



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
FIRST STREET UNDERPASS
BRIDGE REHABILITATION
HIGHWAY 406
ST. CATHARINES, ONTARIO
G.W.P. 2257-13-00; SITE NO. 18-236

GEOCRES NO. 30M3-291**

Report

to

MMM Group Limited

Date: January 6, 2017
File: 11336



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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the proposed rehabilitation of the existing underpass bridge located on Highway 406 at First Street, in St. Catharines, Ontario.

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

Thurber was retained by MMM Group Limited (MMM) to carry out this foundation investigation under the MTO Assignment Number 2014-E0030.

2. SITE DESCRIPTION

The underpass is located at the First Street and Highway 406 crossing in St. Catharines, Ontario.

First Street crosses over Highway 406 on a two-span concrete structure of approximately 55 m in length. The approach fill adjacent to the south and north abutments of the structure is approximately 6.0 m in height.

The terrain adjacent to the structure is generally flat. Residential dwellings are located on the north side of the site. The lands to the southeast are vacant and the lands to the southwest are occupied by a commercial building.

Selected photographs of the immediate surroundings are presented in Appendix E.



The site is situated within the physiographic region known as the Haldimand Clay Plain, which is characterized by glacio-lacustrine deposits laid down in glacial Lake Warren during the Wisconsinian Age. These deposits consist of silts and clays and are generally underlain by a glacial till, which in turn overlies dolomitic limestone bedrock.

3. INVESTIGATION PROCEDURES

The site investigation and field testing for this project were carried out on August 8 and 9, 2016 and consisted of drilling and sampling four boreholes (numbered FSU 16-01 and FSU 16-04) at the site. The boreholes were located on First Street near the existing approaches and abutments. All the boreholes were terminated at 9.8 m depth (Elevations 93.7 to 94.6).

Prior to the start of drilling, the borehole locations were marked/staked in the field and utility clearances were obtained. The co-ordinates and elevations of the as-drilled boreholes were subsequently provided by MMM. The approximate locations of boreholes drilled at the First Street Underpass are shown on a Borehole Locations and Soil Strata drawing included in Appendix C. The coordinates and elevations of these boreholes are given on this drawing and on the individual Record of Borehole Sheets in Appendix A.

A track-mounted CME 75 drill rig was used to drill and sample the boreholes. Hollow stem augers were used to advance the boreholes until the target depth was reached. In general, soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT).

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing. Results of field drilling and sampling are presented on the Record of Borehole sheets in Appendices A and C.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. A standpipe piezometer was installed in a selected borehole (FSU 16-04). The piezometer consisted of a 25 mm Schedule 40 PVC pipe with a 1.5 m long slotted screen enclosed in filter sand to permit groundwater level monitoring. Piezometer installation details, groundwater level observations and water level readings are shown on the Record of Borehole sheets. Upon completion of the drilling operations, the boreholes without piezometers were abandoned in general accordance with Ontario Regulation 903 amended by Ontario Reg. 372. The details of standpipe piezometer installation and borehole completion are summarized in Table 3.1.



Table 3.1 – Borehole Completion Details

Foundation Element	Borehole No.	Borehole Depth / Base Elevation (m)	Piezometer Tip Elevation (m)	Completion Details
North Abutment	FSU 16-01	9.8/94.1	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to 0.5 m, concrete to 0.1 m then asphalt patch to surface.
North Approach	FSU 16-02	9.8/93.7	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to 0.2 m, then concrete and asphalt to surface.
South Abutment	FSU 16-03	9.8/94.6	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to 0.5 m, concrete to 0.1 m then asphalt patch to surface.
South Approach	FSU 16-04	9.8/94.5	9.0/95.3	Borehole backfilled with sand filter from 9.8 m to 5.5 m, bentonite holeplug from 5.5 m to 0.3 m, sand from 0.3 m to 0.15, then concrete to surface.

4. LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size analysis and Atterberg Limits testing. All the laboratory tests were carried out in accordance to MTO and/or ASTM Standards, as appropriate. The results of the laboratory testing are summarized on the Record of Borehole sheets in Appendix A and are presented on the figures included in Appendix B.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendix A for details of the encountered soil stratigraphy. A soil profile of the First Street Underpass site is presented on the “Borehole Locations and Soil Strata” drawing in Appendix C. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions. It must be recognized that soil conditions may vary between and beyond borehole locations. More detailed descriptions of the individual strata are presented below.



In general, the subsurface conditions encountered in the boreholes drilled at the First Street Underpass consist of asphalt over granular fill overlying silty clay embankment fill. An extensive deposit of native silty clay till was contacted below the fill in all the boreholes. Groundwater levels are generally in the order of 7.3 m below original ground surface. More detailed descriptions of the individual stratum are presented below.

5.1 Asphalt and Concrete

The four boreholes were advanced from the top of the road embankment and encountered between 75 mm and 200 mm of asphalt surficially.

Below the asphalt a 400-mm thick layer of concrete was contacted in Boreholes FSU 16-01 and FSU 16-03, drilled through the north and south approach slabs, respectively.

5.2 Gravelly Sand Fill

Granular fill was encountered below the asphalt and concrete in all the boreholes. The granular fill consisted of a brown to grey gravelly sand, some silt and clay. The thickness of the fill was 5.6 m and 1.7 m in Boreholes FSU16-01 and FSU 16-03. In Boreholes FSU16-02 and FSU 16-04, drilled at the approaches, the fill varied from 0.3 m to 1.2 m in thickness.

The depth to the base of the gravelly sand fill ranged from 0.5 m to 2.2 m (Elevations 102.1 to 103.8 m) in Boreholes FSU 16-02 to FSU 16-04. Locally, in Borehole FSU 16-01, the granular fill extended to 6.1 m (Elevation 97.8 m).

In Boreholes FSU 16-02 to 16-04, SPT 'N' values recorded in the granular fill ranged from 8 to 30 blows for 0.3 m penetration indicating loose to compact conditions. In Borehole FSU 16-01, SPT 'N' values ranged from 36 to 51 blows per 0.3 m of penetration, indicating a dense to very dense state. Moisture contents of the granular fill ranged from 4% to 16%.

