation Ratio, OCR	7.9	11.1	10.8
Compression Index, $C_c$	0.69	0.21	0.17

Parameter	Results		
Recompression Index, $C_r$	0.03	0.02	0.023
Coefficient of consolidation, $c_v$ (mm <sup>2</sup> /s)	-	-	0.3
Coefficient of re-consolidation, $c_{vr}$ (mm <sup>2</sup> /s)	-	-	0.8

\*assumed based on consolidation test results carried out as part of the 2020 investigation

Other test results reported in the historic report for the clayey silt include Bulk Density ranging from 18 to 21 kN/m<sup>3</sup> and Laboratory Undrained Shear Strength ranging from 24 to greater than 96 kPa.

### 5.3 Till: Silty Sand to Clayey Sand to Sandy Silt (SM, SC-SM, SC, ML)

A basal till deposit was encountered beneath the clayey silt in all boreholes. The upper portions were typically silty sand with a trace to some gravel. The lower portions consisted of a heterogeneous mix of silt, sand and gravel with a trace of clay. Cobbles were encountered in deposit in Boreholes BH 1 to BH 6. Boulders should also be anticipated to be present in the deposit. In the boreholes which fully penetrated this deposit, the thickness ranged from 7.9 m to 12.5 m and the underside ranged from elevation 113.5 m to 117.4 m.

SPTs conducted in this layer gave N-values ranging from 5 to greater than 100 blows for 150 mm of penetration, indicating a loose to very dense relative density, although typically compact to dense. Refusals within this deposit were likely due to the presence of cobbles and boulders. Penetration through this layer often required the use of coring techniques.

The moisture content of samples tested from the till unit ranged from about 7 to 16%. The results of grain size distribution testing carried out on 12 samples of the till are summarized below and the envelope that defines the limits of the results is shown on Figure C4 Appendix C.

#### Summary of Grain Size Distribution Testing – Glacial Till

Soil Particle	Percentage (%)	
Gravel	0 – 42	
Sand	36 – 60	
Silt	54	18 – 44
Clay		4 – 15

The results of Atterberg Limits testing carried out on the fines of six samples of this material are summarized below and are illustrated on Figure C3 in Appendix C. Three additional samples of the fines portion of the deposit were tested and yielded non-plastic results. The laboratory results indicate that the fines are non-plastic to slightly plastic (ML).

#### Summary of Atterberg Limit Testing – Glacial Till Fines

Parameter	Value
Liquid Limit	15 – 16
Plastic Limit	12 – 13
Plasticity Index	3 – 4

## 5.4 Bedrock

Bedrock was proven by coring in all boreholes except BH 7 and BH 8. The bedrock encountered was described as white and pink, crystalline dolomite. Occasional vertical seams were noted in Boreholes BH 2, BH 3, BH 4 and BH 6. The upper 2.1 m to 5.5 m of the bedrock, where encountered, was indicated to be fractured. Total core recovery ranged from 5% to 100% but was generally between about 50% and 80%.

A summary of the bedrock surface information is provided in Table 5-2, below.

**Table 5-2: Summary of Bedrock Depth/Elevation**

<b>Borehole No.</b>	<b>Depth to Bedrock Surface (mbgs)*</b>	<b>Bedrock Surface Elevation (m)</b>
BH 1	12.3	117.4
BH 2	12.2	117.4
BH 3	13.3	116.5
BH 4	14.3	115.5
BH 5	15.3	114.7
BH 6	16.2	113.5

\* Depth relative to ground surface at the time of the 1971 investigation.

## 5.5 Surface and Groundwater

The groundwater level was measured in the open boreholes during the 1971 drilling investigation. At that time, the groundwater level ranged between about Elevation 129.3 m to 129.9 m.

Standpipe piezometers and monitoring wells were installed in boreholes drilled as part of the 2003 and 2020 investigations at the proposed EBL trail crossing site, located about 40 m to the south. The groundwater measurements taken at those locations as part of that study are summarized in Table 5-1, below. The locations, elevations, and installation details of the piezometers and wells are provided under separate cover (Geocres. No. 31F-241) and reference must be made to the details presented therein.

Based on site visits carried out at both sites, ponded water was observed at or above surface year-round in the area.

The groundwater level at the time of construction may be different from those observations described above and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation.

**Table 5-1: Summary of Groundwater Levels**

Borehole No.	Bottom of Screen Elevation (m)	Screened Unit	Depth (mbgs)	Groundwater Elevation (m)	Date of Measurement
CPR-1	113.1	Bedrock	0.4	129.5	October 22, 2003
			0.6	129.3	February 4, 2004
			0.2	129.7	March 11, 2004
CPR-2	119.8	Till	0.5	129.4	October 22, 2003
			0.0	129.9	February 4, 2004
			0.0	129.9	March 11, 2004
CPR19-2	120.6	Till	1.1	129.0	July 22, 2020
			0.7	129.4	September 29, 2020
			0.8	129.3	September 24, 2021
			0.5	129.6	October 4, 2021
			0.7	129.4	January 21, 2022
CPR19-3	112.4	Bedrock	0.5	129.5	July 22, 2020
			0.1	129.9	September 29, 2020
			0.1	129.9	September 28, 2021
			-0.1 <sup>a</sup>	130.1	October 4, 2021
			-0.3 <sup>a</sup>	130.3	January 21, 2022
CPR19-5	124.8	Clayey Silt	0.8	130.4	April 21, 2020
			1.1	130.1	September 29, 2020
			1.1	130.1	September 28, 2021

Note: <sup>a</sup> negative depth indicates artesian conditions

## 5.6 Analytical Testing

Analytical testing was not carried out as part of the 1971 investigation. However, four samples of the native soils collected during the 2020 investigation carried out at the proposed EBL trail crossing site, approximately 40 m to the south, were submitted for analysis of pH, water soluble sulphate, sulphide and chloride concentrations, resistivity, and conductivity as part of that investigation. The analysis results are included in that report (Geocres No. 31F-241) and are summarized below in Table 5-3, for reference.

**Table 5-3: Summary of Chemical Analysis Results (Geocres No. 31F-241)**

<b>Parameter</b>	<b>Result Range</b>
Depth (m)	0.8 – 2.1
Chloride (µg/g)	14 – 183
Sulphate (µg/g)	17 – 64
Sulphide (%)	<0.04
pH (-)	7.4 – 7.7
Resistivity (Ohm-cm)	2,300 – 6,790
Conductivity (µS/cm)	147 – 435

## 6 MISCELLANEOUS

Overall project management and direction of the field visits were provided by Fred Griffiths, P.Eng.

It is noted that the information provided herein is based on an investigation completed prior to construction of Highway 17 and the existing CPR overhead bridge. It is likely that conditions have changed on site during the intervening years.

Interpretation of the factual data and preparation of this report were carried out by Matt Kennedy, P.Eng. and Fred Griffiths, P.Eng. The report was reviewed by P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



Matt Kennedy, M.Sc.(Eng.), P.Eng.  
Senior Geotechnical Engineer



Dr. Fred Griffiths, P.Eng.  
Senior Geotechnical Engineer,  
Senior Associate



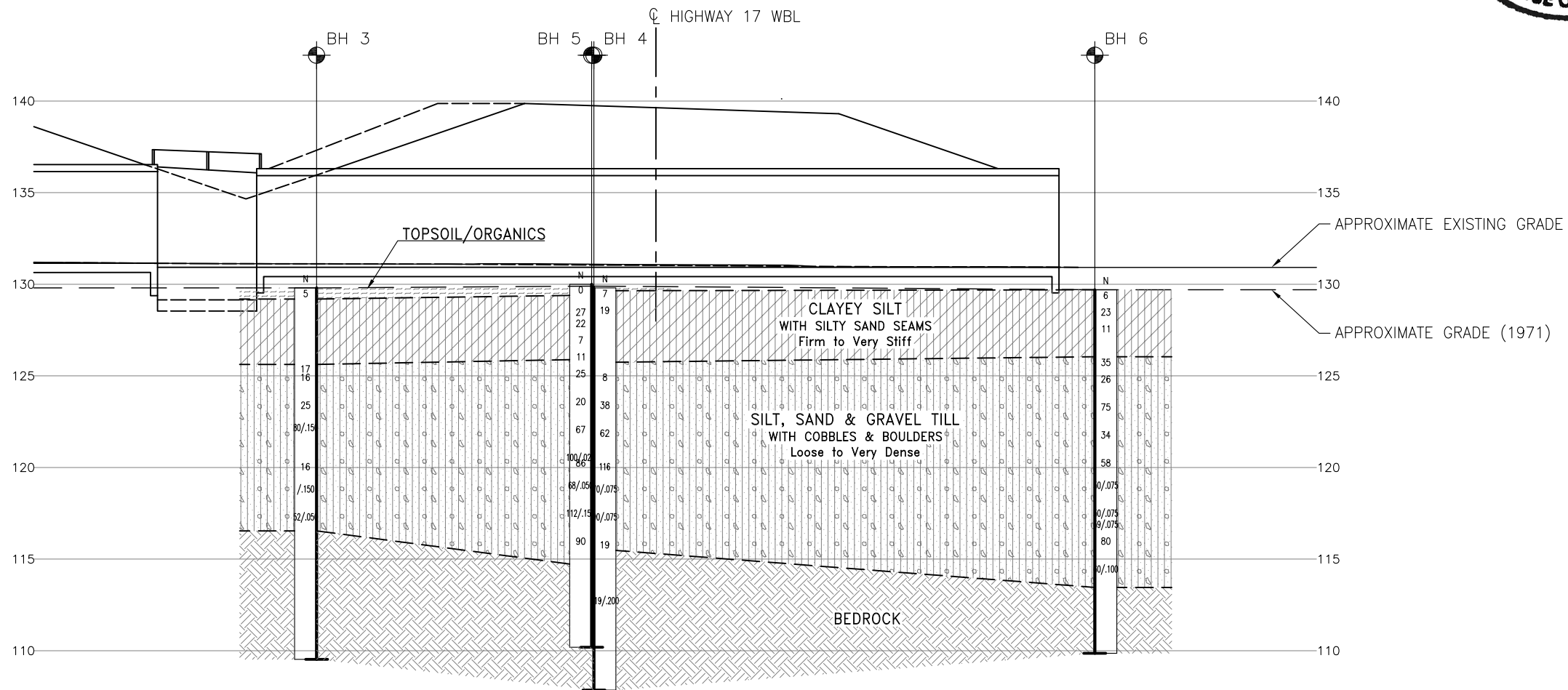
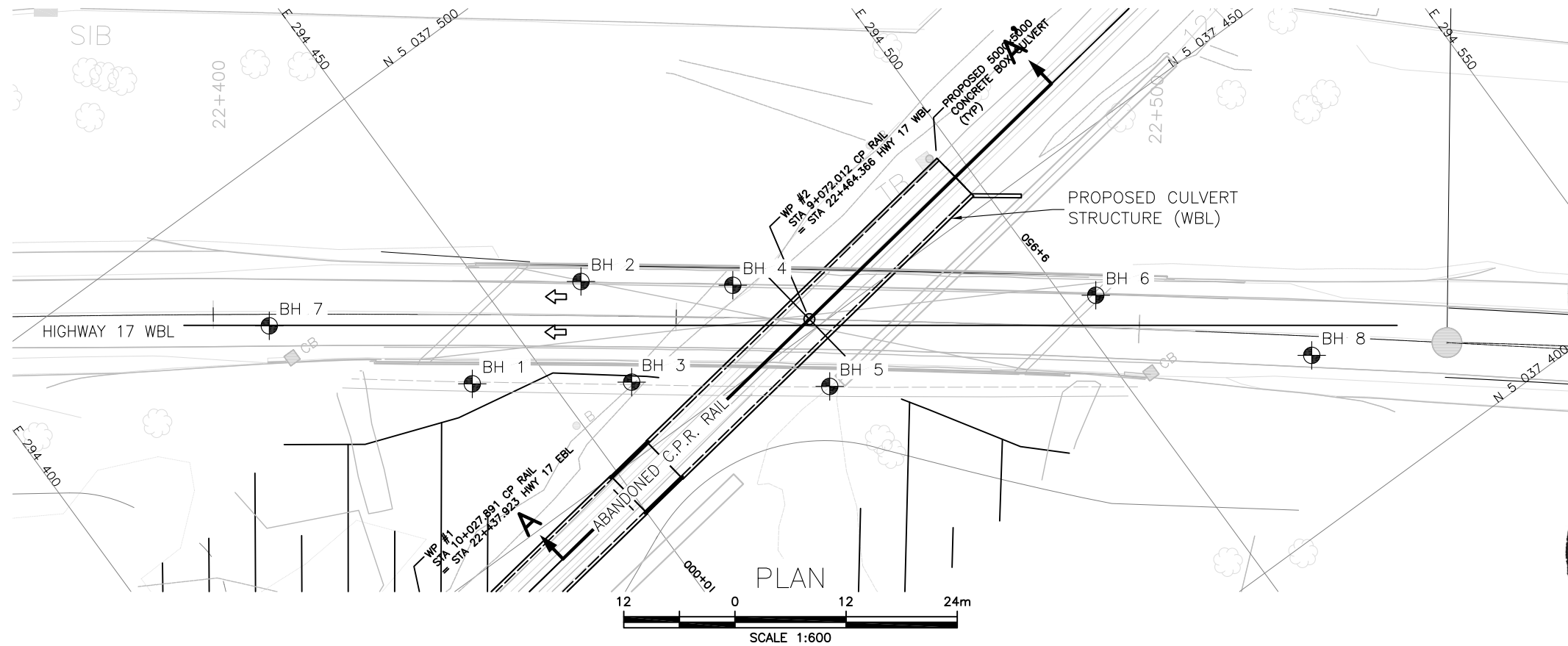
Dr. P.K. Chatterji, P.Eng.  
MTO Review Principal,  
Senior Geotechnical Engineer



