THURBER ENGINEERING LTD.

FOUNDATION INVESTIGATION AND DESIGN REPORT
GENEVA STREET UNDERPASS
BRIDGE REHABILITATION
HIGHWAY 406
ST. CATHARINES, ONTARIO
G.W.P. 2257-13-00; SITE No. 18-230

GEOCRES NO. 30M3-293

Report

to

WSP / MMM Group

Date: January 23, 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 Geneva 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 WSP / MMM Group (MMM) to carry out this foundation investigation under the MTO Assignment Number 2014-E-0030.

2. SITE DESCRIPTION

The underpass is located at the interchange between Geneva Street and Highway 406 in St. Catharines, Ontario.

Geneva Street crosses over Highway 406 on a three-span concrete structure of approximately 85.3 m in length. At this location, the highway is constructed in a 4 m cut while Geneva Street is elevated with 4 m of fill, resulting in approach embankments in the order of 8 m in height. Both abutments are perched within the forward slopes.

The terrain adjacent to the structure is generally flat. Residential dwellings and commercial buildings are located around the interchange area.

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

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 December 20 and 21, 2016 and consisted of drilling and sampling four boreholes (numbered GS 16-01 to GS 16-04) at the site. The boreholes were located on Geneva Street near the existing approaches and abutments. All the boreholes were terminated at 8.2 m depth (Elevations 93.9 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 of the boreholes were obtained by Thurber using a GPS device. The elevations of the as-drilled boreholes were subsequently provided by MMM. The approximate locations of boreholes drilled at the Geneva 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 truck-mounted D25 drill rig was used to drill and sample the boreholes. Solid 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 nominal diameter split spoon sampler in conjunction with the 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 Appendix A.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Standpipe piezometers were installed in Boreholes GS 16-02 and GS 16-03. The piezometers consisted of a 19 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 Approach	GS 16-01	8.2/94.2	None installed	Borehole backfilled with auger cuttings to 0.1 m, then concrete to surface.
Near North Abutment	GS 16-02	8.2/93.9	7.6/94.5	Borehole backfilled with sand filter from 8.2 m to 6.1 m, bentonite holeplug from 6.1 m to 5.5 m, auger cuttings from 5.5 m to 0.10 m, then concrete to surface.
Near South Abutment	GS 16-03	8.2/94.3	7.6/94.9	Borehole backfilled with sand filter from 8.2 m to 6.1 m, bentonite holeplug from 6.1 m to 5.5 m, auger cuttings from 5.5 m to 0.15 m, then concrete to surface.
South Approach	GS 16-04	8.2/94.6	None installed	Borehole backfilled with auger cuttings to 0.1 m, 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 Geneva 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 Geneva Street Underpass consist of asphalt and concrete (approach) slab underlain by granular fill which overlies silty clay and silty sand embankment fill. A deposit of native clayey silt till was contacted below the fill in all the boreholes. Groundwater levels are generally in the order of 3.4 m and 6.1 m below ground surface, at the north and south approaches, respectively. More detailed descriptions of the individual stratum are presented below.

5.1 Pavement Structure and Concrete Slab

The four boreholes were advanced from the top of the road embankment.

Boreholes GS 16-01, GS 16-02 and GS 16-04 encountered between 75 mm and 100 mm of asphalt surficially. A 25 mm thick layer of concrete was contacted surficially in Borehole GS 16-03 which was drilled through the south approach slab.

Granular fill was encountered below the asphalt and concrete in all the boreholes. The granular fill consisted of a brown to grey gravelly sand with some silt. The thickness of the granular fill ranged from 0.6 m in Borehole GS16-04 to 1.3 m in Borehole GS 16-01.

The depth to the base of the gravelly sand fill ranged from 0.7 m to 1.4 m (Elevations 101.0 to 102.1 m).

In Borehole GS 16-01, an SPT ‘N’ value of 49 blows for 0.3 m penetration was recorded in the granular fill indicating a dense condition. Moisture contents of the granular fill ranged from 3 percent to 8 percent.

5.2 Sand and Gravel Fill

Brown sand and gravel fill (possibly abutment wall backfill) containing trace to some silt and clay, was contacted in Boreholes GS 16-02 and GS 16-03 underlying the granular fill at the north and south abutment areas. The thickness of the sand and gravel fill was 2.2 m and 1.5 m in Boreholes GS 16-02 and GS 16-03, respectively.

The depth to the base of the sand and gravel fill was 2.9 m and 2.2 m (Elevations 99.2 and 100.3m) in Boreholes GS 16-02 and GS 16-03, respectively.

In Borehole GS 16-03, SPT 'N' values obtained in the sand and gravel fill were 17 and 34 blows for 0.3 m penetration, indicating a compact to dense state,. In Borehole GS 16-02, the SPT 'N' values ranged from 65 to 78 blows per 0.3 m of penetration indicating a very dense state. Moisture contents of the sand and gravel fill typically ranged from 3 percent to 5 percent. An occasional value of 44 percent was recorded in Borehole GS 16-03.

The results of grain size analyses conducted on two sand and gravel fill samples 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	35 to 50
Sand	38 to 47
Silty and Clay	12 to 18

5.3 Silty Sand Fill and Silty Clay Fill (Embankment Fill)

Brown to greyish brown silty sand fill containing some gravel and trace to some clay, was contacted in Boreholes GS 16-02 and GS 16-04 at 2.9 m depth and 0.7 m depth, respectively. The thickness of the silty sand fill was between 0.4 m and 0.9 m. Greyish brown silty clay fill, some sand to with sand, some gravel and occasional asphalt fragments, was contacted at the south abutment and south approach areas (Boreholes GS 16-03 and GS 16-04) below the sand and gravel fill and silty sand fill. The thickness of the silty clay fill ranged from 1.9 m to 2.7 m.

The depth to the base of the combined silty sand fill and silty clay fill ranged from 3.8 m to 4.1 m (Elevations 98.3 to 99.0 m).

