KGS
GROUP
CONSULTING
ENGINEERS

TRURO CREEK CULVERT REPLACEMENT
GEOTECHNICAL INVESTIGATION AND ASSESSMENT

FINAL

KGS Group 17-0183-002
July 2017

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File No. 17-0183-002

WSP Canada Group Limited
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ATTENTION: Mr. Jim Lukashenko, P.Eng.
Manager, Bridges and Structures

RE: Truro Creek Culvert Replacement
Geotechnical Investigation and Assessment

Dear Mr. Lukashenko:

Please find attached KGS Group's Final Report detailing our geotechnical investigation and assessment for the replacement of three Truro Creek culvert crossings that are located on Winchester Street, Linwood Street and Ness Avenue. This Final Report summarizes the results of the geotechnical investigation and presents geotechnical conclusions and recommendations for the replacement of the three Truro Creek culvert crossings.

We thank you for the opportunity to work on this project. If you have any questions regarding the enclosed information or require additional information, please call the undersigned at (204) 896-1209.

Yours truly,

David Anderson, M.Sc., P.Eng.
Senior Geotechnical Engineer

KWH/DEA/em
Attachment

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1.0 INTRODUCTION

KGS Group was retained by WSP Canada Group Limited (WSP) on March 24, 2017 to complete a geotechnical investigation and assessment for the replacement of three Truro Creek culvert crossings that are located on Winchester Street, Linwood Street and Ness Avenue.

As described in the RFP, three existing culvert crossings on Winchester Street, Linwood Street and Ness Avenue are hydraulically deficient to handle the creek flows during spring run-off and heavy rainfall events. Furthermore, the culverts on Winchester Street and Linwood Street are structurally in poor condition, as the steel culverts are rusting and the concrete headwalls contain cracks and spalls.

Cast in place box culverts are proposed to replace the existing crossings at this time. The proposed culvert sizes for the Truro Creek crossings are summarized below in Table 1.

TABLE 1
TRURO CREEK BOX CULVERT GEOMETRIES

BOX CULVERT PROPERTIES	BOX CULVERT LOCATION		
	NESS AVE.	LINWOOD ST.	WINCHESTER ST.
Culvert Width (m)	3.50	3.50	3.50
Culvert Height (m)	2.30	2.05	2.05
Culvert Length (m)	50.0	19.02	19.02
Culvert Invert (m)	229.85	230.15	230.25
Culvert Embedment (m)	0.3	0.3	0.3
Culvert Slope (%)	0.0	0.0	0.0

The widths and heights of the proposed box culverts were selected to minimize changes to the existing roadway profile over the crossings and headlosses across the box culverts. The proposed box culverts have been designed to meet the City of Winnipeg requirements for obvert clearance, headloss and fish passage.

This report details the results of the geotechnical investigation and assessment completed by KGS Group in May to July 2017.

As a separate part of this assignment KGS Group also completed a hydrologic and hydraulic assessment of each crossing. A report documenting this assessment will be submitted separately.

2.0 SCOPE OF WORK

The detailed scope of work for the geotechnical services was in accordance with KGS Group's proposal, dated February 22, 2017, and the approved change order for additional six shallow roadway test holes, dated April 20, 2017. The scope included the following:

Utility and Site Clearances: KGS Group completed all public utility clearances for site access, including the identification and location of all public underground and overhead utilities prior to commencement of the subsurface investigation.

Test Hole Drilling and Soil Sampling: An on-site drilling program was completed to investigate the subsurface and groundwater conditions at each of the three culvert crossings. The drilling program at each culvert location consisted of advancing one deep test hole to power auger refusal and two road holes through the pavement surface to a depth of 3 m. One additional deep test hole was drilled for the Ness Avenue culvert crossing due to the extended length of the proposed culvert.

Soil Testing: Diagnostic laboratory tests including moisture contents, Atterberg Limit analyses and particle size analyses were performed on select soil samples to determine the relevant engineering index properties of the foundation soils.

Groundwater Investigations: One pneumatic piezometer and one Casagrande tipped standpipe piezometer were installed at each culvert crossing location (TH17-01, TH17-02 and TH17-04) to monitor the groundwater conditions in the clay and till, respectively. Piezometers were monitored three weeks and ten weeks after installation.

Geotechnical Investigation and Assessment Report: The following information is provided and/or discussed in this summary geotechnical investigation and assessment report:

- Detailed test hole logs of site stratigraphy incorporating field observations, laboratory test results and estimated depth of groundwater.
- Recommendations for box culvert foundations, excavations, shoring, walls and other structures including Ultimate Limit States (ULS) and Serviceability Limit States bearing capacity values in accordance with the 2010 National Building Code of Canada.

- Recommendations for box culvert construction including type of backfill, thickness of backfill, and level of compaction.
- Estimates of active, at-rest and passive earth pressure coefficients of the soils.
- Estimated total and differential settlement for the proposed foundation system due to compressible soil and consolidation.
- General recommendations for surface and subsurface drainage.
- Estimates of freeze – thaw susceptibility and evaluation of potential soil expansion and its effect on slabs-on-grade.
- Recommendations for dewatering and creek diversion.
- Estimated existing channel stability based on observed stratigraphy and measured groundwater conditions.

3.0 SITE INVESTIGATION

3.1 TEST HOLE DRILLING AND SAMPLING PROGRAM

A drilling and sampling program consisting of ten test holes was completed on May 10 and 11, 2017. Drilling services were provided by Maple Leaf Drilling Ltd. of Winnipeg, Manitoba with continuous KGS Group supervision. The deep test holes were advanced using a Mobile B54X track mounted drill rig equipped with 125 mm diameter solid stem continuous flight augers, advanced to refusal in the underlying till. Shallow test holes were drilled using a CME-55 truck mounted drill rig equipped with 125 mm diameter solid stem continuous flight augers advanced to a depth of 3 m. The location of the test holes are shown on Figure 1 with the approximate UTM coordinates (Zone 14) and ground elevations for the test holes provided on Table 2.

Representative disturbed soil samples were obtained in the deep test holes at 1.5 m intervals, or at any change in soil strata. Soil samples were obtained at 0.3 m intervals below the bottom of the pavement structure in the shallow test holes to a depth of 3 m. Soil samples were collected directly off the auger flights and visually classified in the field in accordance with the modified Unified Soil Classification System (USCS). Clay samples were field tested with a Field Torvane to evaluate consistency and estimate the undrained shear strength. Standard Penetration Tests (SPTs) were performed in the till to determine the relative in-situ density.

Upon completion of the drilling, each test hole was examined for indications of squeezing, sloughing and seepage. The deep test holes were backfilled with sand and bentonite chips to surface. The shallow test holes through the street were backfilled with bentonite chips, auger cuttings and Quikrete fast-setting concrete. The detailed summary soil logs incorporating all field observations and laboratory testing are provided in Appendix A.

FIGURE 1
APPROXIMATE TEST HOLE LOCATIONS

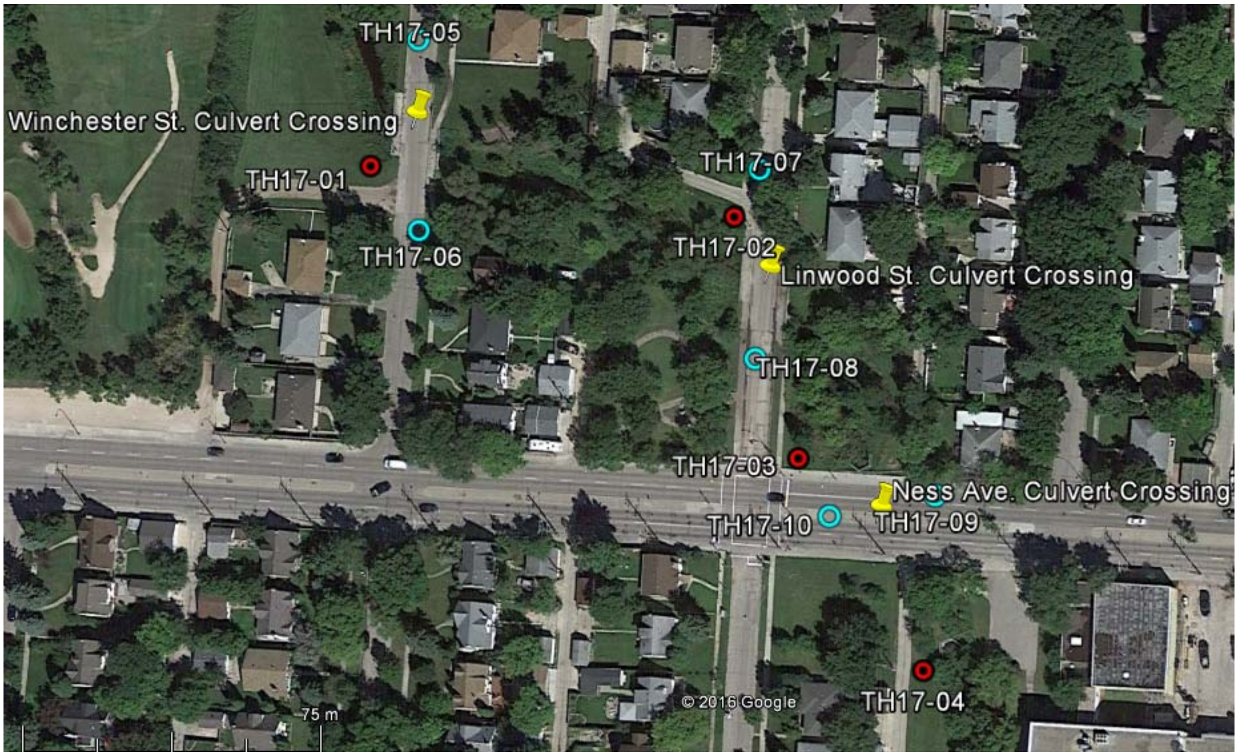


TABLE 2
APPROXIMATE TEST HOLE COORDINATES AND ELEVATION

TEST HOLE ID	APPROXIMATE UTM COORDINATES		GROUND ELEV. (m)note 1	APPROXIMATE TILL ELEV. (m)	APPROXIMATE POWER AUGER REFUSAL ELEV. (m)
	NORTHING (m)	EASTING (m)			
TH17-01	5,527,383	627,229	232.8	221.8	218.4
TH17-02	5,527,372	627,324	233.0	223.0	218.6
TH17-03	5,527,310	627,342	232.7	222.6	220.3
TH17-04	5,527,257	627,375	232.2	222.2	221.4
TH17-05	5,527,416	627,240	232.9	NA	NA
TH17-06	5,527,366	627,242	233.0	NA	NA
TH17-07	5,527,384	627,336	233.3	NA	NA
TH17-08	5,527,335	627,330	232.4	NA	NA
TH17-09	5,527,301	627,377	233.4	NA	NA
TH17-10	5,527,295	627,350	232.5	NA	NA

Note 1. Ground elevation provided by WSP topographic survey from May 2017.

3.2 INSTRUMENTATION

Piezometers were installed in TH17-01, TH17-02 and TH17-04 to monitor groundwater conditions at each culvert crossing. One (1) pneumatic piezometer and one (1) Casagrande tipped standpipe piezometer was installed in each test hole within the clay and till, respectively. Details of the piezometer installations are provided on the test hole logs in Appendix A.

3.3 LABORATORY TESTING

A diagnostic laboratory testing program was performed on select representative soil samples to determine the relevant engineering index properties of the subsurface soils relative to the foundation design. Diagnostic testing included: ninety-nine moisture contents, nine Atterberg Limit analyses and nine particle size analyses.

Laboratory testing was completed at a Standards Council of Canada accredited soil testing laboratory in Winnipeg, Manitoba in accordance with ASTM Standards.

4.0 STRATIGRAPHY AND GROUNDWATER CONDITIONS

4.1 GENERAL SITE STRATIGRAPHY

In general, the stratigraphy at the site has been interpreted by KGS Group to consist of topsoil or a pavement structure overlying, silty clay fill overlying high plasticity clay, silt and silt till. Silt till was encountered at a depth from 10 m to 11 m (Elev. 221.8 m to Elev. 223 m±) below existing ground surface. Power auger refusal occurred in the silt till from 10.9 m to 14.5 m (Elev. 218.4 m± to Elev. 221.4 m±) below existing ground surface.

4.1.1 Winchester Street Culvert Crossing

Three test holes (TH17-01, TH17-05 and TH17-06) were drilled in the area of the Winchester Street culvert crossing. One deep test hole (TH17-01) was drilled south of the culvert inlet west of Winchester Street. Two shallow test holes were drilled through the existing roadway with one located north of the Winchester Street culvert crossing in the south bound lane (TH17-05) and the other located south of the culvert crossing in the north bound lane (TH17-06).

Pavement Structure

The pavement structure on Winchester Street consisted of 51 mm (TH17-05) to 64 mm (TH17-06) of asphalt overlying 140 mm (TH17-06) to 152 mm (TH17-05) of concrete. A 25 mm thick layer of granular fill was encountered south of the culvert and below the concrete in TH17-06. The granular fill was brown, damp, compact to dense and consisted of fine to coarse grained sand, with fine to coarse grained gravel, trace silt and trace clay. The moisture content in the granular fill was 20% as measured from one sample.

Topsoil (OH)

A 0.3 m thick layer of topsoil was encountered from ground surface in TH17-01, a test hole that was drilled off the roadway. The topsoil was dark brown in colour, damp, firm in consistency, of intermediate to high plasticity and contained trace rootlets. There was no topsoil observed under the pavement structure.

Silty Clay Fill (CH)

Silty clay fill was encountered below the pavement structure or topsoil to a depth of 0.9 m (TH17-01) to 1.2 m (TH17-05 and TH17-06) below ground surface. The fill was dark brown to black in colour, damp, stiff to very stiff in consistency, of high plasticity and contained some fine to coarse grained sand, some fine to coarse grained gravel and trace organics.

The moisture content in the silty clay fill varied from 22% to 40% as measured from seven samples. Atterberg Limit testing completed on two (2) fill samples from depths of 0.7 m and 1 m (Elev. 231.9 m± to Elev. 232 m±) below ground surface measured Liquid Limits from 71% to 81%, Plastic Limits from 21% to 26% and Plasticity Index from 50% to 55%, resulting in the material being classified as CH (high plasticity clay). Grain size analyses performed on two samples of clay fill from depths of 0.7 m to 1m below ground surface showed that the fill comprised of 0.1 to 3.5% gravel, 11.3% to 25.8% sand, 21.7% to 30.4% silt and 49% to 58.2% clay sized particles.

Clay (CH)

High plasticity clay was encountered below the silty clay fill at 0.9 m to 1.2 m (Elev. 231.6 m± to Elev. 231.8 m±) below ground surface. The silty clay was brown in colour, damp, stiff to very stiff in consistency, of high plasticity and contained silt inclusions. With depth, the clay became dark grey, moist to wet and soft in consistency. The undrained shear strength of the clay, as estimated by the Field Torvane, decreased with depth and ranged from greater than 100 kPa near the surface to 15 kPa just above the till.

The moisture content in the silty clay generally ranged from 31% to 54% as measured from 19 samples. Higher moisture contents were measured at depth, consistent with the softer consistency. The clay was classified as being of high plasticity based upon Atterberg Limit testing on one sample at a depth of 3.8 m (Elev. 229 m±) which measured a Liquid Limit of 96%, a Plastic Limit of 25% and a Plasticity Index of 71%. A grain size analysis performed on one sample of silty clay at a depth of 3.8 m (Elev. 229.0 m±) from TH17-01 indicated that the silty clay was comprised of 0.1% gravel, 0.5% sand, 20.5% silt and 78.9% clay sized particles.

Silt (ML)

A 0.9 m thick layer of silt was encountered in TH17-01 below the clay at a depth of 9.1 m (Elev. 223.6 m±) below the existing ground surface. The silt was tan, damp to moist, compact and contained trace fine to coarse grained sand and trace fine to coarse grained gravel. An uncorrected standard penetration test (SPT) recorded 32 blows/300 mm. Its moisture content ranged from 13% to 14% as measured from two samples.

Sand (SW)

A 0.9 m thick layer of sand was encountered below the silt at a depth of 10.1 m (Elev. 222.7 m±) below the existing ground surface in TH17-01. The sand was tan, wet, dense, comprised of fine to coarse grained sand and contained trace fine to coarse grained gravel. Poor auger recovery occurred throughout the sand layer. An uncorrected standard penetration test (SPT) within the sand recorded >50 blows/300 mm. The moisture content in the sand was 21% as measured from one sample.