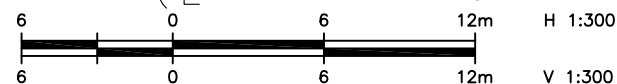


## **Appendix A.**

### **Borehole Location Plan and Stratigraphic Drawings**



SECTION A-A' (Q PROPOSED CULVERT)



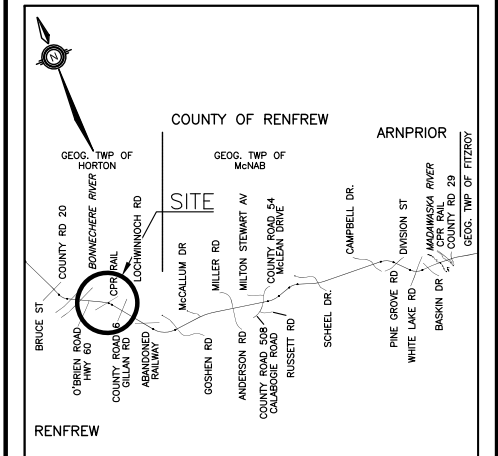
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN



CONT No  
WP No 4068-09-00






HIGHWAY 17 TWINNING  
C.P.R. TRAIL  
WBL STRUCTURE  
BOREHOLE LOCATIONS AND SOIL STRATA

**Ontario** 



## KEYPLAN

## LEGEND

	Borehole
	Borehole (1972 Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

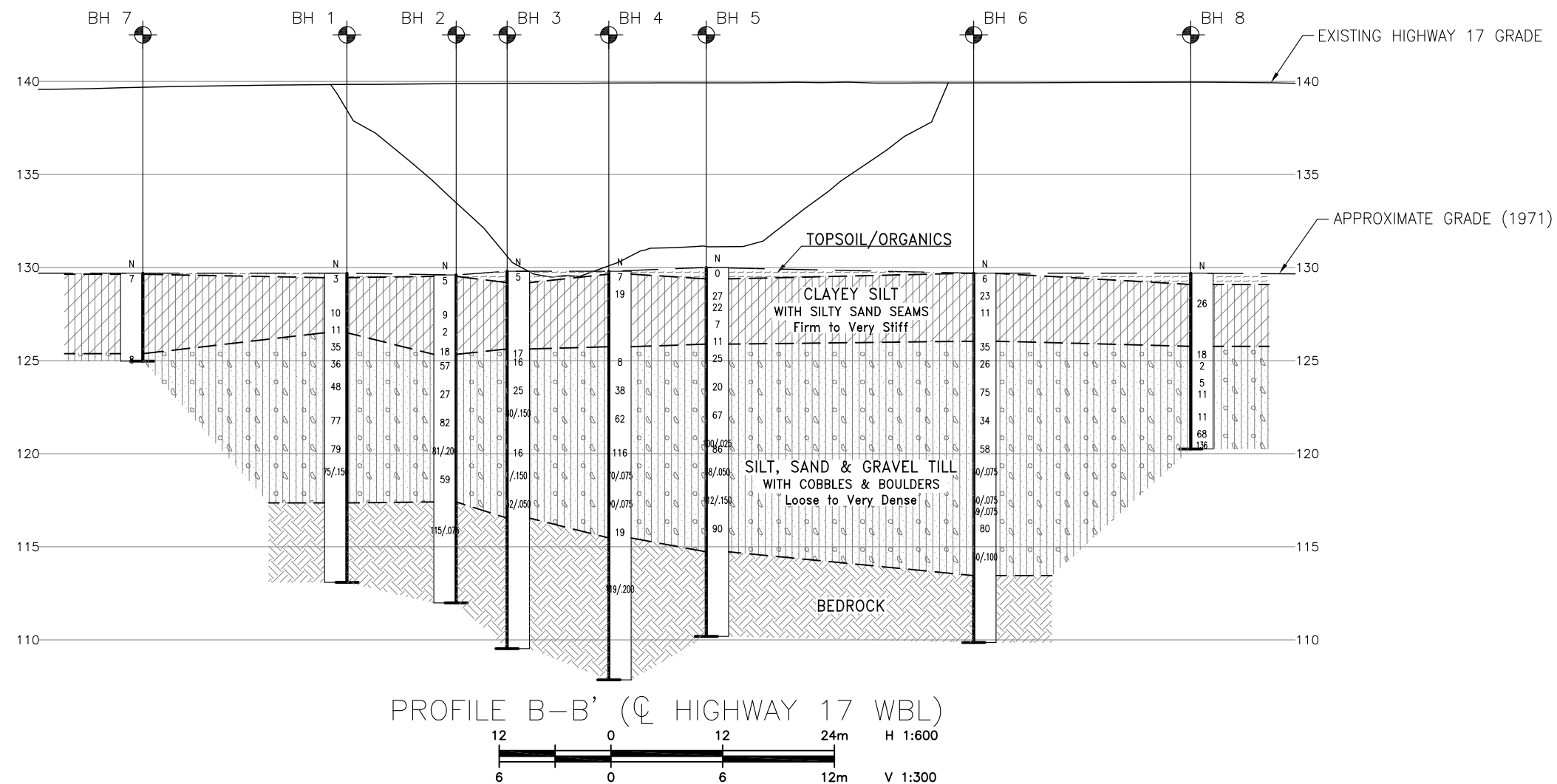
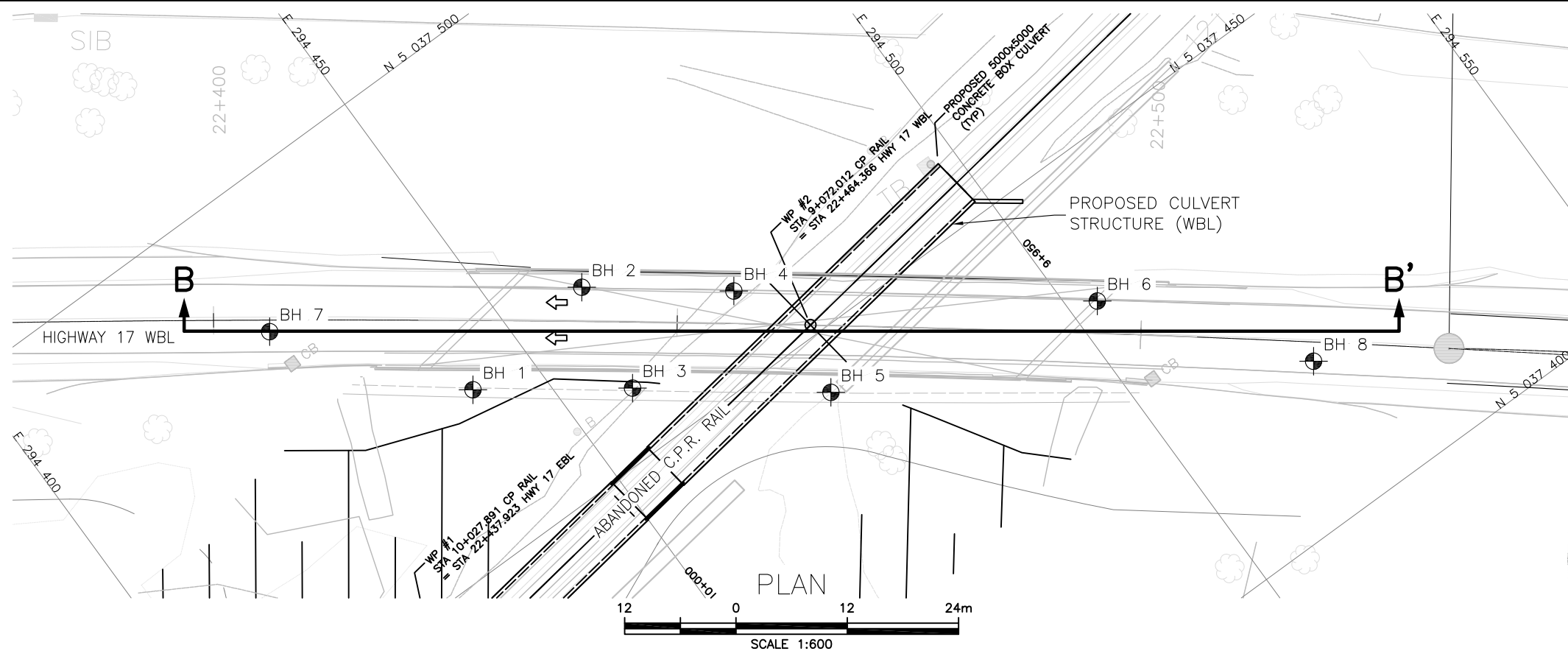
NO	ELEVATION	NORTHING	EASTING
BH 1	129.7	5 037 467.0	294 443.0
BH 2	129.6	5 037 469.0	294 459.0
BH 3	129.8	5 037 457.0	294 457.0
BH 4	129.8	5 037 459.0	294 472.0
BH 5	130.0	5 037 444.0	294 474.0
BH 6	129.7	5 037 435.0	294 503.0
BH 7	129.7	5 037 485.0	294 429.0
BH 8	129.7	5 037 416.0	294 518.0

-NOTES-

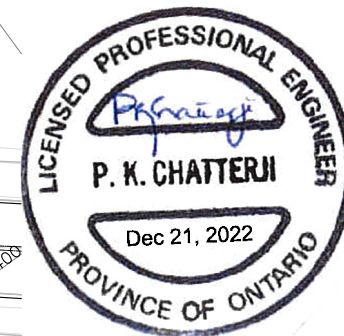
- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Structural elements, surface details and features are for conceptual illustration.
- 3) Coordinate system is MTM NAD 83 Zone 9.

**GEOCRES No. 31F-240**

REVISIONS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
-----------	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--



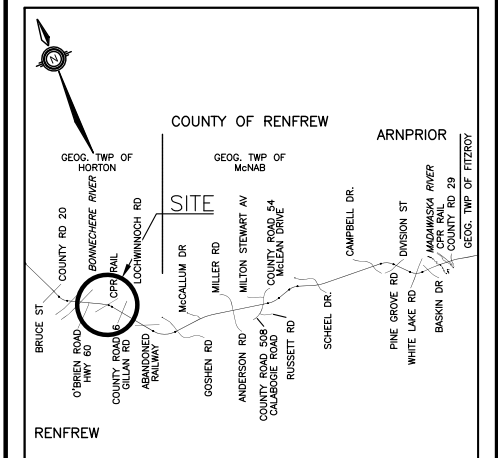
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN



CONT No  
WP No 4068-09-00






HIGHWAY 17 TWINNING  
C.P.R. TRAIL  
WBL STRUCTURE  
BOREHOLE LOCATIONS AND SOIL STRATA

**Ontario** 



## KEYPLAN

### LEGEND

	Borehole
	Borehole (1972 Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
BH 1	129.7	5 037 467.0	294 443.0
BH 2	129.6	5 037 469.0	294 459.0
BH 3	129.8	5 037 457.0	294 457.0
BH 4	129.8	5 037 459.0	294 472.0
BH 5	130.0	5 037 444.0	294 474.0
BH 6	129.7	5 037 435.0	294 503.0
BH 7	129.7	5 037 485.0	294 429.0
BH 8	129.7	5 037 416.0	294 518.0

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Structural elements, surface details and features are for conceptual illustration.
- 3) Coordinate system is MTM NAD 83 Zone 9.

