



THURBER ENGINEERING LTD.



**FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 416 - FALLOWFIELD ROAD
CULVERT REPLACEMENTS
OTTAWA, ON
GWP 4096-16-00
4015-E-0013
ASSIGNMENT #13**

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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation completed for the proposed replacement of five CSP culverts at the Highway 416 Fallowfield Road Interchange within the City of Ottawa. Thurber Engineering Limited (Thurber) carried out the investigation as a sub-consultant to WSP | MMM Group (WSP | MMM) under MTO Agreement Number 4015-E-0013.

The purpose of this investigation was to explore the subsurface conditions at the sites and, based on the data obtained, to provide borehole location plans, records of boreholes, stratigraphic profiles, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions influencing design and construction was developed in the course of the current investigation. No previous foundation investigation information was available for the subject culverts within the Geocres library.

2 SITE DESCRIPTION

The Highway 416 and Fallowfield Road interchange has an existing underpass structure that carries Fallowfield Road over Highway 416. For the purpose of this report, Highway 416 is assumed to run north-south and Fallowfield Road is assumed to run west-east. Fallowfield Road consists of two lanes of traffic in each direction, and Highway 416 is a four-lane (two lanes in each direction) rural divided freeway. The interchange also includes an off-ramp from each highway direction (S-E/W, N-E/W ramps) and two on-ramps for each highway direction (E-S, W-S, E-N, and W-N ramps).

The existing culverts are non-structural corrugated steel pipe (CSP) culverts with reported diameters ranging from 610 mm to 1105 mm and lengths between 23.1 m and 88.0 m.

The site lies within the physiographic region known as the Ottawa Valley Clay Plains. Locally, the bedrock is exposed at several locations along the ramps in the north-west quadrant of the interchange.

Culvert 1 conveys storm water beneath the E-N ramp and is located approximately 240 m north from the bullnose of the ramp/Fallowfield Road. The existing culvert is a non-structural corrugated steel pipe culvert. The culvert is reported to be 610 mm in diameter and approximately 31.0 m long with a generally south to north alignment. The invert of the existing culvert is reported to be at elevation 106.07 m and 105.14 m at the inlet and outlet respectively. The embankment fill height is in the order of 3.9 m with the road surface at

approximate elevation 110.10 m. The embankment sides are sloped at approximately 2H:1V and are vegetated with wild grass and brush. No evidence of settlement or stability concerns were noted.

Culvert 3B conveys storm water beneath the W-S ramp and is located approximately 360 m south of the bullnose of the ramp and Fallowfield Road underpass structure. The Culvert 3B outlet is in close proximity to the inlet of Culvert 3A. The existing culvert is a non-structural corrugated steel pipe culvert. The culvert is reported to be 800 mm in diameter and approximately 30.0 m long with a generally west to east alignment. The invert of the existing culvert is reported to be at elevation 109.23 m and 107.60 m at the inlet and outlet respectively. The embankment fill height is in the order of 4.0 m with the road surface at approximate elevation 112.70 m. The embankment sides are sloped at approximately 2H:1V and are vegetated with wild grass or brush. At the time of the investigation it was noted that there was some erosion of the slopes above the outlet.

Culvert 3A conveys storm water beneath the Highway 416 and the W-N ramp and is located approximately 120 m south of the Fallowfield Road underpass structure. Culvert 3A is constructed of two separate runs of non-structural corrugated steel pipe culvert connected at a catch basing located in the median ditch. The culverts are reported to be 660 mm in diameter at the inlet and 1105 mm at the outlet and approximately 77.8 m long in total with a generally west to east alignment. The invert of the existing culvert is reported to be at elevation 107.32 m and 105.34 m at the inlet and outlet respectively. The embankment fill height is in the order of 2.8 to 3.2 m with the road surface at approximate elevation 109.80 m. The embankment sides are sloped at approximately 2H:1V and are vegetated with wild grass. No evidence of settlement or stability concerns were noted.

Culvert 4 conveys storm water beneath the W-N ramp and S-E/W ramp and is located approximately 40 m south of the centreline of Fallowfield Road. Culvert 4 is constructed of two separate runs of non-structural corrugated steel pipe culvert connected at a catch basin located in the ditch between the two ramps. The culverts are reported to be 900 mm in diameter at the inlet and 1105 mm in diameter at the outlet and approximately 88.0 m in combined length with a generally west to east alignment. The invert of the existing culvert is reported to be at elevation 104.57 m and 102.22 m at the inlet and outlet respectively. The embankment fill heights are in the order of 6.0 to 6.5 m with the road surface at approximate elevation 109.30 m to 110.70 m. The embankment sides are sloped at approximately 2H:1V and are vegetated with wild grass.

Culvert 6 conveys storm water beneath the southbound Highway 416 to the median and is located approximately 180 m north of the centreline of Fallowfield Road underpass structure. The existing culvert is a non-structural corrugated steel pipe culvert. The culvert is reported to be 610 mm in diameter and approximately 23.1 m long with a generally west to east alignment. The invert of the existing culvert is reported to be at elevation 109.43 m and 109.08 m at the inlet and outlet respectively. The embankment fill height is in the order of 1.4 m with the road surface at approximate elevation 110.90 m. A rock cut approximately 2 m in height is present near the culver inlet.

Select photographs showing the existing conditions in the area of the culverts are included in Appendix D for reference.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing program was carried out between March 27th and April 11th, 2017. The field investigation consisted of advancing sixteen boreholes identified as 1 through 16. The drilling was carried out using a combination of CME 45 track mounted drill and portable equipment for off-road boreholes, and a truck mounted CME 55 drill rig for the on-road boreholes. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). The boreholes were sampled to depths ranging from 4.1 to 10.7 m (elev. 98.2 to 105.5 m) below the existing ground surface.

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The drilling supervisor logged the boreholes and processed the recovered soil samples for transport for further laboratory examination and testing.

To allow for measurements of the groundwater level after completion of drilling, a 19 mm diameter standpipe piezometer was installed in every inlet and outlet borehole, with the exception of Borehole 16. The piezometer installation details are illustrated on the respective Record of Borehole sheet, provided in Appendix B. Following completion of the field investigation the remaining boreholes were backfilled in general accordance with MOEE requirements (O.Reg. 903). Boreholes through the embankments were topped with cold patch asphalt to reinstate the traveling surface.

The approximate borehole locations are shown on the Borehole Locations and Soil Strata Drawings included in Appendix A. The coordinates and elevation of the boreholes are provided on these drawings and on the individual Record of Borehole sheets. The following table summarizes which boreholes were drilled at which culvert locations.

Culvert	Inlet Borehole	Embankment Borehole(s)	Outlet Borehole
1	1	2	3
3A	9	4 and 5	6
3B	7	8	9
4	10	11 and 12	13
6	14	15	16

4 LABORATORY TESTING

The recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to gradation analysis (hydrometer and/or sieve) and Atterberg Limit testing. The results of these tests are summarized on the Record of Borehole sheets included in Appendix B. Five samples of soil recovered from within the boreholes were selected and submitted for analytical testing of corrosivity parameters and sulphate content. All laboratory test results from the field investigation are provided in Appendix C.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Location and Soil Strata drawings included in Appendix A. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following sections for each culvert site. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description for interpretation of the site conditions. It must be recognized that the soil and groundwater conditions may vary between and beyond borehole locations.

5.1 Culvert 1 (E-N Ramp): Boreholes 1, 2 and 3

5.1.1 Pavement Structure and Embankment Fill

Asphalt:

Borehole 2 was drilled through the existing E-N Ramp embankment and encountered a surficial layer of asphalt with a thickness of 140 mm.

Rootmat:

A 75 mm thick layer of rootmat was encountered at surface near the inlet and outlet in Boreholes 1 and 3. Recorded moisture contents ranged from 32 to 48%.

Rockfill: Gravel/Cobbles with Sand and Silt:

Below the asphalt pavement in Borehole 2 was a layer of rockfill consisting of gravel and cobbles with sand and silt. The underside of the fill was at 4.7 m below the existing roadway surface (elev. 105.4 m).

The SPT tests conducted in the fill gave N-values ranging from 18 to 52 blows indicating a relative density of compact to very dense. Recorded moisture contents ranged from 3 to 8%. The results of grain size analyses conducted on two samples of the fill are summarized below and are illustrated on Figure C1 in Appendix C. It is noted that the recovered samples do not include cobbles and boulders and the results of grain size analyses only reflect the gradation of the recovered portion of the fill material

Soil Particle	Percentage (%)
Gravel	67 and 51
Sand	22 and 33
Silt and Clay	11 and 16

5.1.2 Silty Sand with Gravel (Till)

A native deposit of silty sand with gravel was encountered below the fill layers in Borehole 2 and below the surficial rootmat Boreholes 1 and 3. All three boreholes were terminated within this layer at elevations ranging from of 100.8 to 102.0 m. The SPT N-values ranged from 9 to greater than 100 blows per 300 mm and, in general, the layer is compact to very dense. In Borehole 1 and 2 this layer was noted to contain occasional to frequent cobbles. A clayey zone was encountered from 3.0 m to 3.8 m in Borehole 3.

The moisture content of the samples tested ranged from 14% to 19%. The results of grain size analyses conducted on four samples of the till are summarized below and are illustrated on Figure C2 in Appendix C.

Soil Particle	Percentage (%)
Gravel	15 - 30
Sand	43 - 52
Silt and Clay	24 - 33

Glacial tills inherently contain cobbles and boulders.

5.1.3 Bedrock

Bedrock was not encountered within the depth of investigation at this culvert site.

5.1.4 Groundwater

Water was flowing through the culvert at the time of the field investigation. Following the completion of drilling, a standpipe piezometer was installed in Boreholes 1 and 3. During a site visit on April 25, 2017 the groundwater in the standpipes were observed at the ground surface (elevation 106.4 m) and 0.2 m (elevation 105.1 m) below the ground surface in Boreholes 1 and 3 respectively.

These observations are considered short term and it should be noted that the groundwater level at the time of construction may vary and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation events.

5.2 Culvert 3A (W-N Ramp and Highway 416): Boreholes 4, 5, 6 and 9

5.2.1 Pavement Structure and Embankment Fill

Asphalt:

Boreholes 4 and 5 were drilled through the existing Southbound and Northbound 416 embankment, respectively. A surficial layer of asphalt with a thickness of 200 mm was recorded in each roadway borehole.

Rootmat:

A 100 mm and 50 mm thick layer of rootmat was encountered at surface near the inlet and outlet in Boreholes 9 and 6, respectively. Recorded moisture contents ranged from 29 to 36%.

Silty Gravel with Sand Fill:

Below the asphalt pavement in Boreholes 4 and 5 was a layer of fill consisting of silty gravel with sand. In both boreholes, the underside of the silty gravel fill was 1.4 m below the existing roadway surface (elev. 108.4 m).

The SPT tests conducted in the gravel fill gave N-values ranging from 29 to 57 blows indicating a relative density of compact to very dense. Recorded moisture contents ranged from 2 to 6%. The results of grain size analyses conducted on two samples of the silty gravel with sand fill are summarized below and are illustrated on Figure C3 in Appendix C.

Soil Particle	Percentage (%)
Gravel	59 and 49
Sand	29 and 37
Silt and Clay	12 and 14

Rockfill:

Below the silty gravel fill in Boreholes 4 and 5 and below the rootmat in Borehole 6 was a layer of rockfill containing variable amounts of gravel, cobbles, sand and silt. The underside of the rockfill was at 2.7 m and 3.0 m (elev. 107.1 m and 106.7) below the existing roadway surfaces in Boreholes 4 and 5, respectively.

The SPT tests conducted in the rockfill gave N-values ranging from 35 to greater than 100 blows indicating a relative density of dense to very dense. Due to the presence of cobbles and boulders, Boreholes 5 and 6 were advanced with casing and coring techniques. Boulders as large as 360 mm were cored within the rockfill. Recorded moisture contents ranged from 7 to 11%. The results of grain size analyses conducted on three samples of the rockfill are summarized below and are illustrated on Figure C3 in Appendix C. It is noted that the recovered samples do not include cobbles and boulders and the results of grain size analyses only reflect the gradation of the recovered portion of the fill material

Soil Particle	Percentage (%)
Gravel	46 - 88
Sand	10 - 33
Silt and Clay	2 - 22

5.2.2 Sand with Gravel and Silt

A 0.3 m thick deposit of native sand with gravel and silt was encountered below the rockfill layer in Borehole 5 and below the rootmat in Borehole 9. The underside of the sand was at 3.3 m (elev. 106.5 m) below the existing roadway surface in Borehole 5 and at 0.4 m (elev. 107.3 m) below the ground surface in Borehole 9.

Recorded moisture contents were 7 and 9%. A single gradation analysis was completed on the sand with gravel and silt, and indicated a material with 39% gravel, 48% sand and 13% fines. The results of the grain size analysis are illustrated on Figure C5 in Appendix C.

5.2.3 Bedrock

The overburden materials were underlain by limestone bedrock. Boreholes 4, 5, 6 and 9 were advanced into the bedrock by coring. The bedrock surface ranges from elevation 105.2 to 107.3 m.

The Total Core Recovery (TCR) ranged from 94 to 100%, the Solid Core Recovery (SCR) ranged from 45 to 100% and the Rock Quality Designation (RQD) ranged from 22 to 100%. Based on the RQD value the bedrock is classified as poor to excellent quality. Unconfined Compressive Strength tests indicated a compressive strength of 159 to 162 MPa. Unconfined Compressive Strengths interpreted from point load tests indicate a very strong rock.

5.2.4 Groundwater

The culvert outlet was partially submerged at the time of the field investigation. Following the completion of drilling a standpipe piezometer was installed in Borehole 6. During a site visit on April 25, 2017 the groundwater in the standpipe was observed at 0.02 m (elevation 106.4 m) below the ground surface.

These observations are considered short term and it should be noted that the groundwater level at the time of construction may vary and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation events.

5.3 Culvert 3B (E-S Ramp): Boreholes 7, 8 and 9

5.3.1 Pavement Structure and Embankment Fill

Asphalt:

Borehole 8 was drilled through the existing E-S Ramp embankment and encountered a surficial layer of asphalt with a thickness of 150 mm.

Rootmat:

A 50 mm and 100 mm thick layer of rootmat was encountered at surface near the inlet in Borehole 7 and outlet in Borehole 9. The moisture content of a single sample was recorded at 29%.

Sand with Gravel Fill:

Below the asphalt pavement in Borehole 8 was a layer of fill consisting of sand with gravel. The underside of the sand with gravel fill was at 0.8 m depth below the existing roadway surface (elev. 111.9 m).

A single SPT test conducted in the sand with gravel fill gave a N-value of 58 blows indicating a very dense relative density. A single moisture content was recorded at 5%.

Gravel with Sand and Silt Fill:

Below the sand with gravel fill in Borehole 8 was a layer of fill consisting of gravel with sand and silt. The underside of the gravel fill was 2.1 m (elev. 110.5 m) below the existing roadway surface.

The SPT tests conducted in the fill gave N-values of 21 and 33 blows indicating a relative density of compact to dense. Recorded moisture contents were 7 and 8%. A single gradation analysis was completed on the gravel fill and indicated a material with 72% gravel, 22% sand and 6% fines. The results of the grain size analysis is illustrated on Figure C4 in Appendix C.

Gravel/Cobbles Fill with Sand:

Below the gravel fill in Borehole 8 and below the rootmat in Borehole 7 was a layer of fill consisting of silty gravel and cobbles with sand. The underside of the gravel and cobble fill was at 4.4 m (elev. 108.3 m) below the existing roadway surface in Borehole 8 and at 1.0 m (elev. 108.7 m) below the ground surface in Borehole 7.

The SPT tests conducted in the fill gave N-values ranging from 5 to 26 blows indicating a relative density of compact. Recorded moisture contents ranged from 9 to 13%. The results of grain size analyses conducted on two samples of the gravel and cobble fill are summarized below and are illustrated on Figure C4 in Appendix C. It is noted that the recovered samples did not include cobbles and boulders and the results of grain size analyses only reflect the gradation of the recovered portion of the fill material

Soil Particle	Percentage (%)
Gravel	47 and 48
Sand	33 and 34
Silt and Clay	20 and 18

5.3.2 Gravel with Sand and Silt to Sand with Gravel and Silt

A deposit of gravel with sand and silt to sand with gravel and silt was encountered below the fill in Boreholes 7 and 8 and below the rootmat in Borehole 9. This layer has a thickness ranging from 0.3 m to 1.5 m with an underside elevation of 106.7 to 107.7 m. Due to the presence of cobbles and boulders, Boreholes 7, 8 and 9 were advanced through this material with casing and coring techniques. Boulders as large as 250 mm were cored within the this layer.

The SPT tests conducted in the fill gave N-values of greater than 100 blows indicating a relative density of very dense. Recorded moisture contents ranged from 7 to 8%. A single gradation analysis was completed on the sand with gravel and silt and indicated a material with 39% gravel, 48% sand and 13% fines. The results of the grain size analysis is illustrated on Figure C5 in Appendix C.

5.3.3 Bedrock

The overburden materials were underlain by limestone bedrock. Boreholes 7, 8 and 9 were advanced into the bedrock by coring. The bedrock surface ranges from elevation 106.7 to 107.7 m.

The Total Core Recovery (TCR) ranged from 96 to 100%, the Solid Core Recovery (SCR) ranged from 85 to 100% and the Rock Quality Designation (RQD) ranged from 59 to 100%. Based on the RQD value the bedrock is classified as fair to excellent quality.

