

**PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT
PROPOSED MCGREGOR CREEK BRIDGE WIDENING
HIGHWAY 401 EBL
HIGHWAY 401/40 INTERCHANGE ONTARIO
SITE NO. 13-232/1
G.W.P. 3093-09-00**

MTO GEOCRES NO. 40J8-52

Prepared for:

Ministry of Transportation Ontario

By:

SPL CONSULTANTS LIMITED

Project: 919-1101 (13-232/1)
December 2011



SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

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PART A
PRELIMINARY FOUNDATION INVESTIGATION REPORT
PROPOSED MCGREGOR CREEK BRIDGE WIDENING
HIGHWAY 401 EBL
HIGHWAY 401/40 INTERCHANGE ONTARIO
SITE NO. 13-232/1

1. INTRODUCTION

SPL Consultants Limited (SPL) was retained by the Ministry of Transportation to conduct a foundation investigation at the McGregor Creek Crossing (Site No. 13-232/1) located on Highway 401 EBL east of Highway 40 near Chatham-Kent, Ontario.

The terms of reference (TOR) for this investigation are outlined in the Request for Proposal (RFP) issued by the Ministry of Transportation (MTO) under Agreement No. 3011-E-0005 dated May 2011 and SPL's subsequent Proposal No. P11.06.024 dated June 2011.

The purpose of the preliminary foundation investigation was to obtain subsurface information at the site by means of a single exploratory borehole. This report presents the factual findings of the foundation investigation carried out at the site, as well as preliminary comments and recommendations related to the design and construction of the proposed widened structure.

The investigation forms part of the larger Highway 401/40 interchange project. The project includes a total of six preliminary foundation investigations; the remaining five are submitted under separate cover. As part of this project a geotechnical (pavement) investigation was also carried out at the site concurrent with the foundation investigations. The results of the pavement investigation are also presented under separate cover.

2. SITE DESCRIPTION

The site is located on Highway 401 EBL crossing the McGregor Creek, east of Highway 40 in the Geographical Township of Harwich, County of Kent, Ontario. The crossing is situated on the generally flat terrain of the St. Clair Clay Plain.

The existing structure at the creek crossing is a reinforced concrete single span rigid frame slab bridge. Site photos are included in Appendix A.

3. INVESTIGATION PROCEDURES

The foundation investigation was carried out in August to September 2011. The scope of work for this assignment included a desk study, field investigations, laboratory testing, analysis and preparation of this report.

3.1 Desk Study

Surficial geology in the area comprises fine-textured glacio-lacustrine and modern alluvial deposits, overlying glacial till.

Bedrock in the general area is black, non-calcareous shale with silty shale interbeds of the upper Devonian Kettle Point formation.

The GEOCRE database includes the results of several previous investigations at the Highway 401/40 interchange including a previous investigation at the McGregor Creek crossing on Highway 401 which is the subject of this report. The existing foundation information at the site is found in the following previous reports:

Table 1 – Previous Foundation Reports at Highway 401/40 Interchange

GEOCRE No.	Location
40J8-15	Highway 40 Underpass – Highway 401/40 Interchange
40J8-14	McGregor Creek Bridge – Highway 40 south of Highway 401
40J8-24	McGregor Creek Bridge – Highway 40 north of Highway 401
40J8-13	McGregor Creek Bridges (EBL and WBL) – Highway 401 East of Highway 40 ¹

These investigation results included in the various reports suggest the general area is underlain by a layer of very stiff, grey, silty clay till. A layer (or layers) of water-bearing sand and gravel was also encountered in some of the boreholes in the general area of the 401/40 interchange.

The previous report for the subject bridge (40J8-13, dated 1959) includes records of three boreholes drilled as part of a proposed (at that time) McGregor Creek diversion crossing. The three boreholes were drilled on the existing Highway 401; Borehole No. 1 and 2 on the west side of the proposed creek diversion to depths of 10.8 m (35.5') and 12.6 m (41.5'), respectively; and Borehole No. 3 on the east side of the creek diversion to a depth of 9.6 m (31.5'). Each borehole encountered very stiff to hard silty clay till underlain by water-bearing sand and gravel to the depth of drilling.

The report recommends the bridge structure be founded on spread footings within the clay till layer at or below 180 m elevation (590'). The actual foundation construction, however, cannot be confirmed based on the information available.

A copy of the previous geotechnical report is included in Appendix B of this report.

3.2 Field Investigation

The field investigation for this site was carried out in August to September, 2011 and included drilling a single borehole on the north side of the crossing in the EBL. BH13-232/2 was drilled for the proposed widening of the WBL bridge immediately north of the subject site and has also been included in this

¹ Subject of this report

report. As mentioned previously, additional shallow boreholes were advanced at the same time for the geotechnical (pavement) portion of the work; the results of these boreholes are submitted with the geotechnical (pavement) investigation report under separate cover.

The boreholes were advanced using a truck-mounted drill rig supplied and operated by London Soil Test Ltd., London, Ontario. Boreholes 13-232/1 and 13-232/2 were advanced using hollow-stem auger drilling as well rock coring techniques (using “N” size triple-tube core barrels) to a depth of 32.1 m and 31.8 m below the existing ground surface, respectively. During drilling, sampling and in-situ testing including Standard Penetration (SPT) Testing and Dynamic Cone Penetration (DCPT) Testing were carried out.

Standpipe piezometers were installed in both boreholes to allow for subsequent measurement of the stabilized groundwater level at the site. The boreholes were backfilled with bentonite and were sealed at the ground surface.

The borehole location is shown in Drawing 2. Borehole records are included in Appendix C of this report.

3.3 Laboratory Testing

Upon completion of drilling and in-situ testing, soil samples were returned to SPL’s laboratory for further examination and classification. A laboratory testing program, including determination of natural water content, soil density, Atterberg limits (plasticity) and grain size distribution (sieve and hydrometer) was carried out on selected representative soil samples.

The results of natural water content tests are included on the borehole logs in Appendix C. The results of plasticity testing are included on the borehole logs, and presented in the Plasticity Chart included as Drawing 3. The results of the determination of grain size distribution are summarized on the borehole logs and are presented in Drawings 4 through 7.

4. SUBSURFACE CONDITIONS

The subsurface conditions at the site are discussed in the following sections. Detailed descriptions of the soil and groundwater conditions encountered at the borehole locations are included in the borehole logs in Appendix C.

4.1 Soil & Rock Conditions

4.1.1 Asphalt

Borehole 13-232/2 was put down from the north paved shoulder of the WBL just east of the subject bridge. A layer of asphalt 250 mm thick was present at this location.

4.1.2 Fill

Immediately underlying the asphalt in borehole 13-232/2 and at the surface in 13-232/1 (which was drilled on the north gravel shoulder of the existing highway EBL) the boreholes encountered a layer of granular fill. The fill extended to a depth of 0.6 m and comprised compact to very dense sand and gravel, which is inferred to be the pavement structure of the highway.

Grain size analysis was carried out on one sample of the granular fill and the results are presented in Figure 4, and are summarized in Table 2 below.

Table 2 – Results of Grain Size Analyses for Granular Fill

Borehole No.	Sample No.	Grain Size Distribution			
		% Gravel	% Sand	% Silt	% Clay
BH13-232/2	SS1	31	62	5	2

Underlying the granular fill a deposit of silty clay fill was encountered and extended to a depth of 3.4 m below grade (180.9 m elevation) in borehole 13-232/1 and to 4.5 m below grade (179.7 m elevation) in borehole 13-232/2. The silty clay fill material was sandy, contained trace to some gravel, topsoil, and was brown in colour. As inferred from SPT “N” values varying between 4 to 12 blows for 0.3 m penetration, and shear vane testing (80 kPa in borehole 13-232/2 between elevation 181 m and 182 m), the consistency of this deposit is firm to stiff. Natural water contents in the silty clay fill material were found to range from 6 to 22.

Grain size analysis was carried out on two samples of the silty clay fill and the results are presented in Figure 5, and are summarized in Table 3 below.

Table 3 – Results of Grain Size Analyses for Silty Clay Fill Material

Borehole No.	Sample No.	Grain Size Distribution			
		% Gravel	% Sand	% Silt	% Clay
BH13-232/1	SS2	2	29	31	38
BH13-232/2	SS3	17	34	27	22

4.1.3 Silty Clay Till

The native soils below the silty clay deposit include a thick deposit of silty clay till. The 1959 borehole logs also indicate a 1.8 m thick layer of silty sandy clay overlying the till deposits. The clay till was present from 3.4 m depth (180.9 m elevation) to 13.7 m depth (170.5 m elevation) in borehole 13-232/1 and from 4.5 m depth (179.7 m elevation) to 12.2 m depth (172 m elevation) in borehole 13-232/2 drilled as part of this current investigation and extended to depths of 8.5 m (174.9 m elevation) to 12.2 m (171.3 m elevation) in the boreholes drilled in 1959.

The results of Atterberg Limits (plasticity) testing on four samples of the silty clay till yielded plastic limits of 11 to 16 and liquid limits of 23 to 33 indicating a low plastic silty clay (CL). The results of the plasticity testing are presented on the Plasticity Chart in Drawing 3. Natural water contents ranged from 9 to 17.

The grain size distributions of three samples of the silty clay till are presented in Drawing 6, and are summarized in Table 4 below.

Table 4 – Results of Grain Size Analyses for Silty Clay Till

Borehole No.	Sample No.	Grain Size Distribution			
		% Gravel	% Sand	% Silt	% Clay
13-232/1	SS7	5	20	41	34
13-232/1	SS9	4	47	31	18
13-232/2	SS6	9	40	27	24

Measurements of unit weight carried out on samples of the silty clay till obtained in both the current and 1959 investigation yielded values of 20.8 kN/m³ to 23.1 kN/m³.

SPT “N” values measured during the current investigations range from 12 to 45. SPT “N” values reported in the previous geotechnical investigation range from 15 to 52. Based on these values the consistency of the silty clay till would be described as stiff to hard.

4.1.4 Sand/Sand and Gravel/Gravelly Sand

Underlying the clay till, there is a water-bearing, cohesionless deposit of sand and gravelly sand. This layer was encountered between 13.7 m depth (170.5 m elevation) to 24.6 m depth (159.6 m elevation) in borehole 13-232/1 and between 12.2 m depth (172 m elevation) to 24.8 m depth (159.4 m elevation). In the 1959 investigation, the boreholes contacted similar soils at depths varying between 8.5 m (174.9 m elevation) and 12.2 m below grade (171.2 m elevation). Till-like layers were noted interbedded within the granular deposits at depths of 19.8 m (164.4 m elevation) in borehole 13-232/1 and at 13.7 m depth (170.5 m elevation) in 13-232/2.