GEOCRES No. 31F-240

REVISIONS									
	DATE	BY	DESCRIPTION						
DESIGN	JG		CHK	MJK		LOAD		DATE	DEC 2022
DRAWN	MFA		CHK	FG	SITE	STRUCT	DWG	2	



## **Appendix B.**

### **Record of Borehole Sheets**



FOUNDATION SECTION

ORIGINATED BY WE

COMPILED BY SO

CHECKED BY MA

SOIL PROFILE		SAMPLES	DYNAMIC PENETRATION BLOWS / FOOT	RESISTANCE	Liquid Limit ———— w <sub>L</sub> Plastic Limit ———— w <sub>P</sub> Water Content ———— w	BULK DENSITY	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		
425.5	Ground Level						
0.0	Organic Silt		1	SS	3		
	Clayey silt, silty sand seams up to 4" thick below el. 420.		2	TW	40		
	Firm to Stiff. Grey		3	SS	10		
415.0			4	SS	11		
10.5	Silty sand, trace of gravel.		5	SS	38		
409.5	Dense. Grey		6	SS	36		
17.0	Glacial Till		7	SS	48		
	Het. mix. of silt, sand & gravel, trace of clay.		8	RC	10%		
			9	SS	77		
	occ. boulders up to 5" in size below el. 405.		10	SS	79		
	Dense to Very Dense Grey		11	SS	75/6		
385.0	-fractured-		12	RC	39%		
40.5	Bedrock		13	RC	87%		
	Crystalline Dolomite		14	RC	89%		
	Sound White		15	RC	91%		
371.0							
54.5	End of Borehole						







DEPARTMENT OF HIGHWAYS- ONTARIO  
MATERIALS & TESTING OFFICE

## RECORD OF BOREHOLE No. 11

FOUNDATION SECTION

JOB 71-11085

LOCATION Sta. 509 + 16 20' Lt.

W.P. 7-67-03

BORING DATE Sept. 7, 8, 9, 10 & 15, 1971

ORIGINATED BY: JH

DATUM Geodetic

BOREHOLE TYPE Diamond Drill Washcoring

COMPILED BY SO

CHECKED BY                     

[illegible]



DEPARTMENT OF HIGHWAYS- ONTARIO  
MATERIALS & TESTING OFFICE

## RECORD OF BOREHOLE No. 5

FOUNDATION SECTION

JOB 71-11085 LOCATION Sta. 509 + 51 20' Rt.

ORIGINATED BY WH

W.P. 7-67-03 BORING DATE Oct. 18, 19 & 20, 1971

COMPILED BY SQ

DATUM Geodetic BOREHOLE TYPE Diamond Drill Washboring

CHECKED BY 7-6

[illegible]







DEPARTMENT OF HIGHWAYS- ONTARIO  
MATERIALS & TESTING OFFICE

## RECORD OF BOREHOLE No. 8

FOUNDATION SECTION

JOB 71-11085

LOCATION Sta. 511 + 31 @

ORIGINATED BY WH

W.P. 7-67-03

BORING DATE Oct. 21 &amp; 22, 1971

COMPILED BY SO

DATUM Geodetic

BOREHOLE TYPE Diamond Drill - Washboring

CHECKED BY F. ID.

SOIL PROFILE		SAMPLES		ELEV. SCALE	DYNAMIC PENETRATION BLOWS / FOOT	RESISTANCE	LIQUID LIMIT — $w_L$ PLASTIC LIMIT — $w_p$ WATER CONTENT — $w$	BULK DENSITY $\gamma$	REMARKS
ELEV. DEPTH	DESCRIPTION	NUMBER	TYPE						
425.5	Ground Level								
0.0	Organic Silt. Brown	1	C.S.						
2.0	Clayey silt silty sand seams up to 1/4" thick throughout.	2	SS						
		3	SS						
		4	TM						
412.6	Grey	5	TM						
12.9	Silty sand, some gravel	6	SS						
	Glacial Till	7	SS						
	Ret. mix. of silt, sand & gravel, trace of clay	8	SS						
	Loose to Very Dense	9	SS						
		10	SS						
		11	SS						
394.5	Grey	12	SS						
31.0	End of Borehole	13	SS						



**Appendix C.**  
**Laboratory Testing**

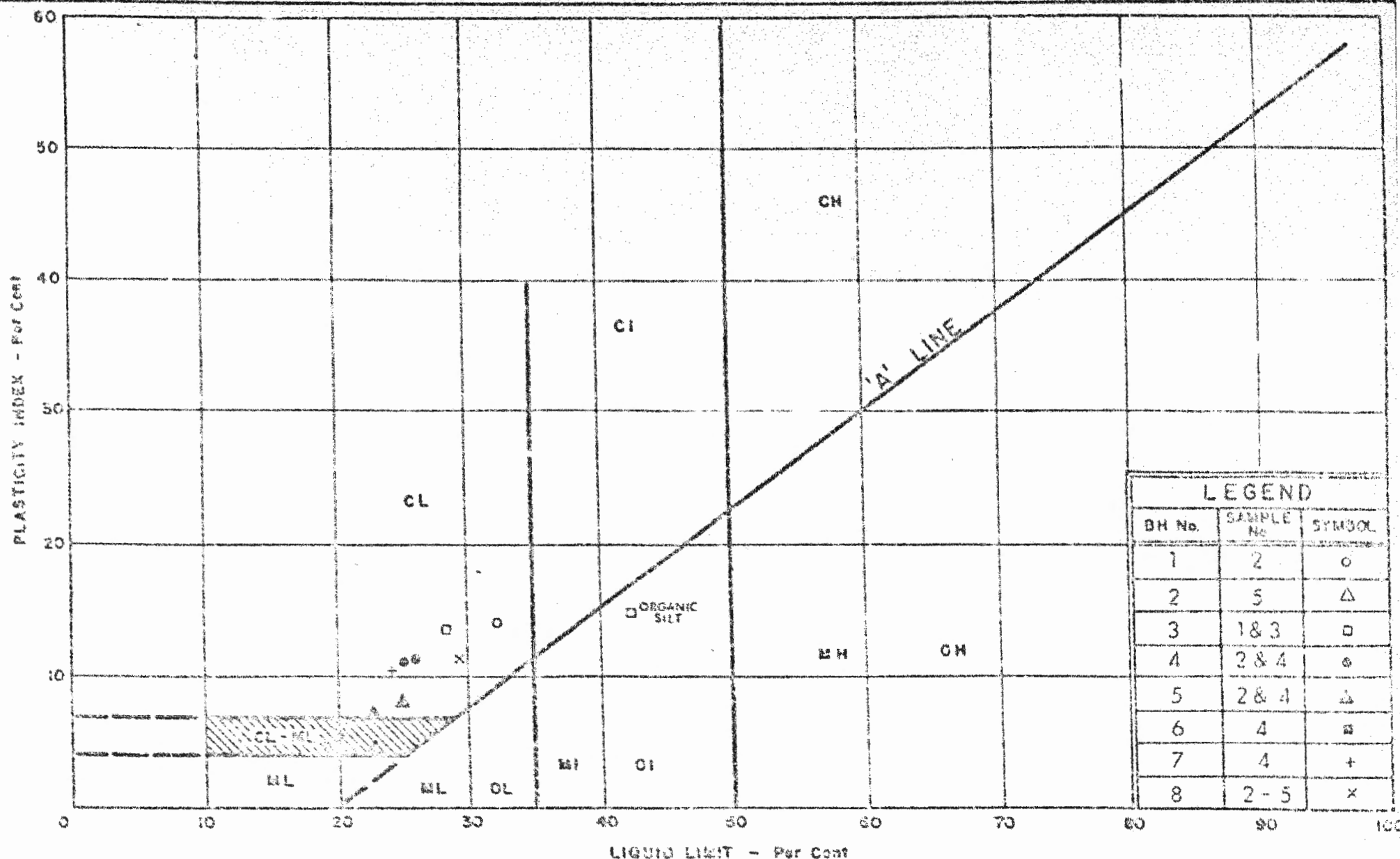


## **Appendix C.1**

**Atterberg Limit Test Results**

**Particle Size Analysis Figures**

**One-Dimensional Consolidation Test Results**



DEPARTMENT OF HIGHWAYS  
MATERIALS and  
TESTING  
DIVISION

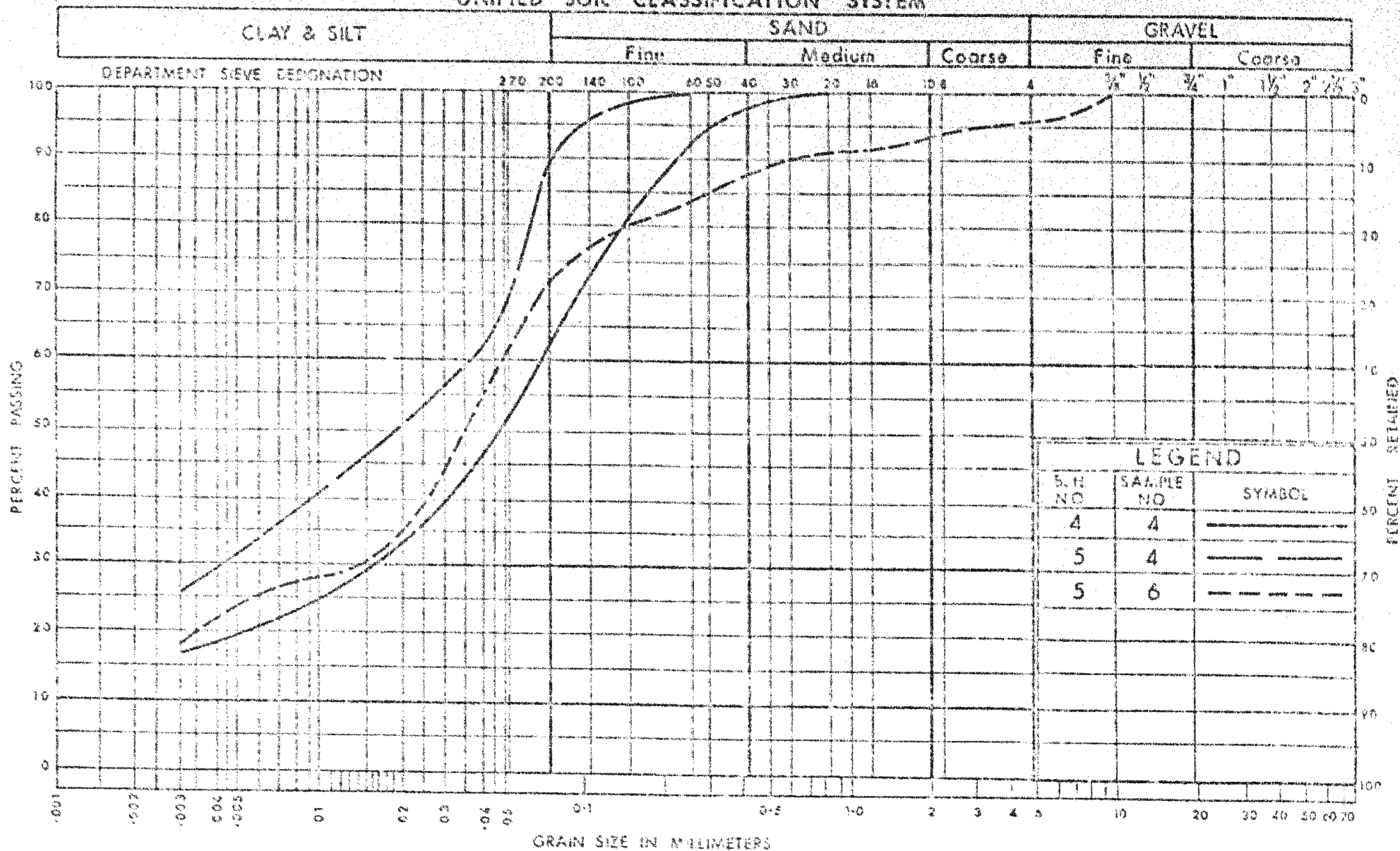
# PLASTICITY CHART CLAYEY SILT THIN SILTY SAND SEAMS