5.3.4 Groundwater

Water was flowing through the culvert at the time of the field investigation. Following the completion of drilling, a standpipe piezometer was installed in Boreholes 7 and 9. During a

site visit on April 25, 2017 the groundwater in the standpipes were observed at 0.25 m below the ground surface (elevation 109.5m) and 0.14 m above the ground surface (elevation 107.8 m) in Boreholes 7 and 9 respectively.

These observations are considered short term and it should be noted that the groundwater level at the time of construction may vary and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation events.

5.4 Culvert 4 (W-N Ramp and S-E/W Ramp): Boreholes 10, 11, 12 and 13

5.4.1 Pavement Structure and Embankment Fill

Asphalt:

Boreholes 11 and 12 were drilled through the existing W-N Ramp and S-E/W ramp embankments and encountered a surficial layer of asphalt with a thickness of 175 mm and 125 mm, respectively.

Rootmat:

A 50 mm thick layer of rootmat was encountered at the surface near the inlet and outlet in Boreholes 10 and 13.

Gravel with Sand and Silt to Silty Gravel with Sand Fill:

Below the asphalt pavement in Borehole 11 and 12 was a fill material consisting of predominantly gravel. This fill layer contained occasional cobbles. The underside of the fill was at 7.8 m and 6.9 m depths (elev. 102.9 m and 102.5) below the existing roadway surface in Boreholes 11 and 12 respectively.

The SPT tests conducted in the fill gave N-values ranging from 8 to greater than 100 blows indicating a relative density of loose to very dense, although most of the fill is in a compact to dense state. Recorded moisture contents ranged from 2 to 22%. The results of grain size analyses conducted on five samples of the gravel fill are summarized below and are illustrated on Figure C6 in Appendix C.

Soil Particle	Percentage (%)
Gravel	38 - 76
Sand	19 - 39
Silt and Clay	5 - 23

5.4.2 Clay

A native deposit of clay with variable amounts of sand and gravel was encountered below the fill in Borehole 12 and below the surficial rootmat in Borehole 13. This layer has a thickness of 2.2 m with an underside elevation of 100.2 to 100.3 m.

The SPT tests conducted in the clay gave N-values ranging from 3 to 22 blows indicating a soft to very stiff state. One N-value of greater than 100 blows was encountered in Borehole 13 likely due to the presence of occasional cobbles within the stratum. Recorded moisture

contents ranged from 18 to 37%. The results of grain size analyses conducted on two samples of the clay are summarized below and are illustrated on Figure C7 in Appendix C.

Soil Particle	Percentage (%)
Gravel	3 and 19
Sand	33 and 18
Silt	42 and 32
Clay	22 and 31

Atterberg Limit testing was completed on two samples of the clay. The results are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graphs are included in Figure C10 of Appendix C. The laboratory results are summarized below and indicate that the clay exhibits low to intermediate plasticity (CL to CI).

Parameter	Value
Liquid Limit	29 and 42
Plastic Limit	16 and 20
Plasticity Index	22 and 13

5.4.3 Silty Sand

A native deposit of Silty Sand with variable amounts of gravel, cobbles, and boulders was encountered in all boreholes. Boulder sizes ranged from 510 to 685 mm. This layer was found below the fill in Borehole 11, and below the clay in Borehole 12 and 13, and below the surficial rootmat in Boreholes 10. All four boreholes were terminated within this layer at elevations of 98.2 to 100.9 m. The SPT N-values ranged from 3 to greater than 100 blows per 300 mm. The deposit is generally dense to very dense.

The moisture content of the samples tested ranged from 8% to 22%. The results of grain size analyses conducted on four samples of the native silty sand are summarized below and are illustrated on Figure C8 in Appendix C.

Soil Particle	Percentage (%)
Gravel	17 - 37
Sand	40 - 49
Silt and Clay	23 - 34

5.4.4 Bedrock

Bedrock was not encountered within the depth of investigation at this culvert site.

5.4.5 Groundwater

Water was flowing through the culvert at the time of the field investigation. Following the completion of drilling, a standpipe piezometer was installed in Boreholes 10 and 13. During a site visit on April 25, 2017 the groundwater in the standpipes were observed at 0.27 m

below the ground surface (elevation 102.3m) and 0.09 m above the ground surface (elevation 105.2 m) in Boreholes 13 and 10 respectively.

These observations are considered short term and it should be noted that the groundwater level at the time of construction may vary and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation events.

5.5 Culvert 6 (Highway 416 Southbound): Boreholes 14, 15 and 16

5.5.1 Pavement Structure and Embankment Fill

Asphalt:

Borehole 15 was drilled through the existing southbound median paved shoulder encountered a surficial layer of asphalt with a thickness of 50 mm.

Silty Sand with Gravel Fill:

Below the asphalt pavement in Borehole 15 was a layer of fill consisting of silty sand with gravel. The underside of the silty sand fill was at 0.9 m depth below the existing roadway surface (elev. 110.0 m).

The SPT tests conducted in the silty sand fill gave N-value of 24 blows indicating a relative density of compact. A single moisture content was recorded at 4%. A single gradation analysis was completed on the silty sand fill and indicated a material with 40% gravel, 48% sand and 12% fines. The results of the grain size analysis is illustrated on Figure C9 in Appendix C.

Rock Shatter Fill:

Below the silty sand fill in Borehole 15 and at surface in Borehole 14 was a layer of rock shatter fill containing gravel and cobble sized particles. This layer has a thickness ranging from 0.9 m to 1.3 m with an underside elevation of 108.6 to 108.7 m.

The SPT tests conducted in the rock shatter fill gave N-values of 13 to greater than 100 blows indicating a relative density of compact to very dense. Recorded moisture contents ranged from 9 to 11%. The results of grain size analyses conducted on two samples of the rock shatter fill are summarized below and are illustrated on Figure C9 in Appendix C. It is noted that the recovered samples did not include cobbles and boulder sizes and the results of grain size analyses only reflect the gradation of the recovered portion of the fill material

Soil Particle	Percentage (%)
Gravel	68 and 69
Sand	28 and 28
Silt and Clay	4 and 3

5.5.2 Clay with Gravel

A 0.5 m thick deposit of clay with gravel was encountered at surface in Borehole 16. This material was noted to contain frequent cobbles and boulders. A single SPT test conducted in the clay with gravel gave a N-value of greater than 100 blows. The N-value of greater than 100 blows was due to the presence of cobbles and boulder within the stratum. A single moisture content was recorded at 36%.

5.5.3 Bedrock

The overburden materials were underlain by limestone bedrock. Boreholes 14, 15 and 16 were advanced into the bedrock by coring. The bedrock surface ranges from elevation 108.6 to 109.0 m.

The Total Core Recovery (TCR) ranged from 94 to 100%, the Solid Core Recovery (SCR) ranged from 81 to 100% and the Rock Quality Designation (RQD) ranged from 26 to 95%. Based on the RQD value the bedrock is classified as poor to excellent quality. Unconfined Compressive Strength tests indicated a compressive strength of 143 to 168 MPa. Unconfined Compressive Strengths interpreted from point load tests indicate a very strong rock.

5.5.4 Groundwater

Following the completion of drilling, a standpipe piezometer was installed in Borehole 14. During a site visit on April 25, 2017 the groundwater in the standpipe was observed at 0.13 m below the ground surface (elevation 109.4m).

These observations are considered short term and it should be noted that the groundwater level at the time of construction and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation events.

5.6 Analytical Testing

Four samples of soil were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis results are summarized in the table below:

Borehole	Sample	Depth (m)	Sulphate (µg/g)	pH (-)	Resistivity (Ohm-cm)	Chloride (µg/g)
1	SS2	0.8 – 1.4	33	7.7	2960	120
7	SS1B	0.1 – 0.6	9	7.8	2700	148
13	SS1	0 – 0.6	47	7.7	1350	239
16	SS1	0 – 0.4	36	7.5	1760	189

6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to existing site features and the anticipated foundation locations. The as-drilled locations and ground surface elevation were surveyed by MMM following completion of the field program.

Marathon Drilling of Greely, Ontario supplied and operated the drilling equipment to conduct the drilling, soil sampling, in-situ testing and borehole decommissioning. The field investigation was supervised on a full time basis by Mr. Chris Murray, E.I.T., Justin Gray, E.I.T., Mr. Nick Weil, and Mr. Sean O'Bryan of Thurber. Overall supervision of the investigation program was conducted by Mr. Shawn Lapain, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa, Ontario. Interpretation of the factual data and preparation of this report were carried out by Mr. Justin Gray, E.I.T. and Mr. Paul Carnaffan P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundation Projects.



Justin Gray, E.I.T.
Geotechnical Engineer-In-Training



Paul Carnaffan, P.Eng.
Principal
Senior Geotechnical Engineer



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**FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 416 - FALLOWFIELD ROAD
OTTAWA, ON**

**4015-E-0013, G.W.P. 4096-16-00
Geocres No.: 31G5-281**

PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This section of the report provides an interpretation of the factual data from Part 1 of this report and presents a foundation engineering assessment and discussion to assist the design team in designing a suitable method for the proposed replacement of the existing culverts crossing Highway 416 and the ramps at the Highway 416 Fallowfield Road interchange. The discussion and recommendations presented in this report are based on the information provided by WSP | MMM and on the factual data obtained during the course of the investigation.

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 or design-build contractor. The construction or design-build 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.

7.1 Proposed Work

The existing culverts are non-structural corrugated steel pipe (CSP) culverts ranging in size from 610 to 1105 mm diameter. It is understood that the culverts are to be replaced due to existing poor conditions and/or to increase the diameter to the current design standard of a minimum 800 mm diameter for freeways.

At the time of preparation of the draft Foundation Investigation and Design Report, it was understood that the replacement culverts are to be circular pipe culverts; in most cases with similar cross-sectional areas and invert elevations as the existing culverts.

All further discussions will be based on the assumption that the replacement culverts are to be circular pipe culverts.

The following table summarizes the existing culvert's size, inlet and outlet invert elevations, and the proposed culvert size as determined by MMM | WSP.

Culvert	Length (m)	Existing Diameter (mm)	Proposed Diameter (mm)	Existing Inlet Invert Elevation (m)	Existing Outlet Invert Elevation (m)	Roadway Elevation (m)	Existing Fill Height (m)
1	31.0	610	800	106.070	105.140	110.100	3.9
3A	77.8	660/1105 (SB 416/ NB 416)	800	107.316	105.341	109.800	2.8/ 3.2
3B	30.0	800	800	109.229	107.600	112.700	4.0
4	88.0	900/1105 (W-N ramp/ S-EW ramp)	900	104.567	102.216	110.700/ 109.300	6.5/ 6.0
6	23.1	610	800	109.432	109.079	110.900	1.4

No previous foundation investigation information for the subject culverts was available in the Geocres Library.

7.2 Design Considerations

Design considerations for the proposed culvert replacements include the following:

- Replacement of the culverts using trenchless techniques would limit the impacts to traffic in terms of required lane reductions and/or ramp closures.
- The main lanes of Highway 416 and the ramps were resurfaced in 2016. Replacement using trenchless techniques would avoid the need for excavation and patching through the new asphalt surface.
- It is noted that rock cuts and shallow bedrock are present throughout portions of the interchange. Replacement of the culverts on new alignments may require rock excavation at some locations.
- Historical contract drawings and the borehole records from the current investigation indicated the presence of rock fill within some of the ramp embankments. The presence of rock fill increases the risk of obstructions for small diameter trenchless installations.
- Adequate space for entry and exit pits is required for trenchless techniques and must be considered.
- The depth of cover at Culvert 6 is only 1.1 m and increasing the culvert diameter could result in a depth of cover of less than 1 m.

Design considerations, including ground conditions, are discussed further in section 8 and Appendix E on a culvert specific basis.

7.3 Frost Depth

The depth of frost penetration at this site is 1.8 m as per OPSD 3090.101. All existing founding soils onsite are considered to have a low susceptibility to frost heave. The need for frost tapers will need to be considered for excavation and backfill for culverts replaced using open cut techniques as per OPSD 803.031. Frost tapers are not required when the frostline falls above the pipe. Frost tapers are not required in rockfills.

8 DESIGN OPTIONS

8.1 Culvert Type and Foundation Alternatives

At the time of preparation of the draft Foundation Investigation and Design Report, it was understood that the replacement culverts are to be circular pipe culverts (Concrete, HDPE, Steel).

8.2 Construction Methodology Alternative

For the proposed culvert replacements, the following construction methods were considered.

- Open Cut with Ramp Closure
Installation of a new culvert using open cut techniques and a full ramp closure would allow for an expedited construction schedule and could reduce costs associated with requiring roadway protection and water diversion. However, it is understood that ramp closures may be restricted to very short duration.
- Open Cut with Staged Replacement
The use of open cut techniques in conjunction with staged culvert replacement is a feasible construction option from a geotechnical perspective. Depending on highway design requirements, the staging may require the use of temporary protection systems or temporary embankment widenings.
- Trenchless Techniques
Trenchless techniques such as Jack and Bore, Micro tunnelling with pipe jacking, Pipe Ramming or Pipe Bursting would have the advantage of minimum disruption to traffic and would avoid an excavation through the existing highway embankment. However, the available cover above the culvert and the fill materials present precludes the use of trenchless for Culverts 3A and Culvert 6 which are both beneath lanes of Highway 416. Regarding Culverts 1, 3B, and 4, cohesionless soils containing cobbles and boulders limit which techniques are feasible.

A detailed comparison of the following open cut and various trenchless methods are included in Appendix E on a culvert by culvert basis.

8.3 Recommended Approach for the Culvert Replacements

From a foundation engineering perspective, replacing each of the existing culverts with a circular pipe culvert using open cut techniques is the recommended culvert replacement option for all culverts. Subsequent discussion with the design team and Ministry staff has indicated that replacement with open cut techniques and short term lane/ramp closures is feasible.

9 CEMENT TYPE AND CORROSION POTENTIAL

Analytical tests were completed to determine the potential for degradation of concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel. The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble

sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. The class of concrete selected should consider the effects of road de-icing salts.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The tests results provided in Section 5.3 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosive effects of road de-icing salts should also be considered.

10 CONSTRUCTION CONSIDERATIONS

Since the recommendation is for replacement of the culverts using open-cut techniques, and the culverts are non-structural culverts, most of the recommendations for excavation, bedding, backfill and pavement reinstatement will be provided in a pavement design memo and will follow OPSS.PROV 421.

It is understood that culverts within the ramps will be completed under full ramp closures and that culverts beneath the lanes of Highway 416 will be completed using full lane closures with traffic by-passed around the work zone using 'ramp surfing'. Therefore, the need for temporary protection systems is not anticipated.

10.1 Excavations

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the fills and native soils above the water table may be classified as Type 3 soil. Any native alluvium or granular soils or fills below the groundwater level are classified as Type 4 soils. Excavation into bedrock can be classified as a Type 1 soil. The sides of temporary excavations must be sloped in accordance with the requirement of the OHSA.

It is recommended that an NSSP be included in the tender documents to alert the Contractor to the potential for encountering cobbles and boulders and obstructions within the rock fill and glacial till deposits during excavation.

10.2 Dewatering and Groundwater Control

Dewatering and a temporary flow passage system will be required for replacement of the culverts. The work should be carried out in accordance with OPSS.PROV 517 Construction Specification for Dewatering.

10.3 Construction Concerns


Potential construction concerns include, but are not necessarily limited to:

- The contractor may encounter obstructions within rock fill embankments or boulders within glacial till deposits during excavation.
- Some rock excavation may be required for replacement on new alignments or for replacement on existing culvert alignments where the culvert diameter is to be increased.

11 CLOSURE

Engineering analysis and preparation of this report were carried out by Mr. Justin Gray E.I.T. and Mr. Paul Carnaffan, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng a Designated Principal Contact for MTO Foundation Projects.

