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## DRAFT GEOTECHNICAL INVESTIGATION REPORT

### TransCanada King's North Connection (KNC) Proposed Undercrossing of Rutherford Road in Vaughan, Ontario

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REPORT

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**DRAFT GEOTECHNICAL INVESTIGATION REPORT  
TRANSCANADA KNC PROJECT  
PROPOSED HDD CROSSING UNDER RUTHERFORD ROAD**

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# **DRAFT GEOTECHNICAL INVESTIGATION REPORT TRANSCANADA KNC PROJECT PROPOSED HDD CROSSING UNDER RUTHERFORD ROAD**

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# DRAFT GEOTECHNICAL INVESTIGATION REPORT TRANSCANADA KNC PROJECT PROPOSED HDD CROSSING UNDER RUTHERFORD ROAD

## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by TransCanada Pipelines Ltd. (TransCanada) to carry out geotechnical investigations at locations selected by TransCanada, SNC-Lavalin (SNC), and Entec Inc. (Entec) for the proposed approximately 11 km length installation of a NPS 36 natural gas pipeline, running parallel to Highway 427 from Albion Road in the City of Toronto, northward to Major Mackenzie Drive in the City of Vaughan, Ontario.

The proposed pipeline installation in general involves the following:

- Open-cut excavation and backfill along the majority of the pipeline route;
- Trenchless (e.g. Horizontal Directional Drilling, HDD) pipe installation undercrossing major highway/road and watercourse crossings; and
- One tie-in facility at each of the south and north ends of the proposed pipeline.

This draft report presents the results of Golder's geotechnical investigation carried out for the proposed approximately 830 m length undercrossing of Rutherford Road in the City of Vaughan, Ontario as shown on Figure 1. The results of Golder's geotechnical investigations along other sections of the pipeline route and at the tie-in facilities in the south and north ends of the pipeline are presented in separate reports.

The professional services retained for this project include only the geotechnical (physical) aspects of the subsurface conditions at the site and exclude construction cost, regulatory and schedule considerations. The presence or implication of possible surface or subsurface contaminants from any source are outside the terms of reference for this study and have not been investigated or addressed. Use of this report is subject to the *Important Information and Limitations of this Report*, which follows the text of this report and forms an integral part of this document.

## 2.0 SITE AND PROJECT DESCRIPTION

It is understood that the proposed NPS 36 pipeline will undercross Rutherford Road by means of HDD method of installation. Land use in the area north and south of Rutherford Road is primarily agricultural. The proposed pipeline route in this area is adjacent to the existing hydro corridor and a PowerStream station is in the vicinity of HDD entry pit.

The terrain in the area adjacent to the site is generally slightly sloping southward, varying from approximately Elevations 197.1 m to 195.1 m.

## 3.0 GEOTECHNICAL INVESTIGATION

### 3.1 Investigation Procedure

A subsurface investigation was carried out by Golder for the proposed HDD crossing between August 13 and September 23, 2014 during which time a total of six (6) boreholes (designated as Boreholes BH-11 to BH-15 and BH-14A) were advanced at the location of the proposed entry and exit pits and along the proposed route as



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directed by Entec and staked out by J.D. Barnes Ltd., Ontario Land Surveyors. Borehole BH-11 was previously planned to be located at the location of the exit pit; however due to land access restrictions, as requested by Entec, it was moved towards west adjacent to the location of the existing PowerStream station on top of a berm surrounding the station.

The Record of Borehole sheets and the results of the laboratory testing are presented in Appendix A and Appendix B, respectively.

The field borehole investigation was carried out using drill rigs supplied by three drilling contractors: Davis Drilling Ltd. and Geo-Environmental Drilling Inc. of Milton, Ontario and Atcost Soil Drilling Inc. of Gormley, Ontario.

The boreholes were advanced to depths ranging from about 10.7 m to 59.7 m as directed by Entec. The boreholes were advanced through the overburden using PQ and HQ size casings and 108 mm inner diameter hollow stem augers. Where possible soil samples were obtained at ground surface and then at intervals of depth of about 0.75 m to 3.0 m in all borehole except Borehole BH-14A, using a 50 mm outer diameter (O.D.) split-spoon samplers driven by an automatic hammer in accordance with Standard Penetration Test (SPT) procedures.<sup>1</sup> Samples of the bedrock were obtained using 'NQ' and 'HQ' size rock core barrels with core lengths between about 17.4 m and 29.4 m.