WP. No. 7-57-03

JOB No. 71-11085

FIG C1

# UNIFIED SOIL CLASSIFICATION SYSTEM



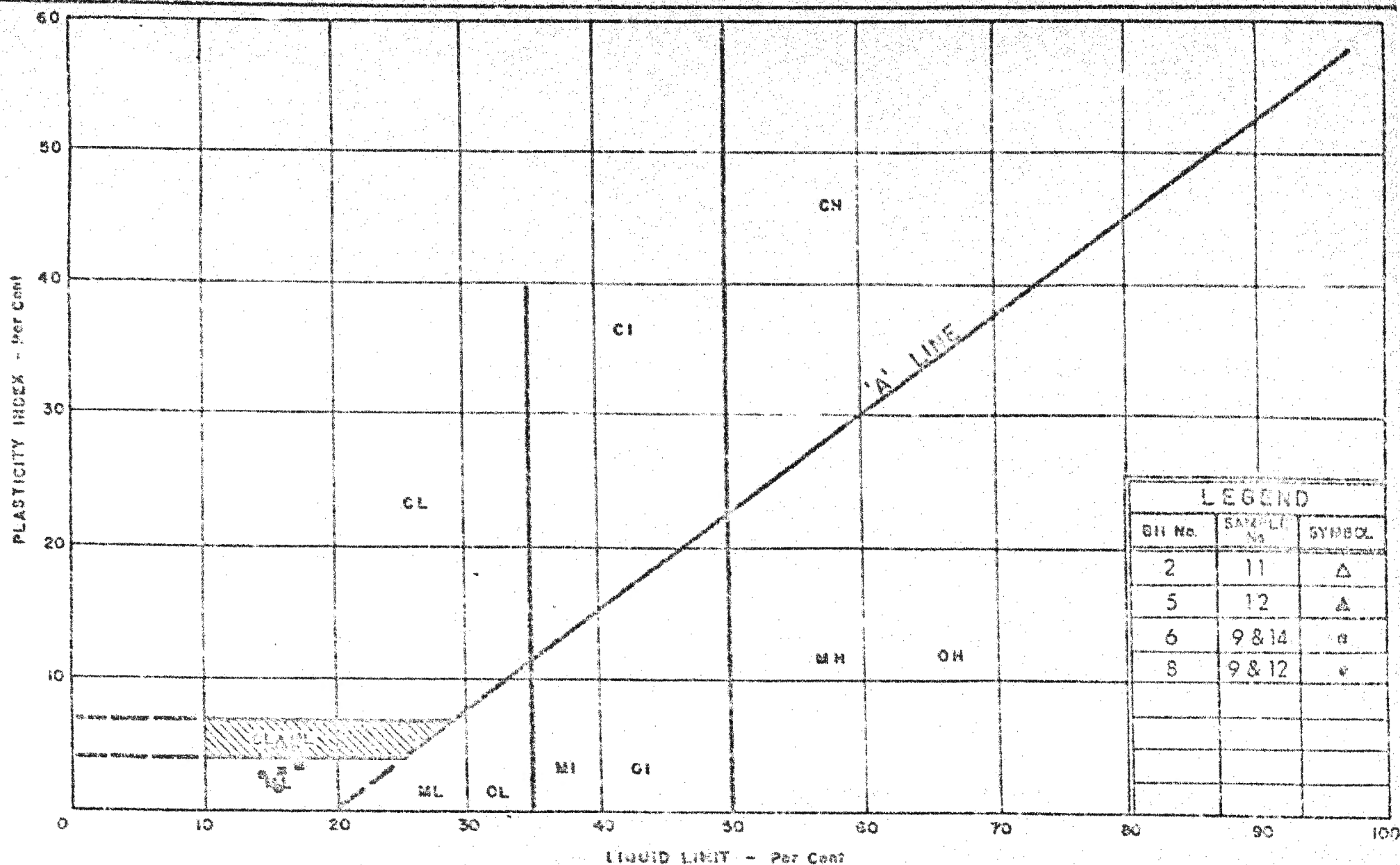
DEPARTMENT  
OF  
TRANSPORTATION AND COMMUNICATIONS

DESIGN SERVICES  
BRANCH

GRAIN SIZE DISTRIBUTION  
CLAYEY SILT  
WITH SILTY SAND SEAMS

W.P. No. 7-67-03  
JOB No. 71-11085  
FIG C2





LEGEND		
BIT No.	SAMPLE No.	SYMBOL
2	11	△
5	12	△
6	9 & 14	□
8	9 & 12	○



DEPARTMENT OF HIGHWAYS  
MATERIALS and  
TESTING  
DIVISION

# PLASTICITY CHART GLACIAL TILL

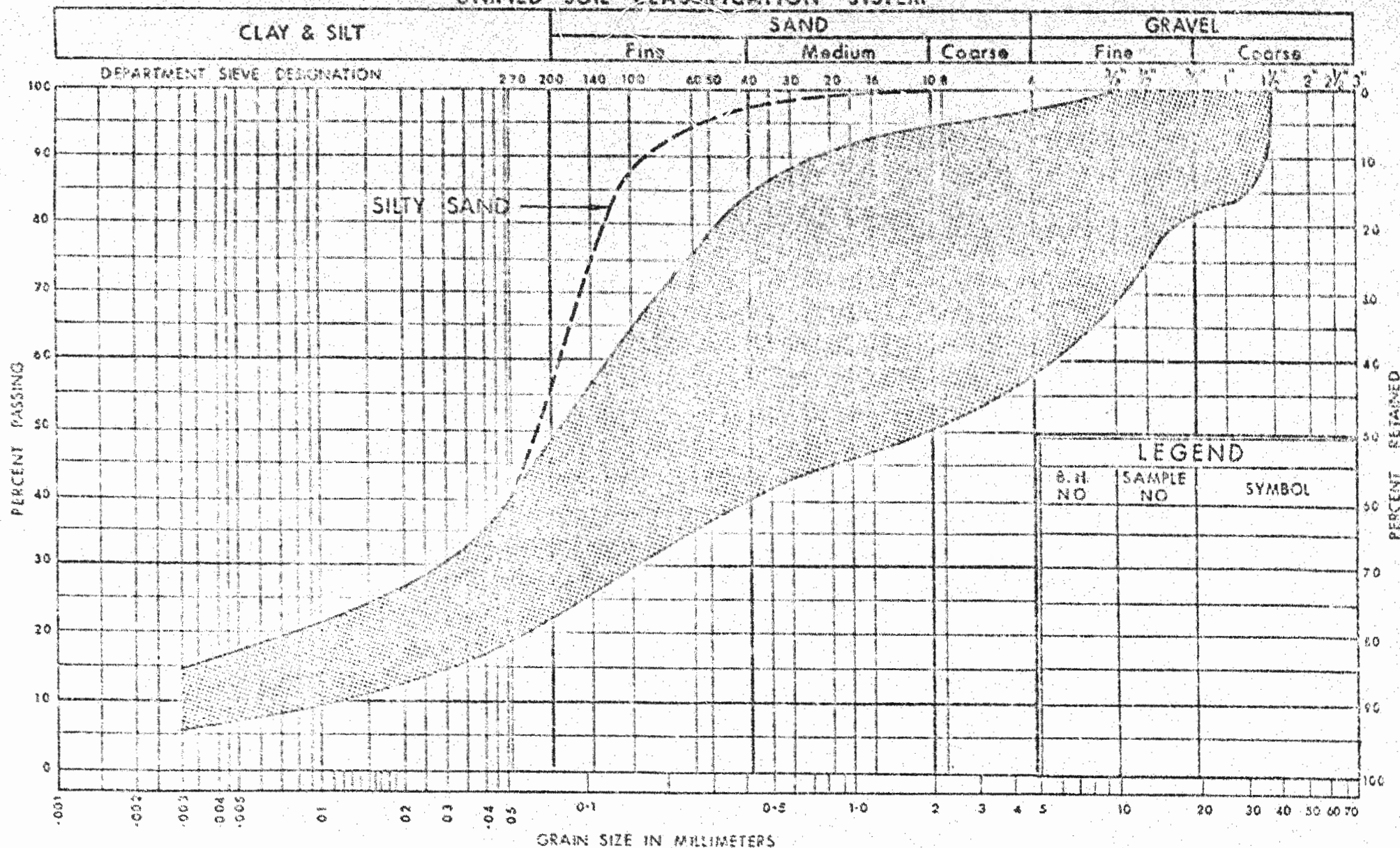
HET. MIXTURE OF SILT, SAND & GRAVEL, TRACE OF CLAY

WP No. 7-67-03

JOB No. 71-11085

FIG. C3

# UNIFIED SOIL CLASSIFICATION SYSTEM



DEPARTMENT  
OF  
TRANSPORTATION AND COMMUNICATIONS



DESIGN SERVICES  
BRANCH

GRAIN SIZE DISTRIBUTION  
GLACIAL TILL  
HET. MIXTURE OF SILT, SAND & GRAVEL, TRACE OF CLAY

W.P. No. 7 - 67 - 03

JOB No. 71-11085

FIG C4

# VOID RATIO - PRESSURE CURVES

JOB NO. 71-11085

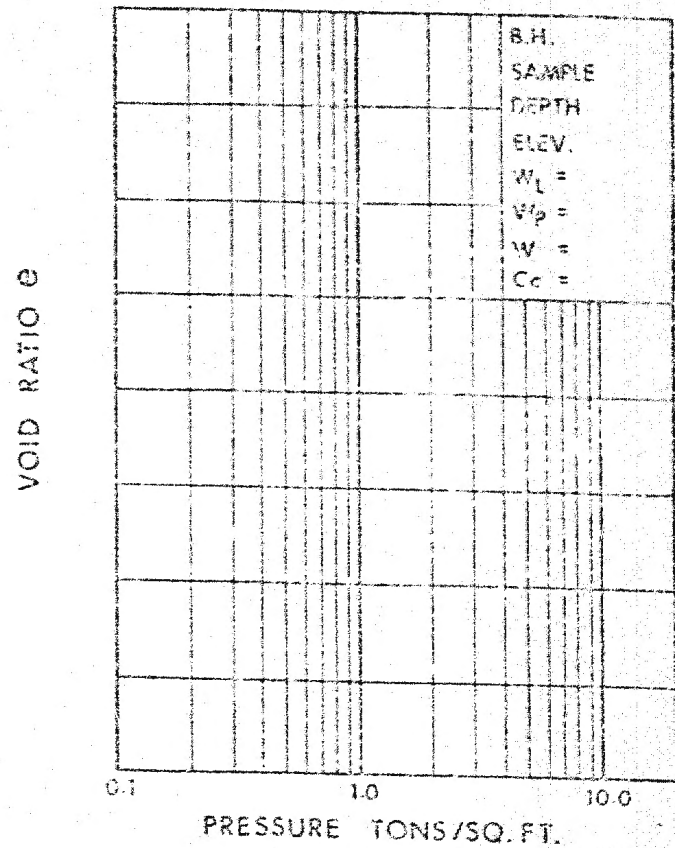
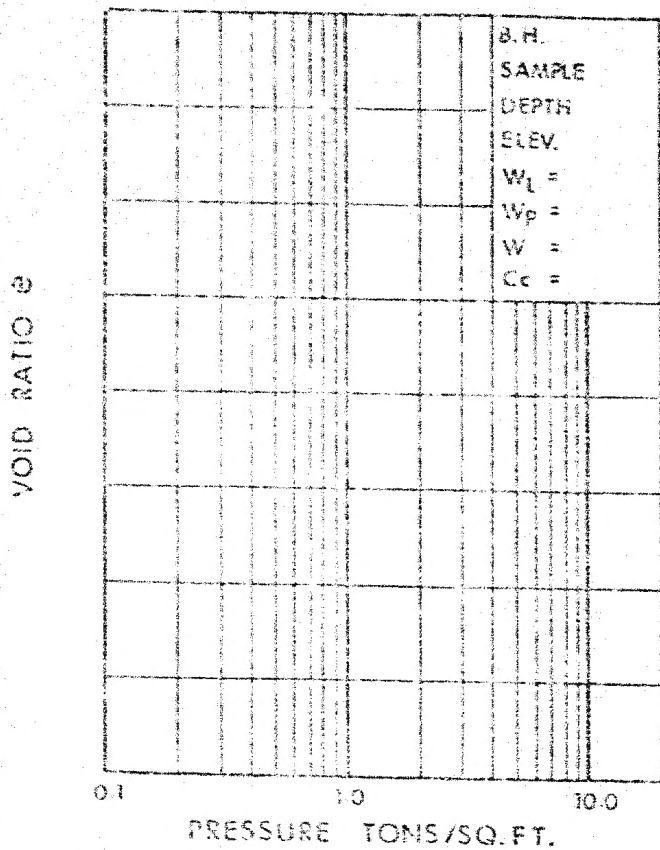
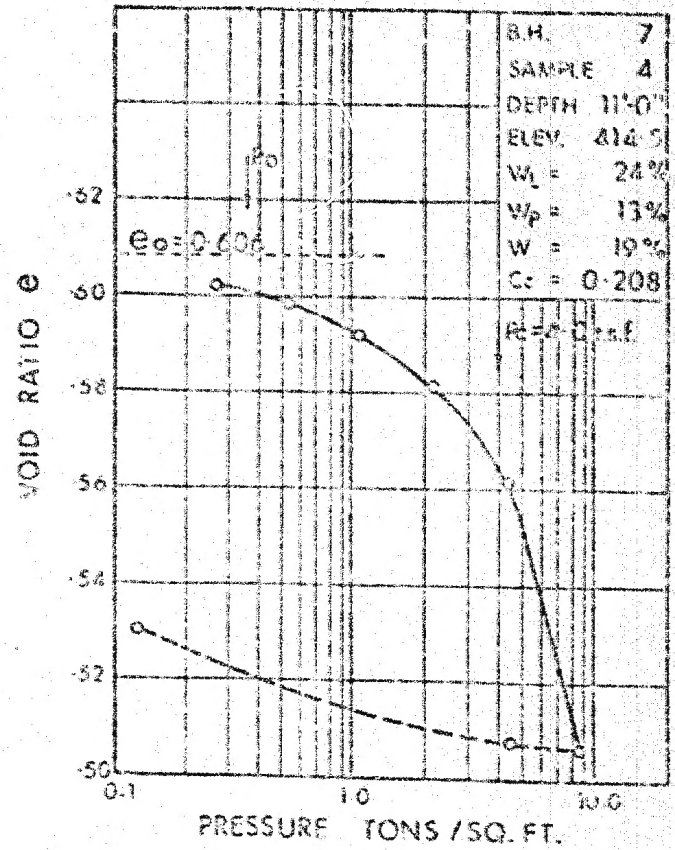
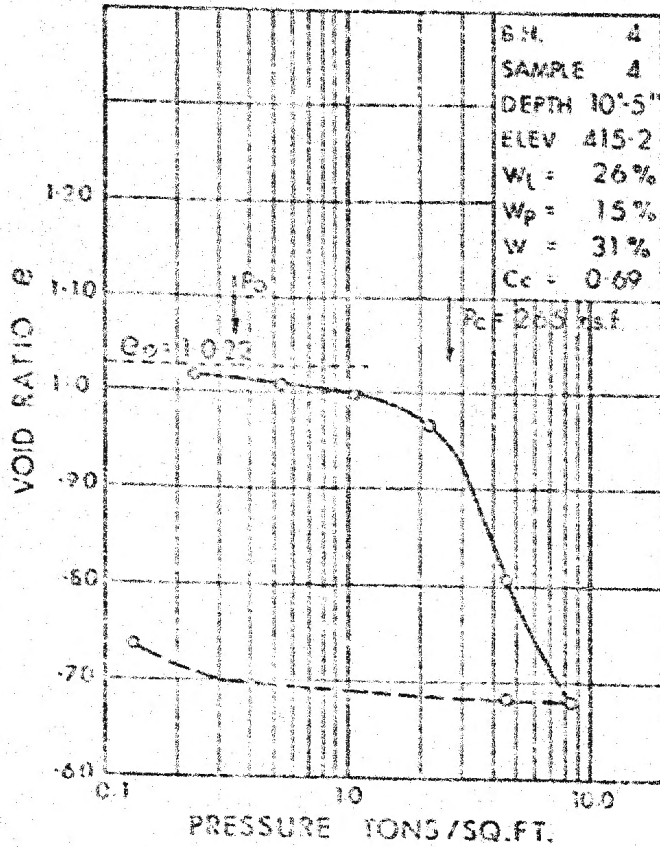