Thurber Engineering Ltd.
Report Prepared By:



Justin Gray, E.I.T.
Geotechnical Engineer-In-Training



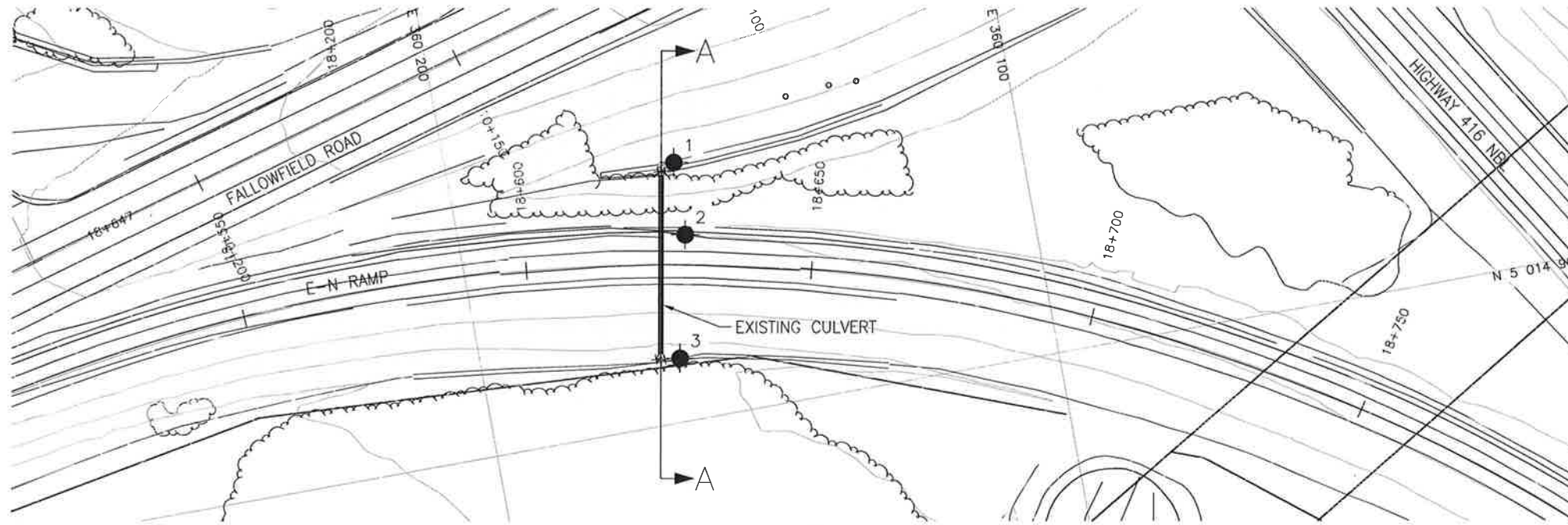
Paul Carnaffan, P.Eng.
Principal
Senior Geotechnical Engineer



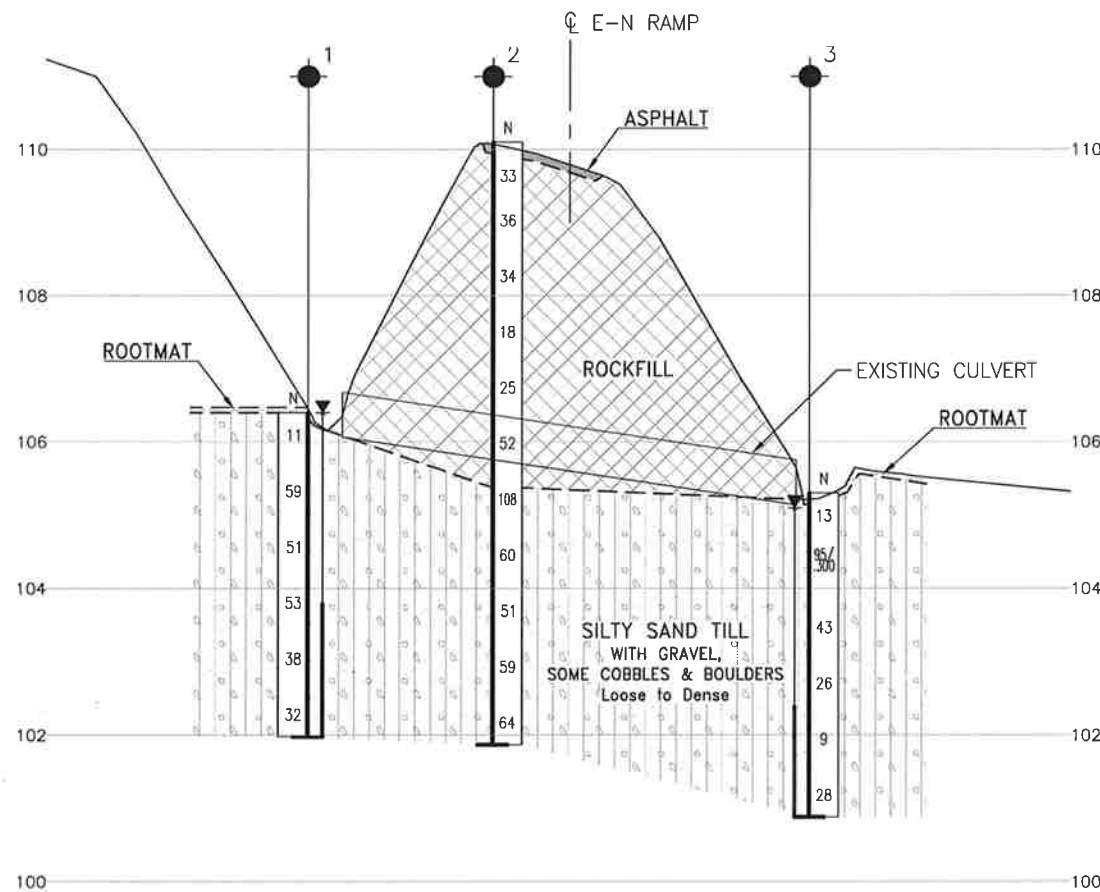
Dr. P.K. Chatterji, P.Eng.
Review Principal,
Senior Geotechnical Engineer

Appendix A.

Borehole Location Plan and Stratigraphic Drawings



PLAN
SCALE 1:1000



SECTION A-A

SCALE 1:500
SCALE 1:100



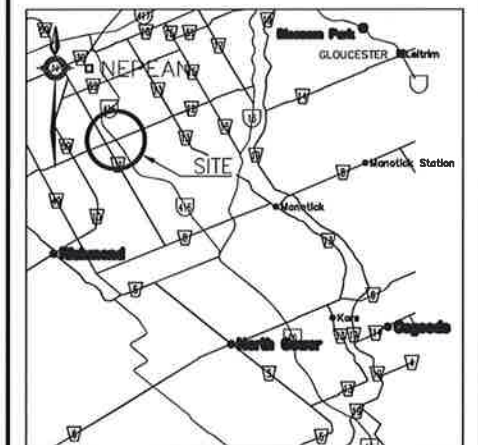
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
GWP No 4096-16-00

HWY 416/FALLOWFIELD RD
E-N RAMP
CULVERT C1
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

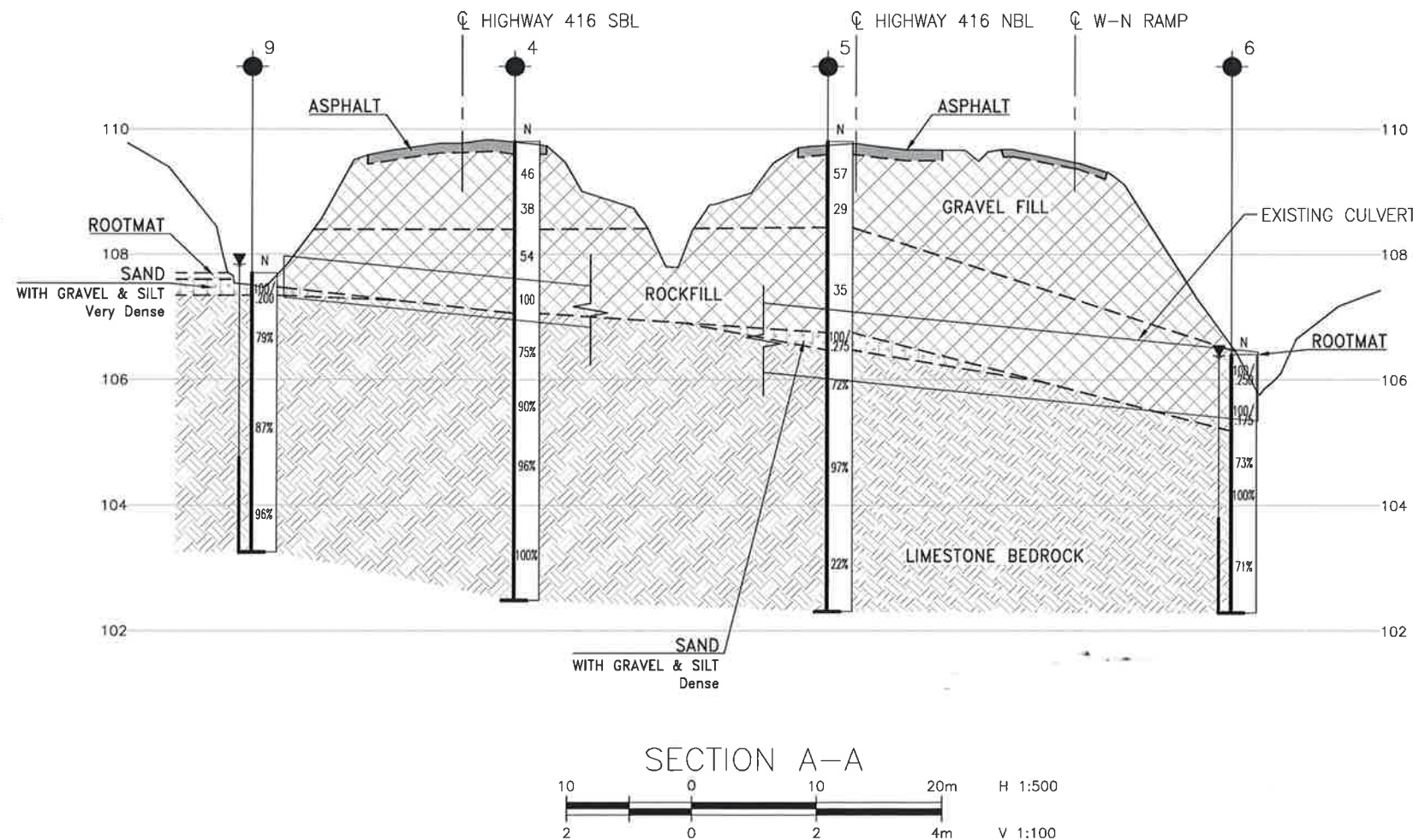
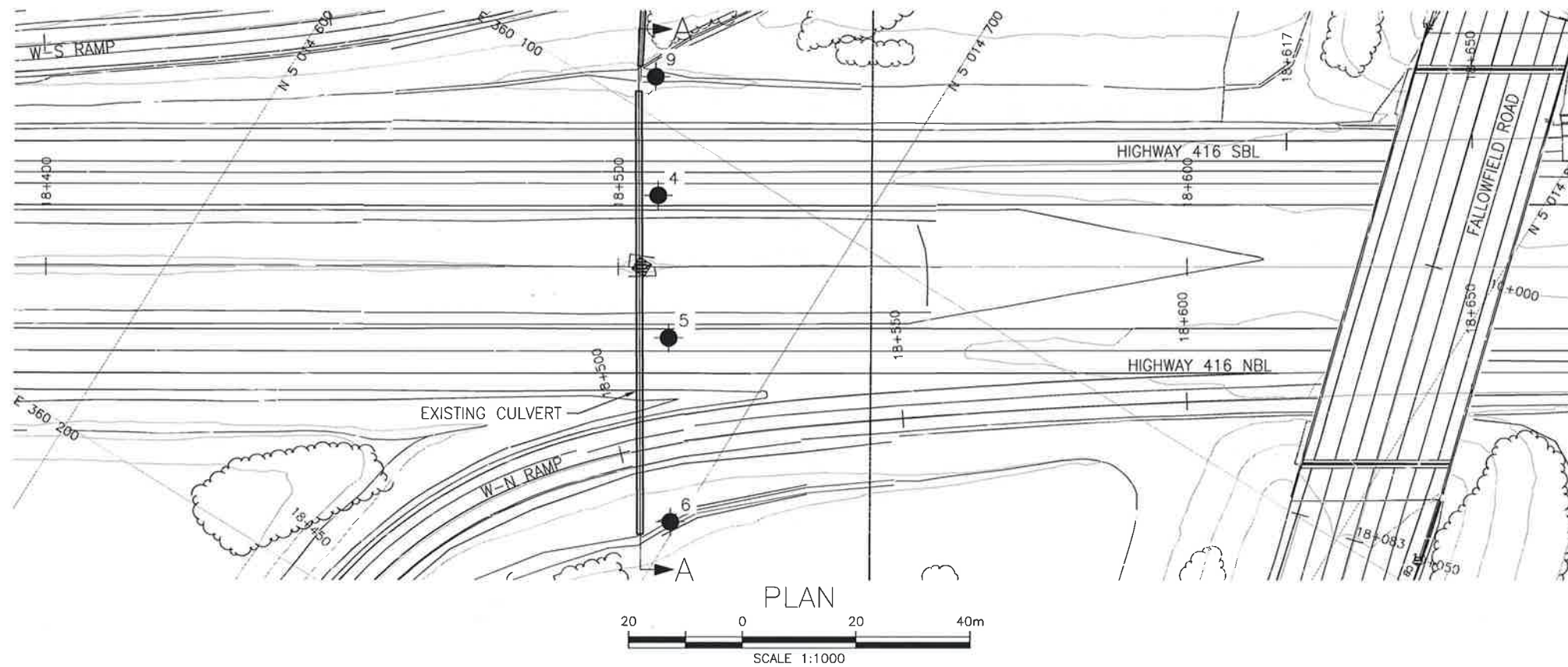
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1	106.4	5 014 854.9	360 160.5
2	110.1	5 014 867.7	360 160.7
3	105.3	5 014 888.9	360 165.5

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 31G5-281

DATE	BY	DESCRIPTION
DESIGN	JG	CHK PC
DRAWN	MFA	CHK JG
DATE	AUG 2017	
LOAD		
STRUCT		
DWG	1	



METRIC
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AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
GWP No 4096-16-00

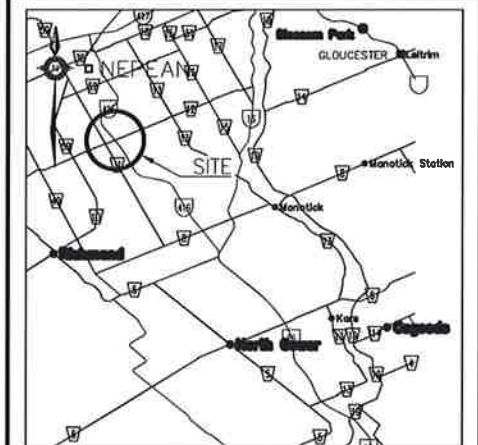
HWY 416/FALLOWFIELD RD
SBL, NBL AND W-N RAMP
CULVERT C3A
BOREHOLE LOCATIONS AND SOIL STRATA



MMM GROUP



THURBER ENGINEERING LTD.



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
4	109.8	5 014 666.7	360 111.3
5	109.8	5 014 681.5	360 131.6
6	106.4	5 014 698.8	360 158.8
9	107.7	5 014 655.3	360 093.8

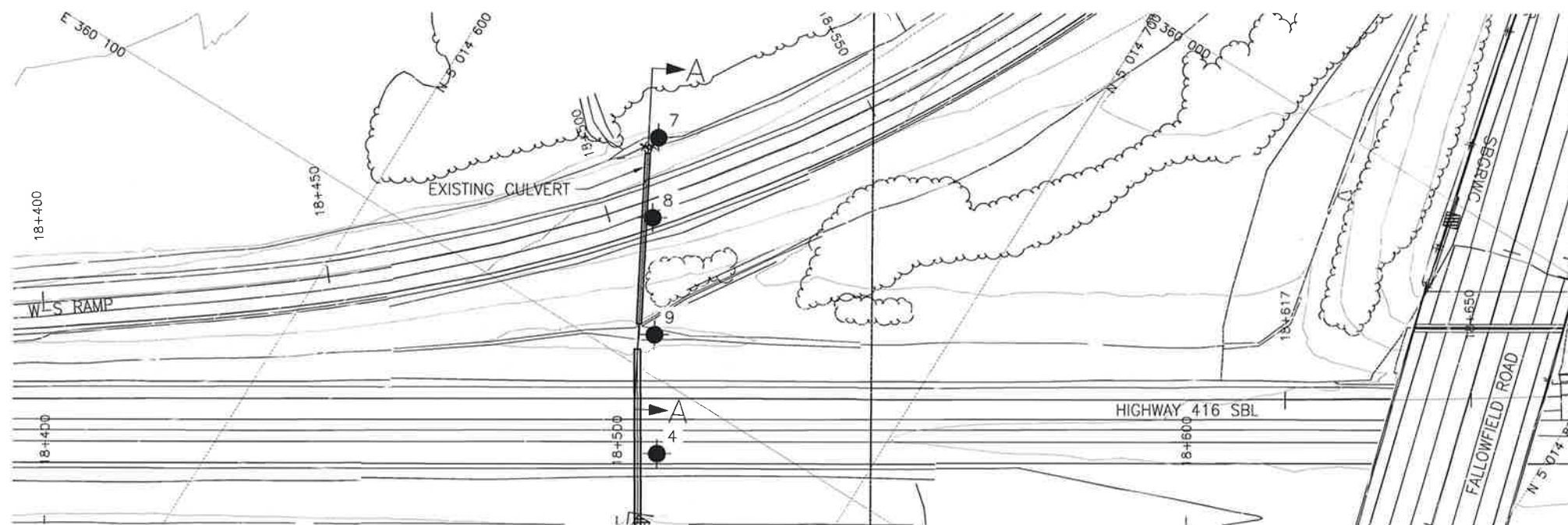
NOTES

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- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 31G5-281