The results of a grain size analyses conducted on a gravelly sand fill sample are presented on the Record of Borehole sheets in Appendix A, and are illustrated in Figure B1 of Appendix B. The laboratory test results are summarized in the following table.

Soil Particle	Percentage (%)
Gravel	31
Sand	52
Silt & Clay	17



5.3 Silty Clay Fill

Grey silty clay fill containing trace to some sand and trace gravel, was contacted in Boreholes FSU 16-03 and FSU 16-04 underlying the granular fill at the west abutment area. The thickness of the silty clay fill was 3.9 m and 0.2 m in Boreholes FSU 16-03 and FSU 16-04, respectively.

The depth to the base of the cohesive fill was 6.1 m and 0.7 m (Elevations 98.3 and 103.6 m) in Boreholes FSU 16-03 and FSU 16-04, respectively.

SPT 'N' values obtained in the silty clay fill ranged from 2 to 22 blows for 0.3 m penetration, indicating a soft to very stiff consistency. Moisture contents of the silty clay fill ranged from 19% to 22%.

The results of grain size analyses conducted on a silty clay fill sample are presented on the Record of Borehole sheets in Appendix A, and are illustrated in Figure B2 of Appendix B. The laboratory test results are summarized in the following table.

Soil Particle	Percentage (%)
Gravel	0
Sand	15
Silt	41
Clay	44

5.4 Silty Clay Till

A deposit of brown to grey silty clay till containing trace to some sand and trace gravel was encountered below the fill in all the boreholes. The silty clay till was contacted at 6.1 m depth (Elevations 97.8 and 98.3 m) in Boreholes FSU 16-01 and FSU 16-03, drilled near the abutments, and at 1.4 m and 0.7 m depth (Elevations 102.1 and 103.6 m), in Boreholes FSU 16-02 and FSU 16-04 drilled at the approaches.

All the boreholes were terminated within the silty clay till at 9.8 m depth (Elevations 93.7 to 94.6).

SPT 'N' values recorded in the silty clay till varied between 8 and 25 blows for 0.3 m of penetration indicating stiff to very stiff consistency. Natural moisture contents of the silty clay till ranged from 16% to 23%.



The results of grain size analyses conducted on samples of the silty clay till are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B3 of Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0
Sand	5 to 7
Silt	42 to 45
Clay	50 to 51

The results of Atterberg Limits tests conducted on samples of the silty clay are provided on the Record of Borehole sheets in Appendix A and illustrated in Figure B4 of Appendix B. The results are summarized as follows:

Index Property	Percentage (%)
Liquid Limit	43 to 46
Plasticity Index	19 to 20

The results of the Atterberg Limits testing indicate the deposit to be of medium plasticity with a group symbol CI.

It is noted that glacial till inherently contains cobbles and boulders.

5.5 Groundwater Conditions

The water levels in the boreholes were observed during the drilling operations and measured upon completion of drilling. All boreholes were open to the depths investigated and dry upon completion of drilling. A standpipe piezometer was installed in Borehole FSU 16-04 to permit longer term monitoring.

Table 5-1. Measured Groundwater Levels

Borehole Number	Date	Groundwater Level		Comment
		Depth (m)	Elevation (m)	
16-01	August 8, 2016	Dry	-	Open Borehole
16-02	August 8, 2016	Dry	-	Open Borehole
16-03	August 9, 2016	Dry	-	Open Borehole



Borehole Number	Date	Groundwater Level		Comment
		Depth (m)	Elevation (m)	
16-04	August 9, 2016	Dry	-	Open Borehole
	September 26, 2106	7.3	97.0	Piezometer

The values shown in Table 5-1 are short-term readings 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 or prolonged precipitation.

6. MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. MMM provided the northing and easting coordinates and ground surface elevations.

Determination Drilling of Hamilton, Ontario, supplied and operated a track-mounted CME 75 drill rig to carry out the drilling, sampling and in-situ testing operations for the boreholes.

The drilling and sampling operations in the field were supervised on a full time basis by Mr. Omar Ali of Thurber. Geotechnical laboratory testing was carried out by Thurber in its MTO-approved laboratory. Overall supervision of the field program was carried out by Mr. Stephane Loranger, CET.

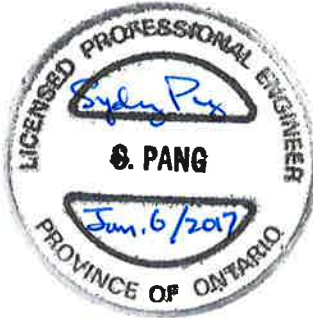
Overall project management was provided by Dr. Sydney Pang, P.Eng. Interpretation of the field data and preparation of this report was completed by Ms. R. Palomeque Reyna, P. Eng. and Dr. Sydney Pang, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7. GENERAL

This report presents interpretation of the geotechnical data provided in the factual report, and provides geotechnical design recommendations related to the roadway protection system design in support of the rehabilitation of the existing First Street Underpass structure at Highway 406 in St. Catharines, Ontario.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction contractor. The contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

The existing bridge is a two-span structure supported on two abutments and one pier. The south and north abutments are supported on spread footings at approximate Elevations 98.5 and 97.5 m, respectively. The centre pier is supported on piles. The span lengths are approximately 27.4m, and the length of the approach slabs is approximately 6.1 m. The ground surface of the bridge is near Elevations 103.5 to 104.4 m.

The present rehabilitation program will include the following:

- Patch repair to deck, waterproofing and paving
- Replacement of barrier walls and repairs to sidewalk if necessary
- Repairs to deck ends and conversion to semi-integral abutments
- Repairs to deck fascia, soffit, and substructure

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- Replace abutment bearings
- Replace approach slabs

Based on information provided by MMM, the change in loading conditions on the foundation elements associated with the rehabilitation works will be negligible.

The discussions and recommendations presented in this report are based on information provided by MMM and on the factual data obtained during the course of this investigation.