The grain size distributions of two samples of the granular soils are presented in Drawing 7, and are summarized in Table 5 below.

Table 5 – Results of Grain Size Analyses for Sand and Gravel/Gravelly Sand

Borehole No.	Sample No.	Grain Size Distribution			
		% Gravel	% Sand	% Silt	% Clay
13-232/2	SS11	43	56	1	
13-232/2	SS13	28	63	5	4

SPT “N” values measured within the sand deposits during the current investigations range from 13 to in excess of 50 blows per 300 mm penetration. The majority of the sand and gravelly sand would be considered dense to very dense based on SPT “N” values.

4.1.5 Bedrock

Bedrock was contacted in borehole 13-232/1 at 24.6 m depth (159.6 m elevation) and at 24.8 m depth (159.4 m elevation) in borehole 13-232/2. The boreholes were cored using “N” size coring equipment from 29 m and 28.8 m depths (155.2 m and 155.4 m elevations), respectively.

The bedrock comprises dark grey, fresh to slightly weathered shale. The shale is very thinly bedded with closely spaced discontinuities. RQD values for the shale bedrock range from 56% to 100%, indicating fair to excellent quality rock.

4.2 Groundwater Conditions

Standpipe piezometers were installed in both boreholes drilled as part of the current investigation. The groundwater elevation at the site was measured in October 2011 and found to be at 8.15 m depth (176.05 m elevation) in borehole 13-232/1 and at 8.96 m depth (175.24 m elevation) in borehole 13-232/2. Both piezometers were installed within the lower granular soil stratum that was intercepted at 13.7 m depth (170.5 m elevation) in borehole 13-232/1 and at 12.2 m depth (172 m elevation) in borehole 13-232/2.

It should be noted that the groundwater levels can vary and are subject to seasonal fluctuations as well as fluctuations in response to major weather events and in response to sustained changes in the level of the creek. If construction is carried out at a time when the creek level is higher than the level at the time of the foundation investigation, a corresponding increase in groundwater levels should be anticipated.

4.3 Summary

A summary of the soil and groundwater conditions encountered at the Hwy 401 and McGregor Creek

crossing location is presented in Table 6 below.²

Table 6 – Simplified Stratigraphy and Groundwater Elevations

Borehole No.	Ground Surface Elevation	Simplified Stratigraphy (Depth, m)						Groundwater Elevation
		Asphalt & Granular Fill	Silt and Clay Fill	Silty/Sandy Clay	Silty Clay Till	Sand/Sand and Gravel	Shale Bedrock	
13-232/1 (2011)	184.2	0.0 – 0.6	0.6 – 3.4	--	3.4 – 13.7	13.7 – 24.6	24.6 – 32.1	176.05 m
13-232/2 (2011)	184.2	0.0 – 0.6	0.6 – 4.5	--	4.5 – 12.2	12.2 – 24.8	24.8 – 31.8	175.24 m
1 (1959)	183.5	--	--	0.0 – 1.8	1.8 – 9.8	9.8 –	--	178.6 m
2 (1959)	183.5	--	--	0.0 – 1.8	1.8 – 12.2	12.2 –	--	177.4 m
3 (1959)	183.8	--	--	0.0 – 1.8	1.8 – 8.5	8.5 –	--	179.3 m

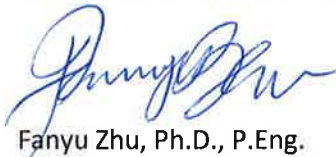
5. CLOSURE

Field investigations for this project were supervised by Philip Resendes, B.Sc. This report was prepared by Ms. Eva Papp, P.Eng. and Mr. Chris Hendry, P.Eng. Mr. Fanyu Zhu, P.Eng., SPL's project manager and designated MTO Contact, and Mr. Shaheen Ahmad, P.Eng., SPL's quality control auditor provided independent review and quality control.

SPL CONSULTANTS LIMITED



Chris Hendry, M.Eng., P.Eng.



Fanyu Zhu, Ph.D., P.Eng.

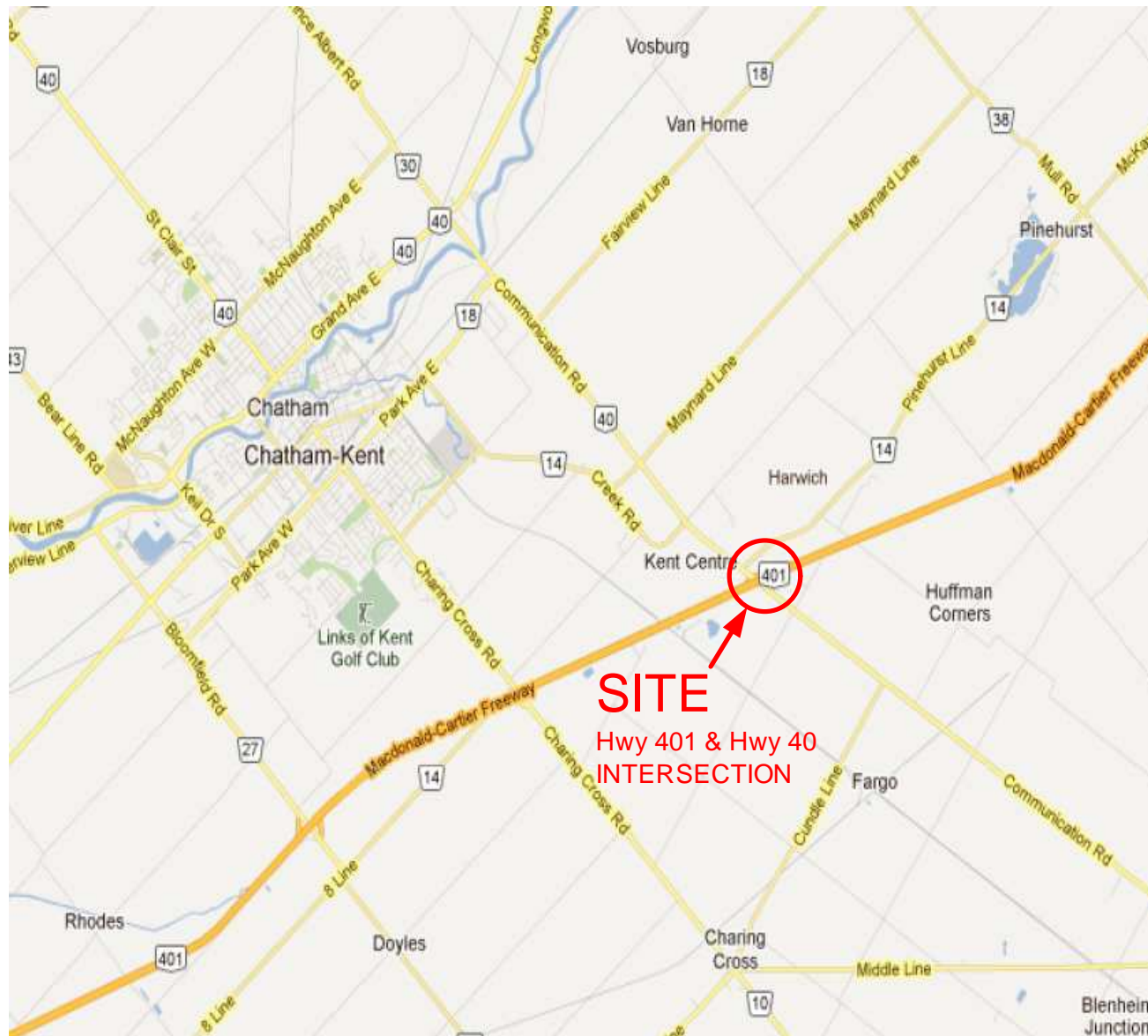



Shaheen Ahmad, M.A.Sc., P.Eng.

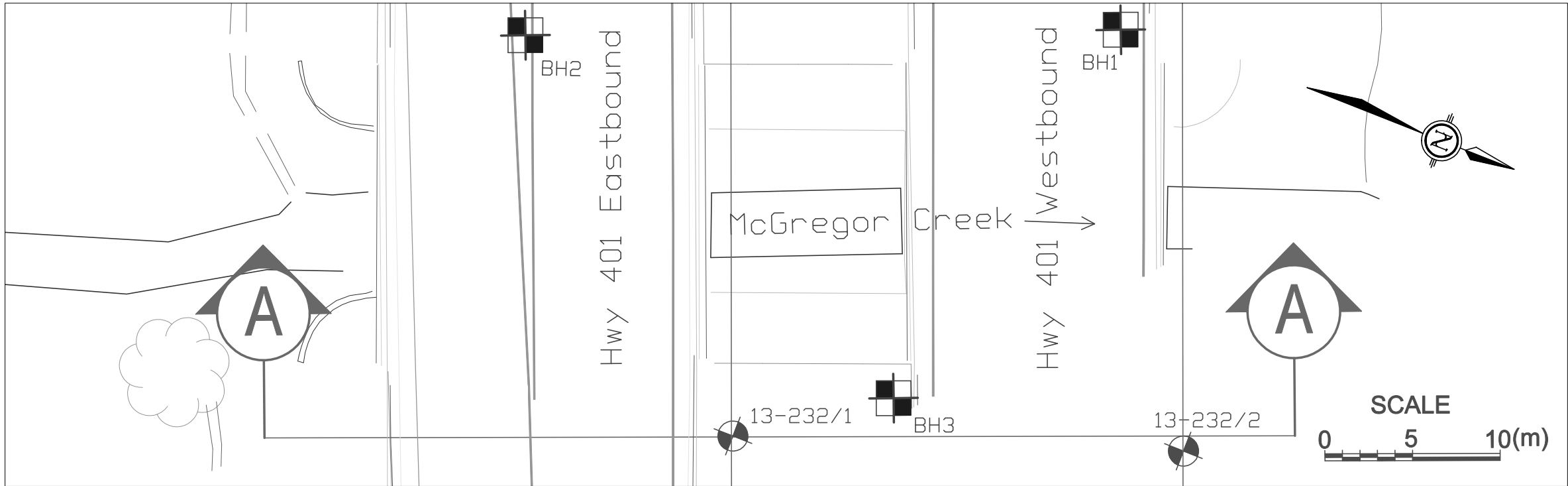


² The values presented for the 1959 investigation have been obtained from a copy of the investigation report which was made available to us. The accuracy of this data has not been verified as part of this study. In particular it is noted that the recorded elevation of the 1959 boreholes is similar to that of the 2011 borehole despite the presence of 3.4 to 4.5 m of fill at the site. It is recommended that these values be treated with caution.