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DESIGN	JG	CHK PC	CODE
DRAWN	MFA	CHK JG	SITE
			STRUCT
			DWG 1



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

CONT No
GWP No 4096-16-00



HWY 416/FALLOWFIELD RD
W-S RAMP
CULVERT C3B
BOREHOLE LOCATIONS AND SOIL STRATA








THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

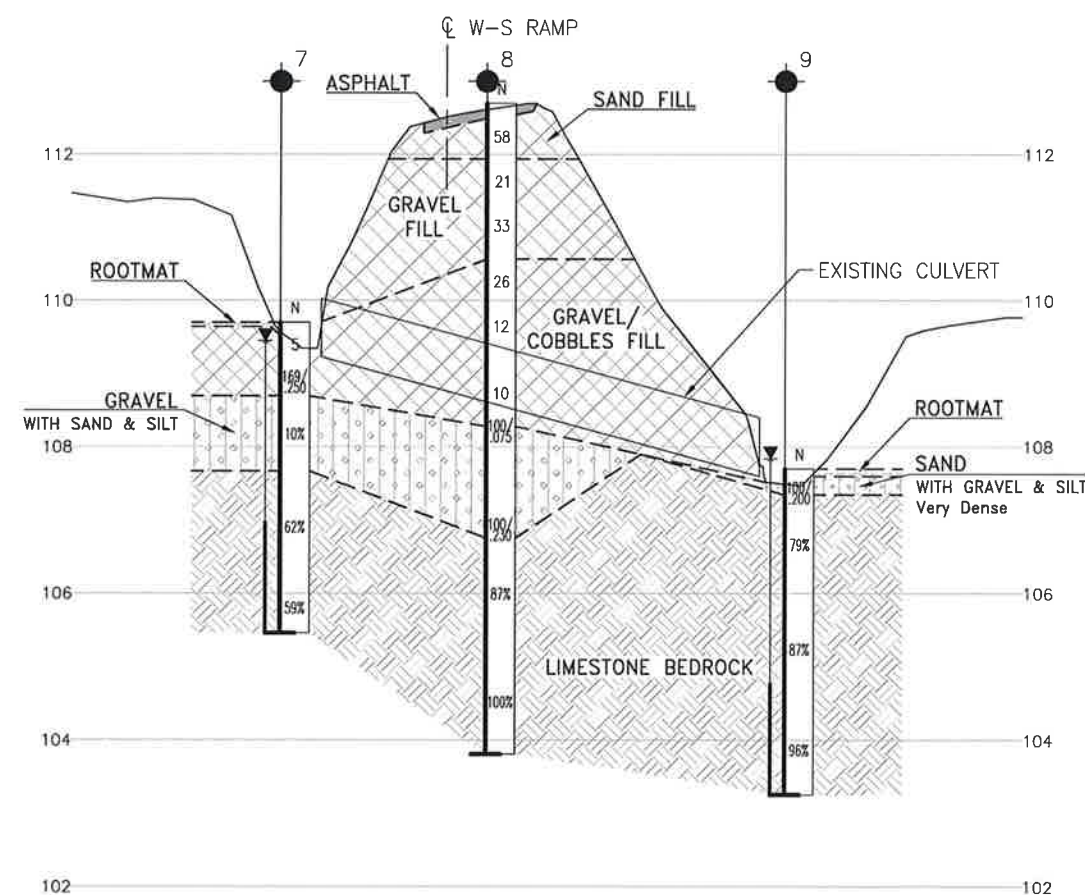
- | | |
|---|---------------------------------------|
|  | Borehole |
|  | Borehole and Cone |
| N | Blows /0.3m (Std Pen Test, 475J/blow) |
| CONE | Blows /0.3m (60' Cone, 475J/blow) |
| PH | Pressure, Hydraulic |
|  | Water Level |
|  | Head Artesian Water |
|  | Piezometer |
| 90% | Rock Quality Designation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

NO	ELEVATION	NORTHING	EASTING
7	109.7	5 014 637.7	360 064.
8	112.7	5 014 644.2	360 076.
9	107.7	5 014 655.3	360 093.

-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. 31G5-281



SECTION A-A



H 1:500

V 1:100

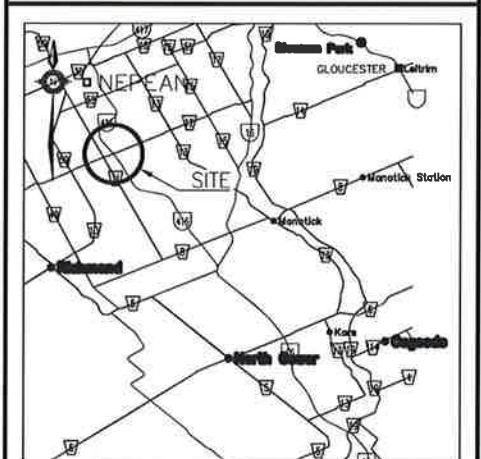


REVISIONS								
	DATE	BY	DESCRIPTION					
	DESIGN JG	CHK PC	CODE	LOAD		DATE	AUG 20	
	DRAWN MFA	CHK JG	SITE	STRUCT		DWG	1	

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

CONT No
GWP No 4096-16-00

HWY 416/FALLOWFIELD RD
W-N AND S-EW RAMP
CULVERT C4
BOREHOLE LOCATIONS AND SOIL STRATA



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

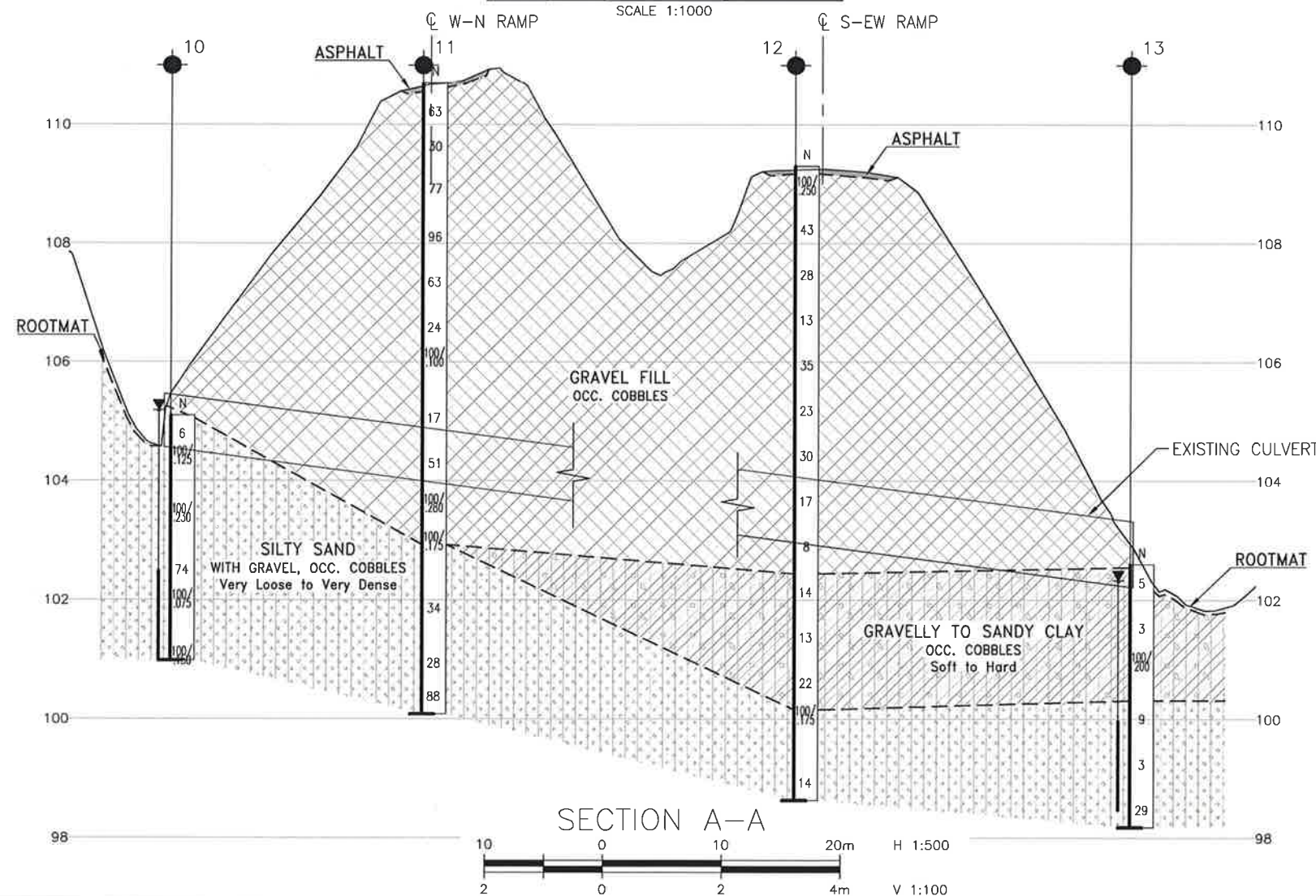
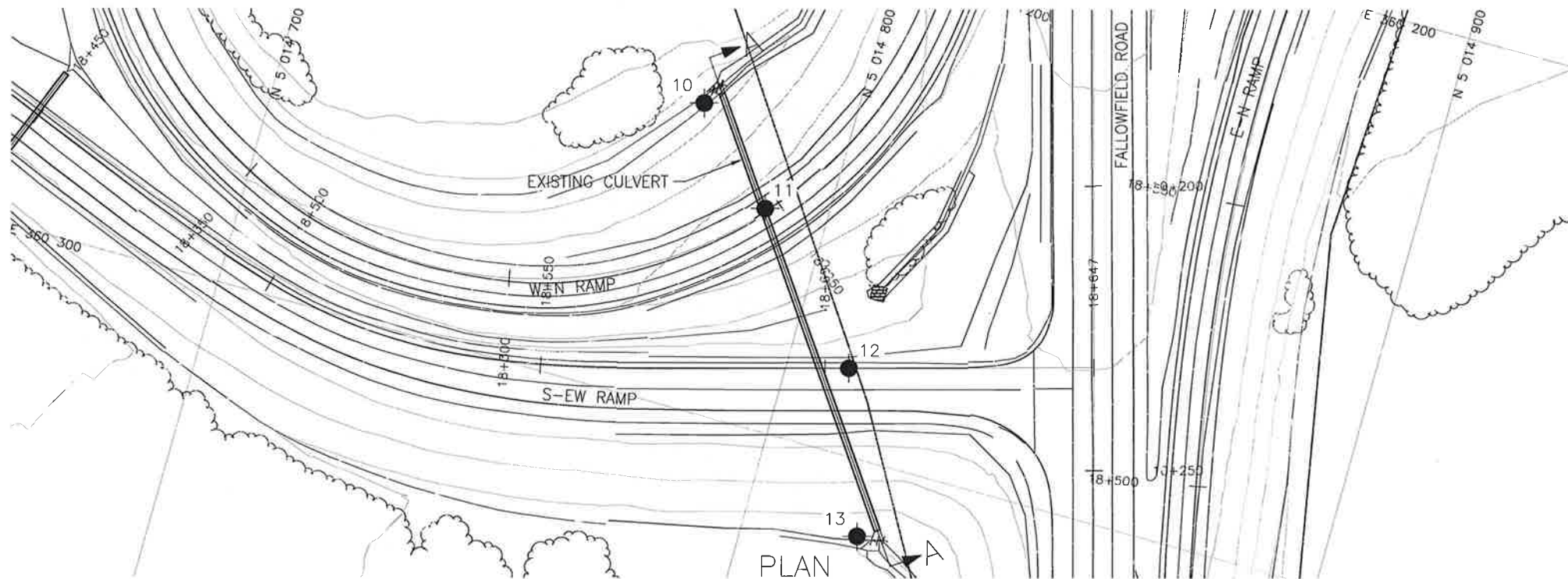
NO	ELEVATION	NORTHING	EASTING
10	105.1	5 014 773.6	360 246.9
11	110.7	5 014 789.0	360 261.9
12	109.3	5 014 810.7	360 285.0
13	102.6	5 014 820.0	360 313.1

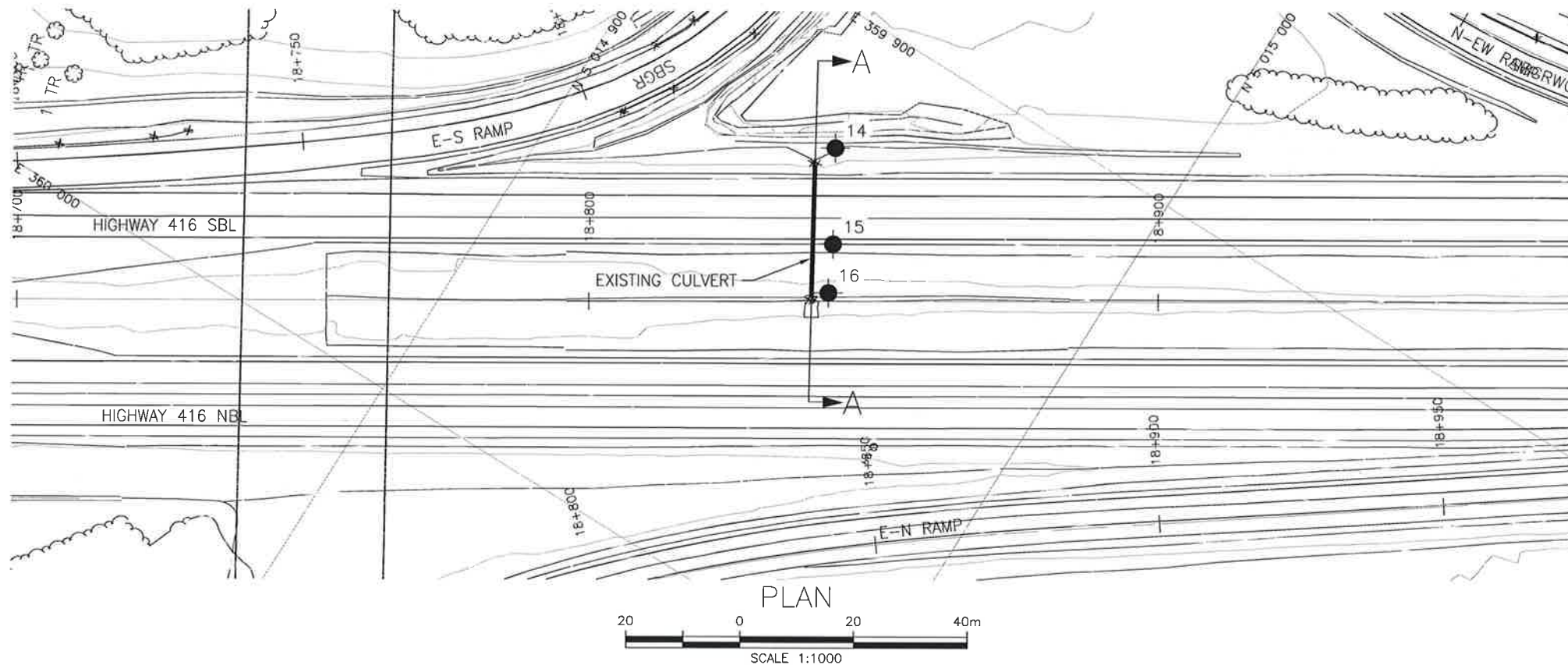
-NOTES-

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- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

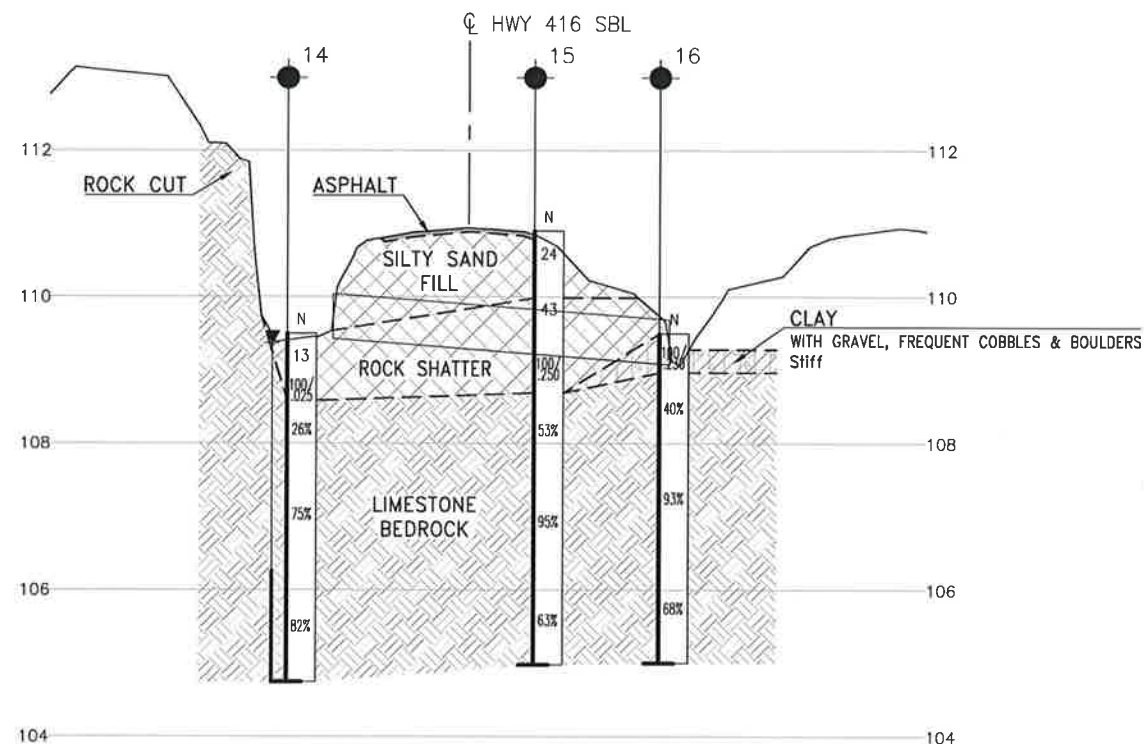
GEOCREs No. 31G5-281

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	JG	CHK PC	CODE
DRAWN	MFA	CHK JG	SITE
			STRUCT
			DWG 1





PLAN



SECTION A-A



H 1:500

V 1:100

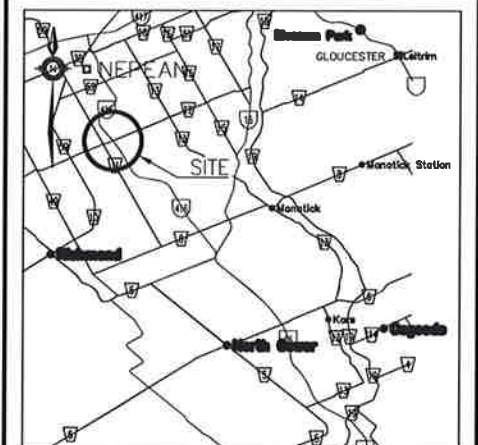
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
GWP No 4096-16-00

HWY 416/FALLOWFIELD RD
SOUTHBOUND LANES
CULVERT C6
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. 31G5-281

[illegible]

Appendix B.