Based on the site conditions and available subsurface information, it is considered suitable to convert the structure into having semi-integral abutments.

8. ROADWAY PROTECTION

Roadway protection will be required during the semi-integral abutment conversion and other aspects of rehabilitation of the underpass. An item titled "Protection System" as per OPSS.PROV 539 should be included in the contract documents. It is recommended that Performance Level 2 as per Clause 539.04.01.01 and the alignment of the roadway protection be specified on the contract drawings.

The design of roadway protection is the responsibility of the Contractor. However, one option that is considered to be suitable for use as temporary shoring at this site is a soldier pile and lagging wall. It is anticipated that the protection system will need to be extended predominantly through the existing gravelly sand fill and silty clay fill into the underlying native glacial tills to develop the required toe resistance. Installation of roadway protection, should consider that the glacial till may contain cobbles and boulders. It is anticipated that the shoring system may be stiffened by cross bracings, where applicable.

A soldier pile and lagging wall may be designed using the parameters given below:

Soil Bulk Unit Weight	γ	=	20 kN/m ³
Submerged Unit Weight (below gwl)	γ'	=	10 kN/m ³
Coefficient of Active Pressure	K_a	=	0.33 (gravelly sand fill)
		=	0.35 (silty clay fill)
		=	0.31 (silty clay till)
		=	
Coefficient of Active Pressure	K_p	=	3.0 (gravelly sand fill)
		=	2.9 (silty clay fill)
		=	3.2 (silty clay till)



It is recommended that lateral earth pressures acting on the wall be computed in accordance with the CHBDC 2014. The surcharge should include soil loadings above the retained soil and other loadings adjacent to the wall. A properly designed and constructed soldier pile and lagging wall will be permeable and therefore water pressure acting on the retained height may be set to zero. The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the roadway protection system.

The designer of the roadway protection system should check whether the depth of the soldier piles is sufficient to provide base fixity.

All roadway protection systems should be designed by a Professional Engineer experienced in such designs.

9. BACKFILL TO ABUTMENTS

All embankment fill must be reconstructed with adequate quality control in accordance with OPSS.PROV 206 and 501 requirements. For backfilling immediately behind the new abutment wall, it is recommended that the new fill material consist of OPSS.PROV.1010 Granular A or B Type II materials. Beyond this zone, Select Subgrade Material (SSM) may be used.

10. LATERAL PRESSURES

Earth pressures acting on the structure may be assumed to be triangular and to be governed by the characteristics of the abutment backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC 2014 but are generally given by the expression:

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

where: p_h = horizontal pressure on the wall at depth h (kPa)
 K = earth pressure coefficient (see Table 10.1)
 γ = unit weight of retained soil (see Table 10.1)
 h = depth below top of fill where pressure is computed (m)
 q = value of any surcharge (kPa).

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I or 1.7 m for Granular A or Granular B Type II. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS 501.



Earth pressure coefficients for backfill to the abutment wall are dependent on the material used as backfill. Typical values are shown in Table 10.1.

Table 10.1 – Earth Pressure Coefficients

Wall Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At rest (Restrained Wall)	0.43	-	0.47	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-

If the support system allows yielding of the wall (unrestrained system), active horizontal earth pressure may be used in the geotechnical design of the structure. If the support system does not allow yielding (restrained system), at-rest horizontal earth pressures should be used.

In conventional design, the use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) might be preferred as it results in lower earth pressures acting on the wall.

The factors in Table 10.1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to be used in design can be estimated from Figure C6.16 in the Commentary to the CHBDC 2014.

It is recommended that perforated sub-drains and/or weep holes be installed, where applicable, to provide positive drainage of the granular backfill behind the abutment walls. Reference may be made to OPSD 3102.100 where appropriate.

11. TEMPORARY EXCAVATIONS



All excavations at this site must be carried out in accordance with the Occupational Health and Safety Act (OHSA). The excavation and backfilling for foundations must be carried out in accordance with OPSS 902.

For the purposes of the OHSA, the fill and the native soils at this site may be classified as Type 3 materials.

Excavation for foundation construction will extend through the pavement structure, gravelly sand fill and silty clay fill, and into the native silty clay till.

The selection of the method of excavation is the responsibility of the contractor and must be based on his equipment, experience and interpretation of the site conditions. Excavations should be inspected regularly for evidence of instability if they have been left open for extended periods of time and following periods of heavy rain or thawing. If required, remedial actions must be taken to ensure the stability of the excavation and the safety of workers. Exposed soil slopes should be covered with plastic sheetings to protect against precipitation and surface runoff.

12. GROUNDWATER AND SURFACE WATER CONTROL

Free standing water was not observed in the boreholes upon completion of drilling. A piezometric level at about Elevation 97 m, or in the order of 7 m depth below existing road grade, was measured in one piezometer. It is therefore anticipated that any excavation that is required to carry out the semi-integral abutment conversion and bridge rehabilitation will not extend below the groundwater level. However, seepage or perched water from the granular fill is to be expected.

The Contractor should be prepared to pump from sumps to remove any remaining seepage water or surface water collecting in an excavation. Unwatering must remain operational and effective until the abutment is backfilled.

The design of the dewatering system that may be required is the responsibility of the Contractor and the Contract Documents must alert him to this responsibility.

13. APPROACH FILLS

Current information indicates that there will not be any grade raise at this site.

Disturbed or regraded earth slopes must be provided with erosion protection in accordance with OPSS.PROV 804.



14. CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to, the issues discussed below.

1. Staging construction and excavations

Care must be taken during excavation to avoid disturbing and undermining travelled lanes of the roadways that will remain open.

2. Existing slopes

Erosion protection should be provided to the exposed embankment surfaces after construction.

3. Footings

Care must be exercised not to undermine the footings during construction.

15. CLOSURE

Engineering analysis and preparation of this foundation design report was carried out by Mr. Ms. Rocío Palomeque Reyna, P.Eng and Dr. Sydney Pang, P.Eng.