FIG. C5



**Appendix D.**  
**Site Photographs**





**Photo 1. Looking north along trail towards existing bridge (2020/04/22)**



**Photo 2. Looking south along trail towards existing east pier (2021/11/05)**





**Photo 3. Looking south from the trail towards east approach and existing drainage culvert (2021/11/05)**



**Photo 4. Looking west from existing Highway 17 shoulder (2019/09/24)**



**Appendix E.**  
**MASW Report**





**GEOPHYSICS GPR INTERNATIONAL INC.**

100 – 2545 Delorimier Street    Tel. : (450) 679-2400  
Longueuil (Québec)    Fax : (514) 521-4128  
Canada J4K 3P7    info@geophysicsgpr.com  
www.geophysicsgpr.com

June 24<sup>th</sup>, 2020

Transmitted by email: [jgray@thurber.ca](mailto:jgray@thurber.ca)  
Our Ref.: GPR-19-01787

Mr. Justin Gray, P.Eng.  
Geotechnical Engineer  
Thurber Engineering Ltd.  
Suite 104, 2460 Lancaster Road  
Ottawa, Ontario K1B 4S5

**Subject:    Shear Wave Velocity Soundings for Determining Site Classifications**  
**Three locations along Highway 17, in Renfrew County (ON)**

Dear Sir,

Geophysics GPR International inc. has been mandated by Thurber Engineering Ltd. to carry out seismic shear wave surveys for three locations along the Trans-Canada Highway, in the Renfrew County (ON). The geophysical investigation used the Multi-channel Analysis of Surface Waves (MASW), the Extended Spatial AutoCorrelation (ESPAC), and the seismic refraction methods. From the subsequent results, the seismic shear wave velocity values were calculated for the soil and the rock, to determine the Site Classes for the different locations.

The surveys were carried out on June 3<sup>rd</sup> and 4<sup>th</sup>, by Mr. Mario Nucciarone, B.Sc. geoph. and Mr. Ange Alexandre Forestier, trainee. Figure 1 shows the regional location of the different sites and the Figures 2a to 2c illustrate the locations of the five seismic lines. These figures are presented in the Appendix.

The following paragraphs briefly describe the survey design, the principles of the testing methods, and the results presented in tables and graphs.



## MASW PRINCIPLE

The *Multi-channel Analysis of Surface Waves* (MASW) and the *Extended SPatial AutoCorrelation* (ESPAC or MAM for *Microtremors Array Method*) are seismic methods used to evaluate the shear wave velocities of subsurface materials through the analysis of the dispersion properties of the Rayleigh surface waves (“ground roll”). The MASW is considered an “active” method, as the seismic signal is induced at known location and time in the geophones’ spread axis. Conversely, the ESPAC is considered a “passive” method, using the low frequency “signals” produced far away. The method can also be used with “active” seismic source records. The dispersion properties are expressed as a change of phase velocities with respect to frequencies. Surface wave energy will decay exponentially with depth. Lower frequency surface waves will travel deeper and thus be more influenced by deeper velocity layering than the shallow higher frequency waves. The inversion of the Rayleigh wave dispersion curve yields a shear wave ( $V_s$ ) velocity depth profile (sounding). Figure 3 schematically outlines the basic operating procedure for the MASW method.

Figure 4 illustrates an example of one of the MASW/ESPAC records, the corresponding spectrogram analysis and resulting 1D  $V_s$  model. The ESPAC method allows deeper  $V_s$  soundings, but generally with a lower resolution for the surface portion. Its dispersion curve can then be merged with the one of higher frequency from the MASW to calculate a more complete inversion.

## INTERPRETATION

The main processing sequence involved data inspection and edition when required; spectral analysis (“phase shift” for MASW, and “cross-correlation” for ESPAC); picking the fundamental mode; and 1D inversion of the MASW and ESPAC shot records using the SeisImagerSW™ software. The data inversions used a nonlinear least squares algorithm.

In theory, all the shot records for a given seismic spread should produce a similar shear-wave velocity profile. In practice, however, differences can arise due to energy dissipation, local surface seismic velocities variations, and/or dipping of overburden layers or rock. In general, the precision of the calculated seismic shear wave velocities ( $V_s$ ) is of the order of 15% or better.

More detailed descriptions of these methods are presented in *Shear Wave Velocity Measurement Guidelines for Canadian Seismic Site Characterization in Soil and Rock*, Hunter, J.A., Crow, H.L., et al., Geological Surveys of Canada, General Information Product 110, 2015.



## SURVEY DESIGN

The seismic acquisition spreads were laid out with basic geophone spacings of 3 metres for the main spread, using 24 geophones. One to two shorter seismic spreads, with geophone spacings of 0.5 and 1.0 metre, were dedicated to the near surface materials.

The seismic records counted 4096 data, sampled at 1000  $\mu$ s for the MASW surveys, and 50  $\mu$ s for the seismic refraction. The records included a pre-triggerring portion of 10 ms. A stacking procedure was also used to improve the Signal / Noise ratio for the seismic records.

The shear wave depth sounding can be considered as the average of the bulk area within the geophone spread, especially for its central half-length.

The seismic records were produced with a seismograph Terraloc MK6 (from ABEM Instrument), and the geophones were 4.5 Hz. An 8 kg sledgehammer was used as the energy source with impacts being recorded off both ends of the seismic spreads.

## RESULTS

The  $\bar{V}_{S30}$  value results from the harmonic mean of the shear wave velocities, from the surface to 30 metres deep. It is calculated by dividing the total depth of interest (30 metres) by the sum of the time spent in each velocity layer from the surface down to 30 metres, as:

$$\bar{V}_{S30} = \frac{\sum_{i=1}^N H_i}{\sum_{i=1}^N H_i / V_i} \quad | \quad \sum_{i=1}^N H_i = 30 \text{ m}$$

(N: number of layers;  $H_i$ : thickness of layer "i" ;  $V_i$ :  $V_s$  of layer "i")

Thus, the  $\bar{V}_{S30}$  value represents the seismic shear wave velocity of an equivalent homogeneous single layer response, between the surface and 30 metres deep.



### **Lochwinnoch & Gillan Roads intersection**

The first geophysical investigations were carried out on Lochwinnoch Road, north-east of HW-17, and on Gillan Road, south-west of Highway 17.

#### **The Lochwinnoch Road seismic spread (SL-1):**

The Lochwinnoch Road seismic line was placed northeast of the intersection between Lochwinnoch Road and Highway 17 (cf. Figure 2a).

The MASW calculated  $V_s$  results are illustrated at Figure 6a also presented at Table 1, for the  $\bar{V}_{s30}$  calculation.

From the seismic refraction data, the rock was calculated between 2 and 3.5 metres deep,  $\pm 1$  metre. Its seismic velocity was calculated between 2280 and 2295 m/s for its shallow portion (cf. Figure 5a).

The calculated  $\bar{V}_{s30}$  value of the actual site is 1340.1 m/s (cf. Table 1), corresponding to the Site Class “B”. However, the Site Classes A and B are not to be used if there is 3 metres or more of unconsolidated material between the rock and the bottom of the spread footing or mat foundation.

If the foundation is 2.25 metres or less from the rock surface, the minimal  $\bar{V}_{s30}^*$  value would be 1513.6 m/s or higher, allowing to use the Site Class “A”.

#### **The Gillan Road seismic spread (SL-2):**

The Gillan Road seismic line was placed southwest of the intersection between Gillan Road and Highway 17 (cf. Figure 2a).

The MASW calculated  $V_s$  results are illustrated at Figure 6a and they are also presented at Table 2, for the  $\bar{V}_{s30}$  calculation. The Seismic Site Class for the actual site is 592.2 m/s, corresponding to the Site Class “C”. Some low seismic velocities were calculated from the surface to approximately 2 metres deep.



From the seismic refraction data, the rock was calculated between 9.5 and 13.5 metres deep ( $\pm 10\%$ ), dipping South-West. The seismic velocity of the shallow portion was calculated to be 2365 m/s (cf. Figure 5a).

### **Algonquin Trail seismic spread (SL-3):**

Seismic-Line 3 was placed on the Algonquin Trail, west of the intersection with the Highway 17 (cf. Figure 2b).

The MASW calculated  $V_s$  results are illustrated in Figure 6b and they are also presented at Table 3, for the  $\bar{V}_{s30}$  calculation. The Seismic Site Class for the actual site is 566.7 m/s, corresponding to the Site Class "C". Some low seismic velocities were calculated from the surface to approximately 2 metres deep.

From the seismic refraction data, the rock was calculated between 11 and 13 metres deep ( $\pm 10\%$ ). Its seismic velocity was calculated between 2440 and 2565 m/s for its shallow portion (cf. Figure 5b).

### **The Bonnechere River Bridge:**

Two seismic lines were localised on each side of the Bonnechere River Bridge. Both were placed on the west side of the highway 17.

#### **Bonnechere River Bridge, North Side (SL-4):**

The Bonnechere River Bridge north side was investigated from the seismic line 4, installed south-west to the Highway 17 (cf. Figure 2c).

The MASW calculated  $V_s$  results are illustrated at Figure 6c and they are also presented at Table 4, for the  $\bar{V}_{s30}$  calculation. This value for the actual site is 260.3 m/s, corresponding to the Site Class "D". Some low seismic velocities were calculated between 1.5 and 5 metres deep.

From the seismic refraction data, the rock was calculated between 37 and 42 metres deep ( $\pm 10\%$ ), dipping South-East.



**Bonnechere River Bridge, South Side (SL-5):**

Seismic line 5, placed southwest to Highway 17, was used to investigate the Bonnechere River Bridge south side (cf. Figure 2c).

The MASW calculated  $V_s$  results are illustrated in Figure 6c and they are also presented at Table 5, for the  $\bar{V}_{s30}$  calculation. The Seismic Site Class for the actual site is 372.1 m/s, corresponding to the Site Class “C”. Some low seismic velocities were calculated from the surface to nearly 1 metre deep.