SPT 'N' values obtained in the silty sand fill were 14 and 38 blows for 0.3 m penetration, indicating a compact to dense state. Moisture contents of the silty sand fill ranged from 5 percent to 13 percent.

SPT 'N' values in the silty clay fill ranged from 15 to 55 blows for 0.3 m penetration, indicating a very stiff to hard consistency. Moisture contents of the silty clay fill ranged from 11 percent to 25 percent.

The results of grain size analyses conducted on one silty sand fill and two silty clay fill samples

are presented on the Record of Borehole sheets in Appendix A, and are illustrated in Figures B2 and B3 of Appendix B. The laboratory test results are summarized in the following table.

Soil Particle	Silty Sand Fill Percentage (%)	Silty Clay Fill Percentage (%)
Gravel	13	7 to 11
Sand	44	22 to 28
Silt	33	29 to 38
Clay	10	32 to 33

5.4 Clayey Silt Till

A deposit of brown to grey clayey silt till with sand and trace gravel, was encountered below the fill in all the boreholes. It is noted that glacial till inherently contains cobbles and boulders. All the boreholes were terminated within the clayey silt till at 8.2 m depth (Elevations 93.9 to 94.6 m).

Most SPT 'N' values recorded in the clayey silt till varied between 26 and 60 blows for 0.3 m of penetration indicating very stiff to hard consistency. Higher SPT 'N' values of greater than 50 blows for less than 0.3 m of penetration were measured near borehole termination depth in Boreholes GS16-03 and GS16-04, indicating the probable presence of cobbles or boulders. Natural moisture contents of the clayey silt till ranged from 8 percent to 17 percent.

The results of grain size analyses conducted on samples of the clayey silt till are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figures B4 and B5 of Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0 to 14
Sand	22 to 34
Silt	39 to 59
Clay	12 to 20

The results of Atterberg Limits tests conducted on samples of the clayey silt till are provided on the Record of Borehole sheets in Appendix A and illustrated in Figure B6 of Appendix B. The results are summarized as follows:

Index Property	Percentage (%)
Liquid Limit	26
Plasticity Index	7 to 9

The results of the Atterberg Limits testing indicate the deposit to be of low plasticity with group symbols CL and CL-ML.

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. Standpipe piezometers were installed in Boreholes GS 16-02 and GS 16-03 to permit longer term monitoring. Groundwater levels measured in the piezometers are presented in Table 5.1.

Table 5-1. Measured Groundwater Levels

Borehole Number	Date	Groundwater Level		Comment
		Depth (m)	Elevation (m)	
GS 16-02	January 4, 2017	3.4	98.7	Piezometer
GS 16-03	January 4, 2017	6.1	96.4	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. Thurber obtained the coordinates of the boreholes using a GPS device. MMM provided the ground surface elevations.

Walker Drilling of Utopia, Ontario, supplied and operated a track-mounted D25 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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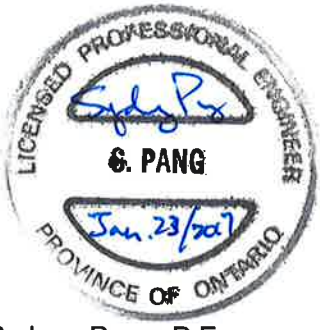
Rocío Palomeque Reyna, P.Eng.
Geotechnical Engineer



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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 Geneva 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 three-span structure supported on two abutments and two piers. Based on a General Arrangement (GA) drawing provided by MMM, the south and north abutments are supported on spread footings at approximate Elevations 98 and 97 m, respectively. The south and north piers are supported on spread footings near Elevations 91 and 92 m, respectively. The south and north approach spans are approximately 34.1 and 33.5 m in length, respectively, whereas the centre span between the piers is about 17.7 m in length. The length of each of the south and north approach slabs is 6.1 m. The ground surface at the bridge is in the order of Elevations 102.1 to 102.8 m.

The present rehabilitation program will include the following:

- Patch repair to abutment walls and wingwalls
- Patch repair piers
- Patch, waterproof and pave deck
- Repair north slope paving and reconstruct south slope paving
- Reconstruct top of wingwall, concrete barrier wall with railing at four ends of expansion joints
- Replace expansion joints
- Reconstruct ballast walls and approach slabs
- Repair deck ends
- Patch repair deck fascia and soffit
- Patch and inject cracks in sidewall and barrier wall.

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.

8. ROADWAY PROTECTION

Roadway protection will be required during the 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 compact to dense granular fill (gravelly sand, sand and gravel, silty sand) and very stiff silty clay fill into the underlying native very stiff to hard clayey silt till 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 (granular fill: gravelly sand, sand and gravel and silty sand)
		=	0.35 (silty clay fill)
		=	0.31 (clayey silt till)
Coefficient of Active Pressure	K_p	=	3.0 (granular fill: gravelly sand, sand and gravel and silty sand)
		=	2.9 (silty clay fill)
		=	3.2 (clayey silt 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 and abutment wall backfill must be reconstructed with adequate quality control in accordance with OPSS.PROV 206 and 501 requirements. For backfilling immediately behind the 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 $\phi = 35°, \gamma = 22.8$ kN/m^3		OPSS Granular B Type I $\phi = 32°, \gamma = 21.2$ kN/m^3		Embankment Fill or Select Subgrade Material $\phi = 30°, \gamma = 20.0$ kN/m^3	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	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	0.33	0.54
At rest (Restrained Wall)	0.43	-	0.47	-	0.50	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-	3.0	-

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 to sand and gravel fill, silty sand fill and silty clay fill, and into the native clayey silt 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

Water was not observed in the boreholes upon completion of drilling. Piezometric levels at about Elevations 98.7 and 96.4 m, or in the order of 3.4 m and 6.1 m depth below existing road grade, were measured in two piezometers installed at the north and south abutments. It is anticipated that any excavation that is required to carry out bridge rehabilitation will not extend below the groundwater level. However, seepage or perched water from the granular fill (gravelly sand, sand and gravel and silty sand) 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 Ms. Rocío Palomeque Reyna, P.Eng and Dr. Sydney Pang, P.Eng.

Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects, reviewed the report.

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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

C_{pen} 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

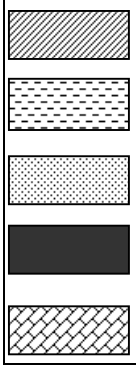
ROCK WEATHERING CLASSIFICATION

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 (MPa)**	**(psi)**	**Field Estimation of Hardness***
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			

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No GS16-01 1 OF 1 METRIC

GWP# 2257-13-00 LOCATION Geneva Street Underpass N 4 779 865.4 E 325 959.6 ORIGINATED BY OA

HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.12.21 - 2016.12.21 CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
102.4	GROUND SURFACE										
0.0	**ASPHALT:** (75mm)										
0.1	Gravelly **SAND**, some silt Dense Brown to Greyish Brown Moist (FILL)		1	GS			102		○		
			1	SS	49				○		
101.0							101				
1.4	Clayey **SILT**, with sand, trace gravel Hard to Very Stiff Reddish Brown Moist (TILL)		2	SS	50				○		2 25 58 15
			3	SS	35		100		○		
			4	SS	26		99		○		
			5	SS	28		98		○ ⊢⊣		0 28 55 17
			6	SS	60		97				
			7	SS	56		96		○		
94.2							95				0 28 54 18
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.1m, THEN CONCRETE FROM 0.1m TO SURFACE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S MTO-11336.GPJ 2015TEMPLATE(MTO).GDT 1/12/17

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No GS16-02 1 OF 1 METRIC

GWP# 2257-13-00 LOCATION Geneva Street Underpass N 4 779 855.3 E 325 957.8 ORIGINATED BY OA

HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.12.20 - 2016.12.20 CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
102.1	GROUND SURFACE						102				
0.0 / 0.1	**ASPHALT:** (75mm)										
	Gravelly **SAND** Grey Moist (FILL)		1	GS					○		
101.4 / 0.7	**SAND** and **GRAVEL**, some silt and clay Very Dense Brown Moist (FILL)		1	SS	78		101		○		
			2	SS	65				○		35 47 18 (SI+CL)
			3	SS	75		100		○		
99.2 / 2.9	Silty **SAND**, some gravel, trace to some clay Compact Brown Moist (FILL)		4	SS	14		99		○		13 44 33 10
98.3 / 3.8	Clayey **SILT**, with sand, trace gravel Hard Brown Moist (TILL)						98				
			5	SS	49		97		○		
			6	SS	60		96		○		4 25 51 20
							95				
93.9			7	SS	47		94		○		
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE OPEN AND DRY UPON COMPLETION. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.										

WATER LEVEL READINGS

DATE	DEPTH(m)	ELEV.(m)
2017.01.04	3.4	98.7

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S MTO-11336.GPJ 2015TEMPLATE(MTO).GDT 1/12/17

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No GS16-03 1 OF 1 METRIC

GWP# 2257-13-00 LOCATION Geneva Street Underpass N 4 779 755.9 E 325 978.8 ORIGINATED BY OA

HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.12.21 - 2016.12.21 CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
102.5	GROUND SURFACE										
0.0	**CONCRETE:** (25mm)										
0.0	Gravelly **SAND** Brown Moist (FILL)		1	GS			102		○		
101.8											
0.7	**SAND** and **GRAVEL**, trace to some silt and clay Compact to Dense Brown Moist (FILL)		1	SS	17				○		
			2	SS	34		101		○		50 38 12 (SI+CL)
100.3											
2.2	Silty **CLAY**, with sand, some gravel, occasional asphalt fragments Very Stiff Greyish Brown Moist (FILL)		3	SS	15		100		○		11 28 29 32
			4	SS	27		99		○		
98.4											
4.1	Clayey **SILT**, with sand, some gravel Very Stiff to Hard Greyish Brown Moist (TILL)		5	SS	27		98		○		14 34 39 13
			6	SS	31		97		○		
	Trace gravel		7	SS	50/ 0.125		96		○		6 32 45 17
94.3							95				
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE OPEN AND DRY UPON COMPLETION. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.										

WATER LEVEL READINGS

DATE	DEPTH(m)	ELEV.(m)
2017.01.04	6.1	96.4

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S MTO-11336.GPJ 2015TEMPLATE(MTO).GDT 1/16/17

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No GS16-04 1 OF 1 METRIC

GWP# 2257-13-00 LOCATION Geneva Street Underpass N 4 779 745.7 E 325 979.6 ORIGINATED BY OA

HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.12.20 - 2016.12.20 CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
102.8	GROUND SURFACE										
0.0	**ASPHALT:** (100mm)										
0.1	Gravelly **SAND** Brown Moist (FILL)		1	GS			102				
102.1 / 0.7	Silty **SAND**, some gravel, some clay Dense Greyish Brown Moist (FILL)		1	SS	38						
101.7 / 1.1	Silty **CLAY**, some sand, some gravel Very Stiff to Hard Greyish Brown Moist (FILL)		2	SS	21		101				
			3	SS	55						
	Trace gravel Brown		4	SS	23		100				7 22 38 33
99.0 / 3.8	Clayey **SILT**, with sand, trace gravel Hard Brown Moist (TILL)		5	SS	50		99 / 98				0 29 59 12
			6	SS	46		97 / 96				7 22 54 17
			7	SS	50/ 0.125		95				
94.6 / 8.2	END OF BOREHOLE AT 8.2m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.1m, THEN CONCRETE FROM 0.1m TO SURFACE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S MTO-11336.GPJ 2015TEMPLATE(MTO).GDT 1/12/17