Silt Till

Silt till was encountered below the sand at a depth of 11 m (Elev. 221.8 m±) below existing ground surface in TH17-01. The silt till was tan in colour, damp, very dense and contained some to with fine to coarse grained sand, some to with fine to coarse grained gravel. Uncorrected standard penetration test (SPT) within the silt till recorded >50 blows/300 mm. Power auger refusal occurred at 14.3 m (Elev. 218.4 m±) below existing ground surface. The moisture content ranged from 8% to 11% as measured from three samples.

4.1.2 Linwood Street Culvert Crossing

Three test holes (TH17-02, TH17-07 and TH17-08) were drilled in the area of the Linwood Street culvert crossing. One deep test hole (TH17-02) was drilled north of the culvert inlet west of Linwood Street. Two shallow test holes were drilled through the existing roadway with one located north of the Linwood Street culvert crossing in the north bound lane (TH17-07) and the other located south of the Linwood Street culvert crossing in the south bound lane (TH17-08).

Pavement Structure

The pavement structure on Linwood Street consisted of 165 mm of concrete overlying silty clay fill in TH17-07 and sandy silt in TH17-08.

Topsoil (OH)

A 0.3 m thick layer of topsoil was encountered from ground surface in TH17-02, drilled off the roadway. The topsoil was dark brown in colour, damp, firm in consistency, of intermediate to high plasticity and contained trace rootlets.

Sandy Silt (SM)

Sandy silt was encountered below the pavement structure in TH17-07 to a depth of 1.1 m (Elev. 232.2 m±). The sandy silt was tan, moist to wet, loose to very loose and contained fine to coarse grained sand and trace clay.

The moisture content in the sandy silt was 21% to 24% as measured from four samples. Atterberg Limit testing measured a Liquid Limit of 19%, a Plastic Limit of 13% and a Plasticity Index of 6%, resulting in a classification of ML (Silt). A grain size analysis performed on one sample of sandy silt at a depth of 0.7 m (Elev. 232.6 m±) in TH17-07 measured a grain size distribution of 0.7% gravel, 26.6% sand, 64.1% silt and 8.6% clay sized particles.

Silty Clay Fill (CH)

Silty clay fill was encountered below the pavement structure or topsoil to a depth of 1.1 m to 2 m below ground surface (Elev. 230.4 m± to Elev. 232.2 m±). The silty clay fill was dark brown to black in colour, damp, stiff to very stiff in consistency, of high plasticity and contained trace fine to coarse grained sand, trace fine to coarse grained gravel and trace organics.

The moisture content in the fill ranged from 14% to 38% as measured from seven samples. Atterberg Limit testing complete on two silty clay fill samples from a depth of 0.7 m below ground surface (Elev. 231.7 m± and Elev. 232.6 m±) measured a Liquid Limit of 66%, a Plastic Limit of 22% and a Plasticity Index of 44%, resulting in a classification of CH (high plasticity clay). A grain size analysis performed on one sample of silty clay fill at a depth of 0.7 m (Elev. 232.6 m±) in TH17-08 measured a grain size distribution of 0.7% gravel, 9.9% sand, 39.2% silt and 50.2% clay sized particles.

Clay (CH)

High plasticity clay was encountered below the silty clay fill at 1.1 m to 2 m below ground surface (Elev. 230.4 m± to Elev. 232.2 m±). The silty clay was brown in colour, damp, stiff in consistency, of high plasticity and contained silt inclusions. With depth the silty clay became dark grey, moist to wet and soft in consistency. The undrained shear strength of the clay, as estimated by the Field Torvane, decreased with depth, ranging from 95 kPa near the surface to 15 kPa just above the till. The moisture content generally increased from 34% near surface to 58% with depth as measured from 14 samples.

Silt (ML)

A 1.5 m thick layer of silt was encountered below the clay at a depth of 8.5 m (Elev. 224.5 m±) below the existing ground surface in TH17-02. The silt was tan, damp to moist, compact and contained trace fine to coarse grained sand and trace fine to coarse grained gravel. The moisture content in the silt from one sample was measured to be 18%.

Silt Till

Silt till was encountered below the silt at a depth of 10.1 m (Elev. 223.0 m±) below existing ground surface in TH17-02. The silt till was tan in colour, damp, compact to very dense and contained fine to coarse grained sand, some to with fine to coarse grained gravel. Uncorrected standard penetration test (SPT) within the till were highly variable and ranged from 20 blows/300 mm to >50 blows/300 mm. Power auger refusal occurred at 14.5 m (Elev. 218.6 m±) below existing ground surface. The moisture content in the silt till ranged from 8% to 9% as measured for three samples.

4.1.3 Ness Avenue Culvert Crossing

Four test holes (TH17-03, TH17-04, TH17-09 and TH17-10) were drilled in the area of the Ness Avenue culvert crossing. Two deep test holes were drilled with one located west of the culvert inlet and north of Ness Avenue (TH17-03) and the other located west of the culvert outlet (TH17-04) south of Ness Avenue. Two shallow test holes were drilled through the existing roadway with one located east of the Ness Avenue culvert crossing in the west bound curb lane (TH17-09) and the other located west of the Ness Avenue culvert crossing in the east bound median lane (TH17-10).

Pavement Structure

The pavement structure on Ness Avenue consisted of 76 mm (TH17-09) to 114 mm (TH17-06) of asphalt overlying 178 mm (TH17-09) to 216 mm (TH17-10) of concrete overlying silty clay fill (TH17-09) or granular fill (TH17-10).

Granular Fill (SM)

A 0.9 m thick layer of granular fill was encountered below the concrete west of the culvert in TH17-10. The granular was brown, damp, compact to dense and consisted of fine to coarse grained sand, with fine to coarse grained gravel, trace silt and trace clay.

The moisture content in the granular fill ranged from 2% to 16% as measured from three samples. A grain size analysis performed on one sample of granular fill at a depth of 0.7 m (Elev. 231.8 m±) from test hole TH17-10 showed that the grain size distribution was 23.9% gravel, 63.6% sand, 10.2% silt and 2.3% clay sized particles.

Topsoil (OH)

A 0.3 m thick layer of topsoil was encountered from ground surface in both test hole TH17-03 and test hole TH17-04, each of which were drilled off the roadway. The topsoil was dark brown in colour, damp, firm in consistency, of intermediate to high plasticity and contained trace rootlets.

Clay Fill (CH)

High plasticity clay fill was encountered below the topsoil (TH17-03 and TH17-04), pavement structure (TH17-09) or granular fill (TH17-10) to a depth of 1.2 m to 2.4 m (Elev. 229.8 m± to Elev. 232.2 m±) below ground surface. The fill was dark brown to black in colour, damp, stiff in consistency, of high plasticity and contained trace to some fine to coarse grained sand, trace fine to coarse grained gravel and trace organics.

Moisture contents ranged from 19% to 42% as measured from ten samples. Atterberg Limit testing complete of one sample at a depth of 0.7 m (Elev. 232.7 m±) measured Liquid Limit of 57%, Plastic Limit of 27% and Plasticity Index of 30%, resulting in a classification of CH (high plasticity clay). A grain size analysis performed on one sample of silty clay fill at a depth of 0.7 m (Elev. 232.7 m±) from TH17-09 showed that the silty clay fill comprised of 0.1% gravel, 10.6% sand, 50.7% silt and 38.6% clay sized particles.

Organic Clay (OH)

A 0.3 m thick layer of organic clay was encountered between the clay fill and the in-situ clay in test holes TH17-03, TH17-04 and TH17-10 at a depth of 2.4 m to 2.7 m below existing ground surface (Elev. 229.8 m± to Elev. 230.3 m±). The organic clay was black in colour, moist, firm in consistency, of intermediate to high plasticity and had a strong organic odour. Its moisture content measured from one sample was 50%.

Clay (CH)

High plasticity clay was encountered below the clay fill and organic clay at a depth of 1.2 m to 2.7 m below ground surface (Elev. 229.5 m± to Elev. 232.2 m±). The clay was brown in colour, damp, stiff to very stiff in consistency, of high plasticity and contained silt inclusions. With depth the clay became dark grey, moist to wet and soft in consistency. Its undrained shear strength of the clay, as estimated by the Field Torvane, decreased with depth and ranged from greater than

100 kPa near the surface to 15 kPa just above the till. Corresponding moisture contents generally ranged from 34% near surface to 66% with depth.

Silt (ML)

A 0.6 m to 0.9 m thick layer of silt was encountered below the clay at a depth of 9.2 m (Elev. 223.5 m±) and 9.4 m (Elev. 222.8 m±) in test holes TH17-03 and TH17-04, respectively. The silt was tan, damp to moist, compact and contained trace fine to coarse grained sand and trace fine to coarse grained gravel. The moisture content in the silt ranged from 16% to 20% as measured from two samples.

Silt Till

Silt till was encountered below the silt at a depth of 10.1 m (Elev. 222.6 m± to Elev. 222.8 m±) below existing ground surface in both test hole TH17-03 and test hole TH17-04. The silt till was tan in colour, damp, compact to very dense and contained some to with fine to coarse grained sand, some to with fine to coarse grained gravel. Uncorrected standard penetration test (SPT) results were >50 blows/300 mm. Power auger refusal occurred at 12.3 m (Elev. 220.3 m±) and 10.9 m (Elev. 221.4 m±) in test holes TH17-03 and TH17-04, respectively. Moisture contents ranged from 8% to 11% as measured in five samples.

4.2 GROUNDWATER CONDITIONS

Some minor squeezing, sloughing and seepage were observed throughout the drilling investigation in the lower reaches of the in-situ silty clay, silt, sand and silt till. At the completion of drilling the deep test holes were generally open to the approximate depth where power auger refusal occurred, while groundwater seepage had risen to 5.2 m to 6.7 m (Elev. 226.3 m± to Elev. 227.5 m±) below ground surface upon the completion of drilling.

Piezometers were installed in TH17-01, TH17-02 and TH17-04 to monitor groundwater conditions at each culvert crossing. One (1) pneumatic piezometer and one (1) Casagrande tipped standpipe piezometer was installed in each test hole within the clay and till, respectively. Details of the piezometer installations are provided on the test hole logs in Appendix A.

The piezometer monitoring results are included in Table 3.

TABLE 3
PIEZOMETRIC MONITORING DATA

Test Hole:	**TH17-01**		**TH17-02**		**TH17-04**	
Culvert Crossing:	**Winchester Street**		**Linwood Street**		**Ness Avenue**	
Ground Elevation (m):	**232.75**		**232.69**		**232.22**	
Piezometer No.:	**PN 037468**	**Standpipe**	**PN 037479**	**Standpipe**	**PN 037467**	**Standpipe**
Tip Elevation (m):	**226.51**	**218.42**	**225.92**	**218.21**	**225.54**	**221.36**
Monitoring Zone:	**Silty Clay**	**Silt Till**	**Silty Clay**	**Silt Till**	**Silty Clay**	**Silt Till**
Date	**Piezometric Elevation (m)**					
1-Jun-17	230.13	227.99	231.31	227.95	229.72	228.13
21-Jul-17	229.99	227.06	229.42	226.89	228.65	226.28

Based on previous experience, groundwater levels will fluctuate seasonally and following precipitation events; hence the actual water level at the time of construction could differ from those reported in this report.

4.3 POTENTIAL DIFFICULT GROUND CONDITIONS

Seepage, squeezing and sloughing was observed throughout the drilling investigation within the lower soft clay and in the till units including the silt, sand and silt till. It can be anticipated that groundwater inflows will be minor during construction from the upper soil strata. However, in the event that water inflows are encountered, it is anticipated that they may be controlled by conventional pumping equipment of sufficient capacity.

5.0 BOX CULVERT FOUNDATION CONSIDERATIONS

The native clay located below the clay fill and organic clay is stiff in consistency and is suitable for supporting the proposed replacement box culvert loads in addition to the applied live load from passing vehicles. The heights and sizes of the box culverts were selected to minimize changes to the existing roadway profile over the crossings and headlosses across the box culverts. The installation of a wider box culvert will result in a larger conveyance area that will equate to a net offloading to the subgrade.

The box culvert structure founded on the native silty clay may be assigned an unfactored Ultimate Limit States (ULS) bearing capacity of 200 kPa and a Serviceability Limit States (SLS) value of 80 kPa. The following should be considered:

- Excavate the existing pavement structure, granular fill, silty clay fill, silt, organic clay and/or topsoil to the intact native silty clay. Sub-excavate a minimum of 600 mm below the proposed bottom slab to expose the subgrade beneath the footprint of the box culvert. Proof rolling and compaction of the subgrade using a heavy sheepsfoot roller should be completed under the supervision of an experienced geotechnical engineer to identify unstable or unsuitable areas. If any soft spots are encountered they should be sub-excavated 600 mm and backfilled with compacted granular fill to 98% Standard Proctor Dry Density (SPMDD).
- A non-woven geotextile fabric should be placed as a separator between the subgrade and compacted granular fill.
- A minimum 150 mm thick layer of granular base and 450 mm thick layer of sub-base should be placed immediately below the slab. All granular should be placed in maximum 150 mm thick lifts and compacted to 98% SPMDD. In plan view, the granular pad supporting the box culvert should extend a minimum of 1 m wider than the edges of the box culvert.
- The granular fill should be well-graded free-draining and include organic-free and non-frozen aggregate conforming to the City of Winnipeg Specifications (CW3110). Sieve analysis and compaction testing of the granular base and subgrade materials should be conducted by qualified geotechnical personnel to ensure that the materials supplied and percent compactions are in accordance with design specifications.
- The inlet and outlet ends of the box culvert shall have cut-off walls to prevent the flow of water under the box culverts which would potentially transport fine grained materials beneath the box culvert and transport the granular fill out from under the box culvert. The cut-off walls shall be formed and cast-in-place concrete, extending to a depth beyond the granular fill and into the native silty clay a minimum depth of 0.4 m.
- A riprap blanket is recommended for the inlet and outlet of the box culvert to minimize the potential for erosion as was recommended in KGS Group’s hydrologic and hydraulic assessment of the crossing.

- Detailed construction records and full time inspection by experienced geotechnical personnel is recommended throughout construction of foundations to ensure that the design capacities indicated in this report are achieved.

5.1 POTENTIAL SETTLEMENT OF BOX CULVERT STRUCTURES

At this time potential settlements are anticipated to be minimal (less than 50 mm) as the installation of a wider box culvert will provide sufficient offloading and will not increase the load on the foundation soils.

5.2 LATERAL EARTH PRESSURE

For design purposes the soils may be assigned active, passive and at-rest lateral earth pressure coefficients as shown in Table 4. Groundwater should be considered in the design as de-watering may be required.

TABLE 4
LATERAL EARTH PRESSURE COEFFICIENTS

BACKFILL MATERIAL	ϕ'	K_a	K_p	K_o
Organic Clay, Silty Clay, Silty Clay Fill	20°	0.49	2.04	0.66
Silt	25°	0.41	2.46	0.58
Sand, Silt Till	30°	0.33	3.00	0.50
Well Graded Granular Fills	35°	0.27	3.69	0.43

5.3 MODULUS OF SUBGRADE REACTION

The modulus of subgrade reaction describes the relationship between soil pressure and deflection. The modulus of subgrade reaction for the in-situ native clay is estimated to range from 5 to 20 MPa/m at the underside of the box culvert structures along Truro Creek. If a more accurate determination of the modulus of subgrade reaction is required, then a plate bearing test is recommended.

5.4 TEMPORARY CONSTRUCTION EXCAVATIONS AND SHORING

Construction excavation details were not available at the time of preparation of this report. Construction excavations will be reviewed and analyzed as part of final design. Preliminary guidance for temporary excavations above water table is provided on Table 5.

TABLE 5
PRELIMINARY RECOMMENDATIONS FOR TEMPORARY DRY EXCAVATIONS

Height of Excavation (m)	Minimum Recommended Side slope
0 – 1.5	1H : 1V
1.5 – 3.0	1.5H : 1V
3.0 – 5.0	2H : 1V
5.0 – 6.5	3H : 1V

Any excavation deeper than 1.5 m should be reviewed and designed by an experienced professional engineer with an expertise in geotechnical engineering. All excavation work should conform to Manitoba Workplace Safety and Health Guideline for Excavation Work.