Where the drilling method allowed, groundwater conditions in the open boreholes were observed during and upon completion of drilling, and monitoring wells were installed within the overburden in Boreholes BH-11, BH-14A and BH-15 to permit monitoring the water level at these locations using 50 mm diameter PVC pipe. In order to monitor the water level in the bedrock, the piezometer installed in Borehole BH-14 consisted of 25 mm diameter PVC pipe. The monitoring wells have slotted screen surrounded with filter sand and bentonite seals placed at selected depths within the boreholes. The boreholes and annulus surrounding the well pipes above the screen were backfilled to the surface with bentonite and cement grout as appropriate. Well installation details and water level readings are presented on the relevant Record of Borehole sheets (BH-11, BH-14, BH-14A and BH-15) in Appendix A. All boreholes which were not instrumented with a monitoring well and/or piezometer were backfilled with Portland cement grout upon completion of drilling in accordance with Ontario Regulation 903, wells (as amended).

The field work was observed on a full-time basis by a member of Golder's engineering staff who arranged for the clearance of underground public and private (carried out by J.D. Barnes Ltd.) utility services, directed the sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil and rock core samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and testing. Classification testing (water content determination, grain size distributions and Atterberg limits) was carried out on selected soil samples. Rock quality (i.e. TCR, SCR, RQD, weathering and strength index) and classification data was recorded in the field based on visual inspection of the recovered rock cores upon extraction from the core barrel. The bedrock was sequentially photographed and selected samples were properly packed and transported to Golder's Mississauga laboratory for strength testing (uniaxial unconfined compression and point load index). The results of the soil and rock laboratory testing are included in Appendix B.

<sup>1</sup> ASTM D1586 – Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils



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The as-drilled borehole locations and ground surface elevations were surveyed by J.D. Barnes Ltd., Ontario Land Surveyors. The locations given in the Record of Borehole sheets and shown on Figure 1 are positioned relative to UTM NAD83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, ground surface elevations and drilled depths are summarized below:

Borehole Designation	Location (UTM NAD 83)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m)	Easting (m)		
BH-11	4,851,062.9	608,908.9	197.1	25.0
BH-12	4,851,193.7	608,796.4	195.1	49.2
BH-13	4,851,374.1	608,680.4	195.8	59.9
BH-14	4,851,485.0	608,508.1	196.8	55.1
BH-14A	4,851,484.3	608,509.3	196.8	10.7
BH-15	4,851,635.5	608,399.2	197.2	24.8

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

The subject HDD site lies within the Peel Plain physiographic region, close to the south limit of the South Slope physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984). A surficial till sheet, which generally follows the surface topography, is present throughout much of this area. The till is typically comprised of cohesive deposits, with occasional sand to silt zones; it is mapped in this area as the Halton Till. Shallow, localized deposits of loose sand and silt and/or soft clay can overlie this uppermost till sheet, and these represent relatively recent deposits, formed in small glacial meltwater ponds scattered throughout the Peel Plain and concentrated near river valleys. The recent sand, silt and clay and uppermost till deposits in this area overlie and are interbedded with stratified deposits of sand, silt and clay. The study area is underlain by shale bedrock of the Georgian Bay Formation.

### 4.2 Subsurface Conditions

The subsurface conditions encountered in the boreholes advanced along the HDD drill path generally consist of a surficial deposit of silty clay underlain by deposits of cohesive and non-cohesive till. In Boreholes BH-11 to BH-13, the till deposit is underlain by a deposit of silty clay-clayey silt while in Borehole BH-15 the till is underlain by a deposit of clayey gravel which is inferred to be residual soil. These deposits are underlain by shale bedrock interbedded with limestone.

#### 4.2.1 Topsoil

An approximately 80 mm thick layer of topsoil was encountered at the ground surface in Borehole BH-11 at about Elevation 197.1 m.