**Symbols, Abbreviations and Terms Used on Test Hole Records
Record of Borehole Sheets**

SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

Desiccated	having visible signs of weathering by oxidization of clay materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "A" size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.

STRATA PLOT:

Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders
Cobbles
Gravel



Sand



Silt



Clay



Organics



Asphalt



Concrete



Fill



Bedrock

TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT “N” Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	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	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, 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.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note - W_L = Liquid Limit

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials.
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 structures are preserved.

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 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

DISCONTINUITY SPACING

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

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

RECORD OF BOREHOLE No 1

1 OF 1

METRIC

GWP# 4068-13-00 LOCATION Culvert 1 - Inlet N 5 014 854.9 E 360 160.5 ORIGINATED BY CAM
 HWY 416 BOREHOLE TYPE HSA COMPILED BY SML
 DATUM Geodetic DATE 2017.04.03 - 2017.04.03 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					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						
							WATER CONTENT (%)							
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT							
							W _p W W _L							
							20 40 60 80 100							
							20 40 60 80 100							
106.4														
0.0														
0.1	ROOTMAT (75 mm)		1	SS	11		106							15 52 33 (SI+CL)
	SILTY SAND with gravel, TILL Compact to very dense Wet													
			2	SS	59		105							
			3	SS	51		104							28 44 28 (SI+CL)
	- Frequent Cobbles/Boulders from 2.0 m to 2.6 m													
			4	SS	53		103							
			5	SS	38		102							
			6	SS	32									
102.0														
4.4	End of Borehole Groundwater in piezometer at Elev. 106.4 m on 25.04.2017													

ONTMT4S HWY 416 CULVERTS.GPJ 2012TEMPLATE(MTO).GDT 25/7/17

RECORD OF BOREHOLE No 2

1 OF 1

METRIC

GWP# 4068-13-00 LOCATION Culvert 1 - Embankment N 5 014 867.7 E 360 160.7 ORIGINATED BY JAG/NNW
 HWY 416 BOREHOLE TYPE HSA/NW Casing/NQ Coring COMPILED BY SML
 DATUM Geodetic DATE 2017.04.03 - 2017.04.10 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					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						
								20 40 60 80 100						
								20 40 60 80 100						
110.1														
0.0	ASPHALT (140 mm)						110							
0.2	ROCKFILL (GRAVEL/COBBLES with sand and silt) Very dense to compact Grey to brown Moist		1	SS	33									
			2	SS	36		109							
	- occasional to frequent cobbles from 0.9 m to 4.4 m, difficult augering		3	SS	34		108							67 22 11 (SI+CL)
			4	SS	18									
			5	SS	25		107							
			6	SS	52		106							51 33 16 (SI+CL)
105.4														
4.7	SILTY SAND with gravel, frequent to occasional cobble/boulder TILL Dense Brown Moist - borehole advanced from 4.7 m to 8.2 m using casing/coring techniques - 430 mm boulder at 4.7 m		7	SS	108		105							
			8	SS	60		104							
			9	SS	51									30 43 27 (SI+CL)
	- 380 mm boulder at 7.0 m		10	SS	59		103							
			11	SS	64		102							
101.9														
8.2	End of Borehole													

ONTMT4S HWY 416 CULVERTS.GPJ 2012TEMPLATE(MTO).GDT 25/7/17

+³, ×³: Numbers refer to
Sensitivity

20
15
10





(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 3

1 OF 1

METRIC

GWP# 4068-13-00 LOCATION Culvert 1 - Outlet N 5 014 888.9 E 360 165.5 ORIGINATED BY CAM/JAG
 HWY 416 BOREHOLE TYPE HSA COMPILED BY SML
 DATUM Geodetic DATE 2017.04.03 - 2017.04.03 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				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						
								20 40 60 80 100						
								20 40 60 80 100						
105.3														
0.0														
0.1	ROOTMAT (75 mm)		1	SS	13		105							26 50 24 (SI+CL)
	SILTY SAND with gravel, TILL loose to dense Brown to Brownish Grey Wet		2	SS	95/ 300mm		104							
			3	SS	43		103							
			4	SS	26		102							
	- clayey from 3.0 m to 3.8 m		5	SS	9		101							
100.8			6	SS	28									
4.4	End of Borehole Groundwater in piezometer at Elev. 105.1 m on 25.04.2017													

ONTMT4S HWY 416 CULVERTS.GPJ 2012TEMPLATE(MTO).GDT 25/7/17

RECORD OF BOREHOLE No 4

1 OF 1

METRIC

GWP# 4068-13-00 LOCATION Culvert 3A - Embankment N 5 014 666.7 E 360 111.3 ORIGINATED BY NNW
 HWY 416 BOREHOLE TYPE HSA/NQ Coring COMPILED BY SML
 DATUM Geodetic DATE 2017.04.10 - 2017.04.10 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					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							PLASTIC LIMIT W P NATURAL MOISTURE CONTENT W LIQUID LIMIT W L				
109.8 0.0	ASPHALT 200 mm							20	40	60	80	100							
0.2	GRAVEL, silty with sand FILL Dense Grey Dry		1	SS	46		109							○				59 29 12 (SI+CL)	
108.4			2	SS	38									○					
1.4	ROCKFILL (GRAVEL/COBBLES, silty with sand) Dense to Very Dense Brown Moist		3	SS	54		108							○				47 33 20 (SI+CL)	
107.1			4	SS	100									○					
2.7	BEDROCK Limestone Fresh Moderately Bedded Very Strong Grey		1	NQ			107											RUN #1 TCR=94% SCR=94% RQD=75%	
			2	NQ				106											RUN #2 TCR=100% SCR=100% RQD=90%
			3	NQ				105											RUN #3 TCR=100% SCR=96% RQD=96% UCS=159MPa
			4	NQ				104											RUN #4 TCR=100% SCR=100% RQD=100%
102.5							103												
7.3	End of Borehole																		

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

RECORD OF BOREHOLE No 5

1 OF 1

METRIC

GWP# 4068-13-00 LOCATION Culvert 3A - Embankment N 5 014 681.5 E 360 131.6 ORIGINATED BY NNW
 HWY 416 BOREHOLE TYPE HSA/NW Casing/NQ Coring COMPILED BY SML
 DATUM Geodetic DATE 2017.04.10 - 2017.04.10 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				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						PLASTIC LIMIT W _P NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L
109.8 0.0	ASPHALT 200 mm													
0.2	GRAVEL, silty with sand FILL Dense Grey Dry		1	SS	57									
			2	SS	29									
108.4														
1.4	ROCKFILL (GRAVEL/COBBLES, silty with sand) Compact to dense Brown to Grey Moist - auger refusal at 1.5 m, borehole advanced with casing/coring techniques from 1.5 m to 3.3 m - frequent cobbles from 1.5 m to 2.1 m - 360 mm boulder at 2.7 m		3	SS	35									
106.7														
3.0	SAND with gravel and silt Dense Grey Wet		4	SS	100/ 275 mm									
106.5			1	NQ										
3.3	BEDROCK Limestone Fresh Moderately Bedded Very Strong Grey		2	NQ										
			3	NQ										
102.3														
7.5	End of Borehole													

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 6

1 OF 1

METRIC

GWP# 4068-13-00 LOCATION Culvert 3A - Outlet N 5 014 698.8 E 360 158.8 ORIGINATED BY NNW
 HWY 416 BOREHOLE TYPE Portable/NQ Casing/BX Coring COMPILED BY SML
 DATUM Geodetic DATE 2017.04.04 - 2017.04.04 CHECKED BY PC

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							
106.4								20 40 60 80 100							
0.0	ROOTMAT (50 mm)		1	SS	100/250 mm			○ UNCONFINED + FIELD VANE							
0.1	ROCKFILL (GRAVEL/COBBLES some sand) Very Dense - 360 mm boulder at 0.3 m		2	SS	100/175 mm			● QUICK TRIAXIAL × LAB VANE							
105.2															
1.2	BEDROCK Limestone Fresh Moderate to thinly bedded Grey		1	BX											
			2	BX											
			3	BX											
			4	BX											
102.3															
4.1	End of Borehole Groundwater in piezometer at Elev. 106.4 m on 25.04.2017														

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

RECORD OF BOREHOLE No 7

1 OF 1

METRIC

GWP# 4068-13-00 LOCATION Culvert 3B - Inlet N 5 014 637.7 E 360 064.0 ORIGINATED BY CAM
 HWY 416 BOREHOLE TYPE Portable/NQ Casing/BX Coring COMPILED BY SML
 DATUM Geodetic DATE 2017.03.27 - 2017.03.27 CHECKED BY PC

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								
								20	40	60	80	100				
109.7																
0.0	ROOTMAT (50mm)															
0.1	GRAVEL/COBBLES, silty with sand FILL Loose to Very Dense Brown Wet		1	SS	5											
108.7			2	SS	169/ 250 mm											48 34 18 (SI+CL)
1.0	GRAVEL with sand and silt - frequent cobbles/boulders cored from 1.0 m to 2.0 m		1	BX												RUN #1 TCR=60% SCR=33% RQD=10%
107.7																
2.0	BEDROCK Limestone Fresh Moderately bedded Grey		2	BX												RUN #2 TCR=100% SCR=95% RQD=62%
105.5			3	BX												RUN #3 TCR=96% SCR=85% RQD=59%
4.2	End of Borehole Groundwater in piezometer at Elev. 109.5 m on 25.04.2017															

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

RECORD OF BOREHOLE No 8

1 OF 1

METRIC

GWP# 4068-13-00 LOCATION Culvert 3B - Embankment N 5 014 644.2 E 360 076.5 ORIGINATED BY SOB
 HWY 416 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY SML
 DATUM Geodetic DATE 2017.03.27 - 2017.03.27 CHECKED BY PC

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				WATER CONTENT (%)					
112.7								20	40	60	80	100					
0.0	ASPHALT 150 mm																
0.2	SAND with gravel FILL Very Dense Brown Moist		1	SS	58												
111.9																	
0.8	GRAVEL with sand and silt FILL Compact to dense Brown		2	SS	21												
			3	SS	33												
110.5																	
2.1	GRAVEL/COBBLES, silty with sand FILL - occasional cobbles 2.1 m to 4.4 m Compact to Very Dense Brown		4	SS	26												
			5	SS	12												
108.3			6	SS	10												
4.4	GRAVEL with sand and silt - frequent cobbles/boulders cored from 4.4 m to 5.9 m - 150 mm cobble at 4.9 m - 250 mm boulder at 5.2 m - 250 mm boulder at 5.5 m		7	SS	100 / 75 mm												
106.7			8	SS	100 /												
5.9	BEDROCK Limestone Fresh Moderately Bedded Grey				230 mm												
			1	NQ													
			2	NQ													
103.8																	
8.9	End of Borehole																

ONTMT4S HWY 416 CULVERTS.GPJ 2012TEMPLATE(MTO).GDT 25/7/17

+³ ×³: Numbers refer to
Sensitivity

20
15
10




(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 9

1 OF 1

METRIC

GWP# 4068-13-00 LOCATION Culvert 3B - Outlet N 5 014 655.3 E 360 093.8 ORIGINATED BY CAM
 HWY 416 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY SML
 DATUM Geodetic DATE 2017.04.11 - 2017.04.11 CHECKED BY PC

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										
107.7								20	40	60	80	100						
0.0																		
0.1	ROOTMAT (100 mm)		1	SS	100/													
107.3	SAND with gravel and silt -weathered limestone Very Dense Grey Wet				200 mm													
0.4	BEDROCK Limestone with occasional shale seam Fresh Moderately Bedded Grey		1	NQ														
			2	NQ														

ONTMT4S HWY 416 CULVERTS.GPJ 2012TEMPLATE(MTO).GDT 25/7/17

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

RECORD OF BOREHOLE No 10

1 OF 1

METRIC

GWP# 4068-13-00 LOCATION Culvert 4 - Inlet N 5 014 773.6 E 360 246.9 ORIGINATED BY CAM
 HWY 416 BOREHOLE TYPE Portable/NQ Casing COMPILED BY SML
 DATUM Geodetic DATE 2017.03.28 - 2017.04.04 CHECKED BY PC

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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W P W W L			
								○ UNCONFINED + FIELD VANE		WATER CONTENT (%)			
								● QUICK TRIAXIAL × LAB VANE					
105.1							20 40 60 80 100						
0.0	ROOTMAT (50 mm)												
0.1	SILTY SAND with gravel, occasional cobbles Very Dense Grey Wet		1	SS	6								
			2	SS	100/ 125 mm								
	- frequent cobbles from 0.7 m to 2.3 m		3	SS	100/ 230 mm								
			4	SS	74								
	- 685 mm boulder cored at 3.1 m		5	SS	100/ 75 mm								
100.9			6	SS	100/ 150 mm								
4.1	End of Borehole Groundwater in piezometer at Elev. 105.2 m on 25.04.2017												

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 11

1 OF 2

METRIC

GWP# 4068-13-00 LOCATION Culvert 4 - Embankment N 5 014 789.0 E 360 261.9 ORIGINATED BY SOB
 HWY 416 BOREHOLE TYPE NW Casing COMPILED BY SML
 DATUM Geodetic DATE 2017.03.28 - 2017.03.28 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								20 40 60 80 100				W P W L				
110.7																
0.0	ASPHALT 175 mm															
0.2	GRAVEL, silty with sand FILL , occasional cobbles Compact to Very Dense Brown		1	SS	63		110									
			2	SS	30											
			3	SS	77		109								58 26 16 (SI+CL)	
			4	SS	96		108									
			5	SS	63		107									
			6	SS	24										38 39 23 (SI+CL)	
	- cobble		7	SS	100 / 100 mm		106									
			8	SS	17		105									
			9	SS	51		104								49 33 18 (SI+CL)	
			10	SS	100 / 280 mm											
102.9			11	SS	100 / 175 mm		103									
7.8	SILTY SAND with gravel Very dense to compact Brown - 510 mm boulder cored at 7.8 m		12	SS	34		102									
			13	SS	28		101								28 46 26 (SI+CL)	

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 11

2 OF 2

METRIC

GWP# 4068-13-00 LOCATION Culvert 4 - Embankment N 5 014 789.0 E 360 261.9 ORIGINATED BY SOB
 HWY 416 BOREHOLE TYPE NW Casing COMPILED BY SML
 DATUM Geodetic DATE 2017.03.28 - 2017.03.28 CHECKED BY PC

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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%) W P W W L				
							20	40	60	80	100	20	40	60			
	Continued From Previous Page		14	SS	88												
100.1																	
10.6	End of Borehole																

RECORD OF BOREHOLE No 12

1 OF 2

METRIC

GWP# 4068-13-00 LOCATION Culvert 4 - Embankment N 5 014 810.7 E 360 285.0 ORIGINATED BY SOB
 HWY 416 BOREHOLE TYPE NW Casing COMPILED BY SML
 DATUM Geodetic DATE 2017.03.29 - 2017.03.29 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				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					
							WATER CONTENT (%)						
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT						
							W _p W W _L						
							20 40 60 80 100						
							20 40 60 80 100						
							20 40 60						
109.3													
0.0	ASPHALT 125 mm		1	SS	100 /								
0.1	GRAVEL with sand and silt, occasional cobbles FILL Very dense to loose Brown				250 mm		109						
			2	SS	43		108						56 37 7 (SI+CL)
			3	SS	28		107						
			4	SS	13		106						
			5	SS	35		105						76 19 5 (SI+CL)
	-poor sample recovery		6	SS	23		104						
			7	SS	30		103						
			8	SS	17		102						19 18 32 31
			9	SS	8		101						
102.5							100						
6.9	CLAY (Cl), gravelly with sand Stiff to very stiff Brown		10	SS	14								
			11	SS	13								
			12	SS	22								
100.2													
9.1	SILTY SAND with gravel, occasional cobbles Very dense Brown		13	SS	100 /								
					175 mm								

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

ONTMT4S HWY 416 CULVERTS.GPJ 2012TEMPLATE(MTO).GDT 25/7/17

RECORD OF BOREHOLE No 12

2 OF 2

METRIC

GWP# 4068-13-00 LOCATION Culvert 4 - Embankment N 5 014 810.7 E 360 285.0 ORIGINATED BY SOB
 HWY 416 BOREHOLE TYPE NW Casing COMPILED BY SML
 DATUM Geodetic DATE 2017.03.29 - 2017.03.29 CHECKED BY PC

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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)						
						20 40 60 80 100 20 40 60 80 100					W P	W	W L				
	Continued From Previous Page																
98.6	SILTY SAND with gravel, occasional cobbles Very dense Brown		14	SS	14		99										
10.7	End of Borehole																