The upper fill, silt and clay may be susceptible to sloughing from wetting and mechanical disturbance. All open excavation side slopes should be covered to prevent saturation of the soil and all surface runoff should be directed away from excavations. All surcharge loads such as stockpiled soil, equipment, etc. should be kept a minimum of 10 m away from the edge of excavations.

Temporary excavation and shoring design should consider that during the geotechnical investigation, minor water infiltration was observed when drilling through the fill, silt and upper silty clay below the water table.

5.5 BOX CULVERT BACKFILL

Free draining granular material should be placed behind the wing walls and next to the culvert side walls for a minimum width of 0.6 m. All backfill should be placed in maximum 150 mm thick lifts and compacted to a minimum of 95% Standard Proctor maximum dry density (SPMDD).

5.6 FROST PENETRATION

The depth of frost penetration will vary depending on air temperature, ground cover, the type of any fill material used during development and other factors.

The expected depth of frost penetration has been estimated assuming a design freezing index of 2680°C-days, taken as the coldest winter over a ten (10) year period. The estimated maximum depth of frost penetration is 2.5 m assuming bare ground and no insulation cover. The clay soils can heave upon freezing and that consideration must be considered in the foundation design. Good positive site drainage must be maintained after development.

Well-graded granular materials should be utilized as structural backfill material as they are less susceptible to the effects of frost heave than fine grained silt and clay materials.

5.7 DEWATERING AND CREEK DIVERSION

The creek flow at the culvert location will need to be diverted or pumped across the culvert crossing to allow for dry working conditions during construction. Dewatering in the excavated area will likely be required and can be achieved by installing a sump pump system.

Dewatering plans must also consider surface drainage that may enter into the drain at the culvert location. All surface drainage should be directed away from any open excavations and trenches.

Temporary cofferdams may be required to block the flow from Truro Creek from entering the excavation during the construction of the purposed box culverts. Pumping equipment can be used to convey the creek flow bypassing the excavated area between the upstream and downstream cofferdams. Temporary cofferdams should either be constructed using sheet pile or compacted clay fill. Clay fill used to construct cofferdams should be compacted to 95% Standard Proctor Dry Density (SPMDD). Clay fill temporary cofferdams should be constructed with a minimum 3 m crest width and 2H:1V side slopes for a maximum height of 4 m. The height of temporary cofferdams should consider the season in which construction is completed, anticipated water level in the channel at the time of construction, the capacity of onsite pumping equipment, and the likelihood of high water in the channel due to heavy precipitation events and/or flooding. Upstream water levels should be monitored closely during construction to ensure that Truro Creek water levels are not rising upstream of the temporary cofferdams.

Temporary cofferdam details were not available at the time of preparation of this report. It is recommended that as a part of final design the proposed temporary cofferdams be analyzed and reviewed.

6.0 SLOPE STABILITY ANALYSIS

6.1 TRURO CREEK BANK INSPECTION

KGS Group completed an inspection of the Truro Creek banks in May 2017 extending for 100 m upstream of the Winchester Street culvert crossing to 60 m downstream of the Ness Avenue culvert crossing to determine what measures if any are required to maintain channel stability. No visible bank instabilities were identified during the inspection.

6.2 TRURO CREEK BANK GEOMETERY

The topographical survey completed by WSP in May 2017 measured side slopes of 3H:1V or flatter, channel depths of less than 3 m and a channel base width of less than 5 m.

6.3 SLOPE STABILITY ANALYSIS METHOD

The slope stability model was a fully coupled model where the measured groundwater regime was first input to the finite element method seepage model SEEP/W to calculate the in-situ effective stress state. The resulting effective stress state was then input to the slope stability model SLOPE/W to estimate stability conditions.

Slope stability modelling was completed using the Morgenstern-Price method of analysis available in the Geo-Studio Slope/W software package for limit equilibrium stability analysis. The method considers both shear and normal interslice forces and it satisfies both moment and force equilibrium.

Stratigraphic and groundwater conditions assigned in the model were based on geotechnical data obtained from the May 2017 geotechnical investigation. KGS Group's site inspection resulted in no observed bank instabilities along Truro Creek in the area under investigation; therefore large strain intact effective shear strength parameters for the silty clay were assumed to be applicable for this analysis with a cohesion, c', of 5 kPa and an internal friction angle, ϕ', of 14 degrees.

Based upon the groundwater monitoring data to date, groundwater levels were assumed to be 1.5 m below ground surface under normal long-term conditions with a creek level at 0.5 m above the bottom of the channel. A saturated slope and a channel water level of 1 m was assumed for the short-term stability case. The stability criteria provided by the City of Winnipeg was a long-term estimated factor of safety of 1.5 and the short-term factor of safety of 1.3.

6.4 STABILITY ANALYSIS RESULTS

The slope stability analysis concluded that the existing Truro Creek channel geometry meets the requirements outline by the City of Winnipeg for both short-term and long-term slope stability. The estimated factor of safety is 1.50 and 1.32 for long-term and short-term slope stability, respectively. No stabilization works are required as the current channel stability is adequate and meets the City of Winnipeg requirements.

Results of the stability analyses are summarized on Table 6 below. The results of stability analyses and screenshots of analysis sections taken from GeoStudio are included in Appendix B showing geometry, material properties, groundwater conditions and potential minimum slip surfaces.

TABLE 6
RESULTS OF SLOPE STABILITY ANALYSIS

Case	Scenario	Estimated Factor of Safety	Stability Criteria
1	Long-Term Condition	1.5	1.5
2	Short-Term Condition	1.32	1.3

Construction excavation details were not available at the time of preparation of this report. Construction excavations will be reviewed and analyzed as part of detailed design. Any excavation deeper than 1.5 m should be reviewed and designed prior to construction by an experienced professional engineer with an expertise in geotechnical engineering.

7.0 EROSION PROTECTION

The replaced box culvert structures along Truro Creek will be protected against scour and erosion with 0.55 m thick riprap blankets that will be extended 10 m upstream and downstream from each culvert, and will be sized based on the City of Winnipeg's Specification CW3615 (i.e. stone sizes ranging from 100 mm to 350 mm in diameter, with at least 75% ranging from 200 mm to 300 mm).

8.0 CONCLUSIONS

Based on our assessment the following conclusions are made:

- In general, the stratigraphy at the site has been interpreted by KGS Group to consist of topsoil or a pavement structure overlying, clay fill, overlying high plasticity clay and silt till. Silt till was encountered at a depth from 10 m to 11 m (Elev. 221.8 m to Elev. 223 m±) below existing ground surface. Power auger refusal occurred in the silt till from 10.9 m to 14.5 m (Elev. 218.4 m± to Elev. 221.4 m±) below existing ground surface.
- Based on the groundwater monitoring data to date, there would appear to be a downward hydraulic gradient. Based on previous experience, groundwater levels will fluctuate seasonally and following precipitation events; hence the actual water level at the time of construction could differ from those reported in this report.
- Observed seepage, squeezing and sloughing conditions throughout the drilling investigation above the silt till were considered minor, while within the silt till the conditions were considered significant. It can be anticipated that groundwater inflows will be minor during construction from the upper soil strata. However, in the event that water inflows are encountered, it is anticipated that they may be controlled by conventional pumping equipment of sufficient capacity.
- The expected depth of frost penetration has been estimated assuming a design freezing index of 2680^{o}C-days, taken as the coldest winter over a ten (10) year period. The estimated maximum depth of frost penetration is 2.5 m assuming no insulation cover.
- The slope stability analysis concluded that the existing Truro Creek channel geometry meets the requirements outline by the City of Winnipeg for both short-term and long-term slope stability. The estimated factor of safety is 1.5 and 1.32 for long-term and short-term slope stability, respectively. No stabilization works are required as the current channel stability is adequate and meets the City of Winnipeg requirements.

9.0 RECOMMENDATIONS

Based on our assessment the following recommendations are made:

- The recommended foundation type for the concrete box culvert structures are shallow foundation bearing directly on the underlying native silty clay.The box culvert structure founded on the native silty clay may be assigned an unfactored Ultimate Limit States (ULS) bearing capacity of 200 kPa and a Serviceability Limit States (SLS) value of 80 kPa.
- Proof rolling and compaction of the subgrade should be completed under the supervision of an experienced geotechnical engineer to identify unstable or unsuitable areas. Proof rolling should be completed using a heavy sheepsfoot roller. If any soft spots are encountered they should be sub-excavated 600 mm and backfilled with compacted granular fill to 98% Standard Proctor Dry Density (SPMDD).
- A non-woven geotextile fabric should be placed as a separator between the subgrade and compacted granular fill.
- A minimum 150 mm thick layer of granular base and 450 mm thick layer of sub-base should be placed immediately below the slab. All granular should be placed in maximum 150 mm thick lifts and compacted to 98% SPMDD. The granular pad supporting the box culvert should extend a minimum of 1 m beyond the edges of the box culvert.
- The granular fill should be well-graded free-draining and include organic-free and non-frozen aggregate conforming to the City of Winnipeg Specifications (CW3110). Sieve analysis and compaction testing of the granular base and subgrade materials should be conducted by qualified geotechnical personnel to ensure that the materials supplied and percent compactions are in accordance with design specifications.
- The inlet and outlet ends of the box culvert shall have cut-off walls to prevent the flow of water under the box culverts which would potentially transport fine grained materials beneath the box culvert and transport the granular fill out from under the box culvert. The cut-off walls shall be formed and cast-in-place concrete, extending to a depth beyond the granular fill and into the native silty clay a minimum depth of 0.5 m.
- A riprap blanket is recommended for the inlet and outlet of the box culvert to minimize the potential for erosion.
- At this time potential settlements are anticipated to be minimal (less than 50 mm) as the installation of a wider box culvert will provide sufficient offloading and will not increase the load on the foundation soils.
- Full-time inspection by experienced geotechnical personnel should be completed throughout construction of foundations to ensure that the design capacities indicated in this report are achieved. Detailed construction records should also be kept by qualified personnel throughout construction.
- Temporary cofferdams may be required to block the flow from Truro Creek from entering the excavation during the construction of the purposed box culverts. Pumping equipment can be used to convey the creek flow across the excavated area between the upstream and downstream cofferdams. Temporary cofferdams should either be constructed using sheet pile or compacted clay fill. Clay fill used to construct cofferdams should be compacted to 95% Standard Proctor Dry Density (SPMDD). Clay fill temporary cofferdams should be constructed with a minimum 3 m crest width and 2H:1V side slopes for maximum fill height of 4 m. The height of temporary cofferdams should

consider the season in which construction is completed, anticipated water level in the channel at the time of construction, the capacity of onsite pumping equipment, and the likelihood of high water in the channel due to heavy precipitation events and/or flooding. Upstream water levels should be monitored closely during construction to ensure that Truro Creek water levels are not rising upstream of the temporary cofferdams.

- The replaced box culvert structures along Truro Creek will be protected against scour and erosion with 0.55 m thick riprap blankets that will be extended 10 m upstream and downstream from each culvert, and will be sized based on the City of Winnipeg’s Specification CW3615 (i.e. stone sizes ranging from 100 mm to 350 mm in diameter, with at least 75% ranging from 200 mm to 300 mm).

10.0 STATEMENT OF LIMITATIONS

10.1 THIRD PARTY USE OF REPORT

This report has been prepared for WSP Canada Group Limited to whom this report has been addressed and any use a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. KGS Group accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions undertaken based on this report. This report has been prepared for the Client to whom this report has been addressed and any use a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. KGS Group accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions undertaken based on this report.

10.2 GEOTECHNICAL INVESTIGATION STATEMENT OF LIMITATIONS

The geotechnical investigation findings and recommendations of this report were prepared in accordance with generally accepted professional engineering principles and practice. The findings and recommendations are based on the results of field and laboratory investigations, combined with an interpolation of soil and groundwater conditions found at and within the depth of the test holes drilled by KGS at this site. If conditions encountered during construction appear to be different from those shown by the test holes drilled by KGS or if the assumptions stated herein are not in keeping with the design, this office should be notified in order that the recommendations can be reviewed and modified if necessary.

APPENDIX A

TEST HOLE LOGS AND LABORATORY DATA

KGS GROUP

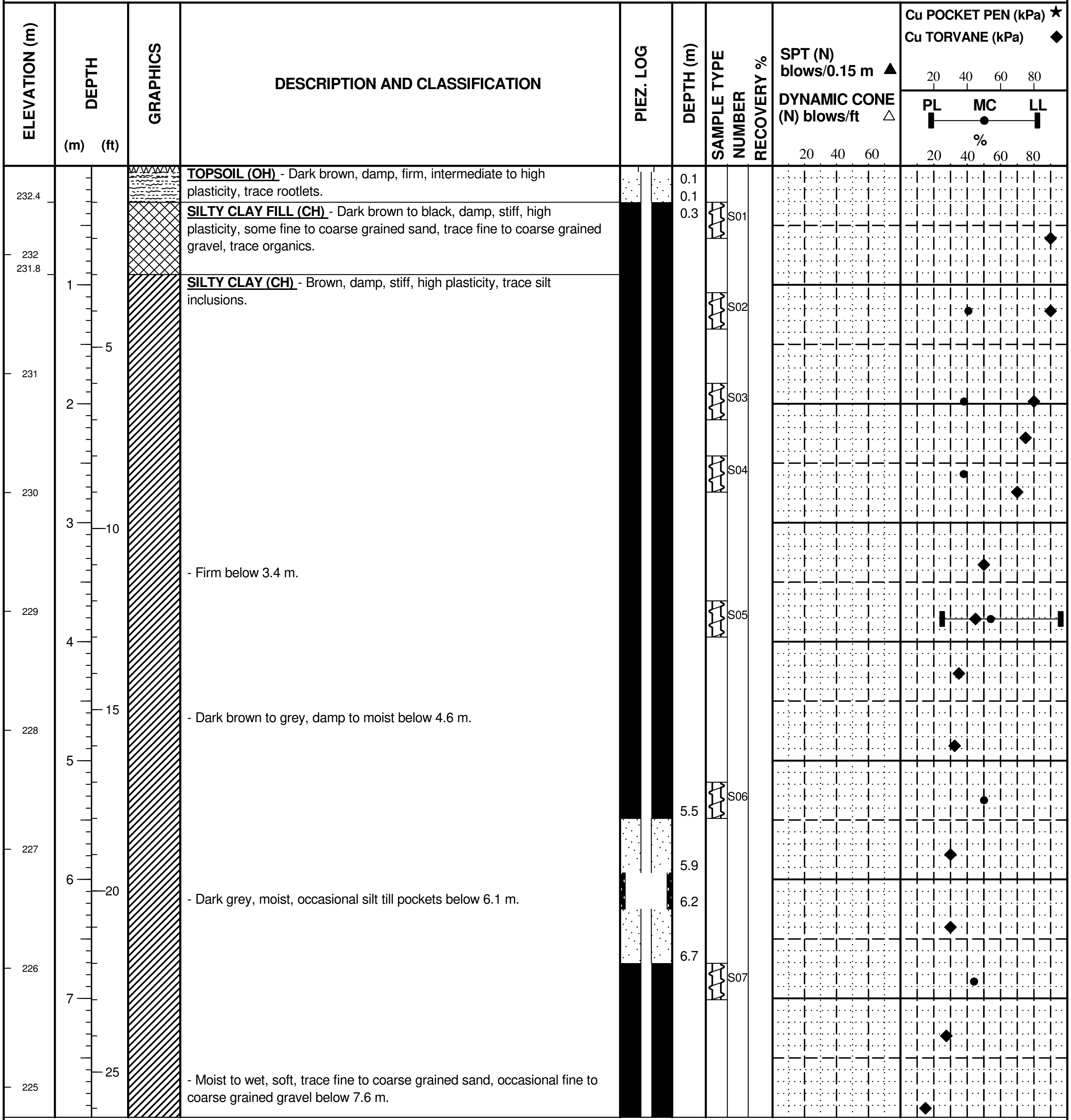
SUMMARY LOG

REFERENCE NO.