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Appendix B

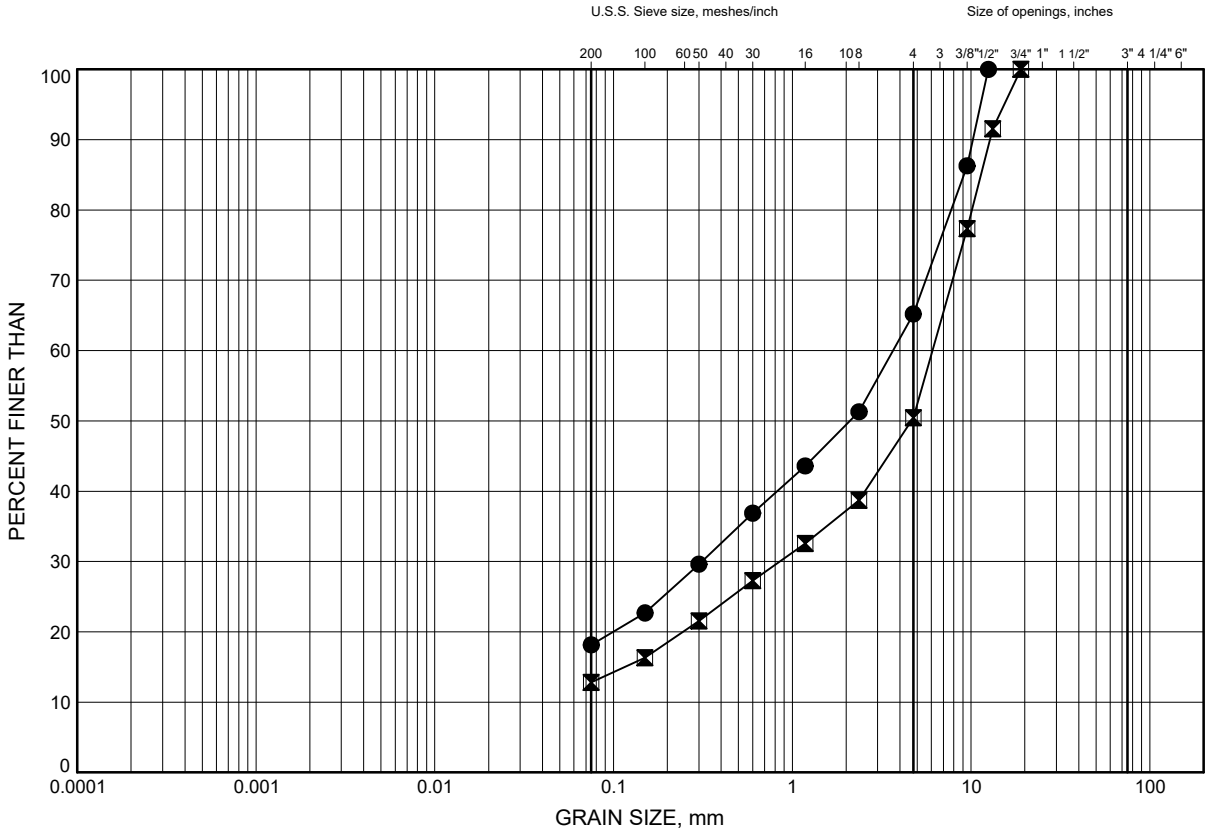
Laboratory Test Results

Geneva Street Underpass

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND and GRAVEL FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GS16-02	1.83	100.31
⧓	GS16-03	1.83	100.67

Date January 2017

GWP# 2257-13-00

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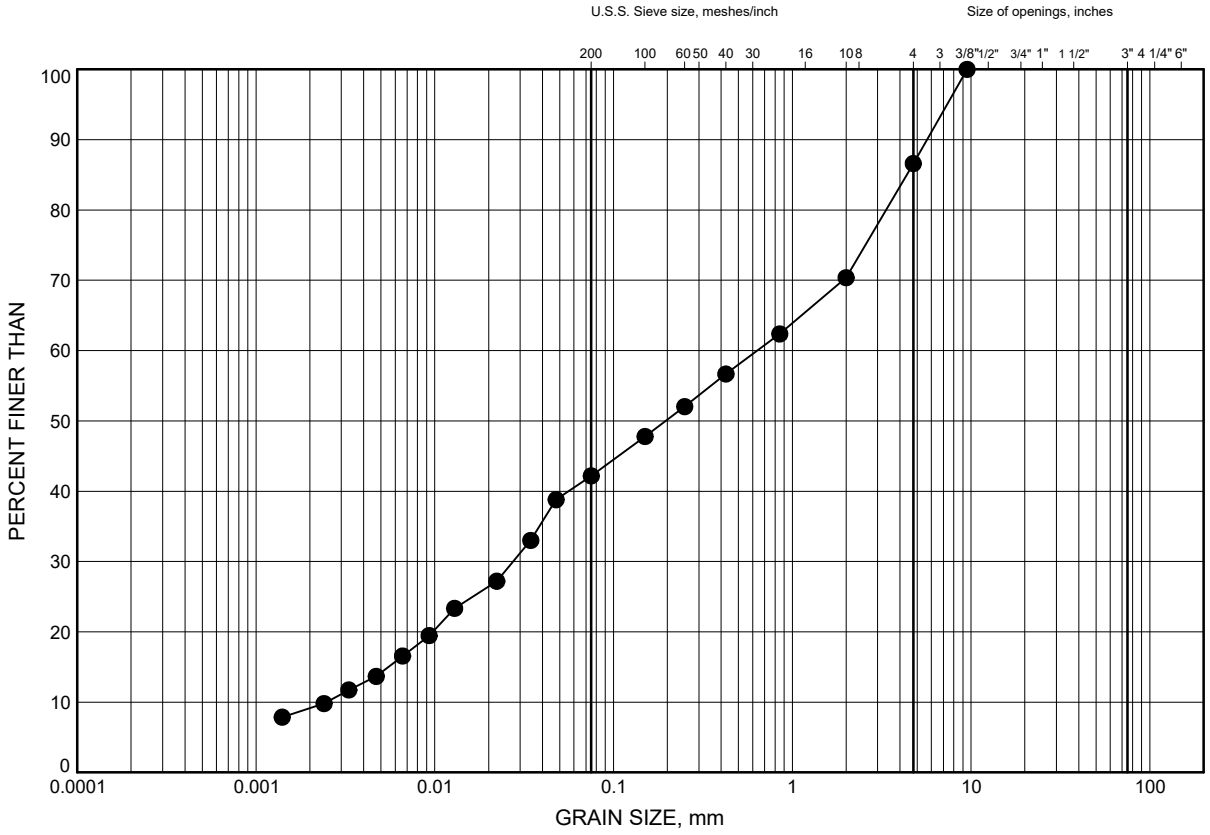
GRAIN SIZE DISTRIBUTION - THURBER MTO-11336.GPJ 1/6/17