Drawings

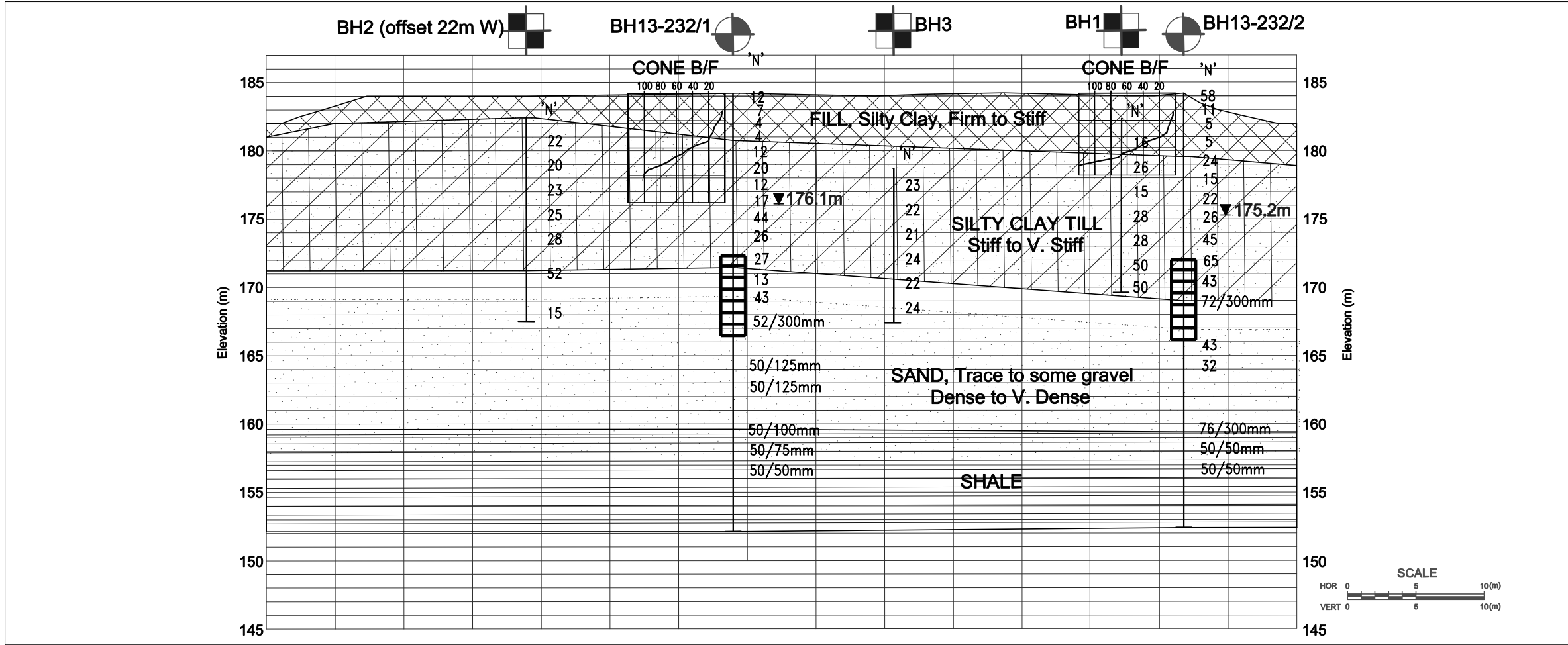
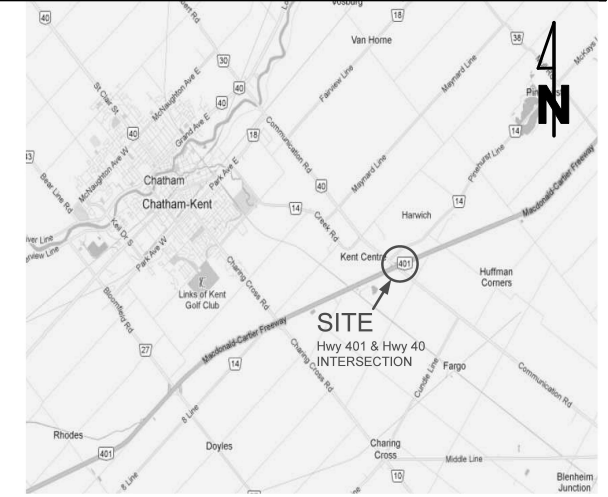


Client: Ministry of Transportation Ontario			Title: SITE PLAN			Project: Foundation Investigation Structure 13-232/1, Hwy 40 & Hwy 401	
Date: DEC 12, 2011	Drawn: NT	Scale: N/A	Project No.: 919-1101				
Original Size: LETTER	Approved: CH	Rev: N/A	Drawing No.: 1		 SPL Consultants Limited Geotechnical * Environmental * Materials * Hydrogeology		



G.W.P. 3093-09-00
Site No. 13-232/1
MTO GEOCRES NO 40J8-52

McGregor Creek Bridge Widening
Highway 401 East of Highway 40
BORE HOLE LOCATIONS & SOIL STRATA



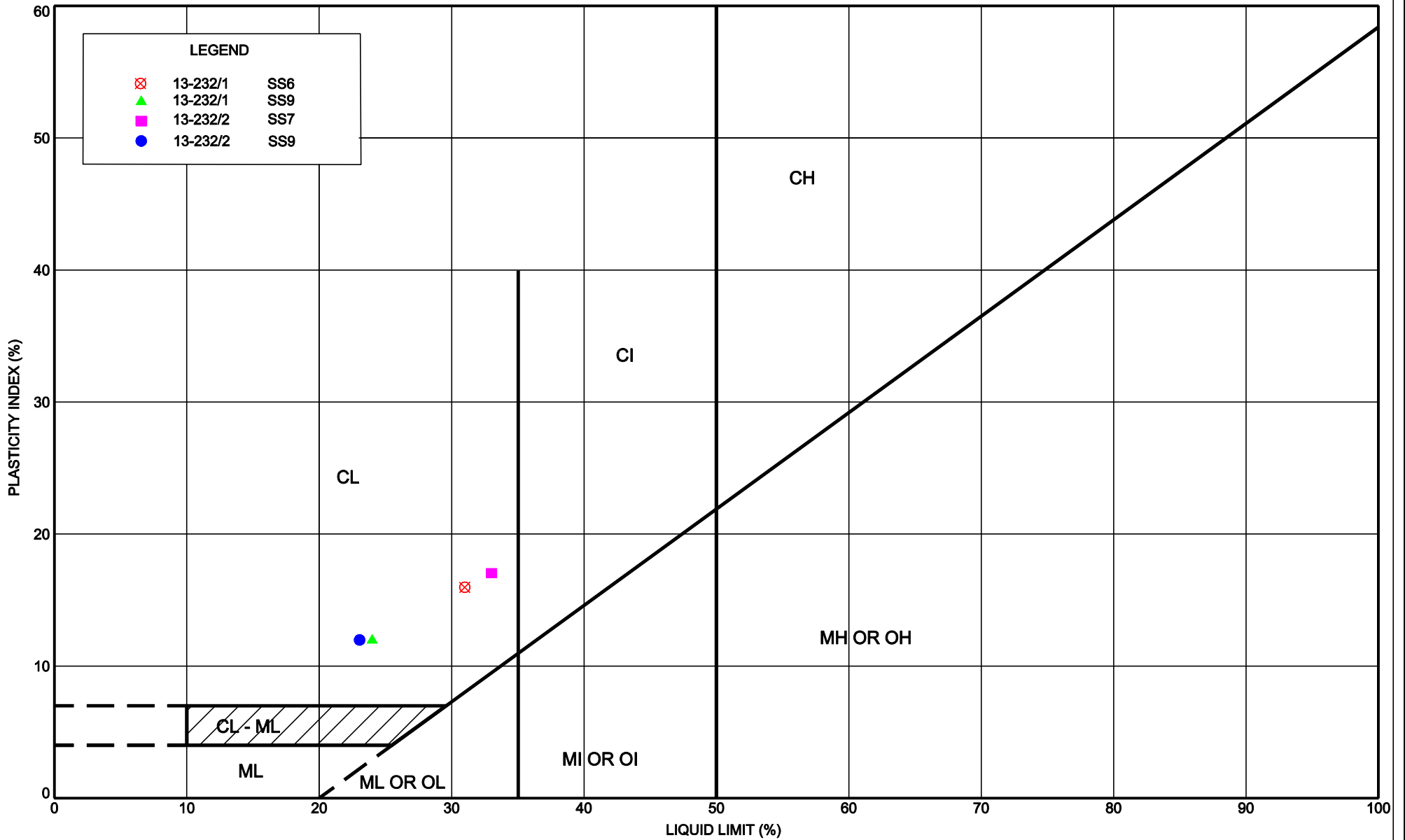
LEGEND


- BH13-232/2: Borehole drilled in 2011
- BH1: Borehole drilled in 1959
- Piezometer
- B / F Cone: Blows/0.3m (60° Cone)
- 'N': Blows/0.3m SPT Test
- Measured Groundwater Level (Oct 17, 2011)