HOLE NO.
TH17-01

SHEET 1 of 2

CLIENT	WSP CANADA GROUP LTD.	JOB NO.	17-0183-002
PROJECT	Truro Creek Culvert Replacements	GROUND ELEV.	232.7 m +/-
		TOP OF PVC ELEV.	232.7 m +/-
SITE	Winchester Street Culvert Crossing	WATER ELEV.	
LOCATION	South of Culvert Inlet	DATE DRILLED	05/11/2017
DRILLING METHOD	125 mm ø Solid Stem Auger, B54X Track Mounted Drill Rig	UTM (m)	N 5,527,383 E 627,229



TOPSOIL (OH) - Dark brown, damp, firm, intermediate to high plasticity, trace rootlets.

SILTY CLAY FILL (CH) - Dark brown to black, damp, stiff, high plasticity, some fine to coarse grained sand, trace fine to coarse grained gravel, trace organics.

SILTY CLAY (CH) - Brown, damp, stiff, high plasticity, trace silt inclusions.

- Firm below 3.4 m.

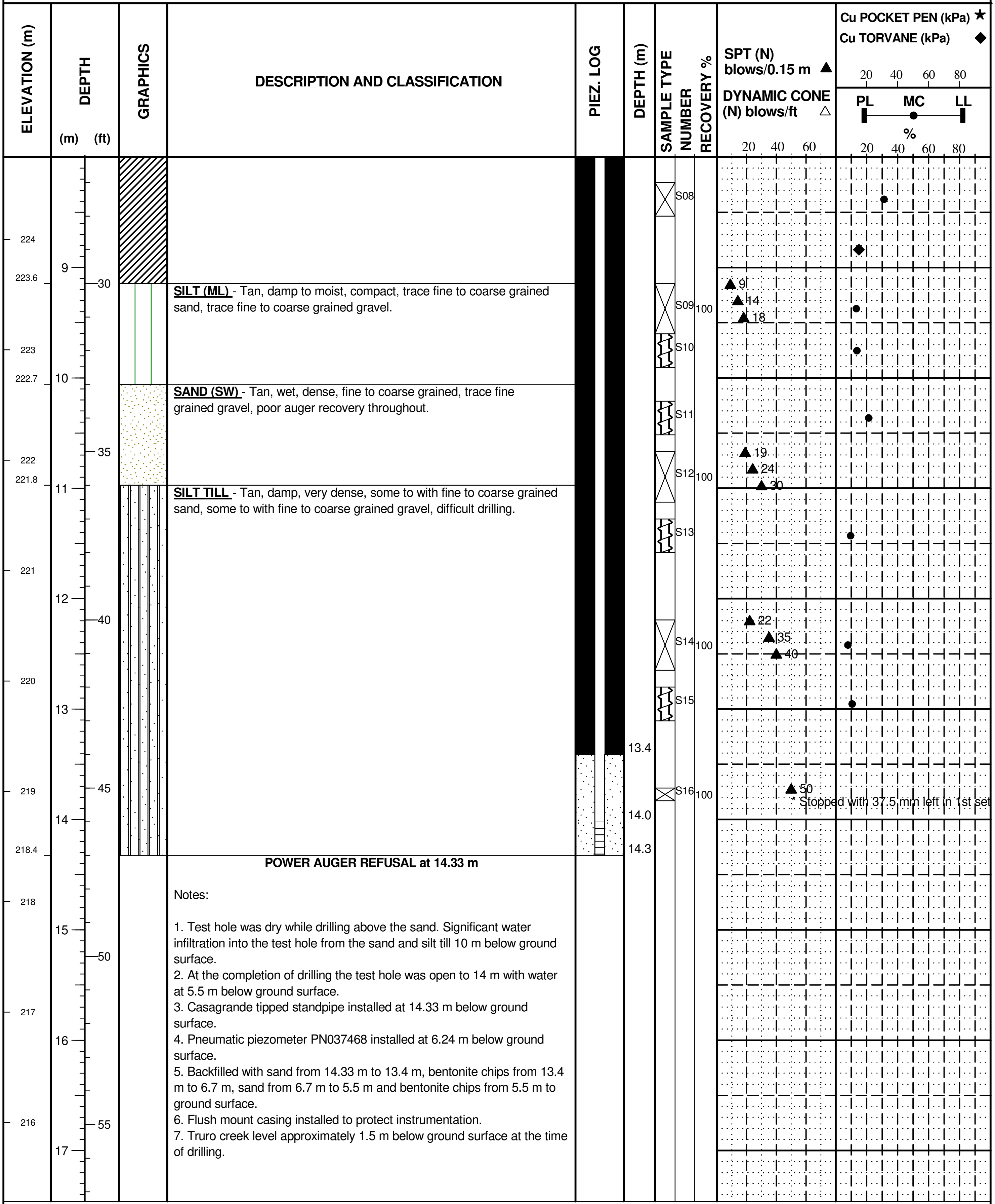
- Dark brown to grey, damp to moist below 4.6 m.

- Dark grey, moist, occasional silt till pockets below 6.1 m.

- Moist to wet, soft, trace fine to coarse grained sand, occasional fine to coarse grained gravel below 7.6 m.

SAMPLE TYPE ⍂ Auger Grab ☒ Split Spoon

CONTRACTOR	INSPECTOR	APPROVED	DATE
Maple Leaf Drilling Ltd.	K. HAMILTON	DEA	18/8/17



SILT (ML) - Tan, damp to moist, compact, trace fine to coarse grained sand, trace fine to coarse grained gravel.

SAND (SW) - Tan, wet, dense, fine to coarse grained, trace fine grained gravel, poor auger recovery throughout.

SILT TILL - Tan, damp, very dense, some to with fine to coarse grained sand, some to with fine to coarse grained gravel, difficult drilling.

POWER AUGER REFUSAL at 14.33 m

Notes:

1. Test hole was dry while drilling above the sand. Significant water infiltration into the test hole from the sand and silt till 10 m below ground surface.
2. At the completion of drilling the test hole was open to 14 m with water at 5.5 m below ground surface.
3. Casagrande tipped standpipe installed at 14.33 m below ground surface.
4. Pneumatic piezometer PN037468 installed at 6.24 m below ground surface.
5. Backfilled with sand from 14.33 m to 13.4 m, bentonite chips from 13.4 m to 6.7 m, sand from 6.7 m to 5.5 m and bentonite chips from 5.5 m to ground surface.
6. Flush mount casing installed to protect instrumentation.
7. Truro creek level approximately 1.5 m below ground surface at the time of drilling.

SAMPLE TYPE ⧉ Auger Grab ☒ Split Spoon

CONTRACTOR	INSPECTOR	APPROVED	DATE
Maple Leaf Drilling Ltd.	K. HAMILTON	DEA	18/8/17

KGS GROUP

SUMMARY LOG

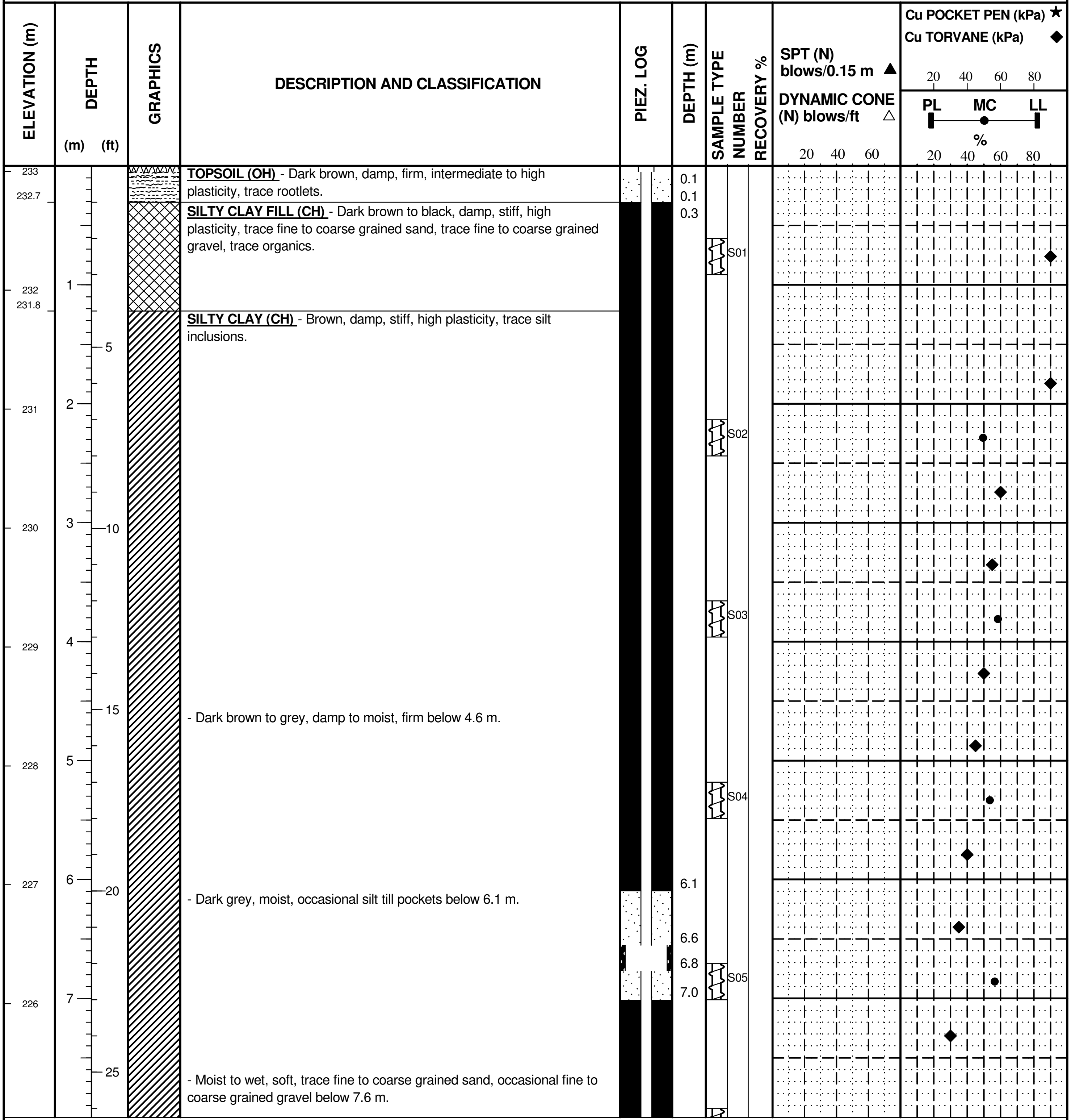
REFERENCE NO.

HOLE NO.
TH17-02

SHEET 1 of 2

CLIENT WSP CANADA GROUP LTD.
PROJECT Truro Creek Culvert Replacements
SITE Linwood Street Culvert Crossing
LOCATION North of Culvert Inlet
DRILLING METHOD 125 mm ø Solid Stem Auger, B54X Track Mounted Drill Rig

JOB NO. 17-0183-002
GROUND ELEV. 233.0 m +/-
TOP OF PVC ELEV.
WATER ELEV.
DATE DRILLED 05/10/2017
UTM (m) N 5,527,372
E 627,324



DESCRIPTION AND CLASSIFICATION

TOPSOIL (OH) - Dark brown, damp, firm, intermediate to high plasticity, trace rootlets.

SILTY CLAY FILL (CH) - Dark brown to black, damp, stiff, high plasticity, trace fine to coarse grained sand, trace fine to coarse grained gravel, trace organics.

SILTY CLAY (CH) - Brown, damp, stiff, high plasticity, trace silt inclusions.

- Dark brown to grey, damp to moist, firm below 4.6 m.

- Dark grey, moist, occasional silt till pockets below 6.1 m.

- Moist to wet, soft, trace fine to coarse grained sand, occasional fine to coarse grained gravel below 7.6 m.

SAMPLE TYPE ⧉ Auger Grab ☒ Split Spoon

CONTRACTOR	INSPECTOR	APPROVED	DATE
Maple Leaf Drilling Ltd.	K. HAMILTON	DEA	18/8/17

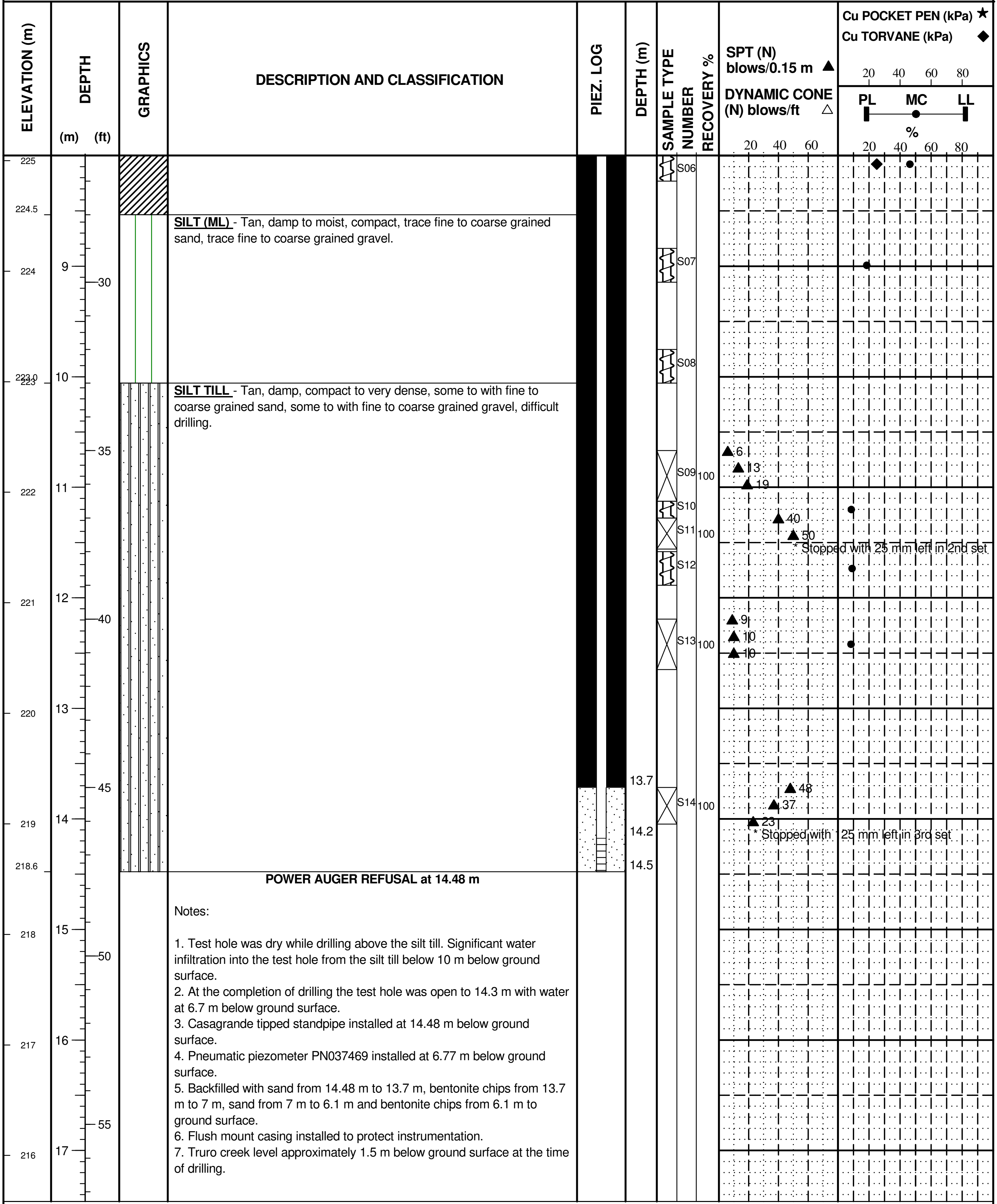
KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH17-02**

SHEET 2 of 2



SILT (ML) - Tan, damp to moist, compact, trace fine to coarse grained sand, trace fine to coarse grained gravel.

SILT TILL - Tan, damp, compact to very dense, some to with fine to coarse grained sand, some to with fine to coarse grained gravel, difficult drilling.

POWER AUGER REFUSAL at 14.48 m

Notes:

1. Test hole was dry while drilling above the silt till. Significant water infiltration into the test hole from the silt till below 10 m below ground surface.
2. At the completion of drilling the test hole was open to 14.3 m with water at 6.7 m below ground surface.
3. Casagrande tipped standpipe installed at 14.48 m below ground surface.
4. Pneumatic piezometer PN037469 installed at 6.77 m below ground surface.
5. Backfilled with sand from 14.48 m to 13.7 m, bentonite chips from 13.7 m to 7 m, sand from 7 m to 6.1 m and bentonite chips from 6.1 m to ground surface.
6. Flush mount casing installed to protect instrumentation.
7. Truro creek level approximately 1.5 m below ground surface at the time of drilling.