#### 4.2.2 Fill

Borehole BH-11 which was advanced on a berm surrounding the PowerStream in the vicinity of HDD entry pit BH-11 penetrated an approximately 4.0 m thick layer of cohesive fill comprised of brown to dark brown silty clay,



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some sand, trace gravel underlying topsoil at about Elevation 197.0 m. The fill deposit contains trace quantities of organic matter and rootlets.

SPT 'N'-values of 5 blows and 13 blows per 0.3 m of penetration were measured within the fill layer, suggesting a firm to stiff consistency.

### 4.2.3 Silty Clay (CL to CI)

A deposit of brown to grey silty clay was encountered at ground surface in Boreholes BH-12 to BH-15 and underlying the fill deposit in Borehole BH-11. The deposit generally contains trace to some sand, trace gravel and contains trace quantities of organic matter, roots and rootlets to a depth of about 0.6 m. The top of the deposit ranges from about Elevations 197.2 m to 194.5 m and the thickness of the deposit varies between about 0.7 m and 2.6 m.

The SPT 'N'-values measured within the silty clay deposit ranges from 5 blows to 24 blows per 0.3 m of penetration. Two in situ field vane tests carried out within this deposit and measured natural undrained shear strengths of about 91 kPa and greater than 96 kPa (i.e. it was not possible to turn the shear vane apparatus) and a remoulded strength of about 33 kPa. The SPT 'N'-values and in situ field vanes suggest firm to very stiff consistency.

An Atterberg limits test was carried out on a selected sample of silty clay deposit and measured a liquid limit of about 30 per cent, a plastic limit of about 16 per cent and a corresponding plasticity index of about 14 per cent. The result of the Atterberg limits test is shown on the plasticity chart on Figure B1 in Appendix B and indicates that the material is classified as silty clay of intermediate plasticity.

### 4.2.4 Silty Clay Till (CL to CI)

A deposit of cohesive till comprised of silty clay, some sand to sandy, trace to some gravel was encountered underlying the silty clay in all boreholes. The presence of cobbles and boulders is inferred from auger grinding and split-spoon sampler bouncing within this deposit. An obstruction (inferred as a boulder) was encountered in Borehole BH-12 at a depth of about 5.5 m within the till deposit; consequently the borehole was moved slightly from the original location. As noted below, various soil pockets, cohesive and/or non-cohesive, were also encountered within the silty clay till in Boreholes BH-11, BH-12, BH-14 and BH-15. The top of the silty clay till stratum ranges from about Elevations 196.2 m to 192.5 m. Borehole BH-15 was terminated within this deposit at a depth of about 24.8 m penetrating it for about 23.4 m. In Boreholes BH-11 to BH-14 where the deposit was fully penetrated, its thickness varies between about 12.8 m and 25.4 m including the thickness of various soil pockets.

The SPT 'N'-values measured within the cohesive till range from 7 blows to 91 blows per 0.3 m of penetration, suggesting a firm to hard consistency. Generally there is a very stiff to hard upper crustal zone with 'N'-values greater than 15 blows per 0.3 m of penetration overlying a zone of firm to stiff consistency with 'N'-values ranging from 7 blows to 15 blows per 0.3 m of penetration. Below about Elevations 180 m to 184 m, the till deposit has a hard consistency with 'N'-values greater than 35 blows per 0.3 m of penetration.

The results of grain size distribution test completed on thirteen (13) samples of the silty clay till to sandy silty clay till are shown on Figures B2-A and B2-B.





Atterberg limits tests were carried out on nine (9) samples of the cohesive till deposit, and measured liquid limits ranging from about 19 per cent to 33 per cent, plastic limits ranging from about 12 per cent to 17 per cent and plasticity indices ranging from about 7 per cent to 15 per cent. The results of the Atterberg limits are shown on the plasticity chart on Figure B3 in Appendix B and indicate that the material is classified as silty clay of low to intermediate plasticity.

An approximately 0.7 m to 1.6 m thick layer of silty sand till was encountered within the silty clay till in Boreholes BH-11 and BH-12, respectively at about Elevations 183.2 m and 179.6 m, respectively. SPT 'N'-values of 20 blows and 95 blows per 0.3 m of penetration were measured at the interface of silty clay till and the silty sand till deposit suggesting that the silty sand till is compact to very dense.