From the seismic refraction and seismic resonance results, the rock was calculated between 27 and 30 metres deep ( $\pm 10\%$ ).



## CONCLUSION

Geophysical surveys were carried out in the vicinity of Highway 17, from the Road 6 to the Bonnechere Bridge, in Renfrew County (ON). The seismic surveys used the MASW and ESPAC analysis, as well as seismic refraction method, to calculate the  $\bar{V}_{S30}$  values so as to determine the Site Classes.

The  $\bar{V}_{S30}$  calculations for the actual sites are presented in Table 1 to 5. They were determined through the MASW, ESPAC and seismic refraction methods, Table 4.1.8.4.A of the NBC, and the Building Code, O. Reg. 332/12.

It must be noted that other geotechnical information gleaned on site; including the presence of liquefiable soils, very soft clays, high moisture content etc. can supersede the Sites Classifications provided in this report based on the  $\bar{V}_{S30}$  values.

The  $V_s$  values calculated are representative of the in-situ materials and are not corrected for the total and effective stresses.

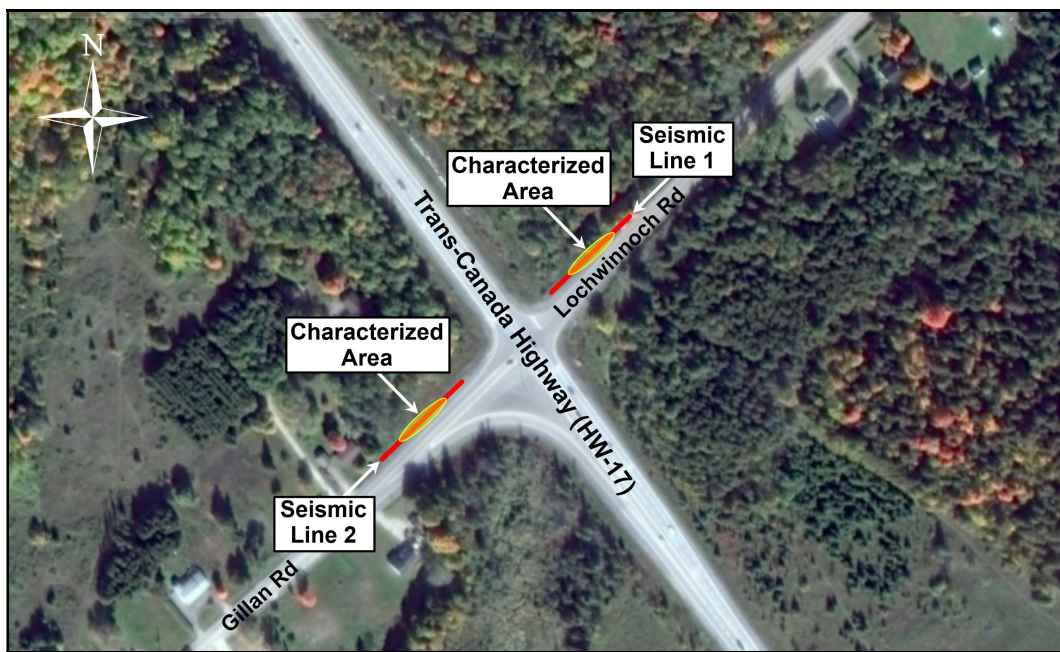
Hoping the whole to your satisfaction, we remain yours truly.

Jean-Luc Arsenault, M.A.Sc., P.Eng.  
Senior Project Manager





**Figure 1: Regional location of the Sites**  
(source: OpenStreetMap©)



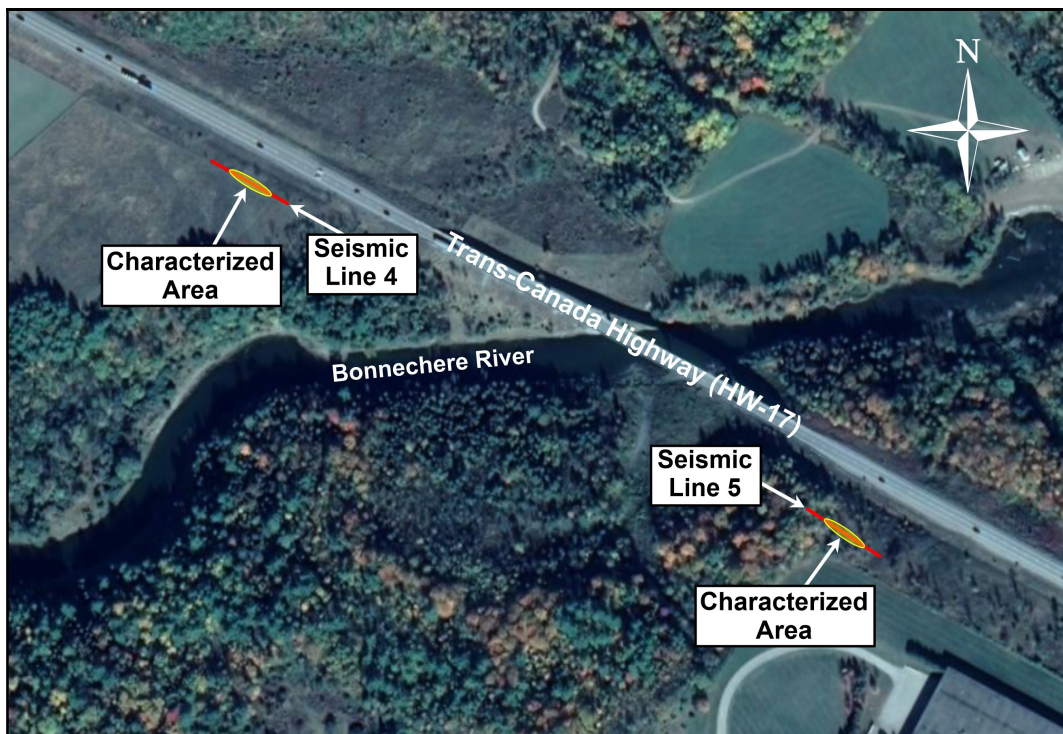
**Figure 2a: Location of the seismic spreads SL-1 and SL-2**  
(source: Google Earth™)







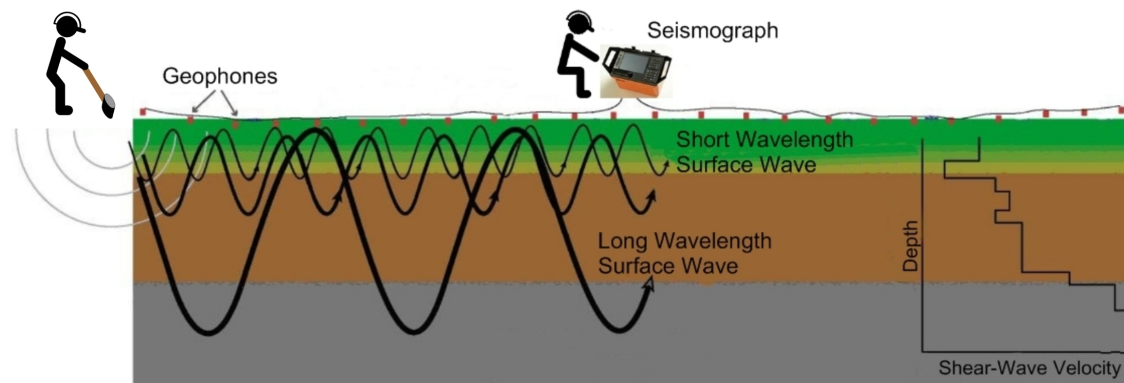
**Figure 2b: Location of the seismic spread SL-3**  
(source: Google Earth™)



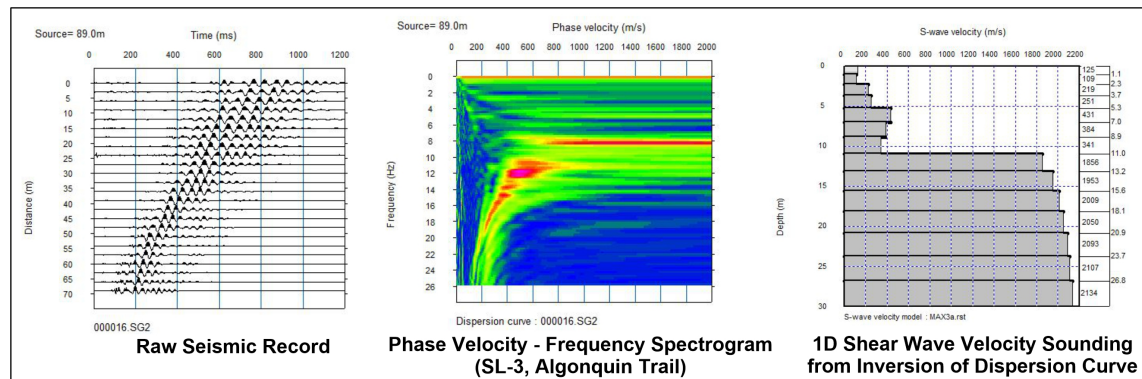
**Figure 2c: Location of the seismic spreads SL-4 and SL-5**  
(source: Google Earth™)





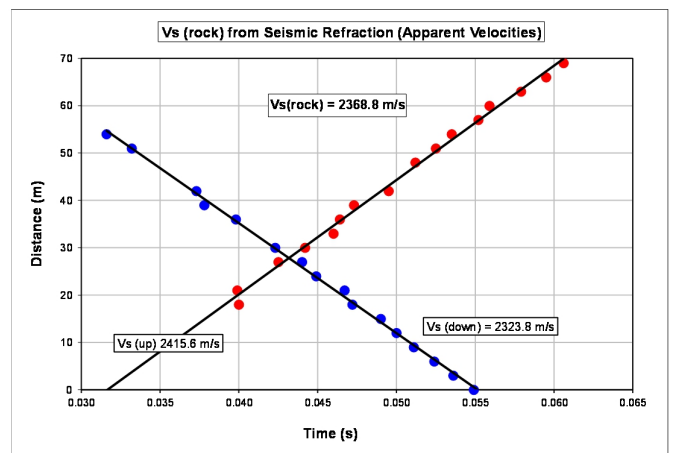
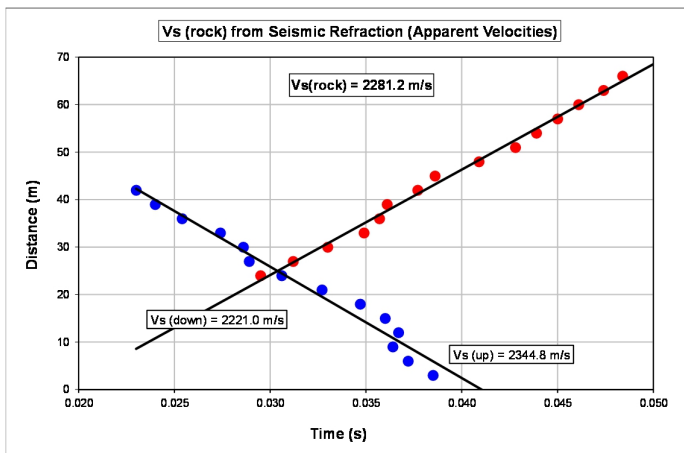
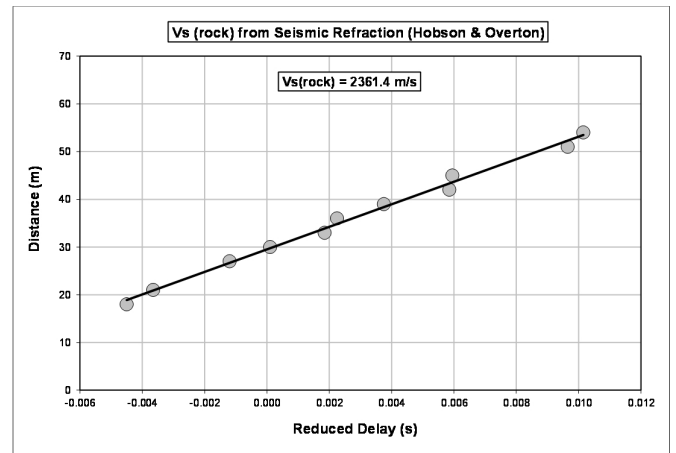
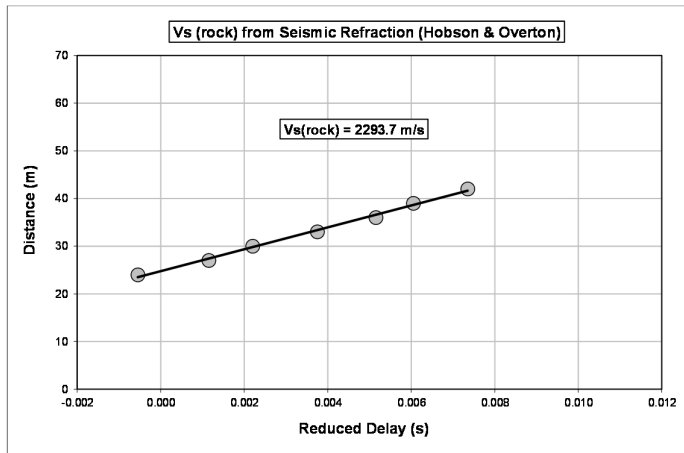