SAMPLE TYPE ▨ Auger Grab ☒ Split Spoon

CONTRACTOR	INSPECTOR	APPROVED	DATE
Maple Leaf Drilling Ltd.	K. HAMILTON	DEA	18/8/17

KGS GROUP

SUMMARY LOG

REFERENCE NO.

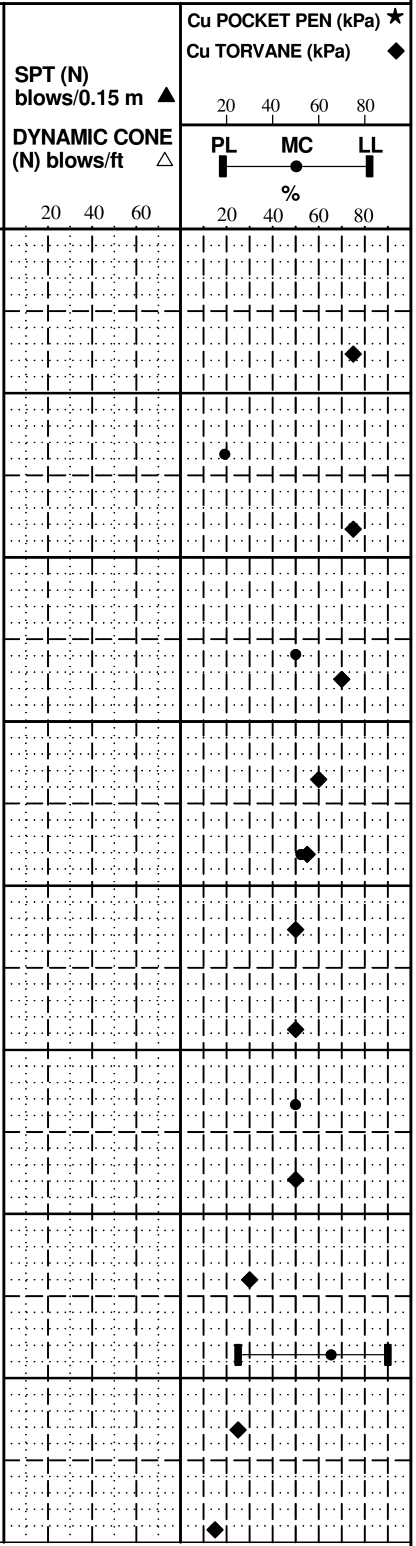
HOLE NO. **TH17-03**

SHEET 1 of 2

CLIENT WSP CANADA GROUP LTD.
PROJECT Truro Creek Culvert Replacements
SITE Ness Avenue Culvert Crossing
LOCATION West of Culvert Inlet
DRILLING METHOD 125 mm ø Solid Stem Auger, B54X Track Mounted Drill Rig

JOB NO. 17-0183-002
GROUND ELEV. 232.7 m +/-
TOP OF PVC ELEV. 232.6 m +/-
WATER ELEV.
DATE DRILLED 05/10/2017
UTM (m) N 5,527,310
E 627,342

ELEVATION (m)	DEPTH (m)	DESCRIPTION AND CLASSIFICATION	SAMPLE NUMBER
	0	**TOPSOIL (OH)** - Dark brown, damp, firm, intermediate to high plasticity, trace rootlets.	
232.4		**SILTY CLAY FILL (CH)** - Dark brown, damp, stiff, high plasticity, some fine to coarse grained sand, trace fine to coarse grained gravel, trace organics.	S01
		- With fine to coarse grained sand, with fine to coarse grained gravel from 0.9 m to 1.4 m.	S02
230.3		**ORGANIC CLAY (OH)** - Black, moist, firm, intermediate to high plasticity, strong organic odour.	S03
229.9		**SILTY CLAY (CH)** - Brown, damp, stiff, high plasticity, trace silt inclusions.	S04
		- Damp to moist, firm below 4 m.	
		- Dark brown to grey below 4.6 m.	S05
		- Dark grey, moist, occasional silt till pockets below 6.1 m.	S06
		- Moist to wet, soft, trace fine to coarse grained sand, occasional fine to coarse grained gravel below 7.6 m.	



SAMPLE TYPE Auger Grab ☒ Split Spoon

CONTRACTOR Maple Leaf Drilling Ltd.
INSPECTOR K. HAMILTON
APPROVED DEA
DATE 18/8/17

GEOTECHNICAL-SOIL LOG U:\FMS\17-0183-002\17-0183-002 - TRURO CREEK CULVERT REPLACEMENTS - LOGS.GPJ

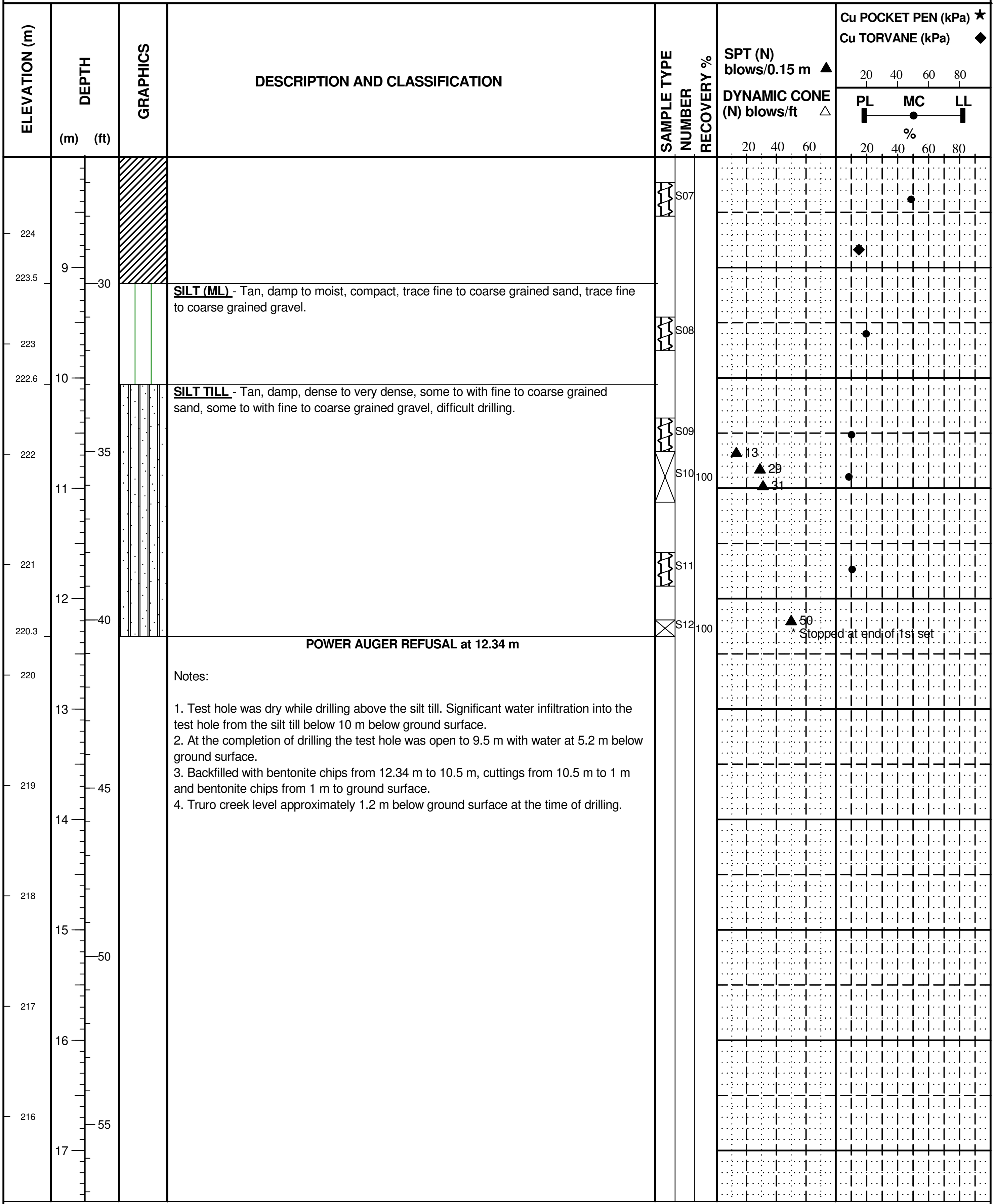
KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH17-03**

SHEET 2 of 2



SILT (ML) - Tan, damp to moist, compact, trace fine to coarse grained sand, trace fine to coarse grained gravel.

SILT TILL - Tan, damp, dense to very dense, some to with fine to coarse grained sand, some to with fine to coarse grained gravel, difficult drilling.

POWER AUGER REFUSAL at 12.34 m

Notes:

1. Test hole was dry while drilling above the silt till. Significant water infiltration into the test hole from the silt till below 10 m below ground surface.
2. At the completion of drilling the test hole was open to 9.5 m with water at 5.2 m below ground surface.
3. Backfilled with bentonite chips from 12.34 m to 10.5 m, cuttings from 10.5 m to 1 m and bentonite chips from 1 m to ground surface.
4. Truro creek level approximately 1.2 m below ground surface at the time of drilling.

SAMPLE TYPE ⌇ Auger Grab ☒ Split Spoon

CONTRACTOR	INSPECTOR	APPROVED	DATE
Maple Leaf Drilling Ltd.	K. HAMILTON	DEA	18/8/17

GEOTECHNICAL-SOIL LOG U:\FMS\17-0183-002\17-0183-002 - TRURO CREEK CULVERT REPLACEMENTS - LOGS.GPJ

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH17-04**

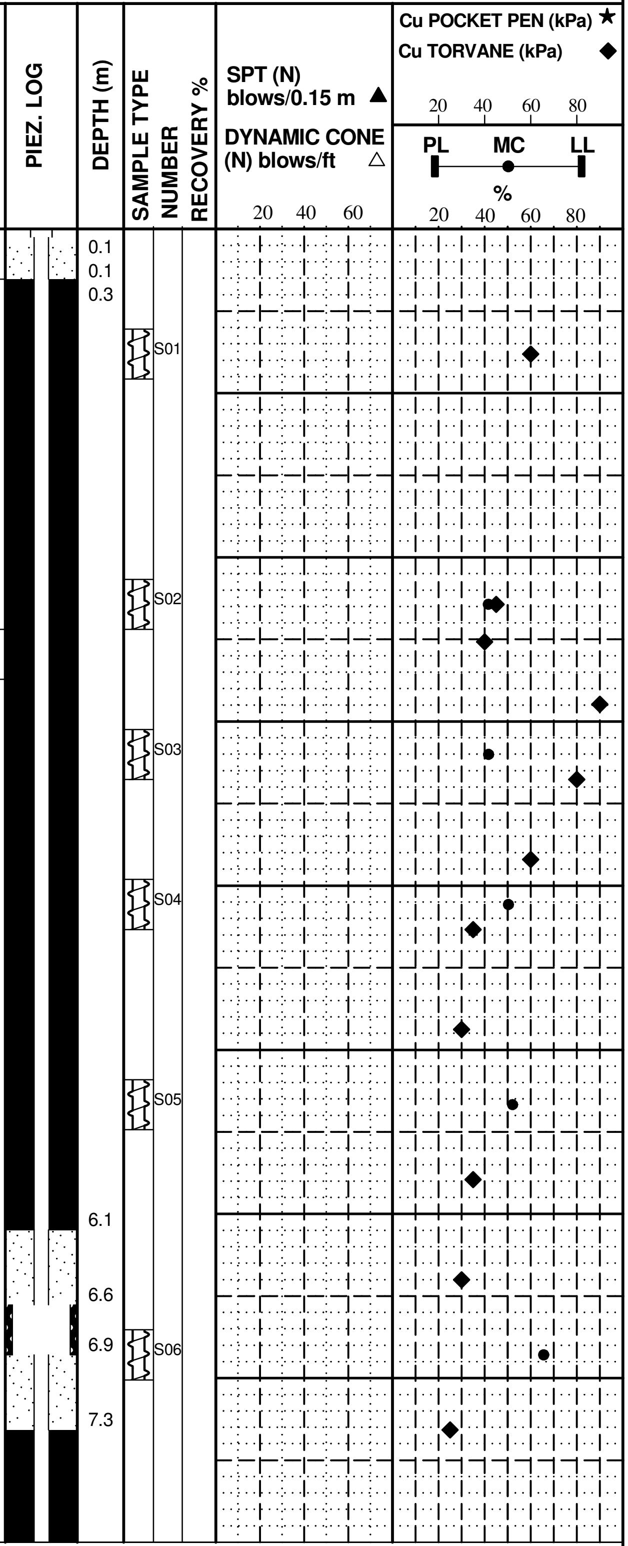
SHEET 1 of 2

CLIENT WSP CANADA GROUP LTD.
PROJECT Truro Creek Culvert Replacements
SITE Ness Street Culvert Crossing
LOCATION West of Culvert Outlet
DRILLING METHOD 125 mm ø Solid Stem Auger, B54X Track Mounted Drill Rig

JOB NO. 17-0183-002
GROUND ELEV. 232.2 m +/-
TOP OF PVC ELEV. 232.2 m +/-
WATER ELEV.
DATE DRILLED 05/10/2017
UTM (m) N 5,527,257
E 627,375

ELEVATION (m)	DESCRIPTION AND CLASSIFICATION
232	**TOPSOIL (OH)** - Dark brown, damp, firm, intermediate to high plasticity, trace rootlets.
231.9	**SILTY CLAY FILL (CH)** - Dark brown to black, damp, stiff, high plasticity, trace fine to coarse grained sand, trace fine to coarse grained gravel, trace organics. - Firm below 1.5 m.
229.8	**ORGANIC CLAY (OH)** - Black, moist, firm, intermediate to high plasticity, strong organic odour.
229.5	**SILTY CLAY (CH)** - Brown, damp, stiff, high plasticity, trace silt inclusions. - Damp to moist, firm below 4 m. - Dark brown to grey below 4.6 m. - Dark grey, moist, occasional silt till pockets below 6.1 m. - Moist to wet, soft, trace fine to coarse grained sand, occasional fine to coarse grained gravel below 7.6 m.