RECORD OF BOREHOLE No 13

1 OF 1

METRIC

GWP# 4068-13-00 LOCATION Culvert 4 - Outlet N 5 014 820.0 E 360 313.1 ORIGINATED BY JAG
 HWY 416 BOREHOLE TYPE HSA COMPILED BY SML
 DATUM Geodetic DATE 2017.04.05 - 2017.04.05 CHECKED BY PC

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								
102.6																
0.9	ROOTMAT (50 mm)															
	CLAY (CL), sandy		1	SS	5											
	Soft to hard															
	Grey		2	SS	3											3 33 42 22
	Wet															
	- occasional cobble		3	SS	100 / 200 mm											
100.3																
2.3	SILTY SAND with gravel		4	SS	9											17 49 27 7
	Very loose to compact															
	Greyish brown		5	SS	3											
	Wet															
98.2			6	SS	29											
4.4	End of Borehole															
	Groundwater in piezometer at Elev. 102.3 m on 25.04.2017															

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

RECORD OF BOREHOLE No 14

1 OF 1

METRIC

GWP# 4068-13-00 LOCATION Culvert 6 - Inlet N 5 014 945.1 E 359 922.2 ORIGINATED BY CAM
 HWY 416 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY SML
 DATUM Geodetic DATE 2017.04.11 - 2017.04.11 CHECKED BY PC

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																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
109.5	ROCK SHATTER FILL (GRAVEL with frequent cobbles/boulders) Compact Grey Wet		1	SS	13																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							




ONTMT4S HWY 416 CULVERTS.GPJ 2012TEMPLATE(MTO).GDT 25/7/17

RECORD OF BOREHOLE No 15

1 OF 1

METRIC

GWP# 4068-13-00 LOCATION Culvert 6 - Embankment N 5 014 953.7 E 359 936.7 ORIGINATED BY CAM
 HWY 416 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY SML
 DATUM Geodetic DATE 2017.04.10 - 2017.04.10 CHECKED BY PC

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					GR SA SI CL			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%)								
110.9								20	40	60	80	100								
0.9	ASPHALT (50 mm)		1	SS	24									○						40 48 12 (SH+CL)
	SILTY SAND with gravel FILL Compact Brown Moist																			
110.0							110							○						69 28 3 (SH+CL)
0.9	ROCK SHATTER FILL (GRAVEL/COBBLES with sand) Very dense Grey - 100 mm cobble cored at 1.4 m - 125 mm cobble cored at 1.5 m		2	SS	43															
			3	SS	100 / 250 mm		109							○						
108.7																				
2.2	BEDROCK Limestone Fresh Moderately Bedded Grey		1	NQ			108													RUN #1 TCR=100% SCR=93% RQD=53%
			2	NQ			107													RUN #2 TCR=100% SCR=97% RQD=95%
	- occasional shale seams from 4.7 m to 5.9 m						106													RUN #3 TCR=94% SCR=94% RQD=63%
			3	NQ																
105.0							105													
5.9	End of Borehole																			


ONTMT4S HWY 416 CULVERTS.GPJ 2012TEMPLATE(MTO).GDT 25/7/17

RECORD OF BOREHOLE No 16

1 OF 1

METRIC

GWP# 4068-13-00 LOCATION Culvert 6 - Outlet N 5 014 957.5 E 359 944.4 ORIGINATED BY CAM
 HWY 416 BOREHOLE TYPE HSA/NW Casing/NQ Coring COMPILED BY SML
 DATUM Geodetic DATE 2017.04.10 - 2017.04.10 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					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								
								20 40 60 80 100								
109.5																
0.0	CLAY with gravel, frequent cobbles/boulders Stiff Brown Wet - auger refusal at 0.4 m BEDROCK Limestone Fresh Moderately bedded Very Strong Grey - occasional shale seams from 3.0 m to 4.5 m		1	SS	100 / 230 mm									RUN #1 TCR=100% SCR=97% RQD=40% UCS=168MPa		
109.0																
0.5			1	NQ												
			2	NQ												
			3	NQ												
105.0																
4.5	End of Borehole															

ONTMT4S HWY 416 CULVERTS.GPJ 2012TEMPLATE(MTO).GDT 25/7/17

Appendix C.

Laboratory Testing

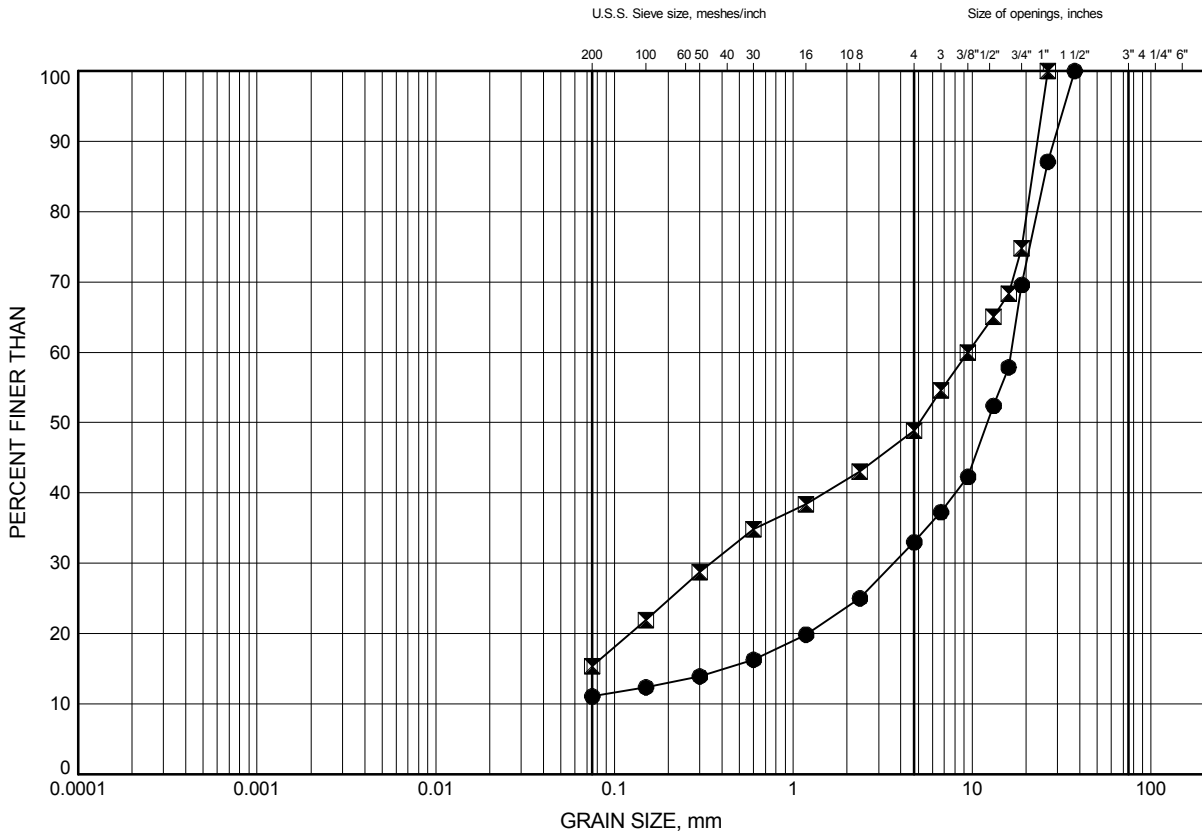
Appendix C.1
Particle Size Analysis Figures

Highway 416 Culverts

GRAIN SIZE DISTRIBUTION

FIGURE C1

Culvert 1, Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	2	1.83	108.26
⊠	2	4.11	105.98

Date June 2017

GWP# 4068-13-00



Prep'd JAG

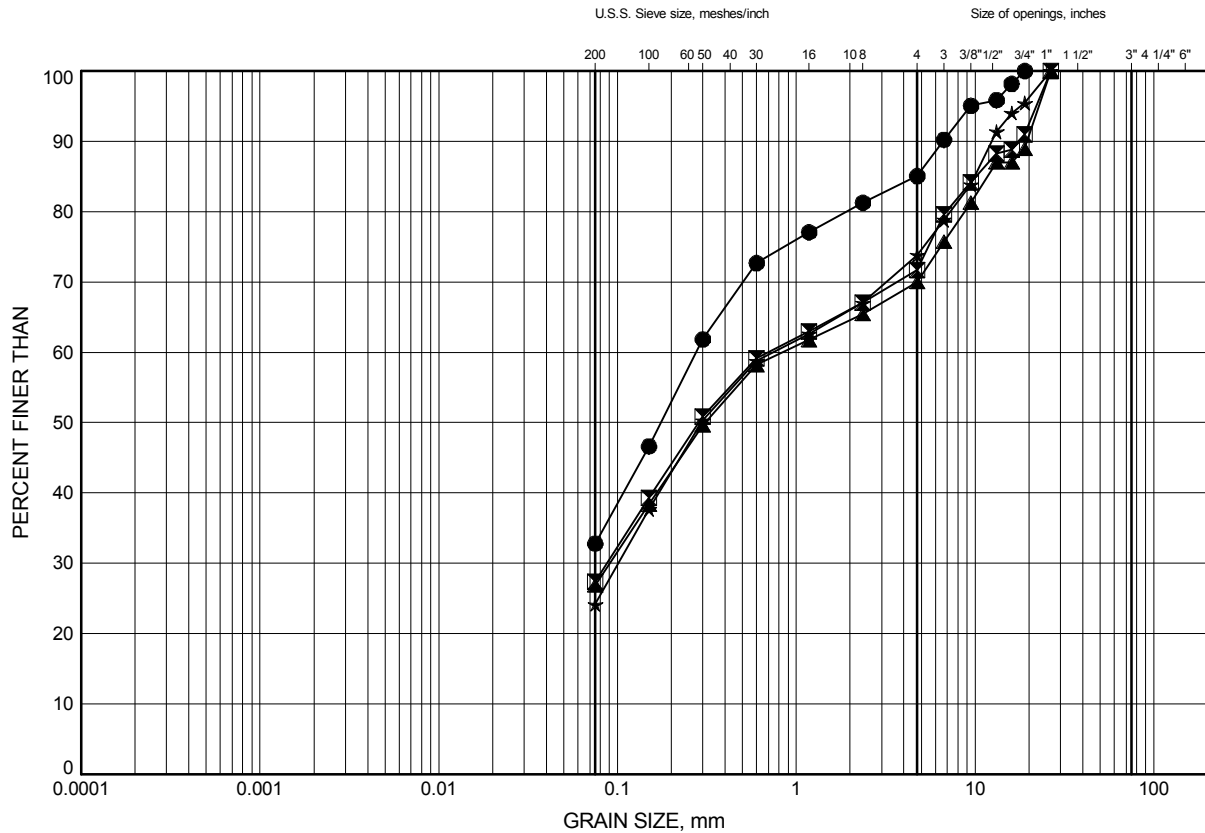
Chkd. PC

Highway 416 Culverts

GRAIN SIZE DISTRIBUTION

FIGURE C2

Culvert 1, Silty Sand with Gravel (Till)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	1	0.30	106.08
⊠	1	1.83	104.55
▲	2	6.40	103.69
★	3	0.30	104.96

Date June 2017

GWP# 4068-13-00



Prep'd JAG

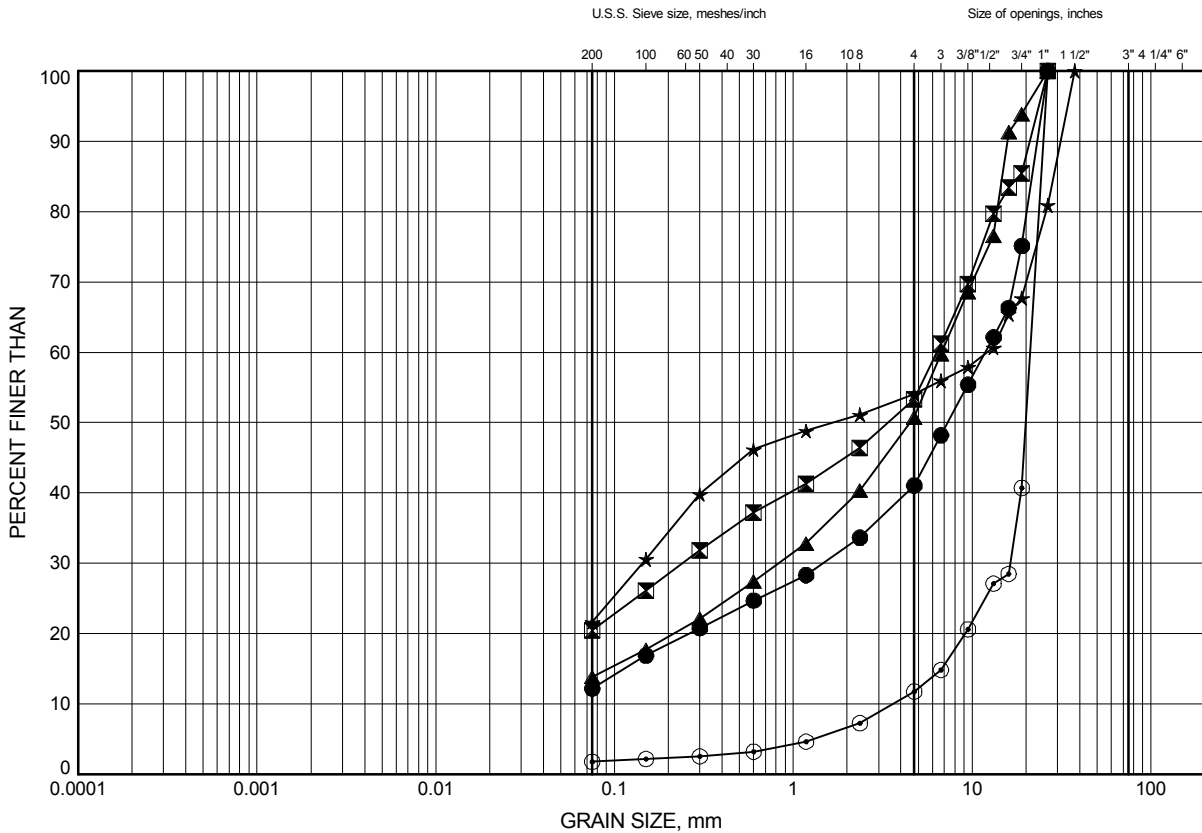
Chkd. PC

Highway 416 Culverts

GRAIN SIZE DISTRIBUTION

FIGURE C3

Culvert 3A, Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	4	1.07	108.75
⊠	4	2.59	107.23
▲	5	1.07	108.71
★	5	2.34	107.44
⊙	6	1.07	105.36

Date June 2017
GWP# 4068-13-00



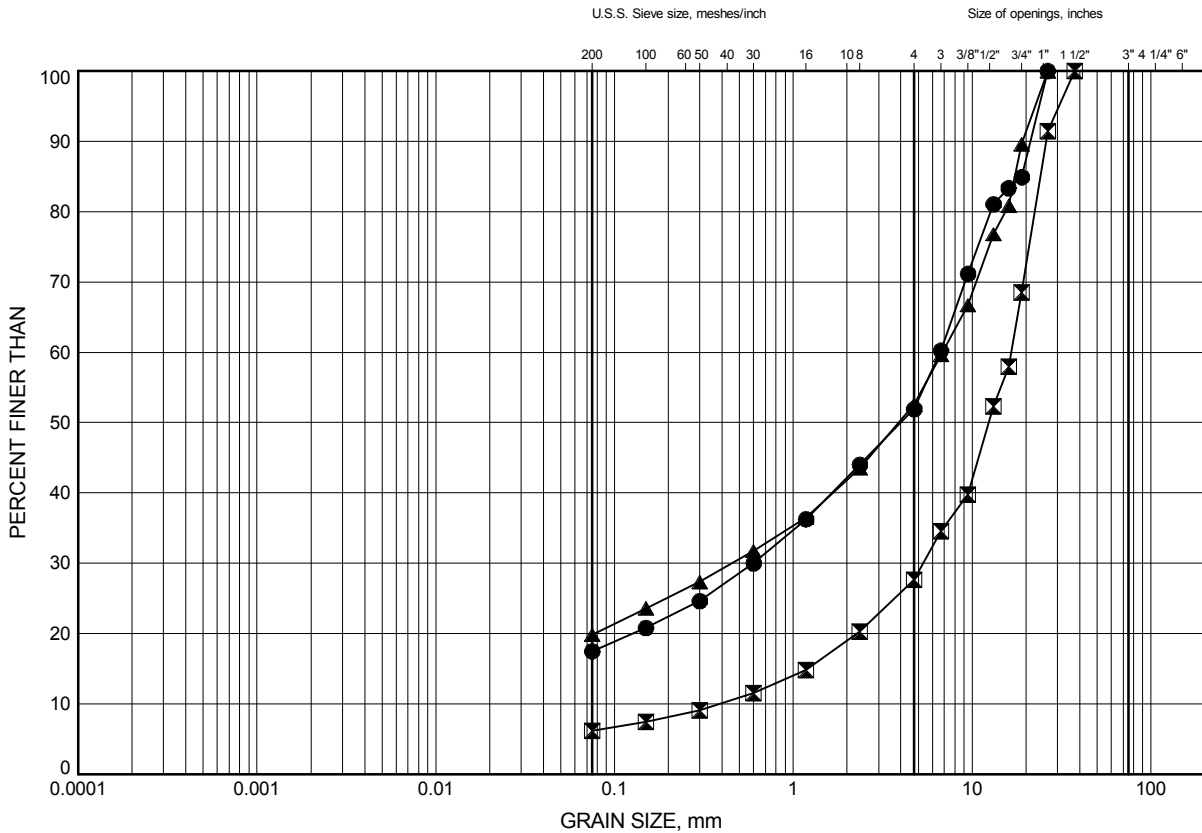
Prep'd JAG
Chkd. PC

Highway 416 Culverts

GRAIN SIZE DISTRIBUTION

FIGURE C4

Culvert 3B, Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	7	0.91	108.80
⊠	8	1.60	111.08
▲	8	3.96	108.72