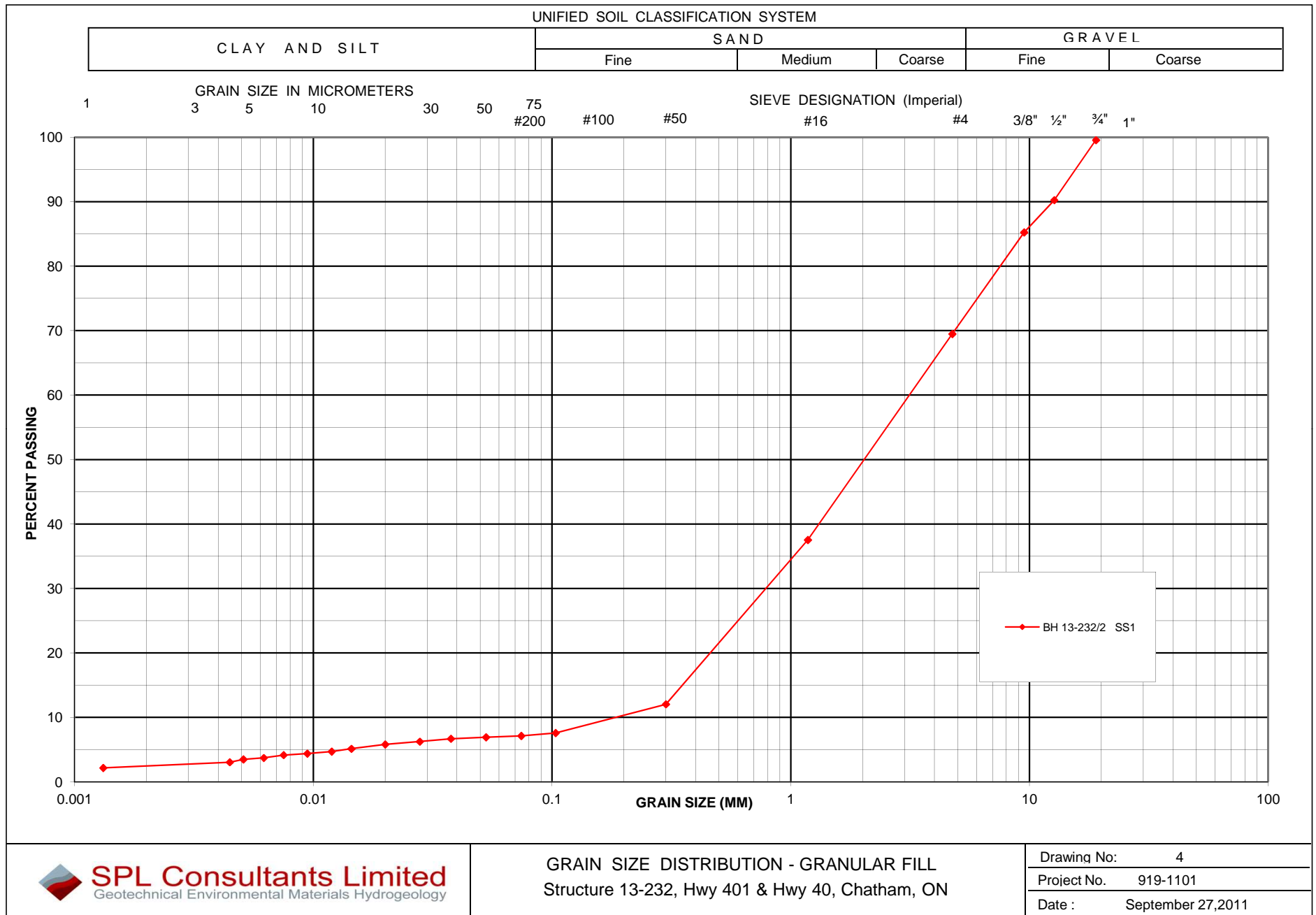
BH No.	ELEVATION	CO-ORDINATES N	CO-ORDINATES E
BH13-232/1	184.2 masl	4692905	410367
BH13-232/2	184.2 masl	4692905	410358

NOTE: LOCATIONS AND ELEVATIONS OF BOREHOLES DRILLED IN 1959 ARE APPROXIMATE ONLY AND HAVE NOT BEEN VERIFIED.

Client: MTO		Project No.: 919-1101	Drawing No.: 2
Drawn: PR	Approved: CH	Title: BOREHOLE LOCATION PLAN & GEOSECTION	
Date: Jan 18, 2012	Scale: As shown	Project: Preliminary Geotechnical Investigation – McGregor Creek Chatham, Ontario	
Original Size: Tabloid	Rev: N/A	SPL Consultants Limited Geotechnical • Environmental • Materials • Hydrogeology	



Client: Ministry of Transportation Ontario		Project No.: 919-1101	Drawing No.: 3
Drawn: EH	Approved: EP	Title: PLASTICITY CHART	
Date: December 18, 2011	Scale: N/A	Project: Preliminary Geotechnical Investigation Structure 13-232/1, Hwy 40 & Hwy 401, Chatham, Ontario	
Original Size: LETTER	Rev: N/A	 SPL Consultants Limited Geotechnical • Environmental • Materials • Hydrogeology	



SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

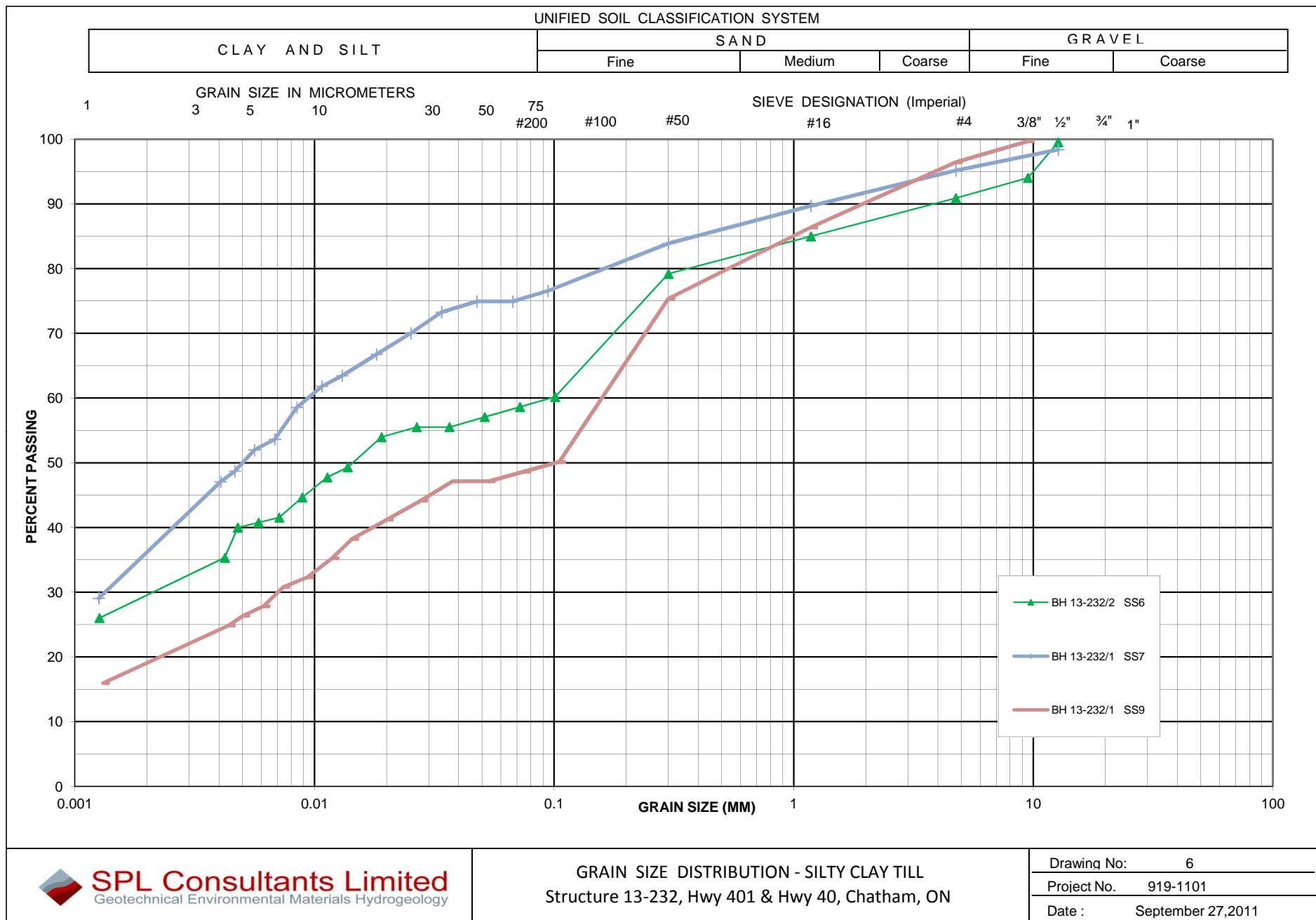
GRAIN SIZE DISTRIBUTION - GRANULAR FILL

Structure 13-232, Hwy 401 & Hwy 40, Chatham, ON

Drawing No: 4

Project No. 919-1101

Date : September 27, 2011



SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

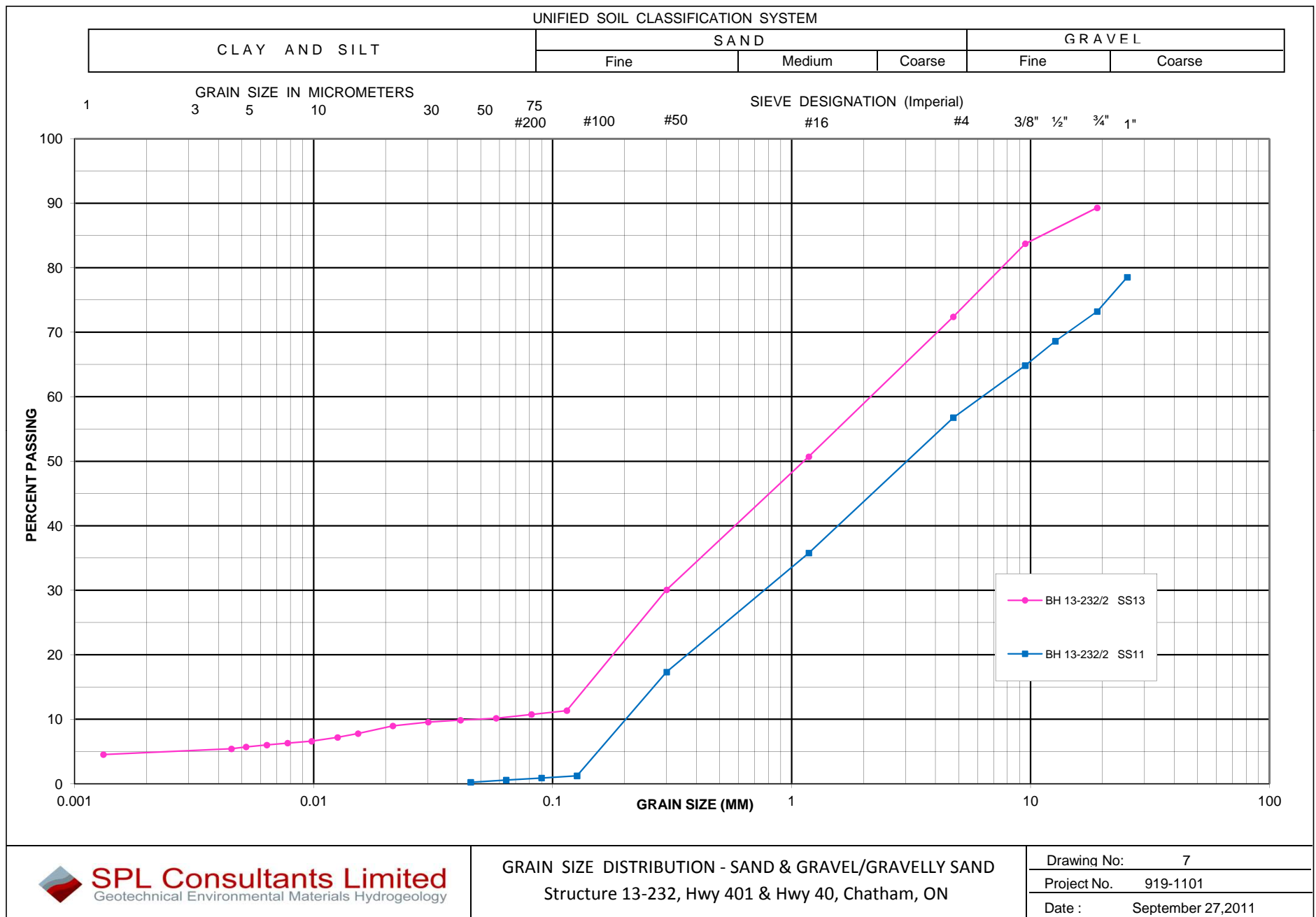
GRAIN SIZE DISTRIBUTION - SILTY CLAY TILL