Elevation scale (m): 231, 230, 229, 228, 227, 226, 225
DEPTH (m): 1, 2, 3, 4, 5, 6, 7
DEPTH (ft): 5, 10, 15, 20, 25



SAMPLE TYPE Auger Grab ☒ Split Spoon

CONTRACTOR Maple Leaf Drilling Ltd.
INSPECTOR K. HAMILTON
APPROVED DEA
DATE 18/8/17

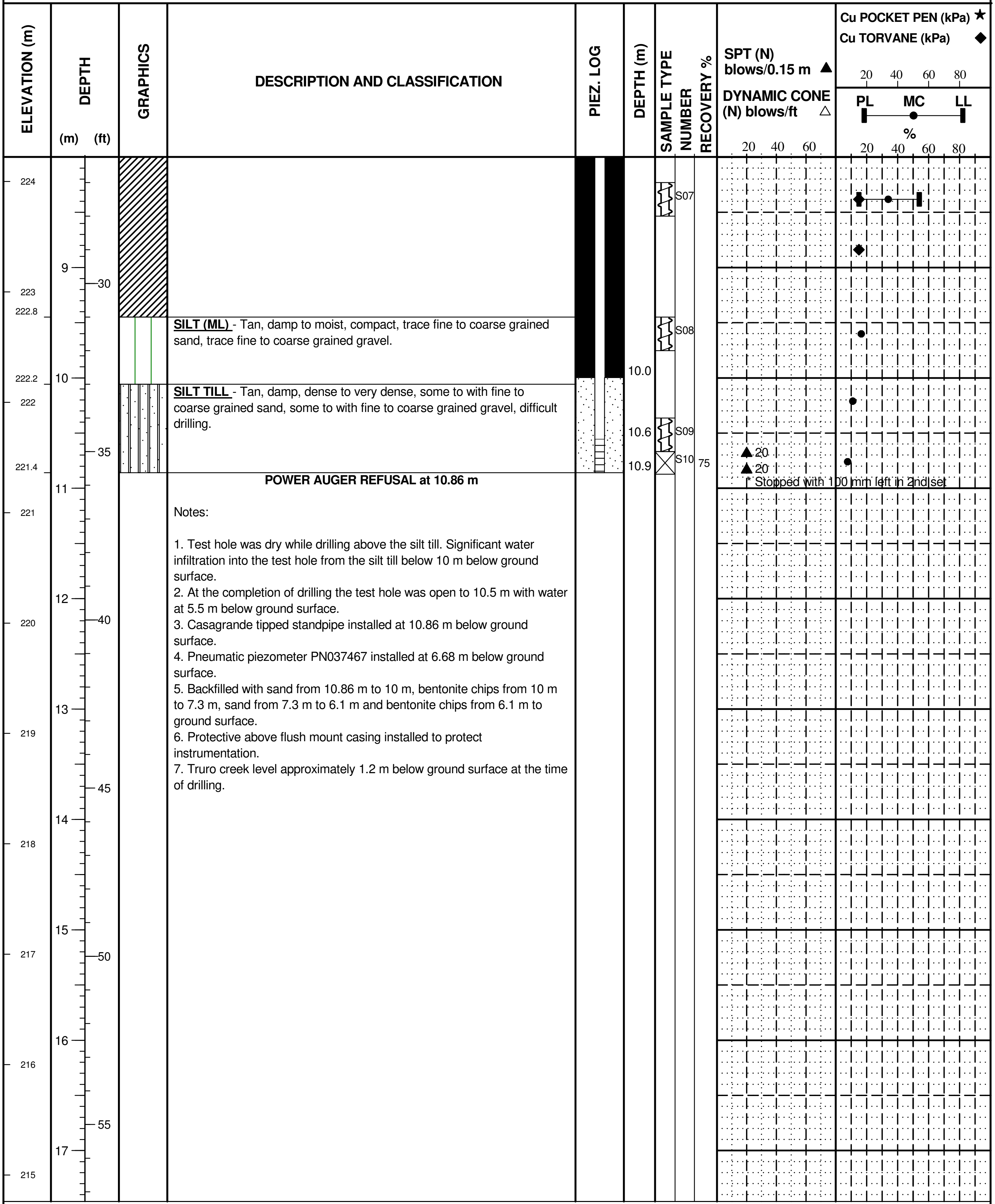
KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO.
TH17-04

SHEET 2 of 2



SILT (ML) - Tan, damp to moist, compact, trace fine to coarse grained sand, trace fine to coarse grained gravel.

SILT TILL - Tan, damp, dense to very dense, some to with fine to coarse grained sand, some to with fine to coarse grained gravel, difficult drilling.

POWER AUGER REFUSAL at 10.86 m

Notes:

1. Test hole was dry while drilling above the silt till. Significant water infiltration into the test hole from the silt till below 10 m below ground surface.
2. At the completion of drilling the test hole was open to 10.5 m with water at 5.5 m below ground surface.
3. Casagrande tipped standpipe installed at 10.86 m below ground surface.
4. Pneumatic piezometer PN037467 installed at 6.68 m below ground surface.
5. Backfilled with sand from 10.86 m to 10 m, bentonite chips from 10 m to 7.3 m, sand from 7.3 m to 6.1 m and bentonite chips from 6.1 m to ground surface.
6. Protective above flush mount casing installed to protect instrumentation.
7. Truro creek level approximately 1.2 m below ground surface at the time of drilling.

SAMPLE TYPE ⌇ Auger Grab ☒ Split Spoon

CONTRACTOR	INSPECTOR	APPROVED	DATE
Maple Leaf Drilling Ltd.	K. HAMILTON	DEA	18/8/17

KGS GROUP

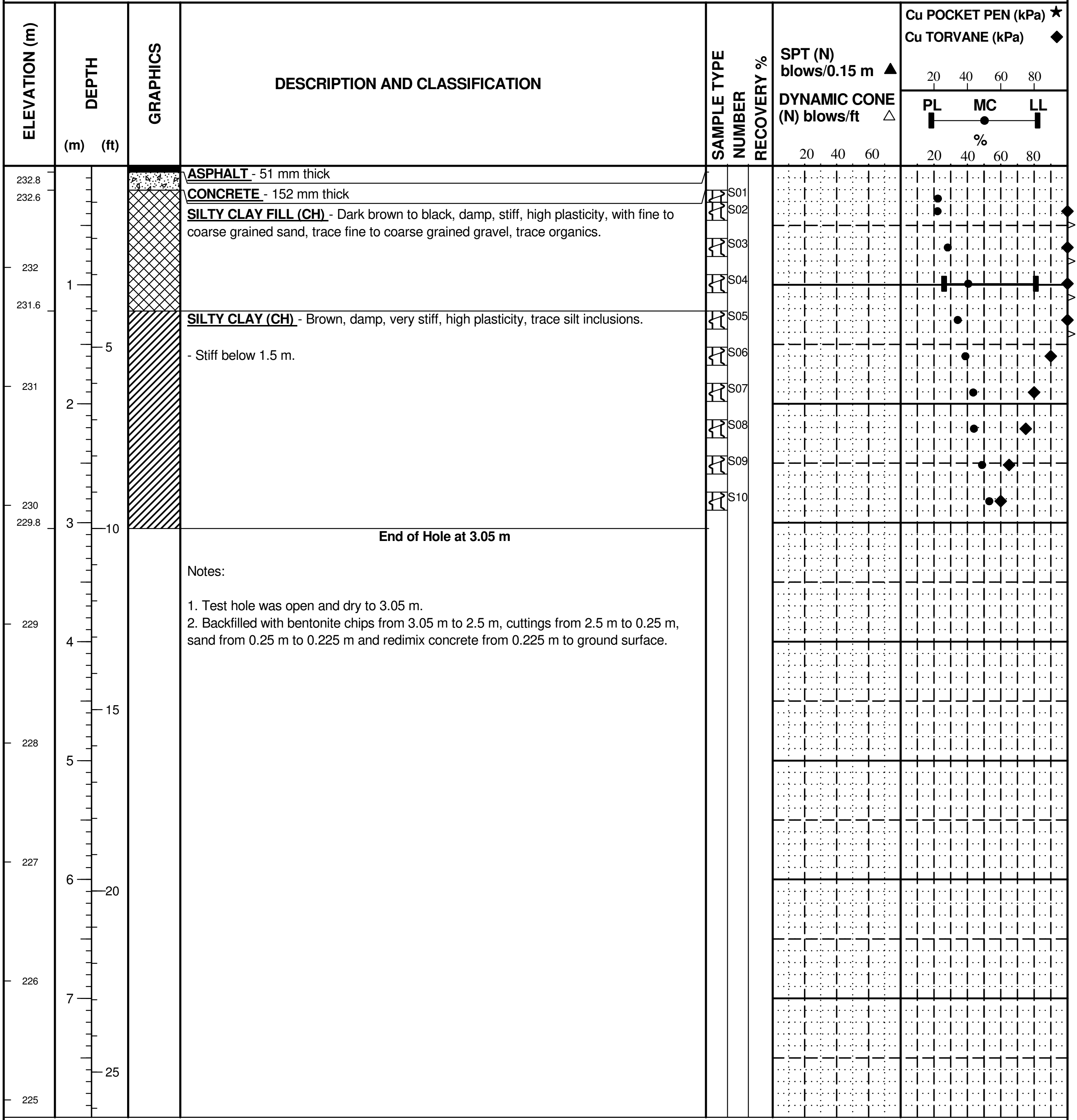
SUMMARY LOG

REFERENCE NO.

HOLE NO.
TH17-05

SHEET 1 of 1

CLIENT	WSP CANADA GROUP LTD.	JOB NO.	17-0183-002
PROJECT	Truro Creek Culvert Replacements	GROUND ELEV.	232.9 m +/-
		TOP OF PVC ELEV.	
SITE	Winchester Street Culvert Crossing	WATER ELEV.	
LOCATION	North of Culvert in Southbound Lane 1 m from Curb	DATE DRILLED	05/11/2017
		UTM (m)	N 5,527,416
DRILLING METHOD	125 mm ø Solid Stem Auger, CME 55 Truck Mounted Drill Rig		E 627,240



ASPHALT - 51 mm thick

CONCRETE - 152 mm thick

SILTY CLAY FILL (CH) - Dark brown to black, damp, stiff, high plasticity, with fine to coarse grained sand, trace fine to coarse grained gravel, trace organics.

SILTY CLAY (CH) - Brown, damp, very stiff, high plasticity, trace silt inclusions.

- Stiff below 1.5 m.

End of Hole at 3.05 m

Notes:

1. Test hole was open and dry to 3.05 m.
2. Backfilled with bentonite chips from 3.05 m to 2.5 m, cuttings from 2.5 m to 0.25 m, sand from 0.25 m to 0.225 m and redimix concrete from 0.225 m to ground surface.

SAMPLE TYPE ⛶ Auger Grab

CONTRACTOR	INSPECTOR	APPROVED	DATE
Maple Leaf Drilling Ltd.	K. HAMILTON	DEA	18/8/17

GEOTECHNICAL-SOIL LOG U:\FMS\17-0183-002\17-0183-002 - TRURO CREEK CULVERT REPLACEMENTS - LOGS.GPJ

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH17-06**

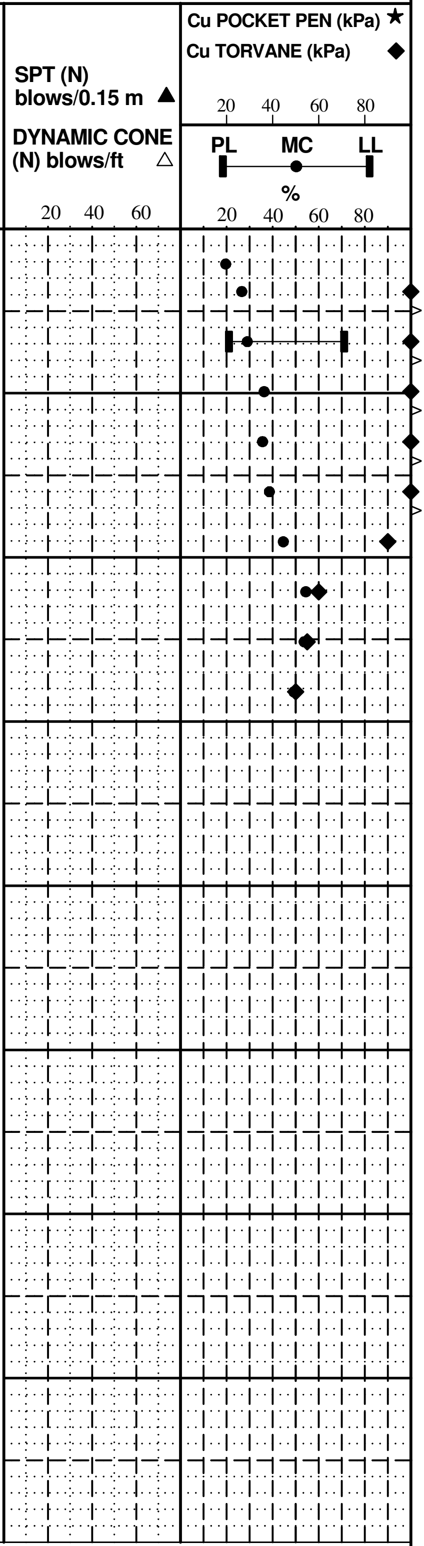
SHEET 1 of 1

CLIENT	WSP CANADA GROUP LTD.	JOB NO.	17-0183-002
PROJECT	Truro Creek Culvert Replacements	GROUND ELEV.	233.0 m +/-
		TOP OF PVC ELEV.	
SITE	Winchester Street Culvert Crossing	WATER ELEV.	
LOCATION	South of Culvert in Northbound Lane 1.6 m from Curb	DATE DRILLED	05/11/2017
		UTM (m)	N 5,527,366 E 627,242
DRILLING METHOD	125 mm ø Solid Stem Auger, CME 55 Truck Mounted Drill Rig		

ELEVATION (m)	DEPTH (m)	DESCRIPTION AND CLASSIFICATION	SAMPLE TYPE NUMBER
233.0	0	**ASPHALT** - 64 mm thick	
232.8		**CONCRETE** - 140 mm thick	S01
232.8		**GRANULAR FILL** - Brown, damp, compact to dense, fine to coarse grained sand, with fine to coarse grained grave, trace silt, trace clay.	S02
		SILTY CLAY FILL (CH) - Dark brown to black, damp, stiff, high plasticity, some fine to coarse grained sand, trace fine to coarse grained gravel, trace organics.	S03 S04
231.8		**SILTY CLAY (CH)** - Brown, damp, very stiff, high plasticity, trace silt inclusions.	S05 S06 S07
		- Stiff below 2.1 m.	S08 S09 S10
230.0	3	**End of Hole at 3.05 m**	

Notes:

1. Test hole was open and dry to 3.05 m.
2. Backfilled with bentonite chips from 3.05 m to 2.5 m, cuttings from 2.5 m to 0.225 m, sand from 0.225 m to 0.2 m and redimix concrete from 0.2 m to ground surface.



SAMPLE TYPE Auger Grab

CONTRACTOR	INSPECTOR	APPROVED	DATE
Maple Leaf Drilling Ltd.	K. HAMILTON	DEA	18/8/17

KGS GROUP

SUMMARY LOG

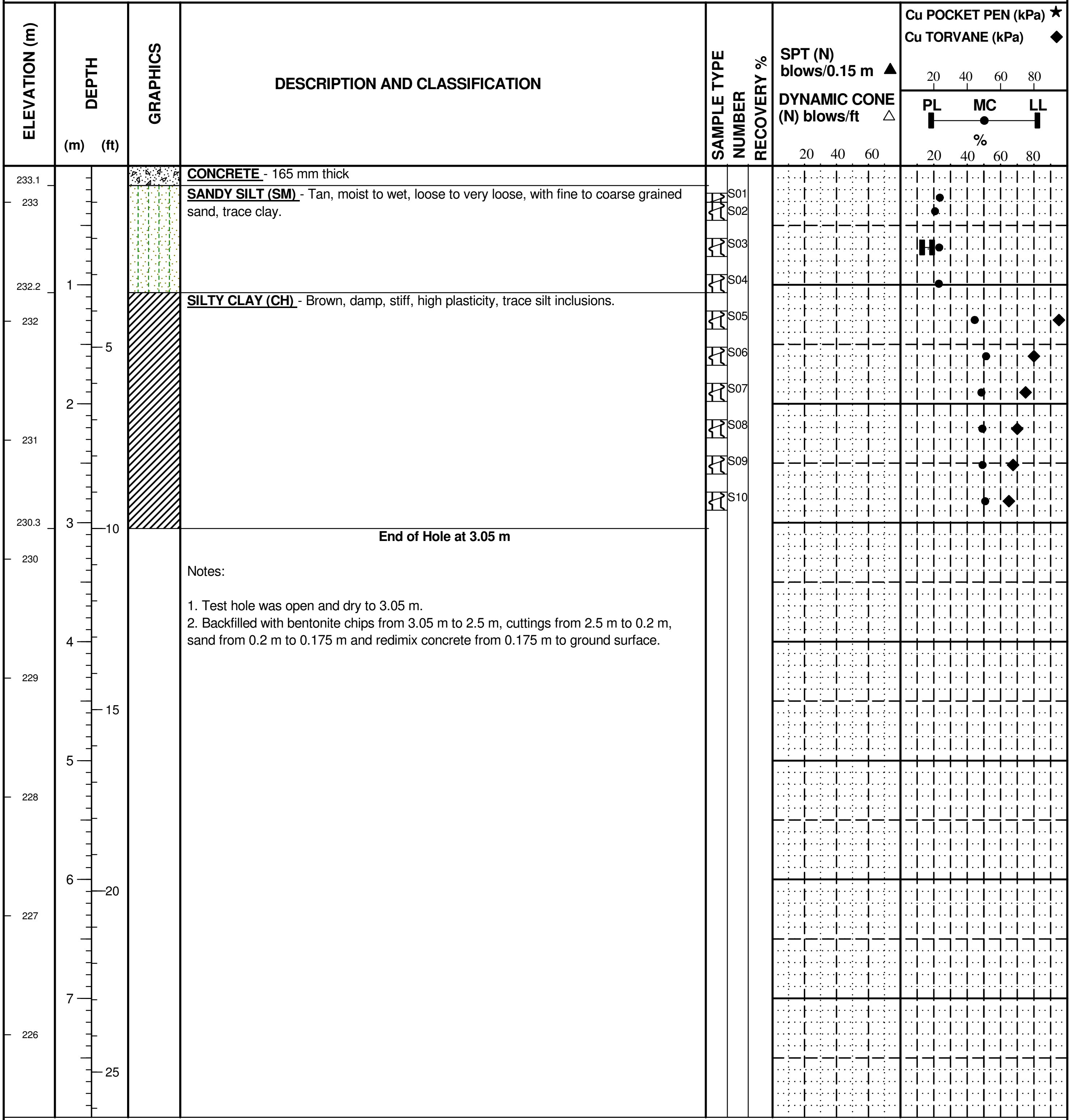
REFERENCE NO.