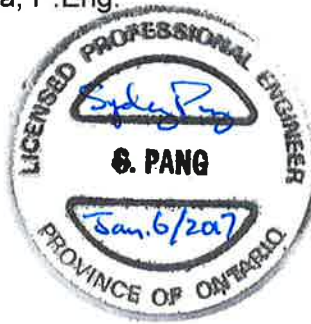
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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT ⁽¹⁾ 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

EXPLANATION OF ROCK LOGGING TERMS


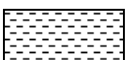

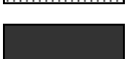

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2m
Thickly bedded	0.6 to 2m
Medium bedded	0.2 to 0.6m
Thinly bedded	60mm to 0.2m
Very thinly bedded	20 to 60mm
Laminated	6 to 20mm
Thinly Laminated	Less than 6mm

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
	(MPa)	(psi)	
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length
Solid Core Recovery:(SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run
Rock Quality Designation:(RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a % of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index:(FI)	Frequency of natural fractures per 0.3m of core run.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS W _L < 50%	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. (W _L < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W _L < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W _L > 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

RECORD OF BOREHOLE No FSU 16-01

1 OF 2

METRIC

GWP# 2257-13-00 LOCATION First Street Underpass N 4 779 739.0 E 323 000.5 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.08.08 - 2016.08.08 CHECKED BY RPR

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _p w w _L				GR	SA	SI	CL
103.9	GROUND SURFACE																		
0.0	ASPAHLT: (75mm)																		
0.1	CONCRETE: (400mm)																		
103.4																			
0.5	Gravelly SAND , some silt and clay Very Dense to Dense Brown Moist (FILL)		1	SS	51		103						○						
			2	SS	36		102						○						
			3	SS	34		101						○				31	52	
			4	SS	30		100						○					17	
																		(SI+CL)	
	Grey		5	SS	38		99						○						
							98											Footings of the bridge at about 5.2m. Borehole moved 5.5m north of the expansion joint	
97.8			6	SS	23		97						○	—	—		0	6	
	Silty CLAY , trace sand Very Stiff to Stiff Brown Moist (TILL)		7	SS	20		96						○				43	51	
			8	SS	15		95						○						
94.1																			
9.8	END OF BOREHOLE AT 9.8m.																		

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No FSU 16-01

2 OF 2

METRIC

GWP# 2257-13-00 LOCATION First Street Underpass N 4 779 739.0 E 323 000.5 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.08.08 - 2016.08.08 CHECKED BY RPR

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									
	Continued From Previous Page																
	BOREHOLE DRY UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.5m, THEN CONCRETE AND ASPHALT TO SURFACE.																

RECORD OF BOREHOLE No FSU 16-02

1 OF 2

METRIC

GWP# 2257-13-00 LOCATION First Street Underpass N 4 779 749.0 E 323 000.2 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.08.08 - 2016.08.08 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
103.5	GROUND SURFACE							20 40 60 80 100					
0.0	ASPHALT: (200mm)							20 40 60 80 100					
0.2	Gravelly SAND , some silt and clay Compact Brown to Grey Moist (FILL)		1	SS	17		103						
			2	SS	11								
102.1							102						
1.4	Silty CLAY , trace sand, trace gravel Stiff to Very Stiff Grey Moist (TILL)		3	SS	9								
			4	SS	12		101						
			5	SS	11		100						
							99						
			6	SS	20		98						
							97						
			7	SS	23		96						
							95						
			8	SS	19		94						
	Stiff		9	SS	8								
93.7													
9.8	END OF BOREHOLE AT 9.8m.												

Continued Next Page

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No FSU 16-02

2 OF 2

METRIC

GWP# 2257-13-00 LOCATION First Street Underpass N 4 779 749.0 E 323 000.2 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.08.08 - 2016.08.08 CHECKED BY RPR


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									
	Continued From Previous Page																
	BOREHOLE DRY UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.2m, THEN CONCRETE AND ASPHALT TO SURFACE.																

RECORD OF BOREHOLE No FSU 16-03

1 OF 2

METRIC

GWP# 2257-13-00 LOCATION First Street Underpass N 4 779 678.8 E 322 997.8 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.08.09 - 2016.08.09 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
104.4	GROUND SURFACE													
0.0	ASPHALT: (100mm)													
0.1	CONCRETE: (400mm)													
103.9							104							
0.5	Gravelly SAND Compact Grey Moist (FILL)		1	SS	16									
			2	SS	30									
102.2							103							
2.2	Silty CLAY , some sand Soft Grey Moist (FILL)		3	SS	2									
			4	SS	2									
							102							
							101							0 15 41 44
							100							
	Trace asphalt pieces Very Stiff		5	SS	22									
							99							
98.3							98							
6.1	Silty CLAY , trace sand Very Stiff Brown Moist (TILL)		6	SS	25									
							97							
			7	SS	16									
							96							
			8	SS	12		95							0 6 43 51
94.6														
9.8	END OF BOREHOLE AT 9.8m.													

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No FSU 16-03

2 OF 2

METRIC

GWP# 2257-13-00 LOCATION First Street Underpass N 4 779 678.8 E 322 997.8 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.08.09 - 2016.08.09 CHECKED BY RPR

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									
	Continued From Previous Page																
	BOREHOLE DRY UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.5m, THEN CONCRETE AND ASPHALT TO SURFACE.																

RECORD OF BOREHOLE No FSU 16-04

1 OF 2

METRIC

GWP# 2257-13-00 LOCATION First Street Underpass N 4 779 668.8 E 322 998.1 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.08.09 - 2016.08.09 CHECKED BY RPR

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								
104.3	GROUND SURFACE							20	40	60	80	100				
0.0	ASPHALT: (150mm)															
0.2	Gravelly SAND		1	SS	8		104									
103.8	Loose Brown Moist (FILL)															
0.5	Silty CLAY, trace sand, trace gravel		2	SS	9		103									
103.6	Firm Grey Moist (FILL)															
0.7	Silty CLAY, trace sand, trace gravel		3	SS	14		102									
	Stiff to Very Stiff Grey Moist (TILL)															
			4	SS	14		101									
			5	SS	15		100									
			6	SS	20		99									
							98									
			7	SS	25		97									
							96									
			8	SS	16		95									
			9	SS	12											
94.5																
9.8	END OF BOREHOLE AT 9.8m.															