Geneva Street Underpass

GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GS16-02	3.35	98.78

Date January 2017

GWP# 2257-13-00

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Chkd. RPR

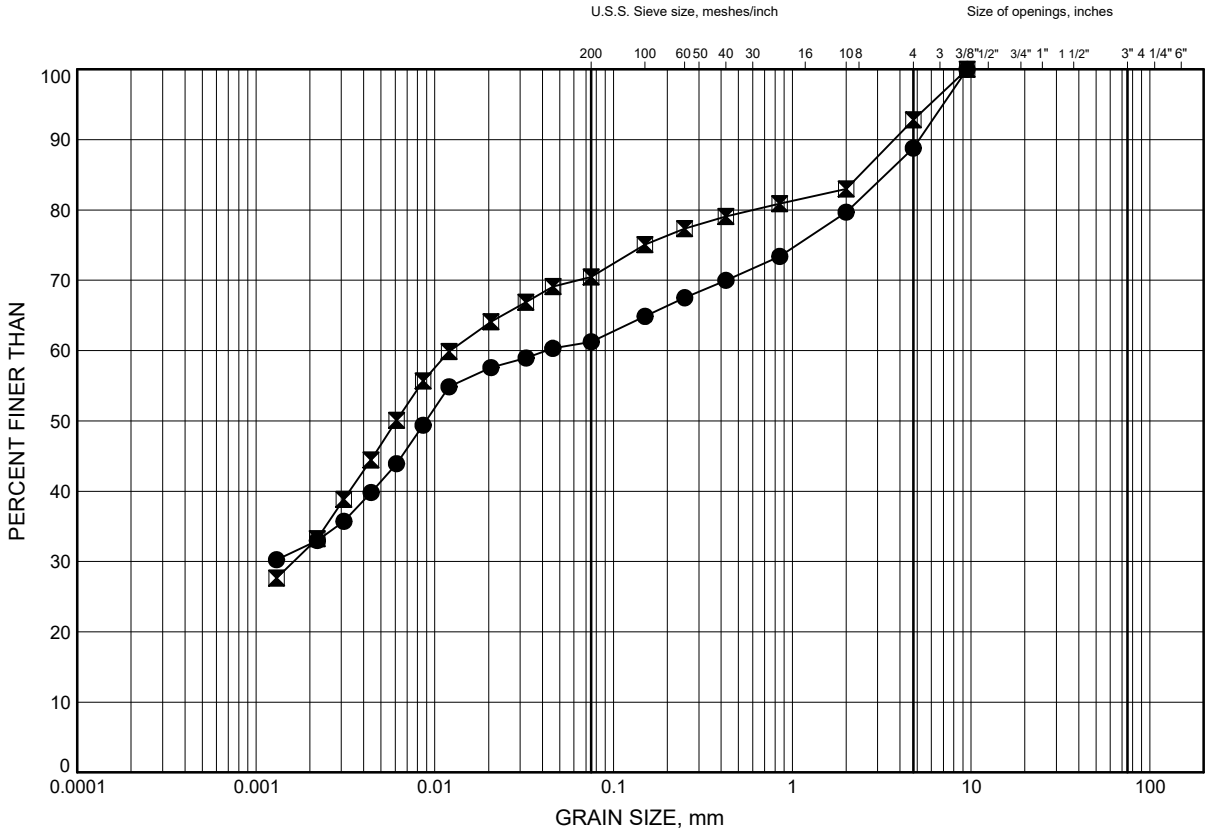
GRAIN SIZE DISTRIBUTION - THURBER MTO-11336.GPJ 1/6/17

Geneva Street Underpass

GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty CLAY FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GS16-03	2.59	99.91
⧓	GS16-04	3.35	99.45