Structure 13-232, Hwy 401 & Hwy 40, Chatham, ON

Drawing No: 6

Project No. 919-1101

Date: September 27, 2011



Appendix A

Site Photos



Highway 401 eastbound over McGregor Creek facing north.



Highway 401 eastbound over McGregor Creek facing east.



Under Highway 401 eastbound bridge over McGregor Creek facing north.

Appendix B

Previous Geotechnical Investigation

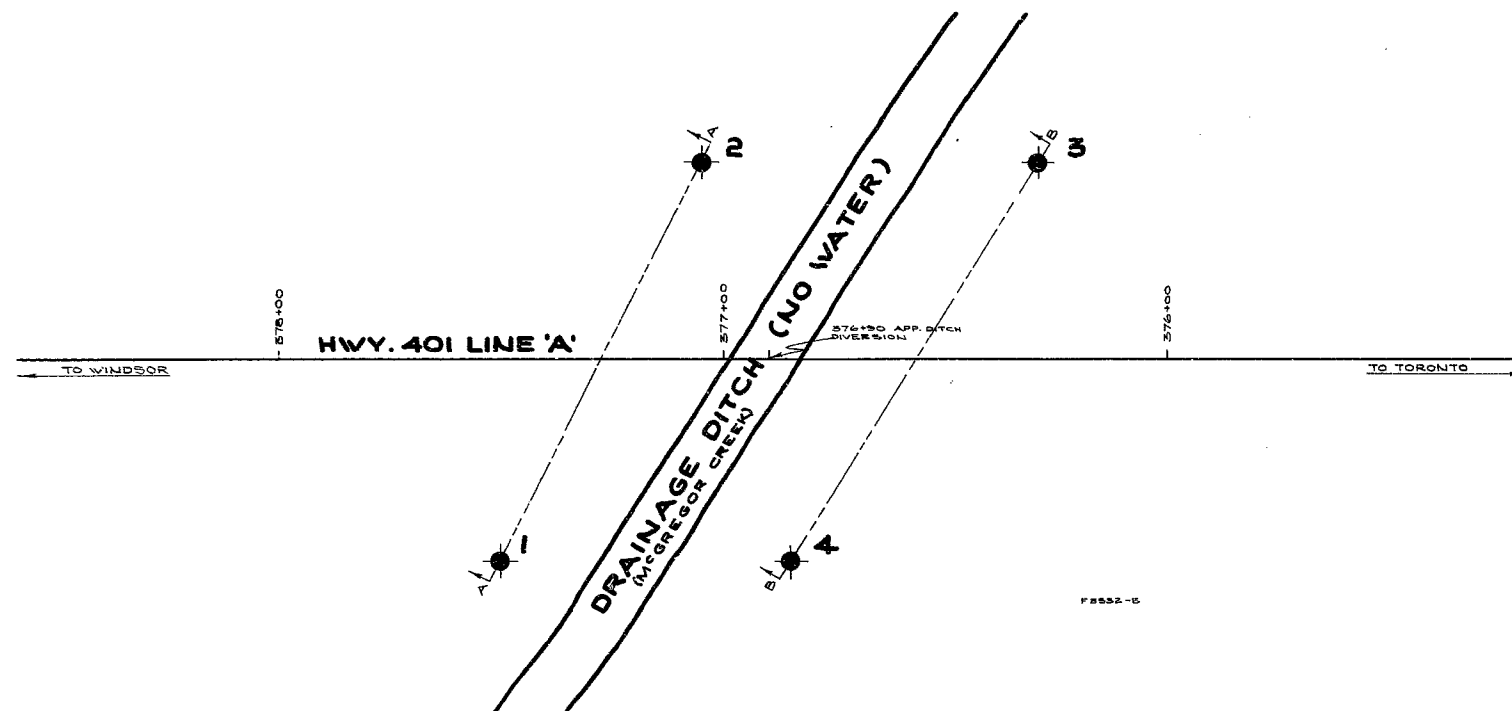
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W.P. 16-59

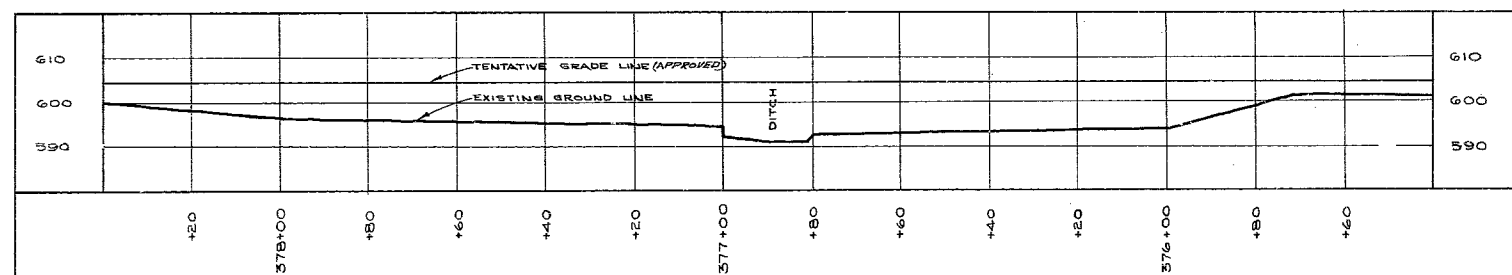
HWY. 401 &

MCGREGOR CR.

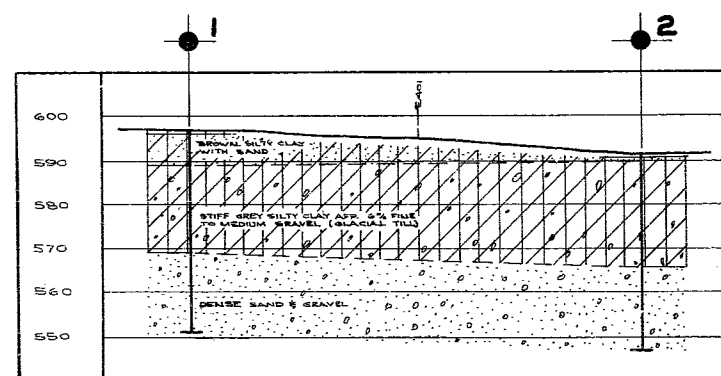
DIV. DIST. # I



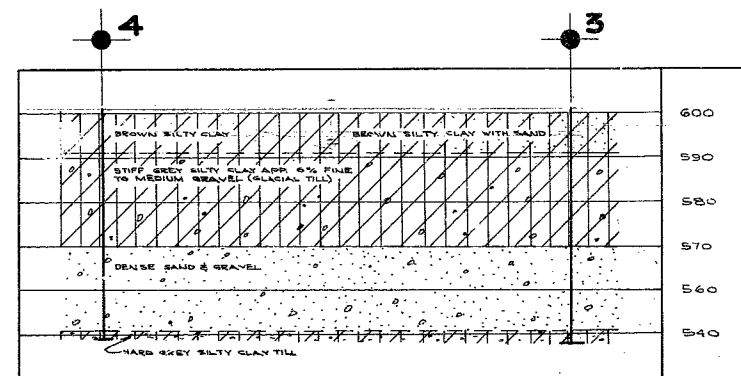
PLAN



PROFILE

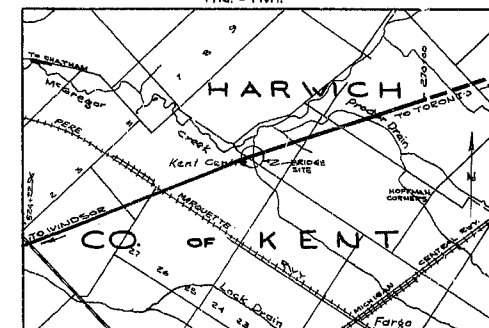


A-A



B-B

KEY PLAN



LEGEND

BORE HOLE
PENETRATION HOLE
BORE & PENETRATION HOLE

HOLE NO.	ELEVATION	STATION	DISTANCE FROM
1	597.0'	577+50	45' LT.
2	592.0'	577+05	45' RT.
3	601.0'	576+30	45' RT.
4	601.0'	576+25	45' LT.

- NOTE -

THE BOUNDARIES BETWEEN SOIL STRATA HAVE BEEN ESTABLISHED ONLY AT BORE HOLE LOCATIONS. BETWEEN BORE HOLES THE BOUNDARIES ARE ASSUMED FROM GEOLOGICAL EVIDENCE AND MAY BE SUBJECT TO CONSIDERABLE ERROR.

401B-13
GEOCRES No.

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & RESEARCH SECTION

DRAINAGE DITCH PROPOSED CROSSING

SHOWING POSITIONS & ELEVATIONS OF HOLES

HWY. 401 DISTRICT 1 COUNTY KENT
TOWNSHIP HARWICH LOT 26 CON. 11/12
LOCATION APP. 3/4 MILE SE CHADHAM
DRAWN BY: T. MELLORS CHECKED BY: W.P. 10-59
DATE 25 MAY 1959 APPROVED BY: DRAWING NO.
SCALE 1 IN. = 20 FT. F59-33A

Mr. A. M. Toye,

August 17, 1959.

Bridge Engineer.