Continued Next Page

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No FSU 16-04

2 OF 2

METRIC

GWP# 2257-13-00 LOCATION First Street Underpass N 4 779 668.8 E 322 998.1 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.08.09 - 2016.08.09 CHECKED BY RPR

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									
	Continued From Previous Page BOREHOLE DRY UPON COMPLETION OF DRILLING. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2016.09.26 7.3 97.0																



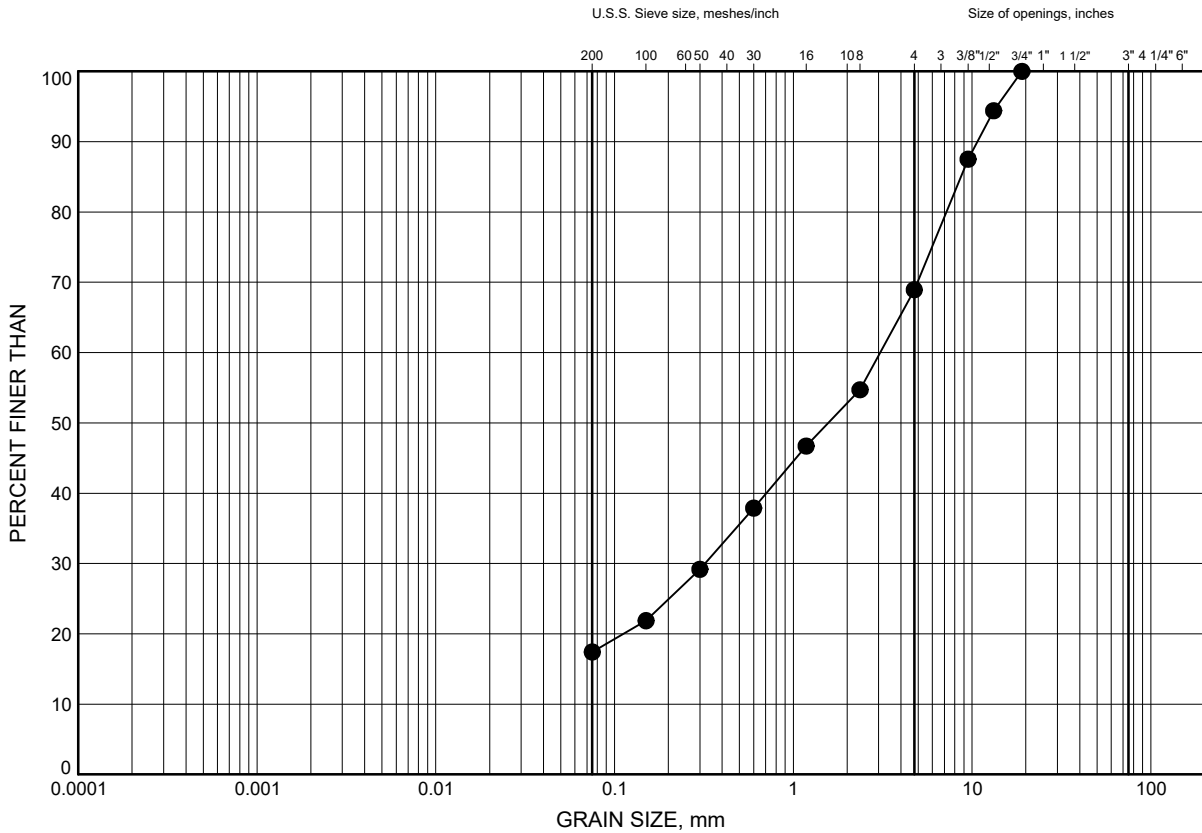
Appendix B

Laboratory Test Results

First Street Underpass
GRAIN SIZE DISTRIBUTION

FIGURE B1

Gravelly SAND FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	FSU 16-01	2.59	101.31