**Figure 3: MASW Operating Principle**



**Figure 4: Example of a MASW / ESPAC record, Phase Velocity - Frequency curve and resulting 1D Shear Wave Velocity Model**



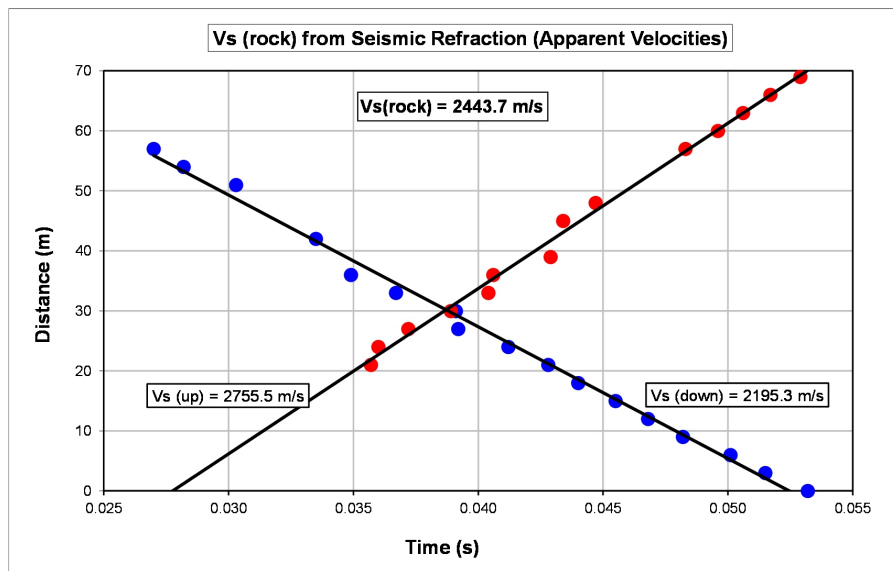
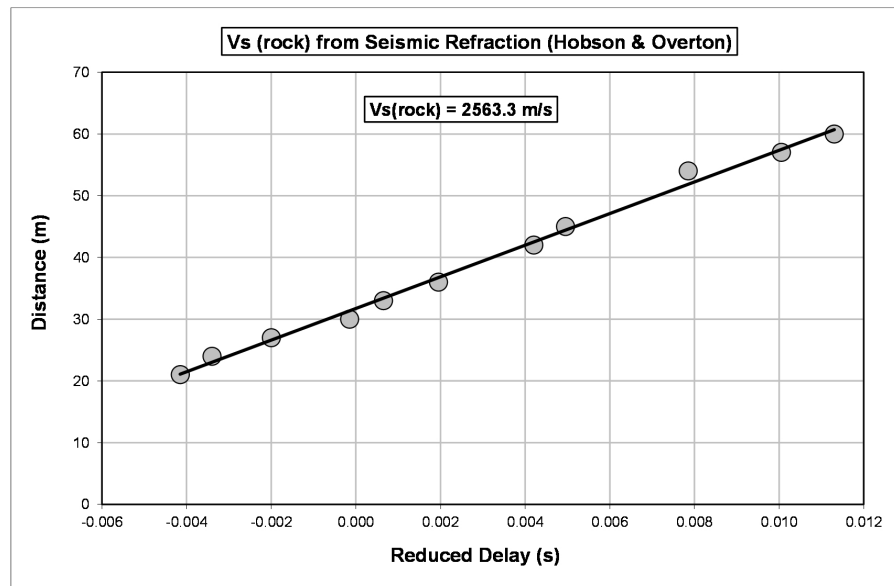


SL-1

SL-2

Figure 5a: Rock  $V_s$  from Seismic Refraction

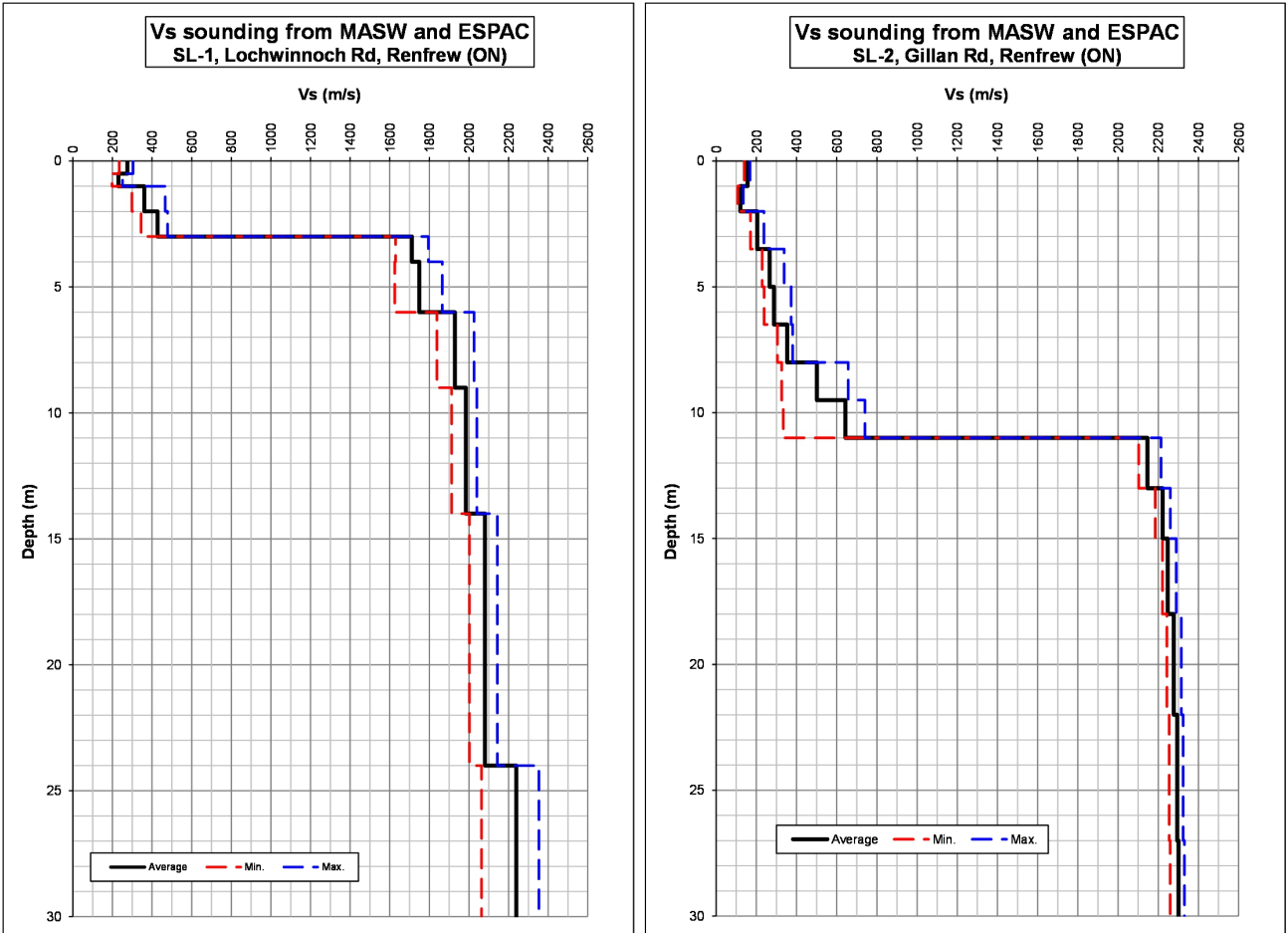




SL-3

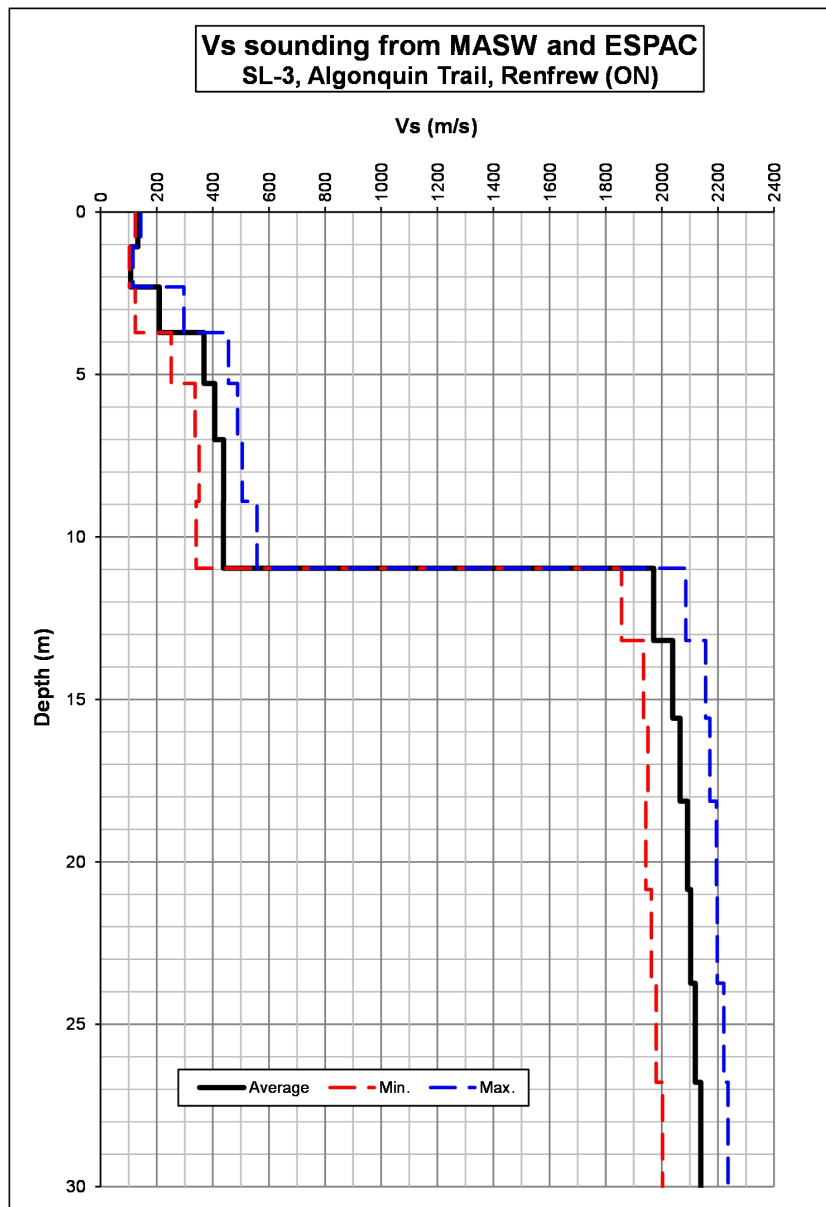
Figure 5b: Rock  $V_s$  from Seismic Refraction