The result of a grain size distribution test completed on a selected sample of the silty sand till is shown on Figure B4 in Appendix B.

#### **4.2.5 Silty Clay Pockets (CL)**

Boreholes BH-11 and BH-14 penetrated approximately 3.1 m and 6.2 m thick pockets of grey silty clay, trace sand, trace gravel within the cohesive till; the top of these pockets were at about Elevations 182.5 m and 189.8 m in Boreholes BH-11 and BH-14, respectively.

The SPT 'N'-values measured within this cohesive deposit range from 6 blows to 15 blows per 0.3 m of penetration. Two in situ field vane tests were carried out within the cohesive soil pocket in Borehole BH-14 and measured undrained shear strengths of 91 kPa and greater than 96 kPa (i.e., it was not possible to turn the shear vane apparatus) and a sensitivity value of 3. The SPT 'N'-values and field vane tests suggest a firm to very stiff consistency for the silty clay pockets.

Atterberg limits tests were carried out on two (2) samples of this deposit and measured liquid limits of about 32 per cent and 39 per cent, plastic limits of about 17 per cent and 15 per cent and corresponding plasticity indices of about 16 per cent and 15 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure B5 in Appendix B and indicate that the material is classified as silty clay of intermediate plasticity.

**Non-cohesive Pockets** Approximately 1.5 m thick layer of sand and gravel was also encountered within the silty clay till in Borehole BH-11 at a depth of about 17.7 m (Elevation 179.4 m). One SPT 'N'-value of 14 blows per 0.3 m of penetration was measured within the sand and gravel pocket suggesting that the material is compact.

Approximately 2.2 m thick layer of silty sand was also encountered within the silty clay till deposit in Borehole BH-15 at a depth of about 14.7 m (Elevation 182.5 m). One SPT 'N'-value of 153 blows per 0.23 m of penetration was measured within the silty sand pocket suggesting that the material is very dense.

#### **4.2.6 Silty Clay-Clayey Silt (CL-ML)**

A deposit of silty clay-clayey silt was encountered underlying the till deposit in Boreholes BH-11 to BH-13. The top of the deposit ranges from about Elevations 175.1 m to 172.6 m. Borehole BH-11 was terminated within this layer penetrating it for a thickness of about 2.6 m and the deposit is about 11.7 m and 7.3 m thick in Boreholes BH-12 and BH-13, respectively.





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The SPT 'N'-values measured within the silt portion of the deposit range from 22 blows to 43 blows per 0.3 m of penetration, indicating the silt is compact to dense within the silty clay-clayey silt portion of the deposit, SPT 'N' values range from 30 blows to 91 blows per 0.3 m of penetration suggesting a very stiff to hard consistency.

The grain size distribution test result for a sample of the silty clay-clayey silt portion of the deposit is shown on Figure B6 in Appendix B.

Atterberg limits tests were carried out on four (4) samples of the silty clay-clayey silt deposit and measured liquid limits ranging from about 22 per cent to 25 per cent, plastic limits of about 18 per cent and plasticity indices ranging from about 4 per cent to 7 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure B7 in Appendix B and indicate that the material is classified as silty clay-clayey silt of low plasticity.

### **4.2.7 Clayey Gravel Residual Soil (GC)**

An approximately 4.4 m thick layer of sandy silty clayey gravel was encountered underlying the till deposit in Borehole BH-14 at about Elevation 170.6 m. The stratum has been classified as residual soil – the term refers to a deposit which is derived by extensive weathering of the underlying bedrock resulting in complete loss of the shale bedrock structure (i.e. has the appearance of a soil).

SPT 'N'-values of 100 blows per 0.01 m of penetration and 140 blows per 0.3 m of penetration were measured within the deposit suggesting the material is very dense.

The grain size distribution result for a selected sample of clayey gravel is shown on Figure B8 in Appendix B.

An Atterberg limits test was completed on the fines portion of a selected sample of clayey gravel layer and measured liquid limit of about 28 per cent, plastic limit of about 15 per cent and a corresponding plasticity index of about 13 per cent. The result of the Atterberg limit test is shown on the plasticity chart on Figure B9 in Appendix B which indicates that the fines of the deposit are silty clay of low plasticity.