Date November 2016
GWP# 2257-13-00

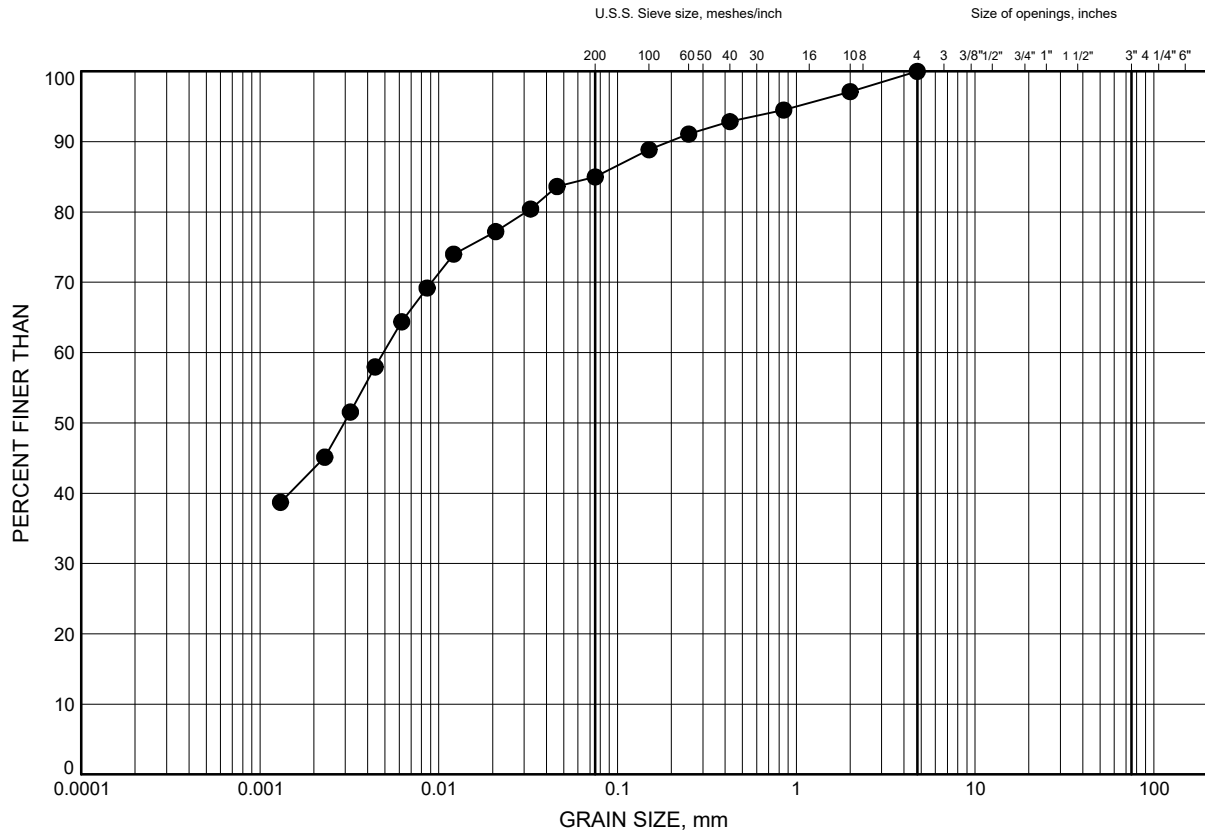


Prep'd AN
Chkd. RPR

First Street Underpass GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty CLAY FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	FSU 16-03	3.35	101.05

Date November 2016

GWP# 2257-13-00



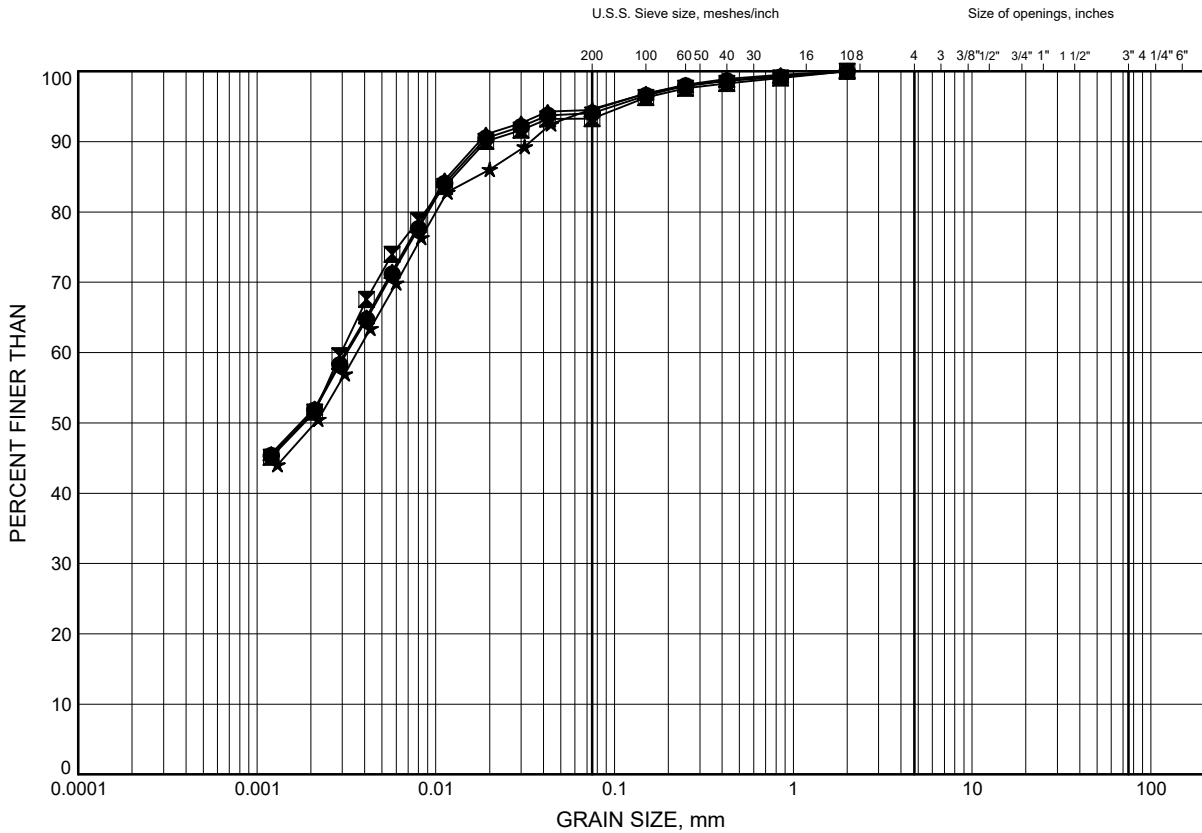
Prep'd AN

Chkd. RPR

First Street Underpass GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty CLAY TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	FSU 16-01	6.40	97.50
⊠	FSU 16-02	7.92	95.58
▲	FSU 16-03	9.45	94.95
★	FSU 16-04	6.40	97.90