**Figure 6a: MASW Shear-Wave Velocity Soundings**

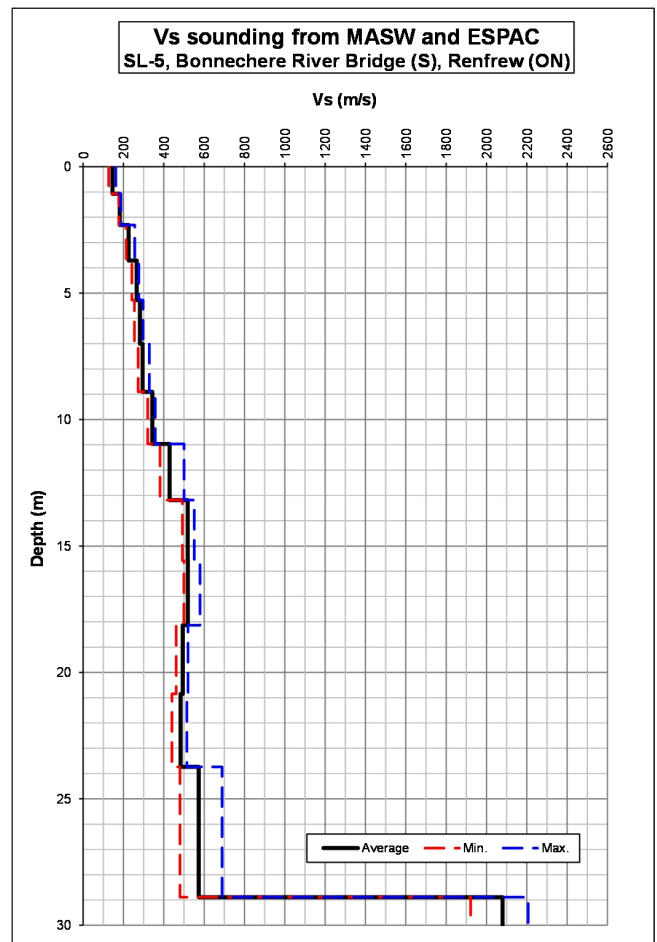
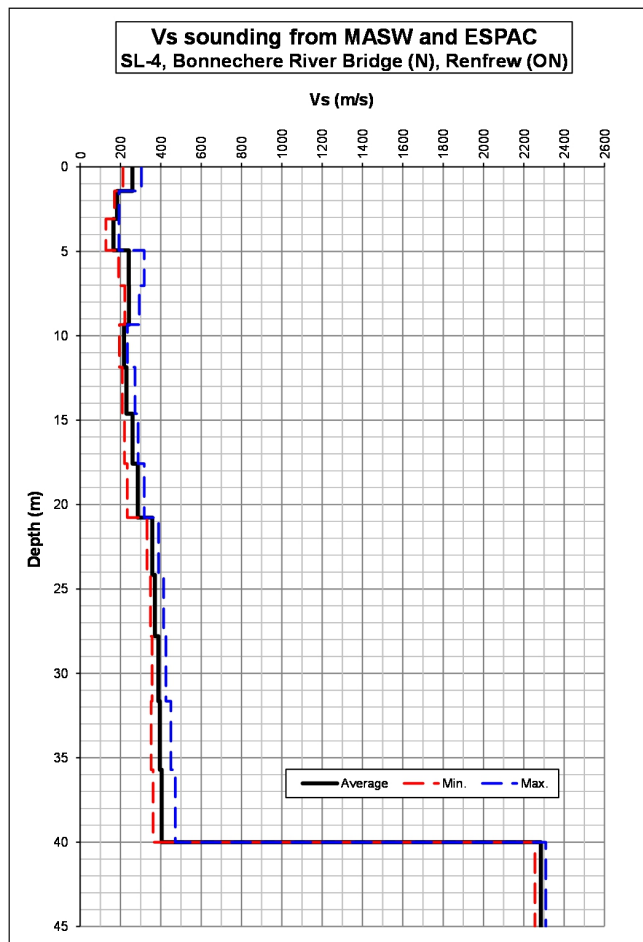




**Figure 6b: MASW Shear-Wave Velocity Sounding**







**Figure 6c: MASW Shear-Wave Velocity Soundings**



**TABLE 1**  
**Lochwinnoch Rd (SL-1)  $V_{S30}$  Calculation for the Site Class (actual site)**

Depth	Vs			Thickness	Cumulative Thickness	Delay for Avg. Vs	Cumulative Delay	Vs at given Depth
	Min.	Average	Max.					
(m)	(m/s)	(m/s)	(m/s)	(m)	(m)	(s)	(s)	(m/s)
<b>0</b>	234.4	275.3	303.8	<b>Ground level while seismic surveys (June 3rd, 2020)</b>				
0.5	198.0	230.3	250.5	0.50	0.50	0.001816	0.001816	275.3
1.0	297.7	360.7	466.1	0.50	1.00	0.002171	0.003987	250.8
2.0	344.4	427.5	478.2	1.00	2.00	0.002772	0.006759	295.9
3.0	1629.2	1712.1	1795.0	1.00	3.00	0.002339	0.009099	329.7
4.0	1625.1	1749.3	1864.8	1.00	4.00	0.000584	0.009683	413.1
6.0	1838.2	1929.0	2025.7	2.00	6.00	0.001143	0.010826	554.2
9.0	1912.5	1984.7	2039.6	3.00	9.00	0.001555	0.012381	726.9
14.0	2002.4	2080.9	2143.6	5.00	14.00	0.002519	0.014901	939.6
24.0	2063.2	2238.6	2353.2	10.00	24.00	0.004806	0.019706	1217.9
<b>30</b>				6.00	30.00	0.002680	0.022387	1340.1

<b><math>V_{S30}</math> (m/s)</b>	<b>1340.1</b>
<b>Class</b>	<b>B <sup>(1)</sup></b>

- (1) The Site Classes A and B are not to be used if there is 3 metres or more of unconsolidated materials between the rock surface and the bottom of the foundation.

**TABLE 2**  
**Gillan Rd (SL-2)  $V_{S30}$  Calculation for the Site Class (actual site)**

Depth	Vs			Thickness	Cumulative Thickness	Delay for Avg. Vs	Cumulative Delay	Vs at given Depth
	Min.	Average	Max.					
(m)	(m/s)	(m/s)	(m/s)	(m)	(m)	(s)	(s)	(m/s)
<b>0</b>	<b>140.3</b>	<b>156.0</b>	<b>168.6</b>	<b>Ground level while seismic surveys (June 3<sup>rd</sup>, 2020)</b>				
1.0	107.2	120.8	135.1	1.00	1.00	0.006409	0.006409	156.0
2.0	171.1	204.6	237.6	1.00	2.00	0.008276	0.014685	136.2
3.5	228.7	266.4	338.6	1.50	3.50	0.007333	0.022018	159.0
5.0	239.0	287.7	373.5	1.50	5.00	0.005631	0.027649	180.8
6.5	304.6	353.8	380.7	1.50	6.50	0.005213	0.032862	197.8
8.0	325.9	501.5	657.2	1.50	8.00	0.004239	0.037101	215.6
9.5	334.5	643.0	740.8	1.50	9.50	0.002991	0.040093	237.0
11.0	2103.0	2145.7	2213.9	1.50	11.00	0.002333	0.042426	259.3
13.0	2185.2	2222.2	2259.8	2.00	13.00	0.000932	0.043358	299.8
15.0	2221.1	2247.1	2289.5	2.00	15.00	0.000900	0.044258	338.9
18.0	2243.0	2277.5	2314.5	3.00	18.00	0.001335	0.045593	394.8
22.0	2254.7	2294.7	2323.6	4.00	22.00	0.001756	0.047349	464.6
27.0	2259.2	2300.9	2330.0	5.00	27.00	0.002179	0.049528	545.1
<b>30</b>				3.00	30.00	0.001304	0.050832	590.2

<b><math>V_{S30}</math> (m/s)</b>	<b>590.2</b>
<b>Class</b>	<b>C</b>



**TABLE 3**  
**Algonquin Trail (SL-3)  $V_{S30}$  Calculation for the Site Class (actual site)**

Depth	Vs			Thickness	Cumulative Thickness	Delay for Avg. Vs	Cumulative Delay	Vs at given Depth
	Min.	Average	Max.					
(m)	(m/s)	(m/s)	(m/s)	(m)	(m)	(s)	(s)	(m/s)
<b>0</b>	<b>123.5</b>	<b>132.9</b>	<b>143.7</b>	<b>Ground level while seismic surveys (June 4<sup>th</sup>, 2020)</b>				
1.1	<b>102.9</b>	<b>107.4</b>	<b>115.5</b>	1.07	1.07	0.008062	0.008062	132.9
2.3	<b>123.6</b>	209.6	296.8	1.24	2.31	0.011506	0.019568	117.9
3.7	251.7	368.8	455.6	1.40	3.71	0.006686	0.026254	141.3
5.3	336.8	407.1	488.2	1.57	5.27	0.004246	0.030501	172.9
7.0	351.1	438.4	504.6	1.73	7.01	0.004252	0.034752	201.6
8.9	341.0	437.7	557.3	1.90	8.90	0.004323	0.039076	227.8
11.0	1856.7	1971.2	2085.7	2.06	10.96	0.004708	0.043784	250.4
13.2	1934.5	2038.4	2156.3	2.23	13.19	0.001129	0.044912	293.6
15.6	1950.8	2065.2	2171.4	2.39	15.58	0.001173	0.046085	338.0
18.1	1942.8	2091.4	2194.3	2.55	18.13	0.001237	0.047322	383.2
20.9	1962.4	2103.1	2197.6	2.72	20.85	0.001300	0.048623	428.8
23.7	1980.0	2119.6	2220.9	2.88	23.74	0.001372	0.049994	474.8
26.8	2002.4	2138.5	2235.6	3.05	26.79	0.001439	0.051433	520.8
<b>30</b>	2100.0	2160.9	2246.5	3.21	30.00	0.001503	0.052936	566.7

<b><math>V_{S30}</math> (m/s)</b>	<b>566.7</b>
<b>Class</b>	<b>C</b>



**TABLE 4**  
**Bonnechere River Bridge (SL-4)  $V_{S30}$  Calculation for the Site Class (actual site)**

Depth	Vs			Thickness	Cumulative Thickness	Delay for Avg. Vs	Cumulative Delay	Vs at given Depth
	Min.	Average	Max.					
(m)	(m/s)	(m/s)	(m/s)	(m)	(m)	(s)	(s)	(m/s)
<b>0</b>	212.3	258.7	303.8	<b>Ground level while seismic surveys (June 4<sup>th</sup>, 2020)</b>				
1.4	<b>169.6</b>	<b>183.0</b>	193.0	1.43	1.43	0.005521	0.005521	258.7
3.1	<b>127.5</b>	<b>164.7</b>	192.4	1.65	3.08	0.009009	0.014530	211.8
4.9	190.8	241.1	317.2	1.87	4.95	0.011340	0.025871	191.1
7.0	221.6	242.1	293.4	2.09	7.03	0.008661	0.034531	203.7
9.3	194.6	217.5	234.1	2.31	9.34	0.009531	0.044062	212.0
11.9	208.9	229.3	272.3	2.53	11.87	0.011620	0.055682	213.1
14.6	220.0	259.3	287.0	2.75	14.62	0.011982	0.067665	216.0
17.6	233.3	285.8	318.0	2.97	17.58	0.011441	0.079106	222.3
20.8	331.6	357.8	388.3	3.19	20.77	0.011150	0.090256	230.1
24.2	348.8	370.4	413.5	3.41	24.18	0.009521	0.099776	242.3
27.8	357.1	388.0	425.7	3.63	27.80	0.009791	0.109567	253.7
<b>30</b>				2.20	30.00	0.005665	0.115232	260.3

<b><math>V_{S30}</math> (m/s)</b>	<b>260.3</b>
<b>Class</b>	<b>D</b>

**TABLE 5**  
**Bonnechere River Bridge (SL-5)  $V_{S30}$  Calculation for the Site Class (actual site)**

Depth	Vs			Thickness	Cumulative Thickness	Delay for Avg. Vs	Cumulative Delay	Vs at given Depth
	Min.	Average	Max.					
(m)	(m/s)	(m/s)	(m/s)	(m)	(m)	(s)	(s)	(m/s)
<b>0</b>	<b>126.4</b>	<b>145.8</b>	<b>161.5</b>	<b>Ground level while seismic surveys (June 4<sup>th</sup>, 2020)</b>				
1.1	177.4	181.2	186.9	1.07	1.07	0.007351	0.007351	145.8
2.3	212.9	225.6	255.8	1.24	2.31	0.006823	0.014174	162.8
3.7	242.0	265.3	276.4	1.40	3.71	0.006211	0.020385	181.9
5.3	253.9	281.9	297.1	1.57	5.27	0.005902	0.026287	200.7
7.0	272.9	294.5	327.8	1.73	7.01	0.006140	0.032427	216.0
8.9	319.8	342.6	358.0	1.90	8.90	0.006437	0.038864	229.0
11.0	381.7	428.2	500.3	2.06	10.96	0.006013	0.044877	244.3
13.2	492.2	518.2	551.1	2.23	13.19	0.005196	0.050074	263.3
15.6	499.5	518.9	579.8	2.39	15.58	0.004612	0.054686	284.8
18.1	461.3	493.7	520.1	2.55	18.13	0.004924	0.059610	304.2
20.9	440.3	483.0	514.4	2.72	20.85	0.005509	0.065119	320.2
23.7	479.7	573.1	688.9	2.88	23.74	0.005972	0.071091	333.9
28.9	1921.1	2079.6	2207.2	5.15	28.89	0.008992	0.080083	360.7
<b>30</b>	1939.3	2103.1	2237.5	1.11	30.00	0.000534	0.080617	372.1

<b><math>V_{S30}</math> (m/s)</b>	<b>372.1</b>
<b>Class</b>	<b>C</b>