### **4.2.8 Shale Bedrock**

Shale bedrock was encountered in Boreholes BH-12 to BH-14 at between about Elevations 163.4 m and 166.2 m. Shale fragments were first observed within the split spoon sampler during auger drilling in all three boreholes; this is inferred to indicate the presence of fractured shale bedrock. Coring operations were undertaken in the boreholes upon refusal to further advancement of split-spoon sampler.

SPT 'N'-values of 50 blows per 0.08 m of penetration, 100 blows per 0.08 m of penetration and 150 blows per 0.05 m of penetration were measured within the fractured shale bedrock .

Core samples were collected from Boreholes BH-12 to BH-14 as shown on Figures B9 to B11 in Appendix B. Based on the review of the bedrock core samples, the bedrock consists of shale of Georgian Bay Formation and is generally described as moderately weathered to fresh, thinly laminated to laminated, grey to dark grey, very fine grained, non-porous, weak to medium strong shale with very thin to thin interbeds (20 mm to 0.2 m) of very fine grained, strong to very strong limestone/dolostone, as presented on the relevant Record of Drillhole sheets. The shale rock contains limestone/dolostone lenses (less than 20 mm) dispersed throughout the core.

The upper 0.2 m to 1.2 m of bedrock in Boreholes BH-13 and BH-14 is highly weathered, extremely weak shale. The degree of weathering of the bedrock samples (i.e. highly weathered to fresh), and the strength classification



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of intact rock mass based on field identification (i.e. extremely weak to very strong) are described in accordance with the International Society of Rock Mechanics (ISRM<sup>1</sup>) standard classification system. The Rock Quality Designation (RQD) measured on the core samples ranges generally from about 50 per cent to 100 per cent, indicating a rock mass of fair to excellent quality as per Table 3.10 of Canadian Foundation Engineering Manual (CFEM).<sup>2</sup> However, upper portions of recovered rock (upper 1 to 1.5 m) often contain fractured, broken and lost core with RQD values ranging from 0 per cent to 48 per cent indicating a rock mass of very poor to poor quality. Due to a mechanical deficiency with the core barrel; a rock core sample was not recovered between depths of 40.0 m and 41.5 m in borehole BH-13; for the other recovered core samples, Total Core Recovery (TCR) varies between 57 per cent and 100 per cent and Solid Core Recovery (SCR) generally ranges from 20 per cent to 100 per cent with some lower values measured in the upper portion of bedrock indicating more weathered and fractured bedrock.

The majority of the logged discontinuities are bedding within the shale bedrock or contacts between shale and limestone interbeds while some discontinuities were logged as joints. In general, the identified discontinuities surfaces are planar or undulating with smooth to rough roughness. Most of the identified bedding and contact surfaces are clean while some have stained or partially coated surfaces; where the bedding discontinuities have an infilling greater than 1 mm the infill material is generally identified as clay.

Three Unconfined Compression (UC) tests (ASTM D7012<sup>3</sup>) were carried out on selected samples of shale bedrock and the measured Uniaxial Compressive Strength (UCS) ranged from approximately 10 MPa to 14 MPa as summarized in Table B1 and detailed in Tables B2 to B4 in Appendix B. One UCS test was also carried out on a selected sample of limestone and the measured UCS was approximately 61 MPa as detailed in Table B5 in Appendix B.

Point load strength index tests (ASTM D5731<sup>4</sup>) were carried out on selected core samples. The axial and diametral point load strength index values (Is50) are shown on the relevant Record of Drillhole sheets in Appendix A and are presented in Table B6 in Appendix B. Eleven (11) axial tests measured Is50 values of between about 0.4 MPa and 1.2 MPa and twenty-four (24) diametral tests measured Is50 values of between about 0.1 MPa and 2.5 MPa on selected shale samples. Also, eight (8) axial tests measured Is50 values ranging from about 4.5 MPa to 9.4 MPa and five (5) diametral tests measured Is50 values ranging from about 3.8 MPa to 10.4 MPa on selected samples of the limestone interbeds.

Based on the laboratory UCS tests and in accordance with Table 3.5 in CFEM (2006), the shale bedrock is classified as weak rock and the limestone interbeds are classified as strong rock.