HOLE NO.
TH17-07

SHEET 1 of 1

CLIENT WSP CANADA GROUP LTD.
PROJECT Truro Creek Culvert Replacements
SITE Linwood Street Culvert Crossing
LOCATION North of Culvert in Northbound Lane 1.3 m from Curb
DRILLING METHOD 125 mm ø Solid Stem Auger, CME 55 Truck Mounted Drill Rig

JOB NO. 17-0183-002
GROUND ELEV. 233.3 m +/-
TOP OF PVC ELEV.
WATER ELEV.
DATE DRILLED 05/11/2017
UTM (m) N 5,527,384
E 627,336



CONCRETE - 165 mm thick

SANDY SILT (SM) - Tan, moist to wet, loose to very loose, with fine to coarse grained sand, trace clay.

SILTY CLAY (CH) - Brown, damp, stiff, high plasticity, trace silt inclusions.

End of Hole at 3.05 m

Notes:

1. Test hole was open and dry to 3.05 m.
2. Backfilled with bentonite chips from 3.05 m to 2.5 m, cuttings from 2.5 m to 0.2 m, sand from 0.2 m to 0.175 m and redimix concrete from 0.175 m to ground surface.

SAMPLE TYPE ⍁ Auger Grab

CONTRACTOR	INSPECTOR	APPROVED	DATE
Maple Leaf Drilling Ltd.	K. HAMILTON	DEA	18/8/17

KGS GROUP

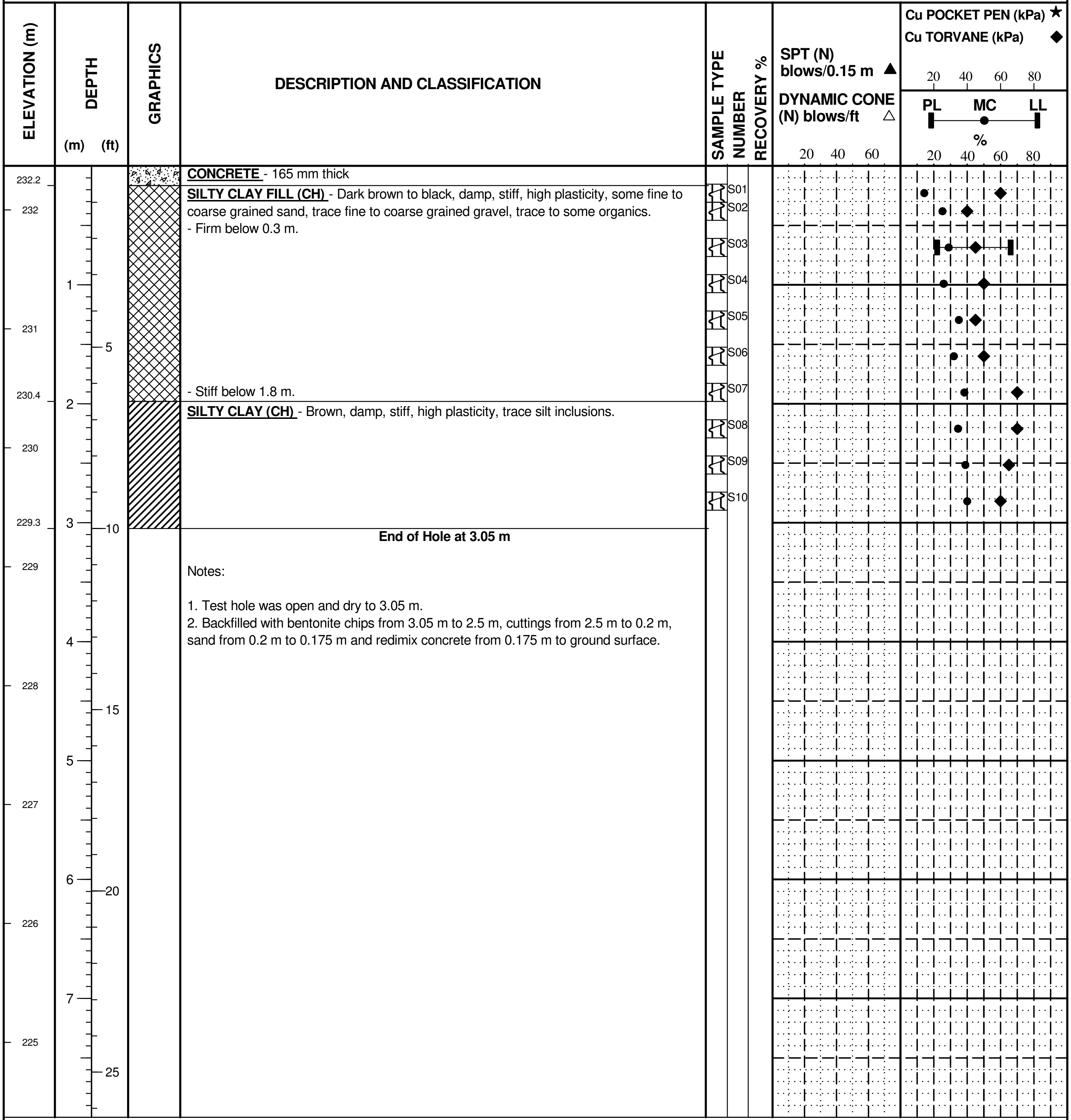
SUMMARY LOG

REFERENCE NO.

HOLE NO.
TH17-08

SHEET 1 of 1

CLIENT	WSP CANADA GROUP LTD.	JOB NO.	17-0183-002
PROJECT	Truro Creek Culvert Replacements	GROUND ELEV.	232.4 m +/-
		TOP OF PVC ELEV.	
SITE	Linwood Street Culvert Crossing	WATER ELEV.	
LOCATION	South of Culvert in Southbound Lane 1.3 m from Curb	DATE DRILLED	05/11/2017
DRILLING METHOD	125 mm ø Solid Stem Auger, CME 55 Truck Mounted Drill Rig	UTM (m)	N 5,527,335 E 627,330



CONCRETE - 165 mm thick

SILTY CLAY FILL (CH) - Dark brown to black, damp, stiff, high plasticity, some fine to coarse grained sand, trace fine to coarse grained gravel, trace to some organics.
- Firm below 0.3 m.
- Stiff below 1.8 m.

SILTY CLAY (CH) - Brown, damp, stiff, high plasticity, trace silt inclusions.

End of Hole at 3.05 m

Notes:

1. Test hole was open and dry to 3.05 m.
2. Backfilled with bentonite chips from 3.05 m to 2.5 m, cuttings from 2.5 m to 0.2 m, sand from 0.2 m to 0.175 m and redimix concrete from 0.175 m to ground surface.

SAMPLE TYPE ⌇ Auger Grab

CONTRACTOR	INSPECTOR	APPROVED	DATE
Maple Leaf Drilling Ltd.	K. HAMILTON	DEA	18/8/17

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO.
TH17-09

SHEET 1 of 1

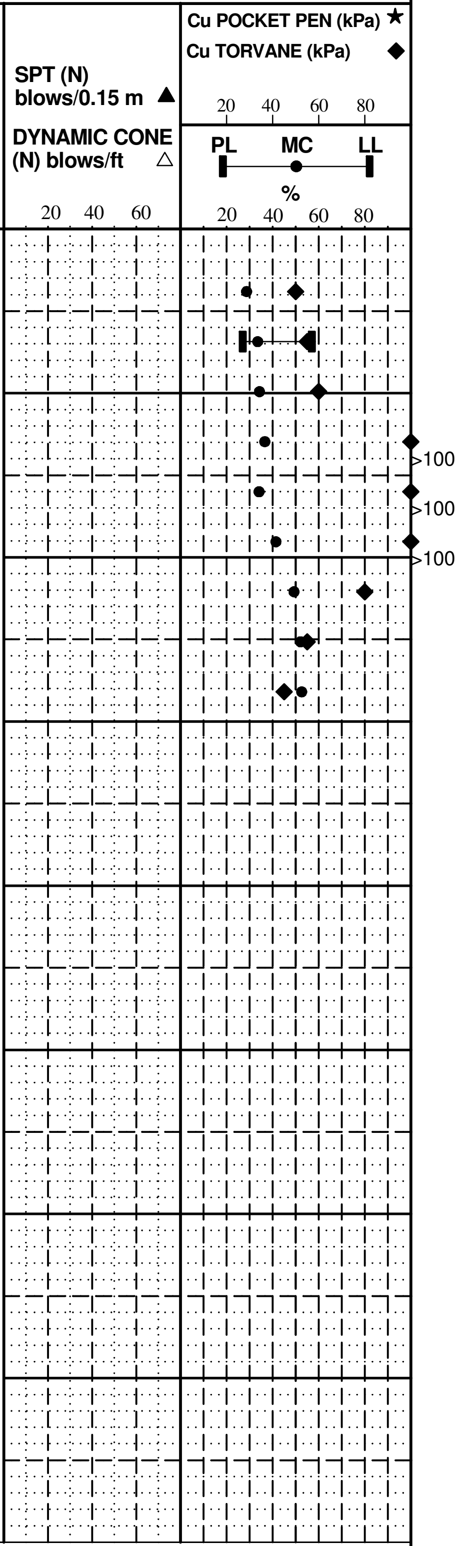
CLIENT WSP CANADA GROUP LTD.
PROJECT Truro Creek Culvert Replacements
SITE Ness Avenue Culvert Crossing
LOCATION East of Culvert in Westbound Curb Lane 1.7 m from Curb
DRILLING METHOD 125 mm ø Solid Stem Auger, CME 55 Truck Mounted Drill Rig

JOB NO. 17-0183-002
GROUND ELEV. 233.4 m +/-
TOP OF PVC ELEV.
WATER ELEV.
DATE DRILLED 05/11/2017
UTM (m) N 5,527,301
E 627,377

ELEVATION (m)	DEPTH (m)	DESCRIPTION AND CLASSIFICATION	SAMPLE TYPE	NUMBER	RECOVERY %
233.3		**ASPHALT** - 76 mm thick			
233.1		**CONCRETE** - 178 mm thick			
233		**SILTY CLAY FILL (CH)** - Dark brown to black, damp, stiff, high plasticity, some fine to coarse grained sand, trace fine to coarse grained gravel, trace organics.	Auger Grab	S01	
			Auger Grab	S02	
	1		Auger Grab	S03	
232.2		**SILTY CLAY (CH)** - Brown, damp, very stiff, high plasticity, trace silt inclusions.	Auger Grab	S04	
			Auger Grab	S05	
	2		Auger Grab	S06	
		- Stiff below 2.13 m.	Auger Grab	S07	
231			Auger Grab	S08	
			Auger Grab	S09	
230.3	3	**End of Hole at 3.05 m**			

Notes:

1. Test hole was open and dry to 3.05 m.
2. Backfilled with bentonite chips from 3.05 m to 2.5 m, cuttings from 2.5 m to 0.275 m, sand from 0.275 m to 0.25 m and redimix concrete from 0.25 m to ground surface.



SAMPLE TYPE Auger Grab

CONTRACTOR
Maple Leaf Drilling Ltd.

INSPECTOR
K. HAMILTON

APPROVED
DEA

DATE
18/8/17

SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH17-10**

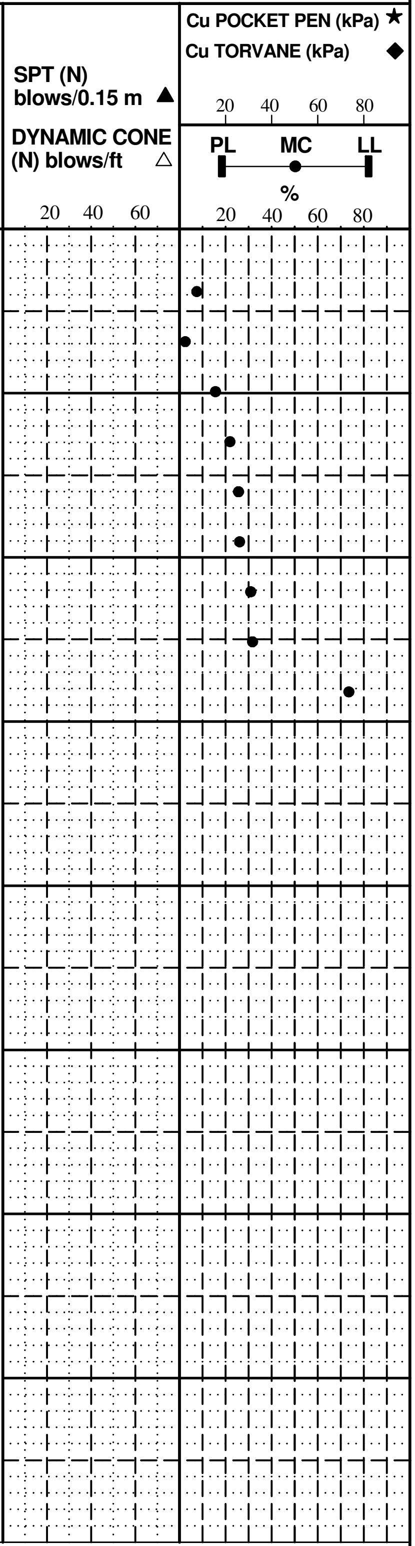
SHEET 1 of 1

CLIENT	WSP CANADA GROUP LTD.	JOB NO.	17-0183-002
PROJECT	Truro Creek Culvert Replacements	GROUND ELEV.	232.5 m +/-
		TOP OF PVC ELEV.	
SITE	Ness Avenue Culvert Crossing	WATER ELEV.	
LOCATION	West of Culvert in Eastbound Median Lane 1.7 m from Curb	DATE DRILLED	05/11/2017
		UTM (m)	N 5,527,295 E 627,350
DRILLING METHOD	125 mm ø Solid Stem Auger, CME 55 Truck Mounted Drill Rig		

ELEVATION (m)	DESCRIPTION AND CLASSIFICATION	SAMPLE TYPE	NUMBER
232.4	**ASPHALT** - 114 mm thick		
232.2	**CONCRETE** - 216 mm thick		
	GRANULAR FILL (SM) - Brown, damp, compact to dense, fine to coarse grained sand, with fine to coarse grained gravel, trace silt, trace clay. - Some silt, some clay below 0.6 m. - With silt, with clay below 0.9 m.	Auger Grab	S01 S02 S03
231.3	**SILTY CLAY FILL (CH)** - Dark brown to black, damp, stiff, high plasticity, some fine to coarse grained sand, trace fine to coarse grained gravel, trace organics.	Auger Grab	S04 S05 S06 S07 S08
229.8	**ORGANIC CLAY (OH)** - Black, moist, firm, intermediate to high plasticity, strong organic odour.	Auger Grab	S09
229.5	**End of Hole at 3.05 m**		