Date November 2016

GWP# 2257-13-00



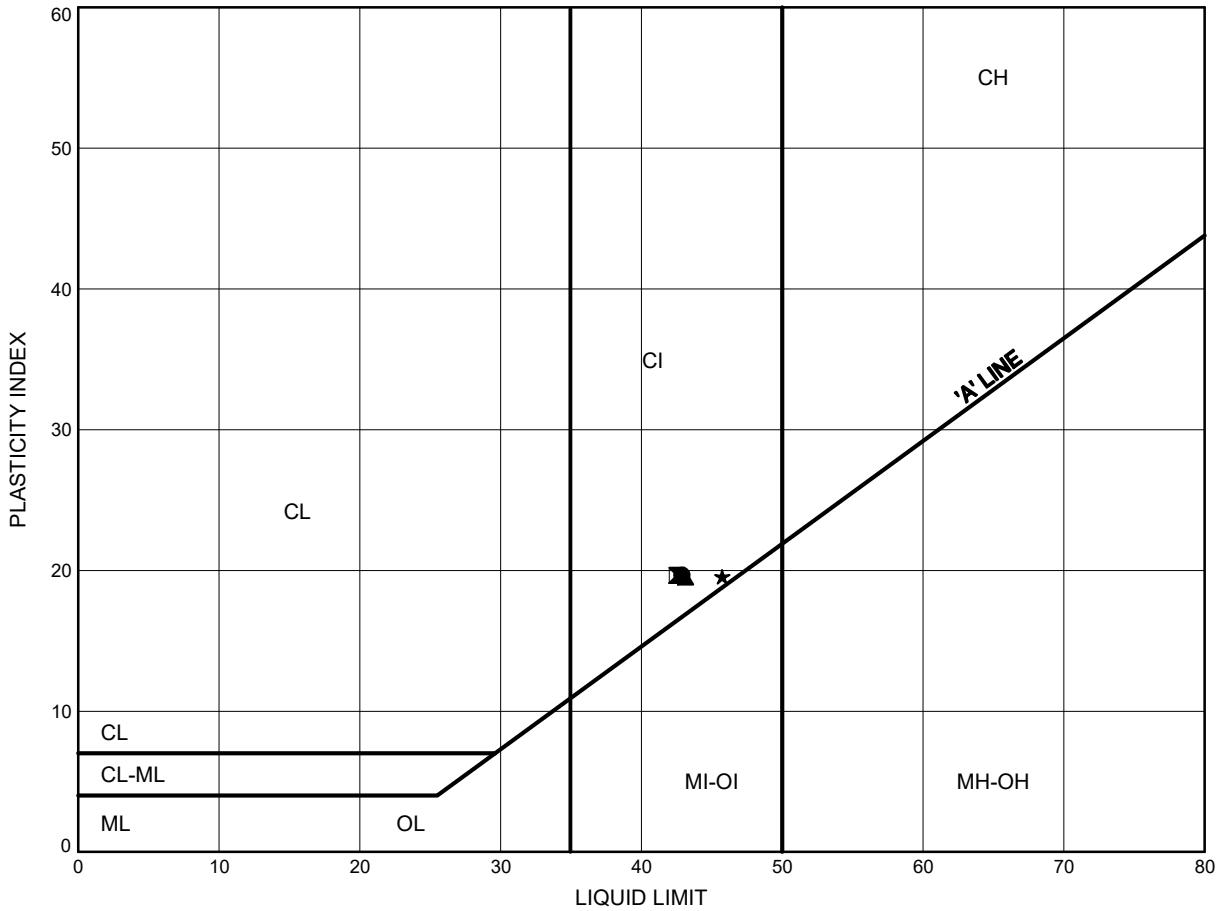
Prep'd AN

Chkd. RPR

First Street Underpass
ATTERBERG LIMITS TEST RESULTS

FIGURE B4

Silty CLAY TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	FSU 16-01	6.40	97.50
⊠	FSU 16-02	7.92	95.58
▲	FSU 16-03	9.45	94.95
★	FSU 16-04	6.40	97.90