Re: FOUNDATION REPORT -

Materials & Research Section.

W.J. F-59-73 -- W.P. 16-59.

Attention: Mr. S. McCombie.

Hwy. 401 Line 'A' & McGregor Creek Diversion Crossing,
Approx. 8 miles S.E. of Chatham (at Kent Centre)
Lots 25 & 26, Con. I E.C.R., Twp. of Harwich.

Enclosed herewith is our detailed report on the foundation investigation at the above noted structure site. A realignment of the creek resulted in a change in structure location and necessitated additional borings. The attached report presents the results of the three additional borings carried out at the final proposed creek diversion crossing site.

For your convenience, principal comments contained in this report are summarized as follows:-

1. Subsoil consists of a dense clay till stratum intercepted by a layer of water-bearing sand and gravel.
2. Strength and compressibility characteristics are such that spread footing support can be obtained in the upper dense clay till. A safe allowable footing pressure of 2 1/2 t.s.f. is recommended. Final depth of footings to be founded will depend on the realigned channel of the creek. To avoid undermining of the footings due to stream erosion and scour, and to allow for future deepening of the creek channel, it is recommended that footings be founded at Elev. 585' (approx. 6 ft. below stream-bed, assuming stream-bed elevation of creek diversion at approx. Elev. 591') or below.

cont'd. /2 ...

Principal Comments: (cont'd.) ...

3. An artesian water condition was noted in the underlying sand and gravel layer during the boring programme. To guard against "piping" during footing excavations, it is recommended that footings should not be founded below Elev. 580'. No excessive seepage problems during footing excavations are anticipated, if footings are founded above Elev. 580'.
4. No approach fill stability problems are anticipated.

L. G. Soderman,
PRINCIPAL SOILS & FOUNDATIONS ENGR.
per:

AKL

AKL/Mdef
Encl.

(A. K. Loh,
Project Foundation Engineer)

cc: Messrs. A. M. Taya
H. A. Tregaskes
D. G. Ramsay
A. Gater
G. U. Howell
J. Roy
A. Watt
Foundation Office
Gen. Files

FOUNDATION REPORT

on

Hwy. 401 Line 'A' & McGregor Creek Diversion Crossing
Approx. 8 miles S.E. of Chatham (at Kent Centre)
Lots 25 & 26, Cen. I E.C.R., Twp. of Harwich.

Bridge Office Dwg. No: BW-285.
Plan No: F-3532-1.
Profile No: F-3532-3.
Chainage: Sta. 372+80.

Distribution:

Mr. A. M. Towe,
Bridge Engineer. (2)

Mr. H. A. Tregaskes,
Construction Engineer. (1)

Mr. D. G. Ramsay,
Rd. Design Engineer. (1)

Mr. A. Gater,
Sr. Proj. Design Engineer. (1)

Mr. G. U. Howell,
District Engr., Chatham. (1)

Mr. J. Roy,
Regional Soils Engr. (1)

Mr. A. Watt,
Ont. Water Resources Commission. (1)

Foundation Section. (1)

Gen. Files. (1)

W.J. F-59-73.

W.P. 16-59.

INTRODUCTION:

Presented in this report are the results of a subsoil investigation carried out at a structure location approximately 8 miles southeast of Chatham (at Kent Centre) where proposed Highway 401 line 'A' crosses the McGreger Creek diversion in Lot 25 & 26, Con. I, township of Harwich (Sta. 372+80, Profile No. F-3532-3). This report contains field and laboratory findings and recommendations for the foundation of the structure.

The field work commenced on July 20, 1959 and was completed on July 21, 1959.

An initial subsoil investigation was carried out between April 24 and April 25, 1959, approximately 400 feet west of the proposed site at the existing Creek Crossing (Sta. 376+90, Profile No. F-3532-3). After the completion of this investigation a creek diversion was proposed at Sta. 372+80. This initial investigation consisting of 4 sampled boreholes was carried out by a continuous flight auger, adapted for soil sampling. Results of this initial investigation are not presented in this report but are kept for references.

DESCRIPTION OF THE SITE AND GEOLOGY

The site and its surrounding areas are generally flat farmlands. The crossing site is located on a cornfield presently under cultivation. Approximately 400 feet west of the site, McGreger Creek meanders on a rather sharp-bottom valley, flowing at a moderate velocity. During spring run-off it has

been reported that half of the valley was flooded. At the time of the investigation, the stream bed of the creek was covered with approximately 2 feet of water. Some minor erosion due to scour are exhibited along the banks of the creek.

Physiographically, the site under consideration is located on a bevelled till plain between the Bothwell sand plain and St. Clair Clay Plains. At this site the dense clay till was found to be overlain by the topsoil only.

FIELDWORK

The fieldwork associated with this investigation was carried out on 2 separate occasions. An initial boring programme consisting of 4 sampled boreholes was carried out at the existing McGregor Creek Crossing between April 24 and April 25, 1959 at Sta. 376+90. After the completion of this investigation a creek diversion was proposed at Sta. 372+80. As a result of this change in structure location, a second investigation consisting of 3 sampled boreholes, was carried out by a continuous flight auger adapted for soil sampling between July 20 and July 21, 1959. This investigation confirmed similar subsoil findings at both investigated sites.

Boreholes were advanced by conventional auger boring procedures. Samples were recovered at depth required by means of a 2" O.D. split barrelled spoon sampler. The dimensions of this spoon sampler and the energy used to drive it conform to the requirements of the Standard Penetration Test. Immediately upon recovery, samples were visually examined and identified

and placed in moisture proof containers for transport to our laboratory. Upon receipt in the laboratory samples were visually examined and identified. Routine index tests were carried out on selected representative samples. Laboratory test results have been presented in the borehole logs and detailed in Table No. 1 under Appendix I.

The location plan and subsoil profile are presented in Drawing No. F-59-73A.

SUBSOIL CONDITIONS

The site is underlain by a dense clay till stratum intercepted by a layer of water-bearing sand and gravel.

In each of the sampled boreholes, the topsoil was found to be underlain by the dense fissured silty clay till, the upper 6 feet of which contains organic matter and has been oxidized to its present brownish colour. Underneath the upper dense clay till stratum, a layer of water-bearing sand and gravel was intercepted at Elev. 569.5' in Boring 1 (approximately 32 ft. in depth), Elev. 561.5' in Boring 2 (approximately 40 ft. depth), and Elev. 573.5' in Boring 3 (approximately 28 ft. depth). This layer of sand and gravel was not fully explored due to "cave in" of the auger holes when this layer was encountered during the boring programme. Reference to our initial boring data at the existing McGregor Creek Crossing shows that this layer of sand and gravel is approximately 19 ft. in thickness and exists in a dense condition. It is underlain by dense clay till of similar deposits as the upper dense clay till. This lower clay till stratum was explored for a distance of 3 ft. in our initial investigation at the existing McGregor Creek Crossing.

In general the soil types encountered are as follows:-

1. Upper Dense Clay Till

This upper stratum of dense clay till, believed to be the result of glaciations was encountered immediately below the topsoil. The upper 6 feet contains decayed and organic matter and has been subjected to oxidation resulting in its present brownish colour. Below the oxidized zone the colour is predominantly grey. The silty clay till is fissured and contains predominantly clay and silt with various percentages of sand and gravel. The average unit weight and moisture content were found to be 138 p.c.f. and 16%. It is of very low plasticity. Due to the gravelly and fissured nature of the dense silty clay till, laboratory strength tests cannot be carried out on the samples. Field tests show an "N" value (standard penetration resistance expressed in blows per foot) of 23 to be representative for the stratum.

2. Sand and Gravel

This formation believed to be of post-glacial origin was encountered immediately below the upper dense clay till stratum. It was intercepted at Elev. 569.5' (approximately 32 ft. depths) in Boring 1, Elev. 561.5' (approximately 40 ft. depth) in Boring 2 and Elev. 573.5' (approximately 28 ft. depth) in Boring 3. According to our boring data at the existing McGregor Creek Crossing, this layer is of the order of 19 ft. in thickness. The material contains predominately fine sand and medium gravel and is water bearing. It exists in a dense condition. An artesian water condition was noted in this layer of sand and gravel and will be discussed under "Water Conditions".

3. Lower Dense Clay Till

This stratum was not explored at this site, but in view of the similarity in geological formation as well as subsoil conditions between this site and the existing McGregor Creek Crossing site previously investigated, it is believed that similar stratifications are likely to be encountered here at this creek diversion site. Reference to this previous investigation shows that this lower stratum was encountered immediately below the layer of sand and gravel. The materials are of similar deposits as the upper clay till stratum. The clay till here exists in a very dense condition with "N" values in excess of 50 registered during the field sampling operations. According to available geological information this clay till extends to a considerable depth over limestone bedrock.

The field and laboratory test results have been summarized in Table No. 1 and are included in this report under Appendix I.

WATER CONDITIONS

Due to the impermeable nature of the clay till it was not possible to accurately establish the ground water table at the site during the boring programme. All the samples obtained below the normal McGregor Creek water level were saturated and it has been assumed that the ground water table is at or close to the creek water level at approximately Elev. 593'.

Artesian water conditions were noted in each of the sampled boreholes when the layer of sand and gravel was en-

countered. The condition was encountered at Elev. 569.5' in Boring 1, Elev. 561.5' in Boring 2 and Elev. 573.5' in Boring 3. The excess hydrostatic head reached Elev. 585.5' in Boring 1, Elev. 581.5' in Boring 2 and Elev. 588' in Boring 3. The critical elevation below which "piping" occurs during footing excavations has been estimated to be at 576' in Boring 1, 570 in Boring 2, and 580 in Boring 3.

FOUNDATION CONSIDERATIONS

The upper dense clay till is competent to provide adequate foundation support for the structure. Subsoil conditions are such that at Elev. 590' or below spread footing support can be obtained in the dense clay till. At this elevation or below, for footings of 7' to 10' wide, a bearing pressure of 2½ t.s.f. incorporating a safety factor of 3 can be used for spread footing design. Settlement consequent upon application of this bearing pressure will be within tolerable limits. To avoid undermining of the footings due to stream erosion and scour and to allow for future deepening of the creek channel, considerations should be given to founding the footings at an elevation below the stream-bed. In view of the fact that Mcgreger Creek is relatively active, it is recommended that footings should be founded at Elev. 585' (approximately 6 ft. below stream-bed assuming stream-bed elevation of creek diversion at 591'.) or below. In order to guard against "piping" during footing excavations due to the artesian water conditions encountered in the underlying sand and gravel layer, they

should not be placed below Elev. 580'. No excessive seepage problems are anticipated if footings are founded above Elev. 580'.