Date January 2017

GWP# 2257-13-00

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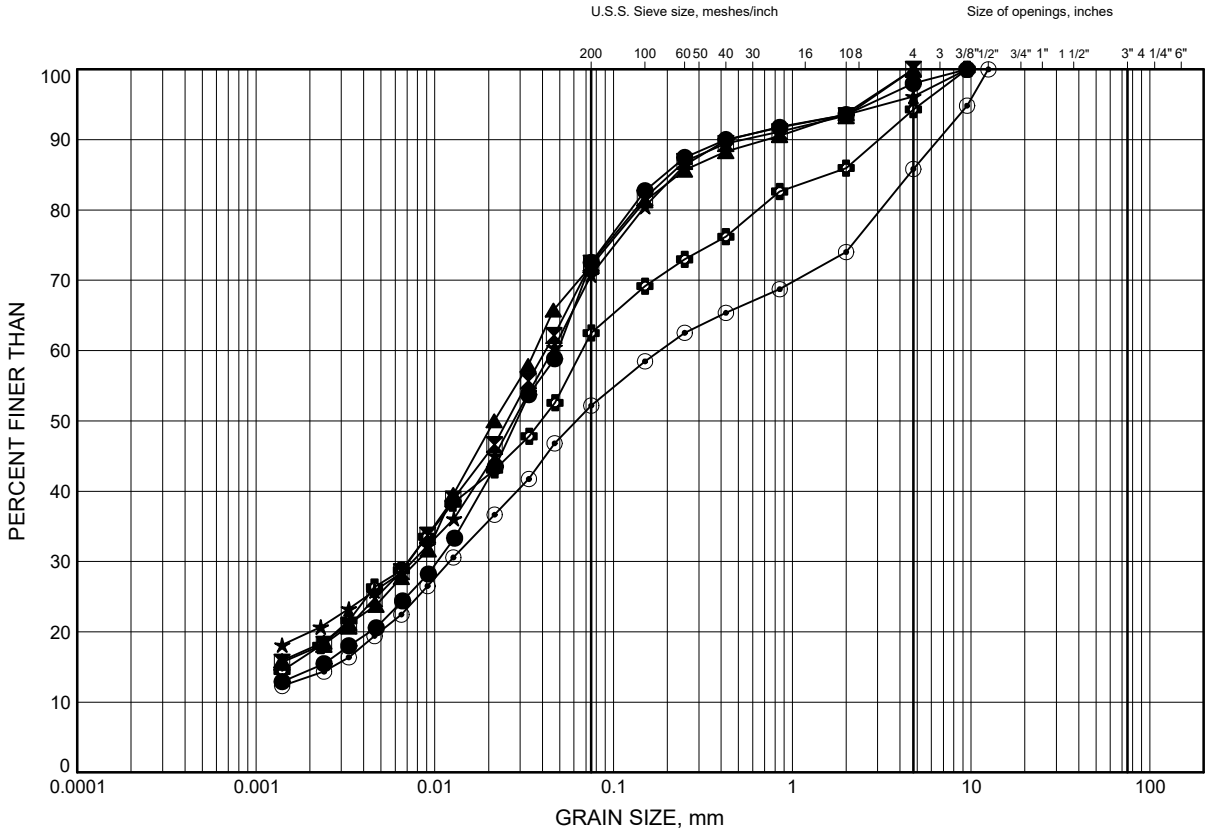
GRAIN SIZE DISTRIBUTION - THURBER MTO-11336.GPJ 1/6/17

Geneva Street Underpass

GRAIN SIZE DISTRIBUTION

FIGURE B4

Clayey SILT TILL, with Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GS16-01	1.83	100.55
⊠	GS16-01	4.88	97.51
▲	GS16-01	7.92	94.46
★	GS16-02	6.40	95.73
⊙	GS16-03	4.88	97.62
✿	GS16-03	7.92	94.57

Date January 2017

GWP# 2257-13-00

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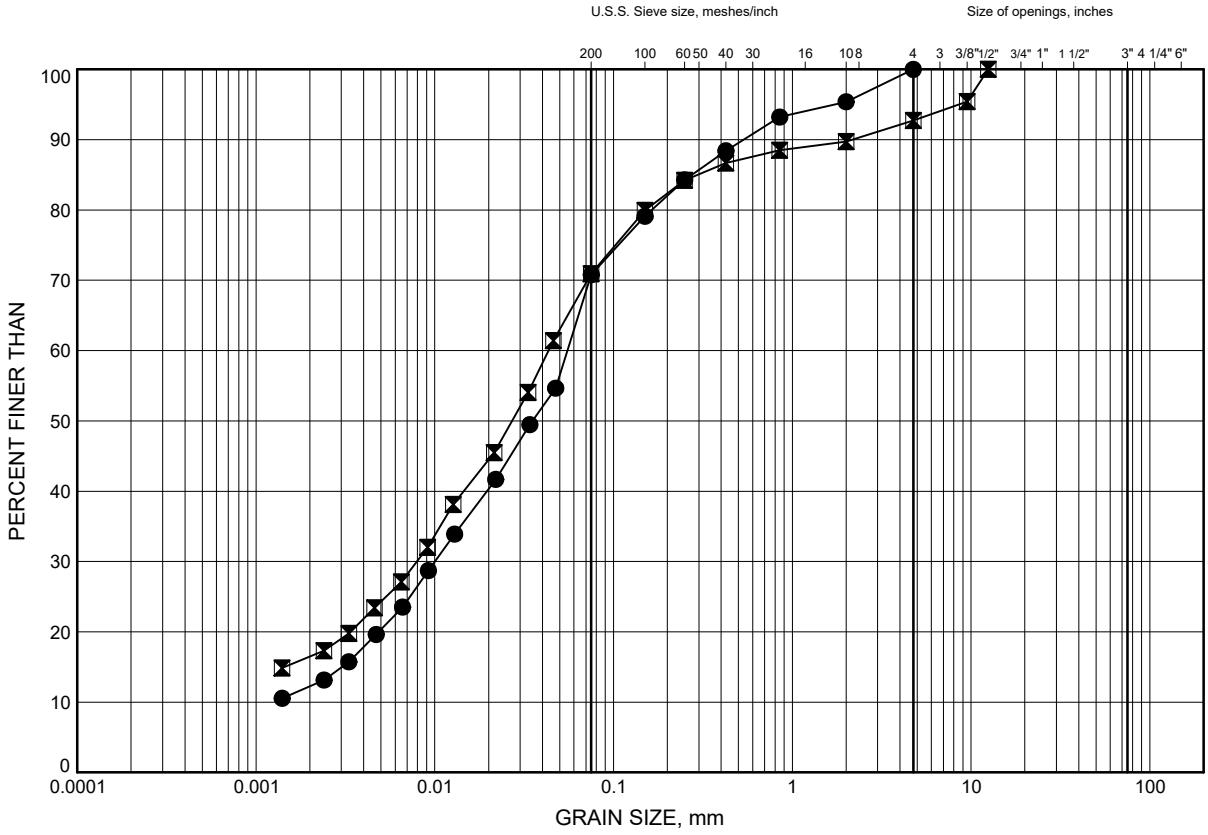
GRAIN SIZE DISTRIBUTION - THURBER MTO-11336.GPJ 1/6/17