Date November 2016

GWP# 2257-13-00



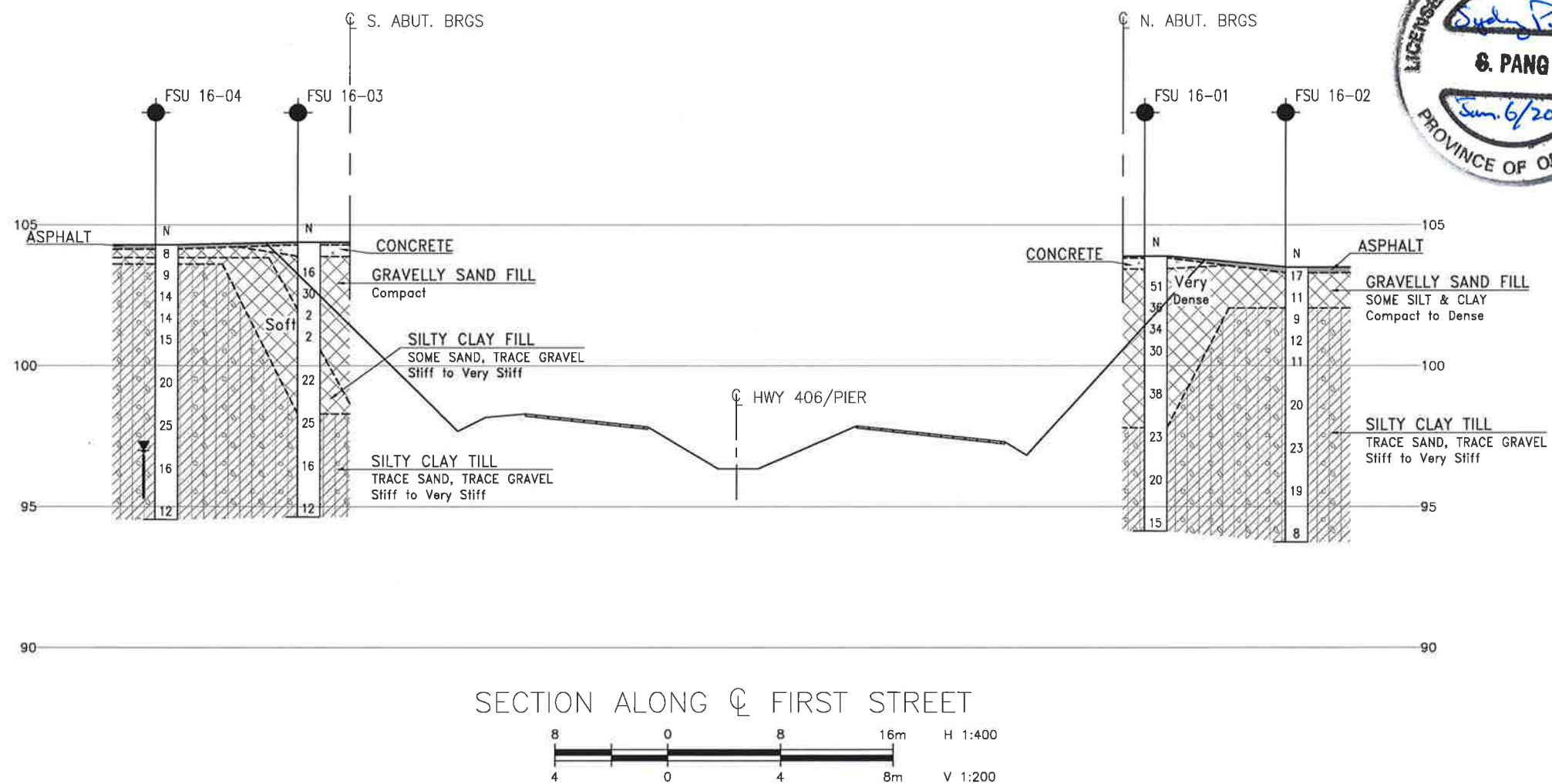
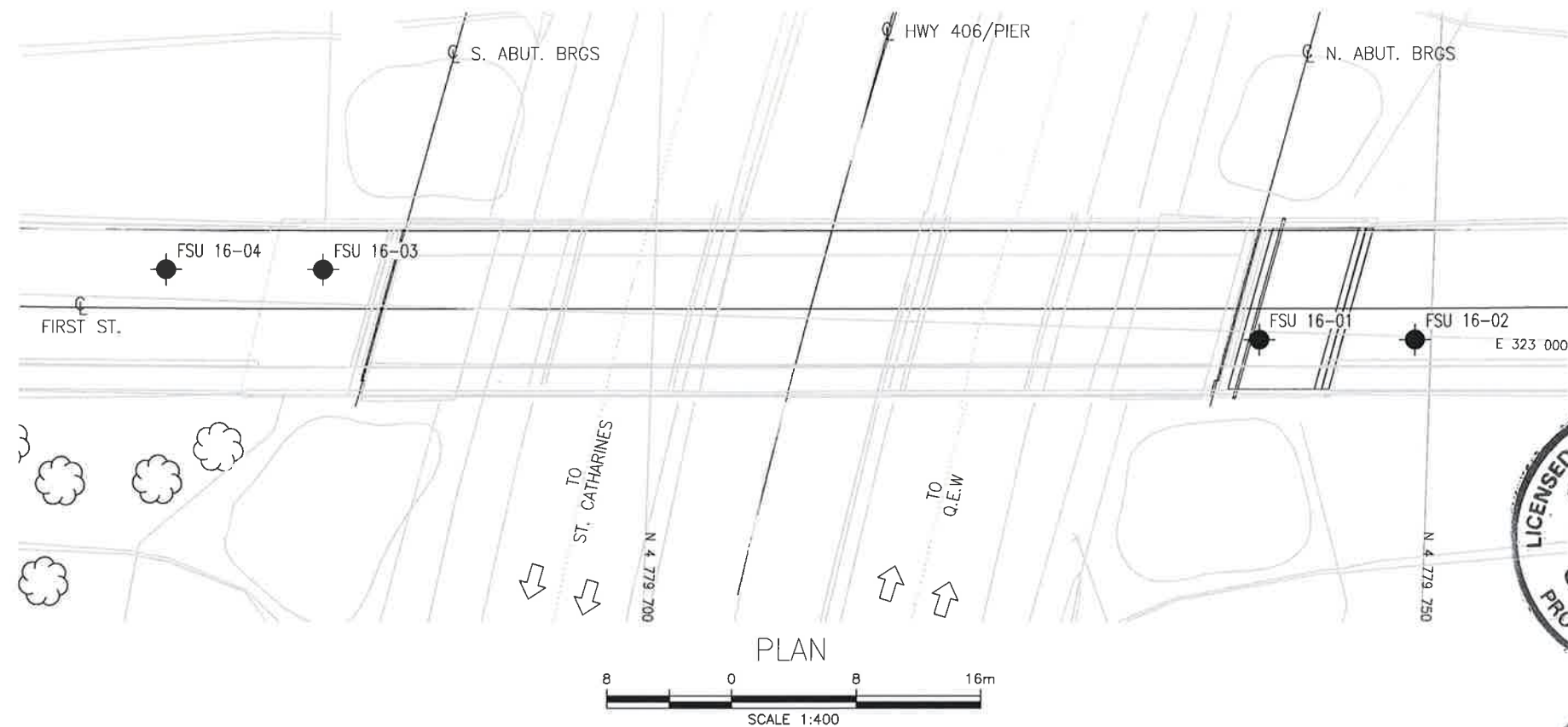
Prep'd AN

Chkd. RPR



Appendix C

Borehole Locations and Soil Strata Drawing



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

CONT No
WP No 2257-13-00






HIGHWAY 406
FIRST STREET UNDERPASS
BRIDGE REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



THURBER ENGINEERING LTD.



KEYPLAN
LEGEND

	Borehole
	Borehole and Cone
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

[illegible]

-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. Surface details and features are for conceptual illustration.

GEOCRES No. 30M3-291

REV	DATE		BY		DESCRIPTION			
	DATE	RPR	CHK	SKP	CODE	LOAD	DATE	JAN 2017
DRAWN	AN	CHK	RPR	SITE	STRUCT	DWG	R2-22	



Appendix D

Selected Site Photographs



Photo 1. - East Side of First Street underpass at Highway 406



Photo 2.- Southeast quadrant of First Street underpass at Highway 406



Photo 3.- Northeast quadrant of First Street underpass at Highway 406



Photo 4. - Northwest quadrant of First Street underpass at Highway 406



Photo 5.- Southwest quadrant of First Street underpass at Highway 406



Appendix E

List of OPS Specifications



1. List of Special Provisions and OPSS Documents Referenced in this Report

- OPSS.PROV 501
- OPSS.PROV 804
- OPSS 902
- OPSS.PROV 539
- OPSS.PROV 206
- OPSD 3102.100
- OPSS.PROV.1010