Under the proposed grade line, the maximum height of fill is approximately 3 ft. The subsoil can safely support this embankment loading.

CONCLUSIONS & RECOMMENDATIONS

1. The site is underlain by a dense clay till stratum intercepted by a layer of water-bearing sand and gravel.
2. Subsoil conditions are such that at Elev. 590' or below spread footing support can be obtained in the dense clay till. At this elevation or below for footings of 7' to 10' wide a bearing pressure of $2\frac{1}{2}$ t.s.f. can be used in spread footing design. Settlement consequent upon application of this bearing pressure will be within tolerable limits. In order to avoid undermining of the footings due to stream erosion and scour and to allow for future deepening of the Creek channel, it is recommended that footings should be founded at Elev. 585' (approximately 6 ft. below stream-bed assuming stream-bed elevation of creek diversion at approximately Elev. 591') or below.
3. To guard against "piping" during footing excavations due to the artesian water conditions encountered in the underlying sand and gravel layer, footings should not be founded below Elev. 580'. No excessive seepage problems during footing excavations are anticipated if footings are founded above Elev. 580'.
4. No approach fill stability problems are anticipated.

AKG
A. K. Loh
Foundation Project Engineer

APPENDIX I.

W.P. 16 - 59 BORE HOLE NO. 1
JOB E 59 - 73 STATION 373+00 (50' RT)
DATUM 601.5' COMPILED BY B.K.
BORING DATE July 21/59 CHECKED BY A.L.

2" DIA. SPLIT TUBE _____
2" SHELBY TUBE _____
2" SPLIT TUBE _____
2" DIA. CONE _____
2" SHELBY _____
CASING _____

1/2 UNCONFINED COMPRESSION (Qu)	---	0
VANE TEST (C) AND SENSITIVITY (S)	---	+ ⁸
NATURAL MOISTURE AND		
LIQUIDITY INDEX	---	X LI
LIQUID LIMIT	---	
PLASTIC LIMIT	---	

SYMBOL	DESCRIPTION	ELEV. FEET	DEPTH FEET	STRENGTH AND PENETRATION RESISTANCE		SAMPLE	NATURAL UNIT WT. P.C.F.	
				P.S.F.				
				BLOWS/FT.		MOIST. CONTENT- % DRY WT.		
				25	50	10	20	30
	↓ Ground level	601.5	0					
	Brown fine sand with organic matter	598.5						
	Stiff grey-brown fissured sandy clay with organic matter	595.5						
	Dense grey fissured silty clay till, gravelly		10					
			20					
		569.5	30					
	Sand & gravel (water-bearing)	566.0						
	End of borehole		40					
	Artesian water conditions @ Elevation 569.5' - excess hydrostatic head reached Elevation 585.5'							

W.P. 16 - 59 ----- BORE HOLE NO. 2 -----
JOB F 59 - 73 ----- STATION 373+00 (50' LT) -----
ELEVATION 601.5' ----- COMPILED BY B.K. -----
BORING DATE July 21/59 ----- CHECKED BY A.L. -----

1/2 UNCONFINED COMPRESSION (Qu) ---	O
VANE TEST (C) AND SENSITIVITY (S) ---	+ S
NATURAL MOISTURE AND	LI
LIQUIDITY INDEX ---	X
LIQUID LIMIT ---	
PLASTIC LIMIT ---	

SYMBOL	DESCRIPTION	ELEV. FEET	DEPTH FEET	STRENGTH AND PENETRATION RESISTANCE	
				P.S.F.	BLOWS/FT.
	↓ Ground level topsoil	601.5	0	25	50
	Stiff grey-brown fissured silty clay with organic matter	594.5			
	Dense grey fissured silty clay till, gravelly				
		561.5	40		
	Clay, sand (water-bearing)	560.0			
	End of borehole				
	Artesian water condition @ Elev. 561.5'				

CONSISTENCY		SAMPLE	NATURAL UNIT WT. P. C. F.
MOIST. CONTENT - % DRY WT.			
10	20	30	
		x	S1 130.0
	x		S2 144.2
	x		S3 135.9
		x	S4 136.9
x			S5 --
	x		S6 137.6
x			S7 --

B.H. 2

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS AND RESEARCH SECTION

W.P. 16 - 59 BORE HOLE NO. 3

JOB F 59 - 73 STATION 372/59 (E)

DATUM 601.5' _____ COMPILED BY B.K. _____

BORING DATE July 20/59 CHECKED BY A.L.

2" DIA. SPLIT TUBE -----
2" SHELBY TUBE -----
2" SPLIT TUBE -----
2" DIA. CONE -----
2" SHELBY -----
CASING -----

LEGEND

1/2 UNCONFINED COMPRESSION (Qu) -----	O
VANE TEST (C) AND SENSITIVITY (S) -----	+ ^s
NATURAL MOISTURE AND	
LIQUIDITY INDEX -----	LI
LIQUID LIMIT -----	X
PLASTIC LIMIT -----	—

SYMBOL	DESCRIPTION	ELEV. FEET	DEPTH FEET	STRENGTH AND PENETRATION RESISTANCE	
				P. S. F.	
	↓ Ground level	601.5	0	25	50
	topsoil	601.0			
	Stiff brown fissured silty clay with organic matter				
	Dense grey-brown fissured silty clay till, gravelly	595.5			
		592.5	10		
	Dense grey fissured silty clay till, gravelly				
			20		
		573.5			
	Fine silty sand (water-bearing)	570.0	30		
	End of borehole				
	Artesian water condition @ Elev. 573.5' - excess hydrostatic head reached Elev. 588'				

Cone Penetration
Refusal @ Elev. 568'

CONSISTENCY		SAMPLE	NATURAL UNIT WT. P.C.F.
MOIST. CONTENT- % DRY WT.			
10	20	30	
	X		S1 132.0
	X		S2 138.2
	X		S3 135.8
	X		S4 131.8
	X		S5 136.1
		X	S6 --

B.H. 3

Appendix C



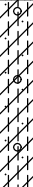
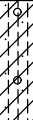
Borehole Logs (Record of Borehole Sheets)

RECORD OF BOREHOLE No BH13-232/1

1 OF 4

METRIC

W.P. 3093-09-00 LOCATION N 4692905; E 410367 ORIGINATED BY PR
DIST HWY 40 BOREHOLE TYPE Hollow Stem Augers/Rock Coring COMPILED BY NT
DATUM Geodetic DATE 31/08/2011 - 01/09/2011 CHECKED BY EP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p	W	W _L			WATER CONTENT (%)	
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE							
184.2 0.0	FILL sand and gravel brown, moist compact		1	SS	12		184									
183.6 0.6			Fill: Silty Clay sandy, trace gravel brown, moist firm	2	SS		7	183								
	3	SS		4												
	4	SS		4												
	5	SS		12												
180.9 3.4	SILTY CLAY TILL some sand, trace gravel brown, moist stiff							181								
								180								
179.6 4.6	SILTY CLAY TILL some sand, trace gravel grey, moist stiff to very stiff (CL)		6	SS	20			179								
									178							5 20 41 34
			7	SS	12											
							177									
			8	SS	17		176									
175.1 9.2	SILTY CLAY TILL trace gravel, with sand layers, pockets grey, moist hard to very stiff (CL)		9	SS	44		175						21.9	4 47 31 18		

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

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METRIC

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

RECORD OF BOREHOLE No BH13-232/1

3 OF 4

METRIC

W.P. 3093-09-00 LOCATION N 4692905; E 410367 ORIGINATED BY PR
DIST HWY 40 BOREHOLE TYPE Hollow Stem Augers/Rock Coring COMPILED BY NT
DATUM Geodetic DATE 31/08/2011 - 01/09/2011 CHECKED BY EP

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	20						40	60	80
			16	SS	50/ 125mm		164													
	with silt till layers very dense						163													
			17	SS	50/ 125mm															
	some gravel dark grey very dense						162													
			18				161													
							160													
159.6 24.6	SHALE weathered, grey		19	SS	50/ 100mm		159													
			20	SS	50/ 75mm		158													
							157													
			21	SS	50/ 50mm		156													
155.2 29.0	auger refusal SHALE TCR=100% SCR=100% RQD=56% HARD LAYER=22%						155													

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONL MOT SPL-M-MTO-919-1101-HWY401-40-OTTAWA-OFFICE MODIFIED BY EVA.GPJ ON MOT.GDT 16/2/12

RECORD OF BOREHOLE No BH13-232/1

4 OF 4

METRIC

W.P. 3093-09-00 LOCATION N 4692905; E 410367 ORIGINATED BY PR
DIST HWY 40 BOREHOLE TYPE Hollow Stem Augers/Rock Coring COMPILED BY NT
DATUM Geodetic DATE 31/08/2011 - 01/09/2011 CHECKED BY EP