Geneva Street Underpass

GRAIN SIZE DISTRIBUTION

FIGURE B5

Clayey SILT TILL, with Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GS16-04	4.88	97.92
⧓	GS16-04	6.40	96.40

Date January 2017

GWP# 2257-13-00

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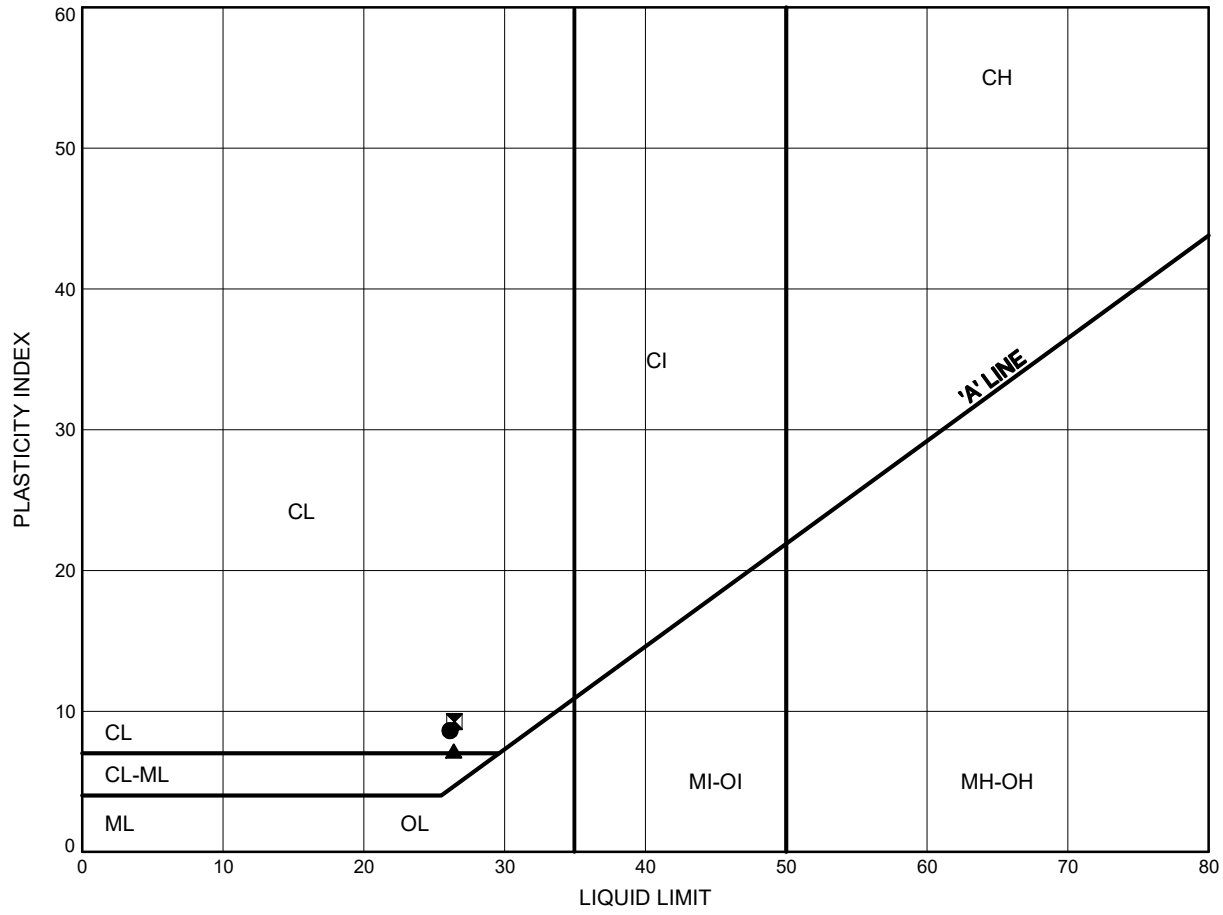
GRAIN SIZE DISTRIBUTION - THURBER MTO-11336.GPJ 1/6/17

Geneva Street Underpass

ATTERBERG LIMITS TEST RESULTS

FIGURE B6

Clayey SILT TILL, with Sand



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GS16-01	4.88	97.51
⊠	GS16-02	6.40	95.73
▲	GS16-04	6.40	96.45

Date January 2017

GWP# 2257-13-00

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THURBALT MTO-11336.GPJ 1/6/17