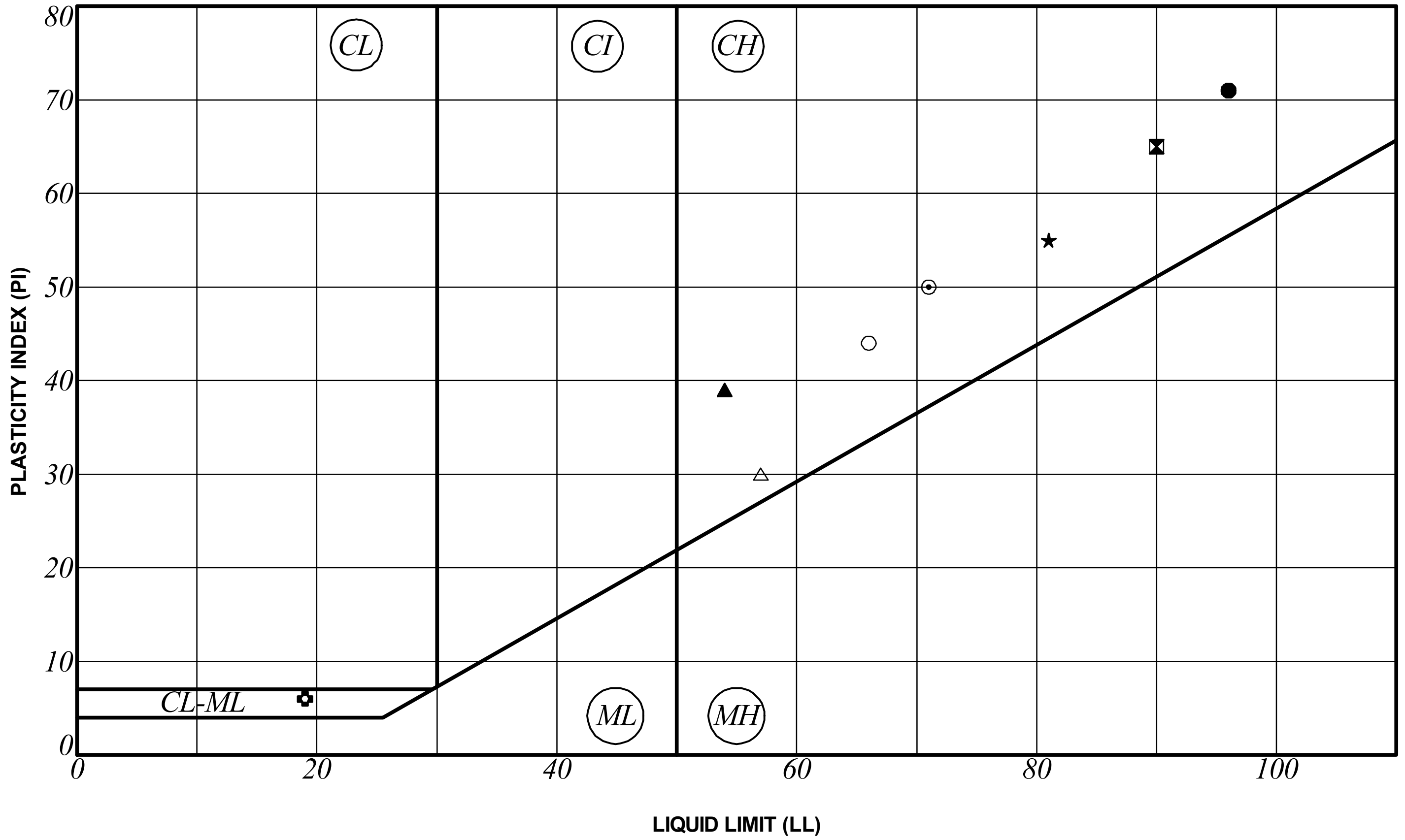
Notes:

1. Test hole was open and dry to 3.05 m.
2. Backfilled with bentonite chips from 3.05 m to 2.5 m, cuttings from 2.5 m to 0.35 m, sand from 0.35 m to 0.325 m and redimix concrete from 0.325 m to ground surface.



SAMPLE TYPE 🗎 Auger Grab

CONTRACTOR	INSPECTOR	APPROVED	DATE
Maple Leaf Drilling Ltd.	K. HAMILTON	DEA	18/8/17



SYMBOL	HOLE	DEPTH (m)	SAMPLE #	LL	PL	PI	% SAND	% SILT	% CLAY	% MC	CLASSIFICATION
●	TH17-01	3.8	S05	96	25	71	0.5	20.5	78.9	54.1	CH
⧗	TH17-03	6.9	S06	90	25	65	3.0	16.3	80.7	65.4	CH
▲	TH17-04	8.4	S07	54	15	39	10.9	37.4	46.7	33.9	CH
★	TH17-05	1.0	S04	81	26	55	25.8	21.7	49.0	40.5	CH
⊙	TH17-06	0.7	S03	71	21	50	11.3	30.4	58.2	29.0	CH
✿	TH17-07	0.7	S03	19	13	6	26.6	64.1	8.6	23.2	ML
○	TH17-08	0.7	S03	66	22	44	9.9	39.2	50.2	28.9	CH
△	TH17-09	0.7	S02	57	27	30	10.6	50.7	38.6	33.5	CH

Notes:
ML - Low Plasticity Silt
MH - High Plasticity Silt
CL-ML - Silty Clay
CL - Low Plasticity Clay
CI - Intermediate Plasticity Clay
CH - High Plasticity Clay
LL - Liquid Limit
PL - Plastic Limit
PI - Plasticity Index
MC - Moisture Content
NP - Non-Plastic

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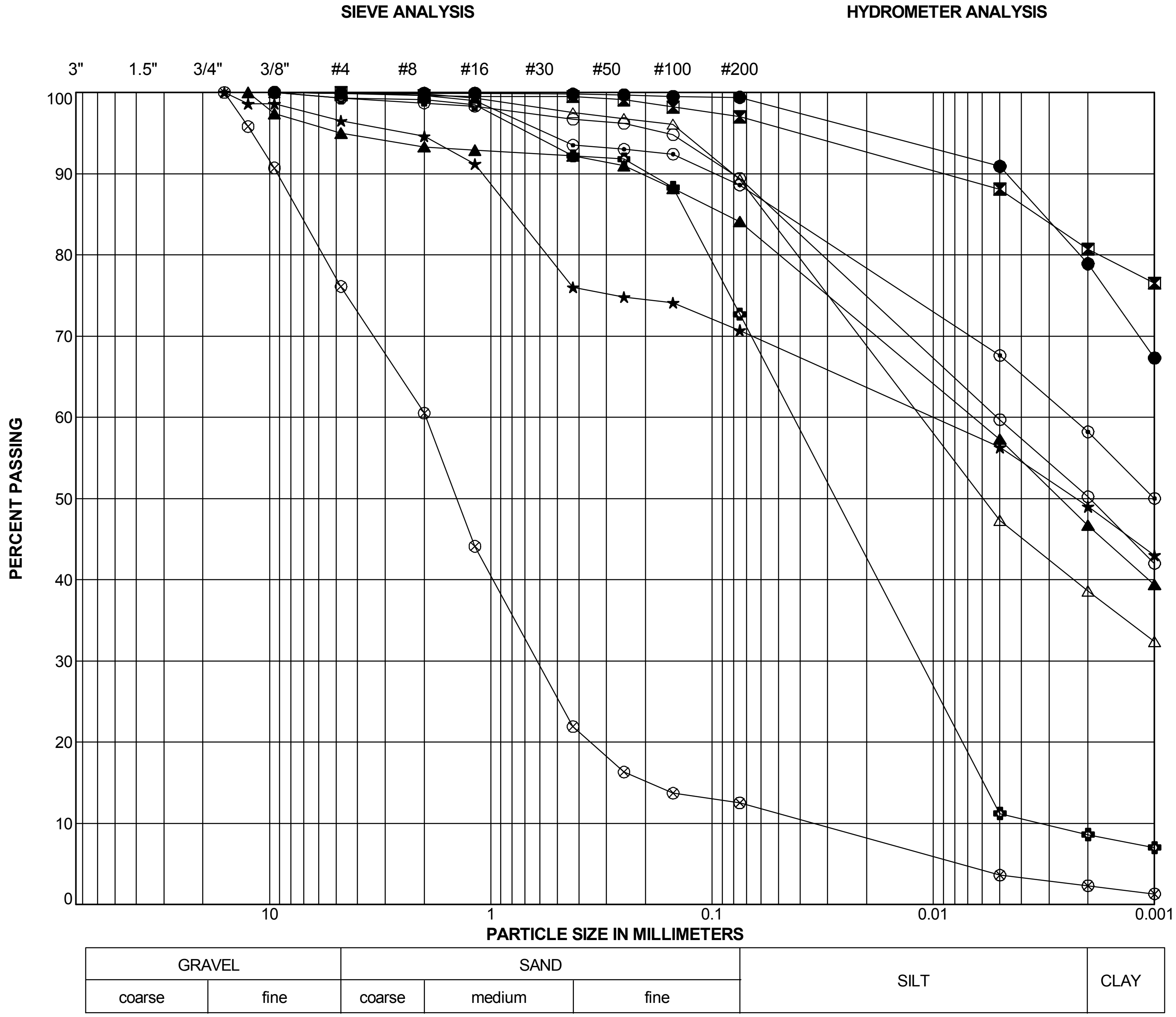
Truro Creek Culvert Replacements

A-LINE PLOT

June 2017 | **Figure A-1** | **Page 1 of 1**



SYMBOL	HOLE	DEPTH (m)	SAMPLE #	% GRAVEL	% SAND	% SILT	% CLAY	% SILT & CLAY	Cu	Cc	CLASSIFICATION
●	*TH17-01*	*3.8*	*S05*	*0.1*	*0.5*	*20.5*	*78.9*	*99.4*			*CH*
⧗	*TH17-03*	*6.9*	*S06*	*0.0*	*3.0*	*16.3*	*80.7*	*97.0*			*CH*
▲	*TH17-04*	*8.4*	*S07*	*5.0*	*10.9*	*37.4*	*46.7*	*84.1*			*CH*
★	*TH17-05*	*1.0*	*S04*	*3.5*	*25.8*	*21.7*	*49.0*	*70.7*			*CH*
⊙	*TH17-06*	*0.7*	*S03*	*0.1*	*11.3*	*30.4*	*58.2*	*88.6*			*CH*
✚	*TH17-07*	*0.7*	*S03*	*0.7*	*26.6*	*64.1*	*8.6*	*72.7*	*13.1*	*0.9*	*ML*
○	*TH17-08*	*0.7*	*S03*	*0.7*	*9.9*	*39.2*	*50.2*	*89.4*			*CH*
△	*TH17-09*	*0.7*	*S02*	*0.1*	*10.6*	*50.7*	*38.6*	*89.3*			*CH*
⊗	*TH17-10*	*0.7*	*S02*	*23.9*	*63.6*	*10.2*	*2.3*	*12.5*	*56.1*	*5.5*	*SM*

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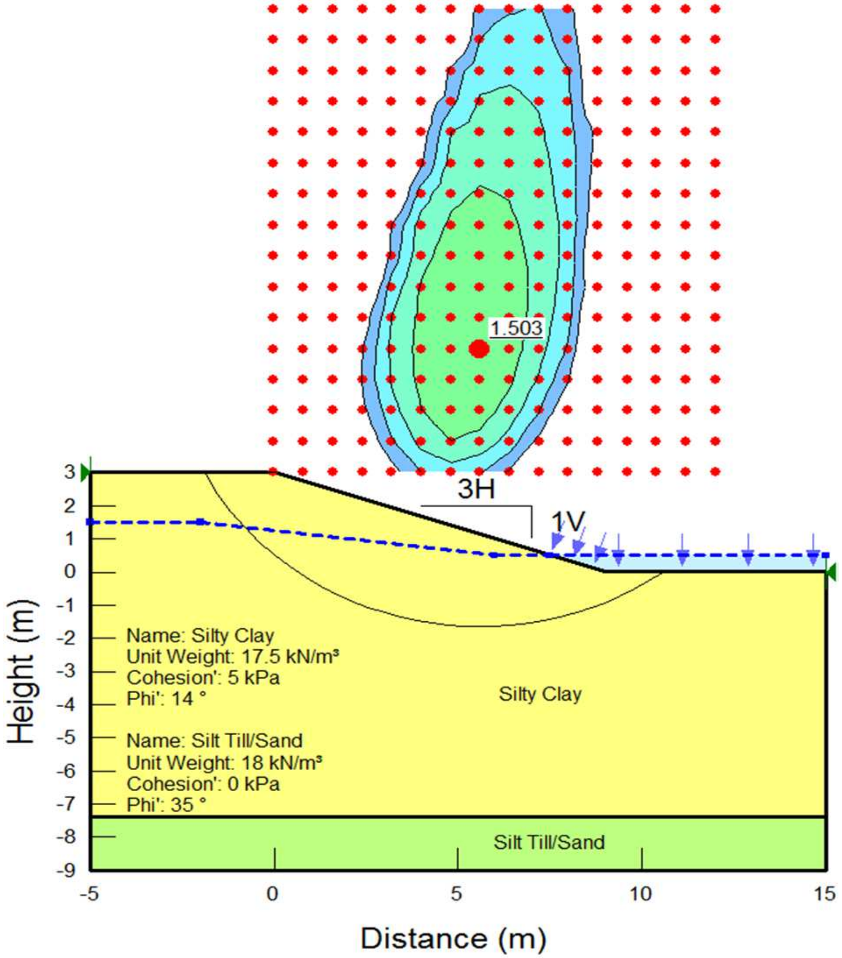
Truro Creek Culvert Replacements

GRAIN SIZE ANALYSES

June 2017	**Figure A-2**	**Page 1 of 1**

APPENDIX B

SLOPE STABILITY ANALYSIS



NOTES:

1) Truro Creek channel geometry based on 2017 WSP topographic survey.
2) Channel slopes based on typical values along the reach.
3) Deepest section along the reach analyzed.
4) Groundwater conditions based on monitoring results from June 2017 to July 2017.
5)

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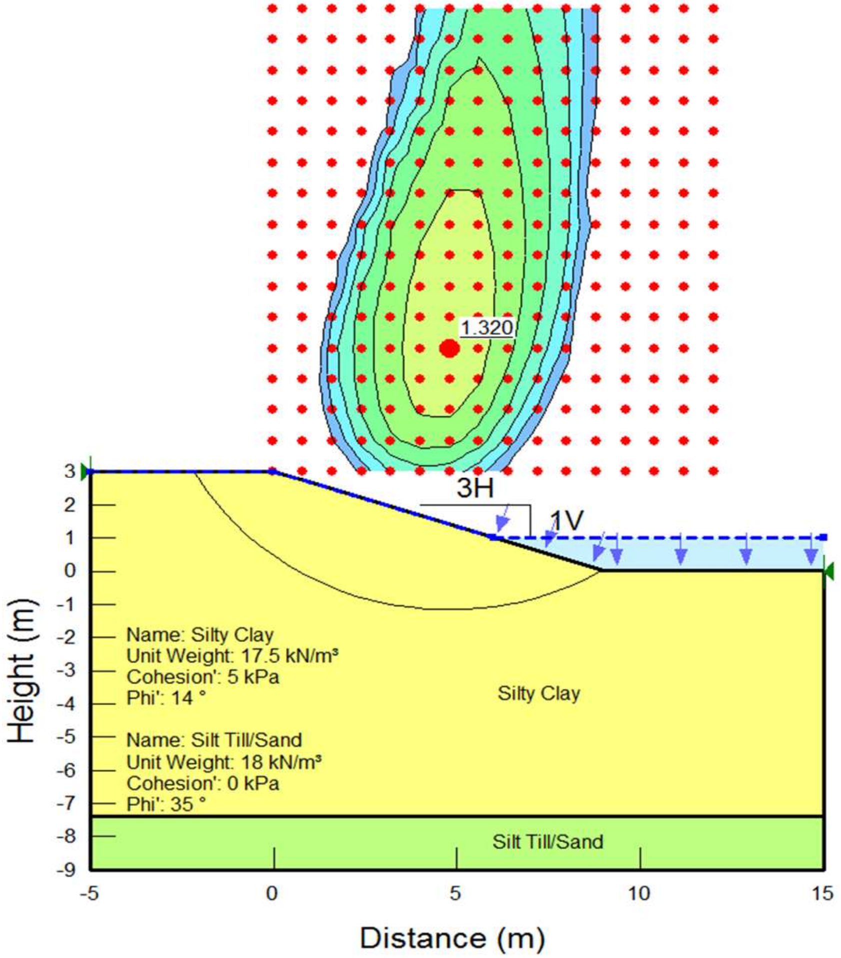
TRURO CREEK

SLOPE STABILITY ANALYSIS

CASE 1: LONG-TERM CONDITION

JULY 2017	Figure B1	0 Rev



NOTES:

1) Truro Creek channel geometry based on 2017 WSP topographic survey.
2) Channel slopes based on typical values along the reach.
3) Deepest section along the reach analyzed.
4) Groundwater conditions based on monitoring results from June 2017 to July 2017.

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TRURO CREEK

SLOPE STABILITY ANALYSIS

CASE 1: SHORT-TERM CONDITION

JULY 2017	Figure B2	0 Rev