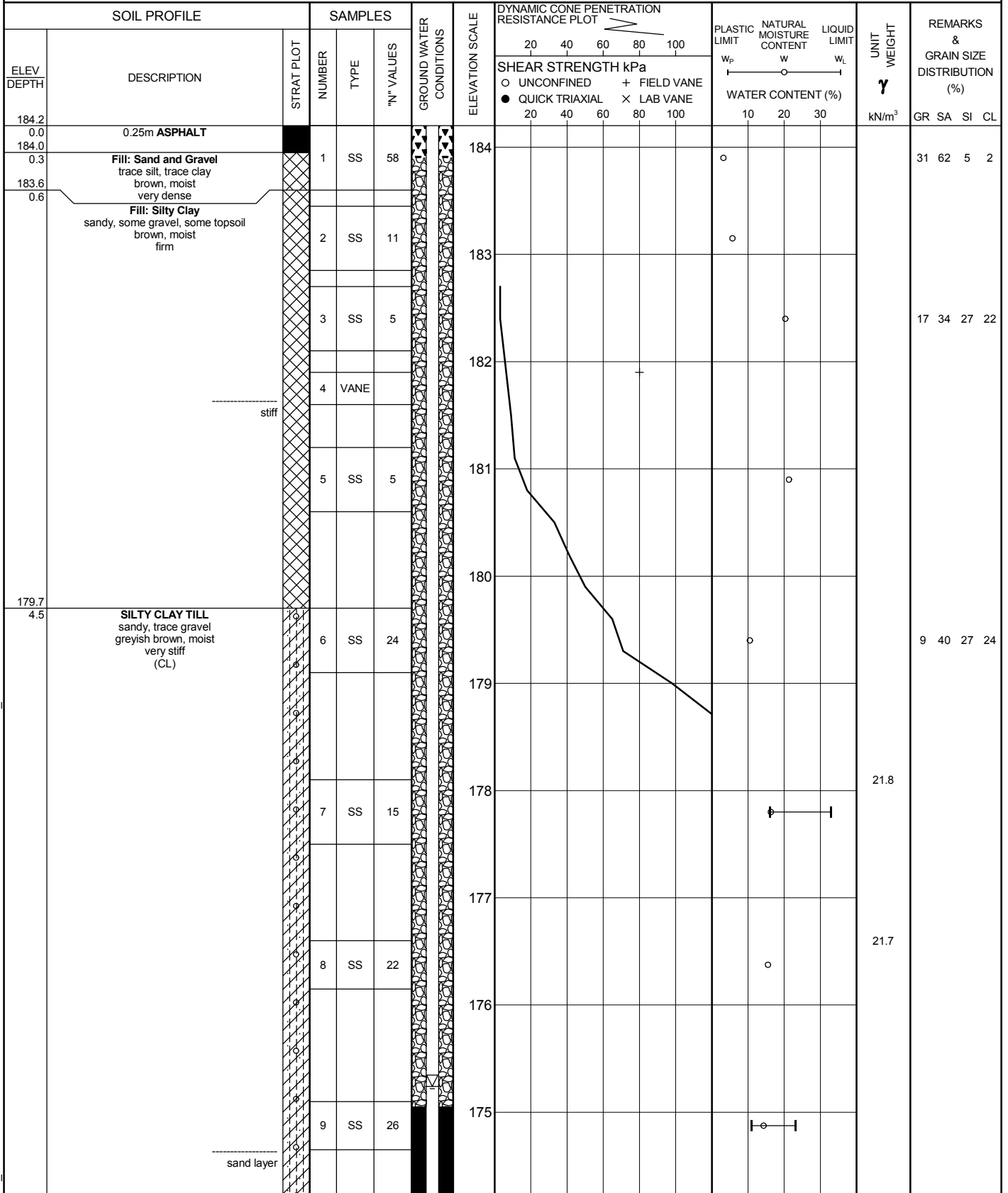
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									WATER CONTENT (%)					
							20	40	60	80	100											
154.0																						
30.3	SHALE TCR=100% SCR=100% RQD=100% HARD LAYER=25%																					
153.0																						
31.2	SHALE TCR=100% SCR=100% RQD=100% HARD LAYER=28%																					
152.1																						
32.1	END OF BOREHOLE																					
<div>Notes: 1) Piezometer installed to 15.25m upon completion of drilling. 2) Water level in Piezometer</div> <table><tr><td>Date</td><td>Depth (m)</td><td>Elevation (m)</td></tr><tr><td>10/18/11</td><td>8.15</td><td>176.05</td></tr></table>																	Date	Depth (m)	Elevation (m)	10/18/11	8.15	176.05
Date	Depth (m)	Elevation (m)																				
10/18/11	8.15	176.05																				

RECORD OF BOREHOLE No BH13-232/2

1 OF 4

METRIC

W.P. 3093-09-00 LOCATION N 4692905; E 410358 ORIGINATED BY PR
DIST HWY 40 BOREHOLE TYPE Hollow Stem Augers/Rock Coring COMPILED BY NT
DATUM Geodetic DATE 29/08/2011 - 30/08/2011 CHECKED BY EP



METRIC

+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

ON MOT SPL-M -MTO-919-1101-HWY401-40-OTTAWA-OFFICE MODIFIED BY EVA.GPJ ON MOT.GDT 16/2/12

METRIC

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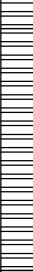

+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

RECORD OF BOREHOLE No BH13-232/2

4 OF 4

METRIC

W.P. 3093-09-00 LOCATION N 4692905; E 410358 ORIGINATED BY PR
DIST HWY 40 BOREHOLE TYPE Hollow Stem Augers/Rock Coring COMPILED BY NT
DATUM Geodetic DATE 29/08/2011 - 30/08/2011 CHECKED BY EP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
154.0 30.2	SHALE TCR=100% SCR=100% RQD=95% HARD LAYER=11%						154									
							153									
152.4 31.8	END OF BOREHOLE															
	Notes: 1) Piezometer installed to 15.2m upon completion of drilling. 2) Water level in Piezometer Date Depth (m) Elevation (m) ----- 10/18/11 8.96 175.24															

ONL MOT SPL-M-MTO-919-1101-HWY401-40-OTTAWA-OFFICE MODIFIED BY EVA.GPJ ON MOT.GDT 16/2/12

Appendix D

Explanation of Terms used in Report

Explanation of Terms Used in the Record of Borehole

Sample Type

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO	Drive open
DS	Dimension type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Spoon sample
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

Penetration Resistance

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in) required to drive a 50 mm (2 in) drive open sampler for a distance of 300 mm (12 in).

WH – Samples sinks under “weight of hammer”

Dynamic Cone Penetration Resistance, N_d :

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in) to drive uncased a 50 mm (2 in) diameter, 60° cone attached to “A” size drill rods for a distance of 300 mm (12 in).

Textural Classification of Soils

Classification	Particle Size
Boulders	> 200 mm
Cobbles	75 mm - 200 mm
Gravel	4.75 mm - 75 mm
Sand	0.075 mm – 4.75 mm
Silt	0.002 mm-0.075 mm
Clay	<0.002 mm

Coarse Grain Soil Description (50% greater than 0.075 mm)

Terminology	Proportion
Trace	0-10%
Some	10-20%
Adjective (e.g. silty or sandy)	20-35%
And (e.g. sand and gravel)	> 35%

Soil Description

a) Cohesive Soils(*)

Consistency	Undrained Shear Strength (kPa)	SPT “N” Value
Very soft	<12	0-2
Soft	12-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very stiff	100-200	15-30
Hard	>200	>30

(*) Hierarchy of Shear Strength prediction

1. Lab triaxial test
2. Field vane shear test
3. Lab. Vane shear test
4. SPT “N” value
5. Pocket penetrometer

b) Cohesionless Soils

Density Index (Relative Density)	SPT “N” Value
Very loose	<4
Loose	4-10
Compact	10-30
Dense	30-50
Very dense	>50

Soil Tests

w	Water content
w_p	Plastic limit
w_l	Liquid limit
C	Consolidation (oedometer) test
CID	Consolidated isotropically drained triaxial test
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement
D_R	Relative density (specific gravity, G_s)
DS	Direct shear test
ENV	Environmental/ chemical analysis
M	Sieve analysis for particle size
MH	Combined sieve and hydrometer (H) analysis
MPC	Modified proctor compaction test
SPC	Standard proctor compaction test
OC	Organic content test
U	Unconsolidated Undrained Triaxial Test
V	Field vane (LV-laboratory vane test)
γ	Unit weight

Explanation of Terms Used in the Bedrock Core Log

Strength (ISRM)

Term	Grade	Description	Unconfined Compressive Strength	
			(MPa)	(psi)
Extremely weak rock	RO	Indented by thumbnail	0.25-1.0	36-145
Very weak	R1	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife	1.0-5.0	145-725
Weak rock	R2	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer	5.0-25	725-3625
Medium Strong	R3	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of geological hammer	25-50	3625-7250
Strong rock	R4	Specimen require more than one blow of geological hammer to fracture it	50-100	7250-14500
Very strong rock	R5	Specimen requires many blows of geological hammer to fracture it	100-250	14500-36250
Extremely strong rock	R6	Specimen can only be chipped with geological hammer	>250	>36250

Bedding (Geological Society Eng. Group Working Party, 1970. Q.J. of Eng. Geol. Vol. 3)

Term	Bed Thickness	
Very thickly bedded	>2 m	>6.5 ft
Thickly bedded	600 mm-2 m	2.00-6.50 ft
Medium bedded	200 mm-600 mm	0.65-2.00 ft
Thinly bedded	60 mm-200 mm	0.20-0.65 ft
Very thinly bedded	20 mm-60 mm	0.06-0.20 ft
Laminated	6 mm-20 mm	0.02-0.06 ft
Thinly laminated	<6 mm	<0.02 ft

TCR (Total Core Recovery)

Sum of lengths of rock core recovered from a core run, divided by the length of the core run and expressed as a percentage.

SCR (Solid Core Recovery)

Sum length of solid, full diameter drill core recovered expressed as a percentage of the total length of the core run.

RQD (Rock Quality Designation, after Deere, 1968)

Sum of lengths of pieces of rock core measured along centreline of core equal to or greater than 100 mm from a core run, divided by the length of the core run and expressed as a percentage. Core fractured by drilling is considered intact. RQD normally quoted for N-size or H-size core.

RQD(%)	Rock Quality
90-100	Excellent
75-90	Good
50-75	Fair
25-50	Poor
0-25	Very poor

Weathering (ISRM)

Term	Grade	Description
Fresh	W1	No visible sign of rock material weathering
Slightly weathered	W2	Discolouration indicates weathering of rock material and discontinuity surface. All the rock material may be discoloured by weathering and may be somewhat weaker than in its fresh condition
Moderately weathered	W3	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a corestone
Highly weathered	W4	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a continuous framework or as corestones
Completely weathered	W5	All rock material is decomposed and/or disintegrated to a soil. The original mass structure is still largely intact
Residual soil	W6	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported

(FI) Fracture Index

Expressed as the number of discontinuities per 300mm (1 ft). Excludes drill-induced fractures and fragmented zones. Reported as ">25" if frequency exceeds 25 fractures/0.3m.

Broken Zone

Zone of full diameter core of very low RQD which may include some drill-induced fractures.

Fragmented Zone

Zone where core is less than full diameter and RQD = 0.

Discontinuity Spacing (ISRM)

Term	Average Spacing	
Extremely widely spaced	>6 m	>20.00 ft
Very widely spaced	2 m-6 m	6.50-20.00 ft
Widely spaced	600 mm-2 m	2.00-6.50 ft
Moderately spaced	200 mm-600 mm	0.65-2.00 ft
Closely spaced	60 mm-200 mm	0.20-0.65 ft
Very closely spaced	20 mm-60 mm	0.06-0.20 ft
Extremely closely spaced	<20 mm	>0.06 ft

Note: Excludes drill-induced fractures and fragmented rock.

Discontinuity Orientation

Discontinuity, fracture and bedding plane orientations are cited as the acute angle measured with respect to the core axis. Fractures perpendicular to the core axis are at 90° and those parallel to the core axis are at 0°.