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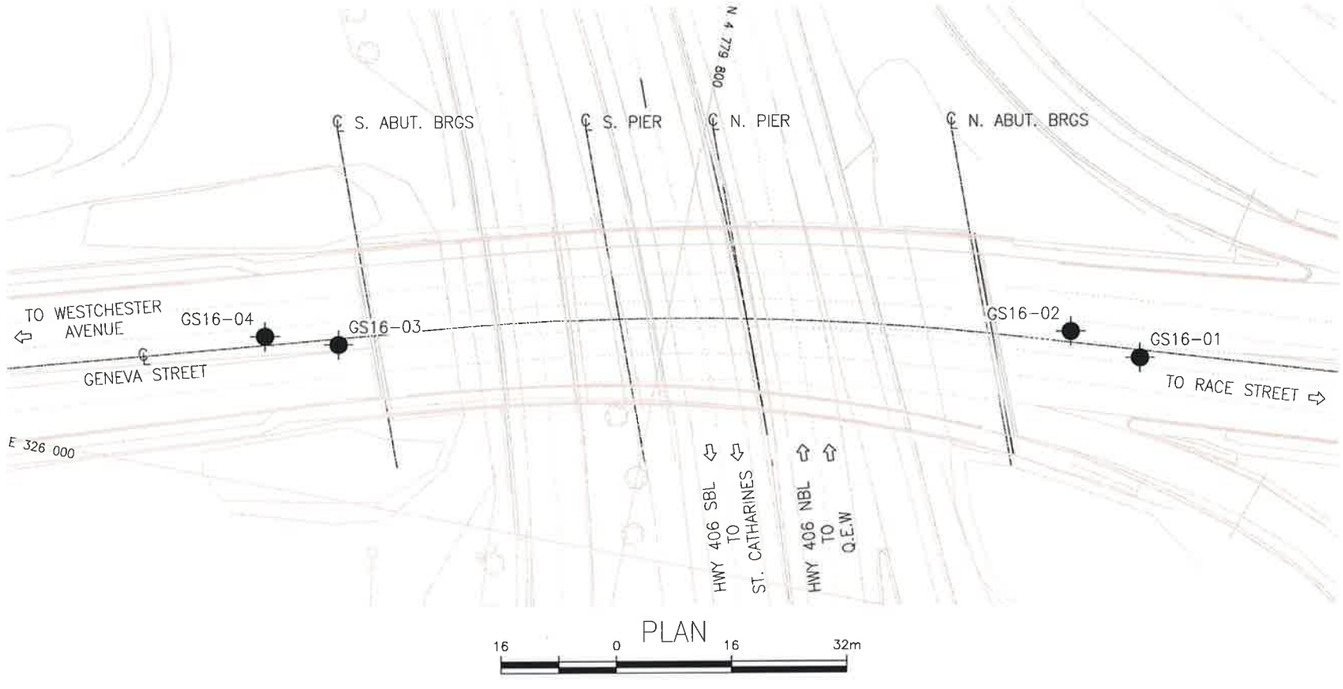
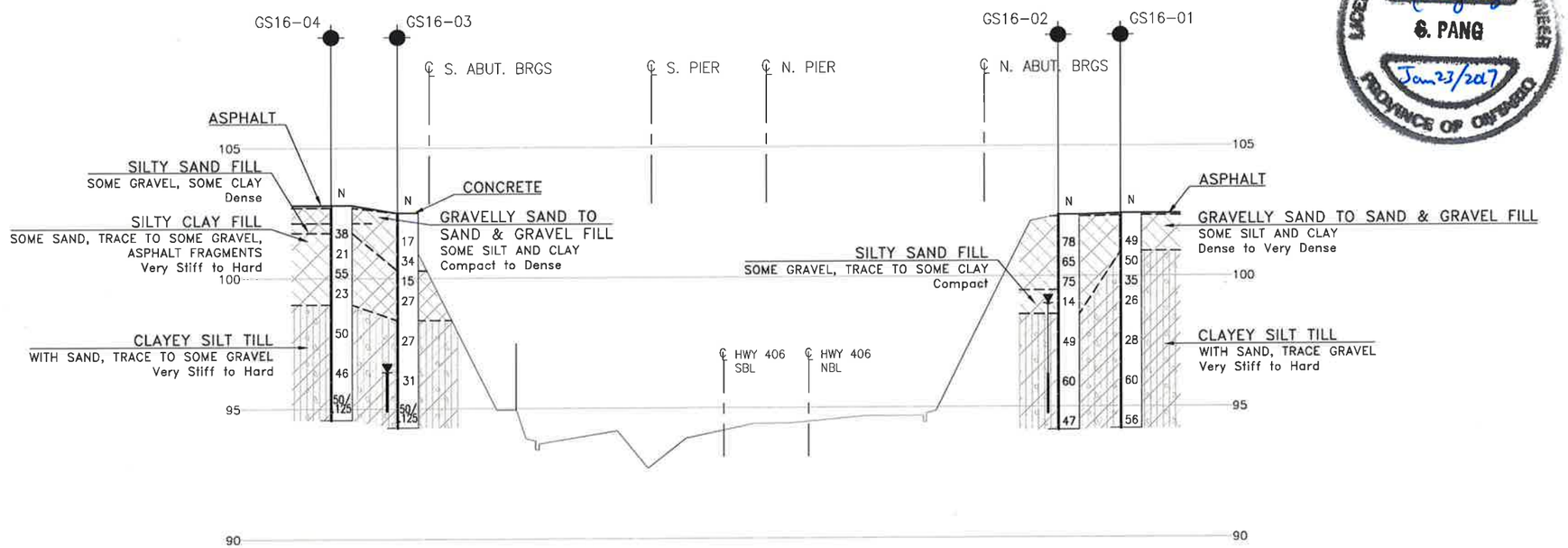
Appendix C

Borehole Locations and Soil Strata Drawing



PLAN

16 0 16 32m



PROFILE ALONG ℄ GENEVA STREET

16 0 16 32m H

4 0 4 8m V

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Jan 23/17
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
S. PANG
Jan 23/2017
PROVINCE OF ONTARIO

CONT No
WP No 2257-13-00

SHEET

HIGHWAY 406
GENEVA STREET UNDERPASS
BRIDGE REHABILITATION
BOREHOLE LOCATIONS AND SOIL STRATA

MMM GROUP

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

NO	ELEVATION	NORTHING	EASTING
GS16-01	102.4	4 779 865.4	325 959.6
GS16-02	102.1	4 779 855.3	325 957.8
GS16-03	102.5	4 779 755.9	325 978.8
GS16-04	102.8	4 779 745.7	325 979.6

-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. 30M3-293

REVISIONS		
DATE	BY	DESCRIPTION

DESIGN	RPR	CHK	SKP	CODE	LOAD
DRAWN	AN	CHK	RPR	SITE	STRUCT

DATE JAN 2017
DWG 1

FILENAME: H:\Drafting\11000\11336\TED-11336-PLPR-GSU.dwg
PLOTDATE: 1/23/2017 11:20 AM

THURBER

Appendix D

Selected Site Photographs

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

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

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

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

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

THURBER

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