Date June 2017
GWP# 4068-13-00



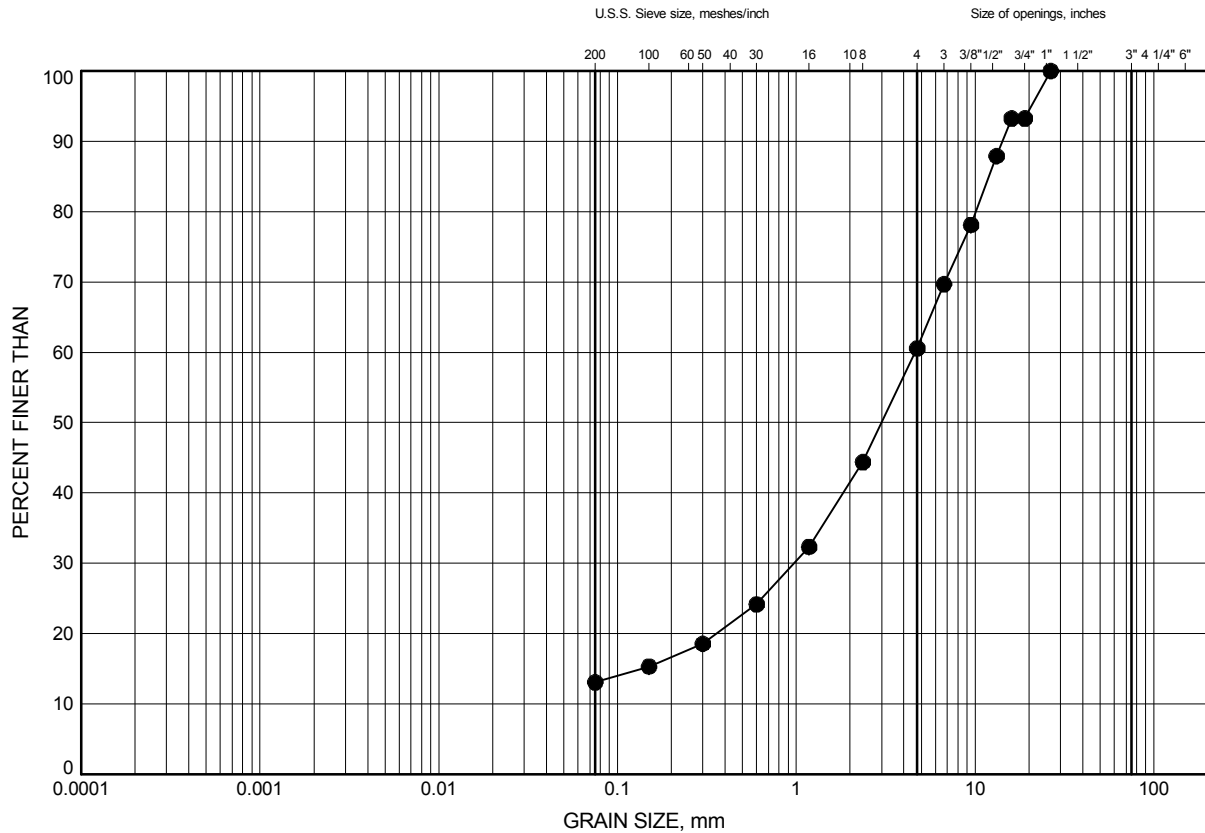
Prep'd JAG
Chkd. PC

Highway 416 Culverts

GRAIN SIZE DISTRIBUTION

FIGURE C5

Culvert 3A/3B, Sand with Gravel and Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	9	0.23	107.44

Date June 2017
GWP# 4068-13-00



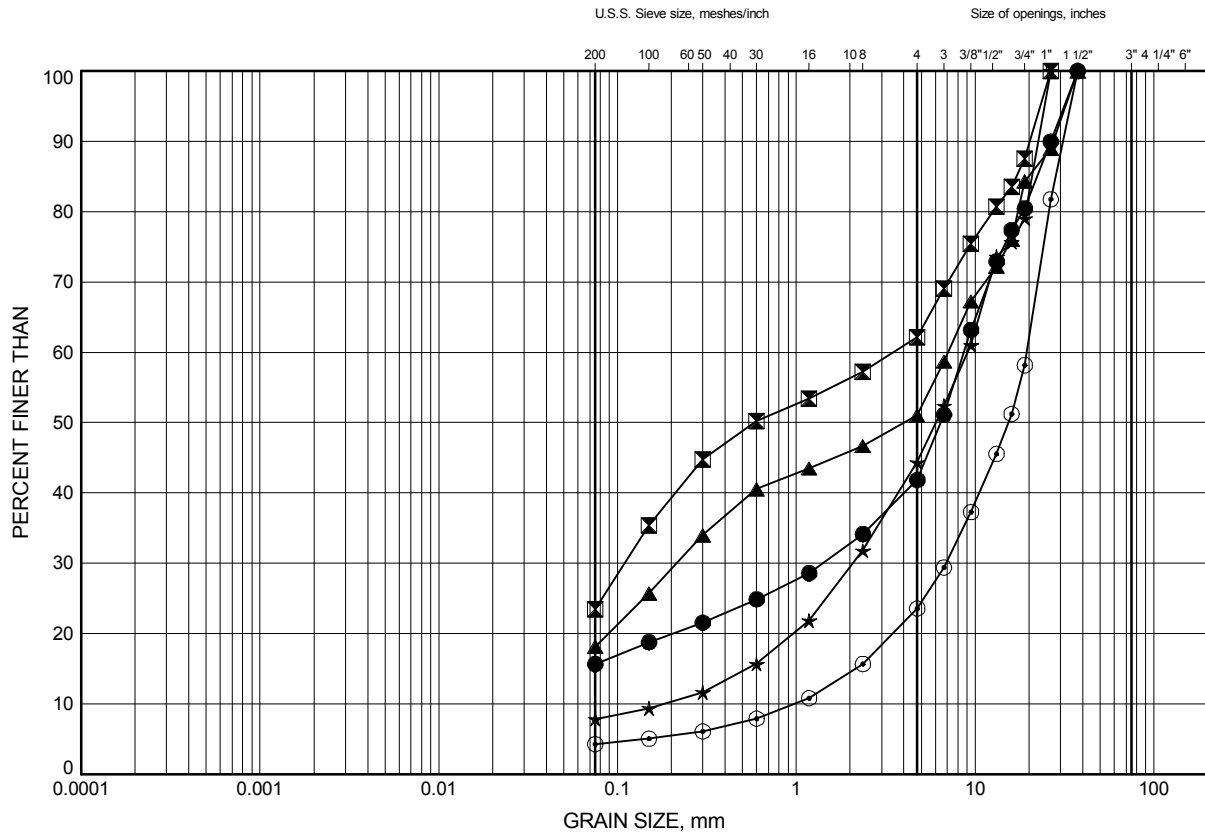
Prep'd JAG
Chkd. PC

Highway 416 Culverts

GRAIN SIZE DISTRIBUTION

FIGURE C6

Culvert 4, Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	11	1.80	108.89
⊠	11	4.11	106.57
▲	11	6.40	104.29
★	12	1.07	108.24
⊙	12	4.11	105.19

Date June 2017

GWP# 4068-13-00



Prep'd JAG

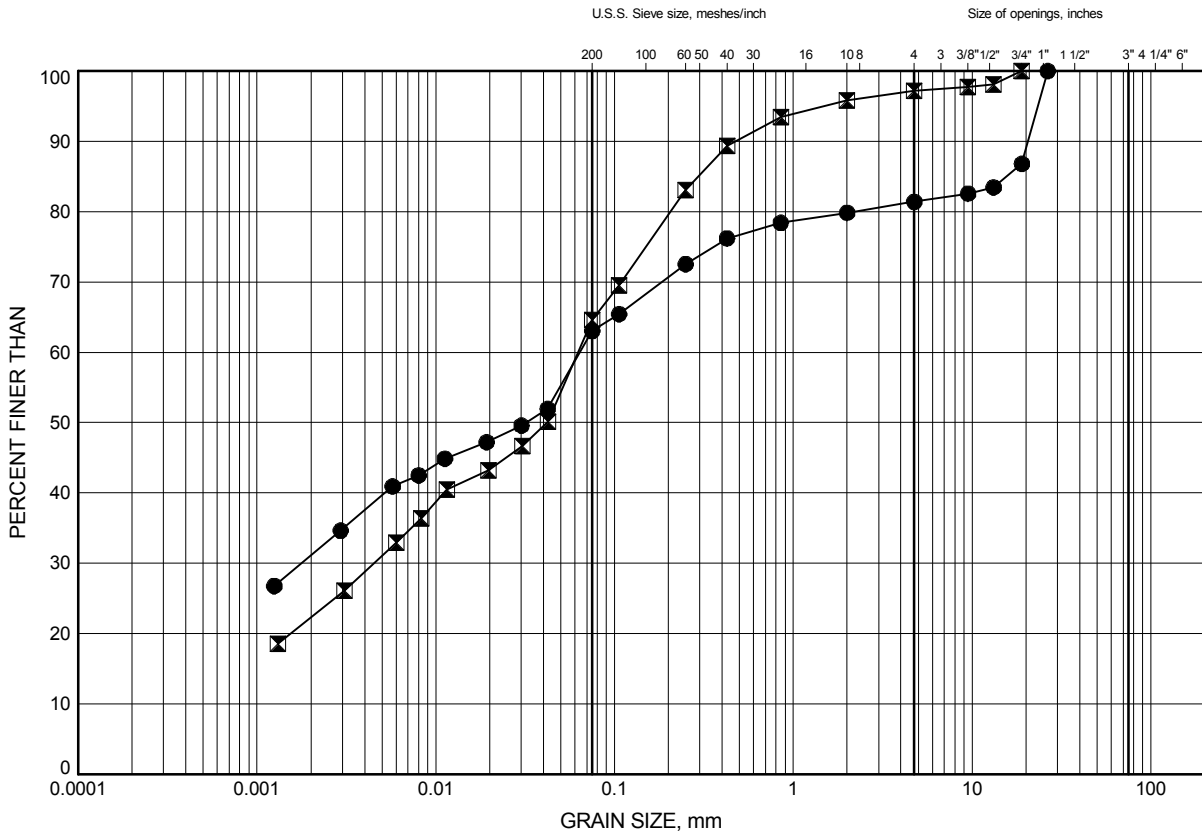
Chkd. PC

Highway 416 Culverts

GRAIN SIZE DISTRIBUTION

FIGURE C7

Culvert 4, Clay



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	12	7.16	102.15
⊠	13	1.07	101.50

Date June 2017
GWP# 4068-13-00



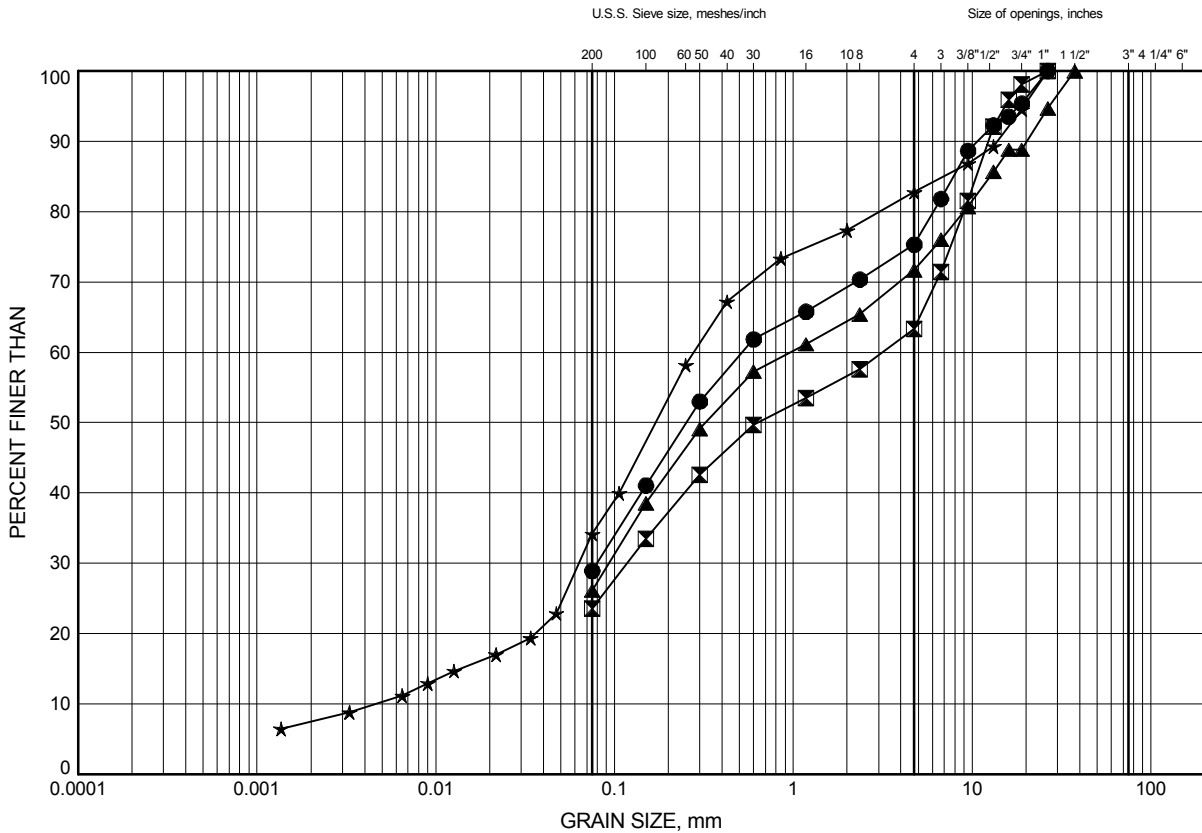
Prep'd JAG
Chkd. PC

Highway 416 Culverts

GRAIN SIZE DISTRIBUTION

FIGURE C8

Culvert 4, Silty Sand with Gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	10	0.69	104.38
⊠	10	2.59	102.47
▲	11	9.75	100.94
★	13	2.59	99.98

Date June 2017
GWP# 4068-13-00



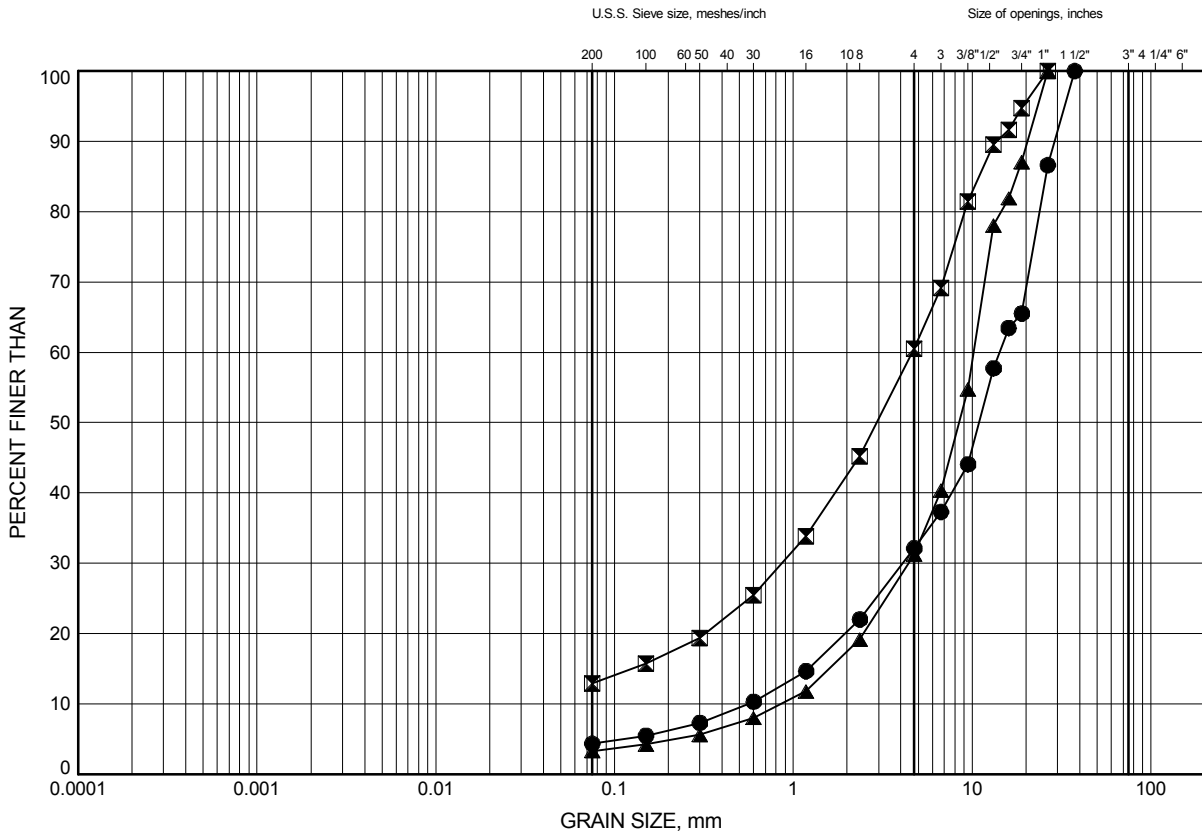
Prep'd JAG
Chkd. PC

Highway 416 Culverts

GRAIN SIZE DISTRIBUTION

FIGURE C9

Culvert 6, Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14	0.30	109.16
◻	15	0.30	110.58
▲	15	1.07	109.82