### 4.3 Groundwater Conditions

Monitoring wells were installed in Boreholes BH-11, BH-14, BH-14A and BH-15 and the details of the well installation are shown on the relevant Record of Borehole sheets in Appendix A. The groundwater level measurements in the wells are summarized below:

<sup>1</sup> International Society of Rock Mechanics Commission on Test Methods, 1985. Int. J. Rock Mech. Min. Sci. & Geomech. Abstr. Vol 22, No. 2 pp. 51-60.

<sup>2</sup> Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4<sup>th</sup> Edition.

<sup>3</sup> ASTM D7012 - Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens.

<sup>4</sup> ASTM D5731 - Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classification.



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Borehole	Ground Surface Elevation (m)	Screened Depths (m)	Screened Deposit	Depth to Water (m)	Groundwater Elevation (m)	Date Measured
BH-11	197.1	16.8 to 19.8	Sand and Gravel/ Sandy Silty Clay till	6.2	190.9	September 23, 2014
				4.9	192.2	October 15, 2014
BH-14	196.8	32.0 to 36.6	Shale Bedrock	4.4	192.4	August 26, 2014
				3.5	193.3	September 22, 2014
				3.2	193.6	October 17, 2014
BH-14A	196.8	7.6 to 10.7	Silty Clay	2.5	194.3	September 22, 2014
				1.8	195.0	October 14, 2014
BH-15	197.2	13.7 to 16.7	Silty Clay Till/Silty Sand	3.5	193.7	August 14, 2014
				3.8	193.4	September 22, 2014
				4.1	193.1	October 17, 2014

Based on the water level readings obtained to date in the monitoring wells / piezometers installed in the boreholes (as per above), it is considered that the general groundwater table in this section of the project area is at Elevations 194 m to 195 m (i.e., at about 2 m to 3 m below ground surface). There may be some slight variations in water pressure within the different stratigraphic units however it is not possible to make conclusions in this regard based on the readings obtained to date. It is likely, however, that the water levels in the monitoring wells installed in Boreholes BH-11 and BH-15 are still stabilizing. Further monitoring of the water levels in the wells should be conducted to establish stabilized water levels.

Cement grout was noted in the monitoring well installed at the location of Borehole BH-14 during the development of the well for the hydrogeology studies on October 17, 2014. The grout accumulation may have affected the water inflow to the well and further monitoring of the groundwater levels as noted above will be required to confirm stabilized groundwater levels.

It should be noted that groundwater level is subject to seasonal fluctuations and precipitation events, and should be expected to be higher during wet seasons.



## **5.0 DISCUSSION**

This section of the report provides engineering discussion and recommendations for the geotechnical design aspects of the proposed HDD, based on our interpretation of the borehole information and on our understanding of the project requirements. The information in this portion of the report is provided for planning and design purposes for the guidance of the design engineers. Where comments are made on construction, they are provided only in order to highlight aspects of construction which could affect the design of the project. Contractors bidding on or undertaking any work at the site should examine the factual results of the investigation, satisfy themselves as to the adequacy of the information for construction and make their own interpretation of the factual data as it affects their proposed construction techniques, schedule, equipment capabilities, costs, sequencing and the like.

Golder's professional services for this report address only the geotechnical (physical) aspects of the subsurface conditions at this site.

At the time of preparation of this report, the HDD design for the proposed undercrossing was in the preliminary stages and the alignment and depth of the bore-path had not yet been finalized. Therefore, the recommendations contained in this report should be reviewed by this office when the final design is available.

### **5.1 Proposed Pipeline Alignment / Inferred Subsurface Conditions**

It is understood that the proposed NPS 36 pipe will be installed by HDD method of excavation under Rutherford Road in Vaughan, Ontario.

With the HDD method, a small rotating and steerable drill bit is launched from the surface at a shallow angle and is used to drill a pilot hole supported with drilling fluid. Once the pilot bore is complete, the drill head is replaced with a back-reamer or expander which enlarges the drill hole. Once the desired size is reached, the product pipe is attached to the reaming head and pulled through the bore.