Date June 2017

GWP# 4068-13-00



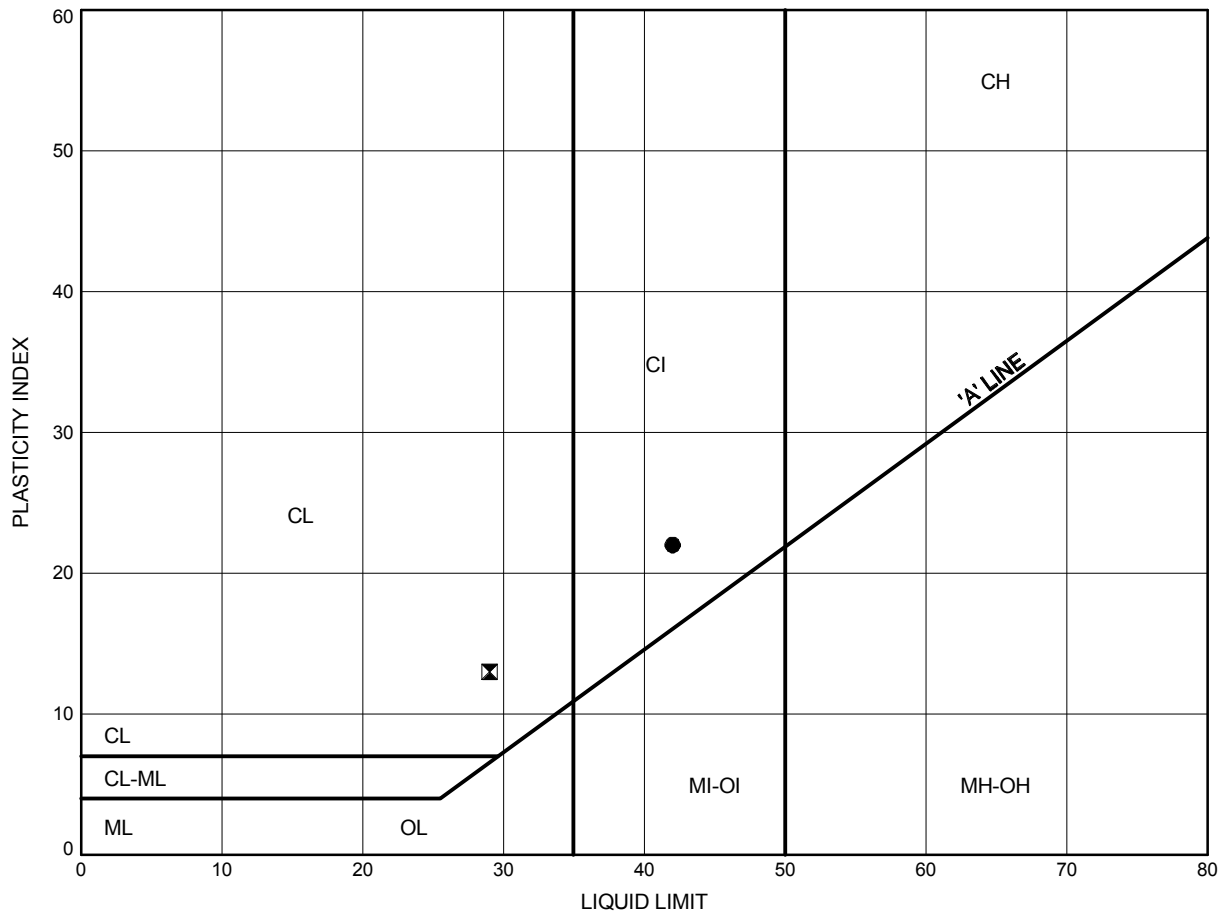
Prep'd JAG

Chkd. PC

Appendix C.2
Atterberg Limit Analysis Figures

Highway 416 Culverts ATTERBERG LIMITS TEST RESULTS

FIGURE C10



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	12	7.16	102.15
⊠	13	1.07	101.50

Date . June 2017

GWP# . 4068-13-00



Prep'd JAG

Chkd. PC

Appendix C.3
Analytical Testing Results

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B 4S5
Attn: Justin Gray

Client PO: 16498
Project: 416 Fallowfield
Custody: 14052

Report Date: 9-May-2017
Order Date: 3-May-2017

Order #: 1718305

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID	Client ID
1718305-01	BH1, SS2, 2'6"-4'6"
1718305-03	BH7, SS1B, 0'2"-2'
1718305-04	BH13, SS1, 0'-2'
1718305-05	BH16, SS1, 0'-1'3"

Approved By:



Dale Robertson, BSc
Laboratory Director

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 16498

Report Date: 09-May-2017

Order Date: 3-May-2017

Project Description: 416 Fallowfield

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	4-May-17	4-May-17
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	4-May-17	5-May-17
Resistivity	EPA 120.1 - probe, water extraction	5-May-17	5-May-17
Solids, %	Gravimetric, calculation	9-May-17	9-May-17

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 16498

Report Date: 09-May-2017

Order Date: 3-May-2017

Project Description: 416 Fallowfield

Client ID:	BH1, SS2, 2'6"-4'6"	BH7, SS1B, 0'2"-2'	BH13, SS1, 0'-2'	BH16, SS1, 0'-1'3"
Sample Date:	03-Apr-17	27-Mar-17	05-Apr-17	09-Apr-17
Sample ID:	1718305-01	1718305-03	1718305-04	1718305-05
MDL/Units	Soil	Soil	Soil	Soil

Physical Characteristics

% Solids	0.1 % by Wt.	90.7	91.3	76.4	73.2
----------	--------------	------	------	------	------

General Inorganics

pH	0.05 pH Units	7.71 [1]	7.76 [1]	7.67	7.47
Resistivity	0.10 Ohm.m	29.6	27.0	13.5	17.6

Anions

Chloride	5 ug/g dry	120 [1]	148 [1]	239	189
Sulphate	5 ug/g dry	33 [1]	9 [1]	47	36

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 16498

Report Date: 09-May-2017

Order Date: 3-May-2017

Project Description: 416 Fallowfield

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
General Inorganics									
Resistivity	ND	0.10	Ohm.m						

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 16498

Report Date: 09-May-2017

Order Date: 3-May-2017

Project Description: 416 Fallowfield

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	19.8	5	ug/g dry	19.9			0.2	20	
Sulphate	15.1	5	ug/g dry	14.8			2.4	20	
General Inorganics									
pH	7.71	0.05	pH Units	7.70			0.1	10	
Resistivity	29.8	0.10	Ohm.m	29.6			0.5	20	
Physical Characteristics									
% Solids	59.4	0.1	% by Wt.	58.2			2.0	25	

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 16498

Report Date: 09-May-2017

Order Date: 3-May-2017

Project Description: 416 Fallowfield

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	129	5	ug/g	19.9	109	78-113			
Sulphate	115	5	ug/g	14.8	100	78-111			

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 16498

Report Date: 09-May-2017
Order Date: 3-May-2017
Project Description: 416 Fallowfield

Qualifier Notes:

Login Qualifiers :

Sample - One or more parameter received past hold time -
Applies to samples: BH1, SS2, 2'6"-4'6", BH7, SS1B, 0'2"-2'

Sample Qualifiers :

1 : Holding time had been exceeded upon receipt of the sample at the laboratory.

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable
ND: Not Detected
MDL: Method Detection Limit
Source Result: Data used as source for matrix and duplicate samples
%REC: Percent recovery.
RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.
Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Appendix D.

Site Photographs



Photo 1. Culvert 1, Looking north towards inlet and side slope.



Photo 2. Culvert 1, Looking north at culvert crossing.



Photo 3. Culvert 1, Looking north at outlet and side slope



Photo 4. Culvert 3B, Looking north at inlet and side slope



Photo 5. Culvert 3B, Looking south at culvert crossing



Photo 6. Culvert 3A/3B, Looking south towards outlet of 3B



Photo 7. Culvert 3A/3B, Looking south towards inlet of 3A and outlet of 3B



Photo 8. Culvert 3A, Looking south toward outlet



Photo 9. Culvert 4, Looking southeast towards inlet



Photo 10. Culvert 4, Looking north towards mid length junction between W-N and S-EW ramps



Photo 11. Culvert 4, Looking west towards outlet



Photo 12. Culvert 6, Looking north towards inlet and rock cut



Photo 13. Culvert 6, Looking north towards inlet

Appendix E.
Replacement Method Comparison Tables

Table 1 - Culvert 1, E-N Ramp

Replacement Option	Open Cut with Ramp Closure	Trenchless Methods			
		Jack and Bore	Microtunnelling	Pipe Ramming	Pipe Bursting
Advantages	<ul style="list-style-type: none"> • Simple construction • Easily handle over sized obstacles 	<ul style="list-style-type: none"> • Readily available equipment 		<ul style="list-style-type: none"> • Handles cobble sized obstructions well • Advancement past some larger obstructions possible • New alignment or same alignment options available 	<ul style="list-style-type: none"> • Maintains existing alignment
Disadvantages	<ul style="list-style-type: none"> • Deep excavation with large cut and fill volumes • Requires ramp closure • Requires cut in recently paved road surface 	<ul style="list-style-type: none"> • Incapable advancing through oversize obstructions • Prone to misalignment if obstructions encountered • Requires entry/exit pits and access 	<ul style="list-style-type: none"> • Difficulty maintaining face pressure if voids in rock fill encountered • Difficulty advancing if cobbles/boulders > 30% of machine diameter • Requires entry/exit pits and access 	<ul style="list-style-type: none"> • Boulder sized obstructions may require manual removal with controlled blasting • Trouble maintaining alignment if obstructions encountered • Requires entry/exit pits and access 	<ul style="list-style-type: none"> • Pipe bursting on CSP's not ideal • Limited contractors available • Requires displaceable material • Upsizing to 800 mm may be difficult • Requires entry/exit pits and access
Relative Cost	Moderate	Moderate	High	Moderate	Moderate
Relative Risks	<ul style="list-style-type: none"> • Low Risk 	<ul style="list-style-type: none"> • Very High Risk considering expected oversize obstacles 	<ul style="list-style-type: none"> • Very High Risk considering expected oversize obstacles 	<ul style="list-style-type: none"> • High Risk considering expected oversize obstacles 	<ul style="list-style-type: none"> • High Risk considering expected oversize obstacles and CSP
Summary	Recommended	Not Feasible	Not Feasible	Feasible	Feasible

Table 2 - Culvert 3A, Highway 416 and W-N Ramp

Replacement Option	Open Cut with Staged Replacement/Ramp Closure	Trenchless Methods			
		Jack and Bore	Microtunnelling	Pipe Ramming	Pipe Bursting
Advantages	<ul style="list-style-type: none"> • Simple construction • Easily handle oversized obstacles 				
Disadvantages	<ul style="list-style-type: none"> • Requires lane closures • Must be completed in a staged approach 				<ul style="list-style-type: none"> • Pipe bursting on CSP's not ideal • Limited contractors available • Requires displaceable material • Requires entry/exit pits and access
Relative Cost	Moderate				
Relative Risks	<ul style="list-style-type: none"> • Low Risk 	<ul style="list-style-type: none"> • Bedrock encountered above invert – NOT FEASIBLE 	<ul style="list-style-type: none"> • Bedrock encountered above invert – NOT FEASIBLE 	<ul style="list-style-type: none"> • Bedrock encountered above invert – NOT FEASIBLE 	<ul style="list-style-type: none"> • Very High Risk considering expected oversize obstacles, limited cover and CSP
Summary	Recommended	Not Feasible	Not Feasible	Not Feasible	Not Feasible

Table 3 - Culvert 3B, W-S Ramp

Replacement Option	Open Cut with Ramp Closure	Trenchless Methods			
		Jack and Bore	Microtunnelling	Pipe Ramming	Pipe Bursting
Advantages	<ul style="list-style-type: none"> • Simple construction • Easily handle oversized obstacles 	<ul style="list-style-type: none"> • Readily available equipment 		<ul style="list-style-type: none"> • Handles cobble sized obstructions well • Advancement past some larger obstructions possible • New alignment or same alignment options available 	<ul style="list-style-type: none"> • Maintains existing alignment • Installs slightly larger culvert diameter
Disadvantages	<ul style="list-style-type: none"> • Deep excavation with large cut and fill volumes • Requires ramp closure • Requires cut in recently paved road surface 	<ul style="list-style-type: none"> • Incapable advancing through oversize obstructions • Prone to misalignment if obstructions encountered • Requires entry/exit pits and access 	<ul style="list-style-type: none"> • Difficulty maintaining face pressure if voids in rock fill encountered • Difficulty advancing if cobbles/boulders > 30% of machine diameter • Requires entry/exit pits and access 	<ul style="list-style-type: none"> • Boulder sized obstructions may require manual removal with controlled blasting • Trouble maintaining alignment if obstructions encountered • Requires entry/exit pits and access 	<ul style="list-style-type: none"> • Pipe bursting on CSP's not ideal • Limited contractors available • Requires displaceable material • Requires entry/exit pits and access
Relative Cost	Moderate	Moderate	High	Moderate	Moderate
Relative Risks	<ul style="list-style-type: none"> • Low Risk 	<ul style="list-style-type: none"> • Very High Risk considering expected oversize obstacles 	<ul style="list-style-type: none"> • Very High Risk considering expected oversize obstacles 	<ul style="list-style-type: none"> • High Risk considering expected oversize obstacles 	<ul style="list-style-type: none"> • High Risk considering expected oversize obstacles and CSP
Summary	Recommended	Not Feasible	Not Feasible	Feasible	Feasible

Table 4 - Culvert 4, W-N and S-EW Ramps

Replacement Option	Open Cut with Ramp Closures	Trenchless Methods			
		Jack and Bore	Microtunnelling	Pipe Ramming	Pipe Bursting
Advantages	<ul style="list-style-type: none"> • Simple construction • Easily handle oversized obstacles 	<ul style="list-style-type: none"> • Readily available equipment 		<ul style="list-style-type: none"> • Handles cobble sized obstructions well • Advancement past some larger obstructions possible • New or same alignment options 	<ul style="list-style-type: none"> • Maintains existing alignment • Installs slightly larger culvert diameter
Disadvantages	<ul style="list-style-type: none"> • Deep excavation with large cut and fill volumes • Requires ramp closure • Requires cut in recently paved road surface 	<ul style="list-style-type: none"> • Incapable advancing through oversize obstructions • Prone to misalignment if obstructions encountered • Requires entry/exit pits and access 	<ul style="list-style-type: none"> • Difficulty maintaining face pressure if voids in rock fill encountered • Difficulty advancing if cobbles/boulders > 30% of machine diameter • Requires entry/exit pits and access 	<ul style="list-style-type: none"> • Boulder sized obstructions may require manual removal with controlled blasting • Trouble maintaining alignment if obstructions encountered • Requires entry/exit pits and access 	<ul style="list-style-type: none"> • Pipe bursting on CSP's not ideal • Limited contractors available • Requires displaceable fill • Contractors may not be able to replace 1105 mm size pipe • Requires entry/exit pits and access
Relative Cost	Moderate	Moderate	High	Moderate	Moderate
Relative Risks	<ul style="list-style-type: none"> • Low Risk 	<ul style="list-style-type: none"> • Very High Risk considering expected oversize obstacles 	<ul style="list-style-type: none"> • Very High Risk considering expected oversize obstacles 	<ul style="list-style-type: none"> • High Risk considering expected oversize obstacles 	<ul style="list-style-type: none"> • High Risk considering expected oversize obstacles and CSP
Summary	Recommended	Not Feasible	Not Feasible	Feasible	Feasible for 800 mm culvert

Table 5 - Culvert 6, Highway 416 Southbound

Replacement Option	Open Cut with Staged Replacement	Trenchless Methods			
		Jack and Bore	Microtunnelling	Pipe Ramming	Pipe Bursting
Advantages	<ul style="list-style-type: none"> • Simple construction • Easily handle oversized obstacles 				
Disadvantages	<ul style="list-style-type: none"> • Requires lane closures • Must be completed in a staged approach 				
Relative Cost	Moderate				
Relative Risks	<ul style="list-style-type: none"> • Low Risk 	<ul style="list-style-type: none"> • Inadequate cover, mixed face materials – NOT FEASIBLE 	<ul style="list-style-type: none"> • Inadequate cover, mixed face materials – NOT FEASIBLE 	<ul style="list-style-type: none"> • Inadequate cover, mixed face materials – NOT FEASIBLE 	<ul style="list-style-type: none"> • Inadequate cover, mixed face materials – NOT FEASIBLE
Summary	Recommended	Not Feasible	Not Feasible	Not Feasible	Not Feasible

Appendix F.

List of Special Provisions and OPSS Documents Referenced in this Report

1. The following OPSS Documents are referenced in this report:

OPSS.PROV 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS.PROV 517	Construction Specification for Dewatering
OPSD 803.031	Frost Treatment – Pipe Culverts Frost Penetration Line Between Top of Pipe and Bedding Grade
OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario

2. Suggested Text for NSSP on “Obstructions”

“Excavations could encounter obstructions such as cobbles and boulders embedded in the fill and native till soils. Such obstructions may impede excavation progress. The Contractor should use appropriate equipment and methodologies to penetrate the obstructions.”