Based on the preliminary design drawings provided by Entec, the following information is known for the proposed crossing:

**Proposed NPS 36 Pipeline Information**

	<b>833.4 m</b>
Approximate Ground Elevation at Entry Pit (North of Rutherford Road)	196.8 m
Approximate Ground Elevation at Rutherford Road	195.3 m
Approximate Ground Elevation at Exit Pit (South of Rutherford Road)	193.7 m
Approximate Invert Elevation	145.0 m
Approximate Depth of Entry and Exit Pits	4.2 m

For the currently proposed invert level of Elevation 145 m the HDD alignment would extend through the overburden strata as listed below (beginning with the uppermost stratum) and be within the shale bedrock that was encountered at about Elevation 163 m to 165 m.. In general, the subsurface conditions are considered suitable for HDD installation methods although there will be challenges to be overcome through proper



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## DRAFT GEOTECHNICAL INVESTIGATION REPORT TRANSCANADA KNC PROJECT PROPOSED HDD CROSSING UNDER RUTHERFORD ROAD

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equipment selection and fluid pressures within the glacial till deposit and careful consideration should be given to nature of non-cohesive deposits/pockets (i.e., non-cohesive portions of the silt to silty clay-clayey silt, clayey gravel and non-cohesive soil pockets) with respect to anticipated stand up time within the non-cohesive portions of the deposits.

**Surficial Silty Clay:** The stratum generally consists of firm to very stiff silty clay. The bottom elevation of the deposit ranges from about Elevation 195.9 m in Borehole BH-15 (adjacent to the location of the proposed entry pit) to about Elevation 193.0 m in Borehole BH-11 (adjacent to the location of the proposed exit pit). The elevations of the bottom of excavation at the location of the entry and exit pits are about 192.6 m and 189.5 m, respectively. Therefore, the HDD installation will likely be initiated below the surficial silty clay from the silty clay till deposit. However, the excavation of the entry and exit pits will be through this deposit which will be discussed in the following sections.

**Silty Clay Till Deposit:** The silty clay till deposit is generally very stiff to hard with occasional cobbles/boulders; the deposit contains interlayers/pockets of silty clay and silty sand till, sand and gravel, silty sand. The bottom of the deposit ranges from about Elevations 175.1 m to 170.7 m. Due to the complex depositional history of till materials, there is a potential for fractures and fissures, as well as sand seams, to be present within the till. Sand zones, as encountered at the site, and potential fissures/fractures provide an increased permeability to allow for possible fluid migration to the surface or loss of drilling fluid circulation during the drilling operation within this deposit.

Cobbles and boulders which are typically present within the glacial tills in southern Ontario were encountered within the boreholes advanced at this site. The borehole drilling method, without coring of boulders and the random distribution of cobbles/boulders, does not permit measurement of the size of the cobbles and boulders nor an estimate of the quantity (overall volume) of these materials.

Encountering cobbles and boulders within the till deposit could result in difficulties in advancing the bore through the cobble/boulder zones and could lead to deviation of the HDD alignment. Further, cobbles/boulders within the till deposits can originate from the igneous and metamorphic rocks of the Canadian Shield and, these can have unconfined compressive strengths of up to 250 MPa. Therefore, suitable equipment will be required to remove any cobbles/boulders encountered during drilling or boring.

The tunneling/boring conditions can be described as hard within the very stiff to hard the silty clay till materials. Stand up time for the unsupported excavation face within this deposit is expected to be greater than 30 hours with the exception of the silty sand till pockets which can be described as cohesive running.

**Silt to Silty Clay-Clayey Silt:** The deposit is predominantly compact silt of slight plasticity to very stiff to hard silty clay-clayey silt of low plasticity with the bottom of the deposit ranging from about Elevation 165.3 m to 163.4 m at the two borehole locations where the deposit was penetrated. The HDD installation within this deposit is expected to be below the groundwater table. The non-cohesive silt zones of this deposit, below the groundwater table, are expected to be generally less stable and more erodible than the cohesive zones. Therefore, sloughing and bore wall instability are expected within this deposit. The tunneling conditions can be described as flowing within the non-cohesive zones of the deposit to cohesive running or rapidly raveling within the low plastic (cohesive) zones of the deposit. Stand up time for the unsupported excavation face within the cohesive zones is expected to be between 5 minutes and 50 minutes whereas the stand-up time for the non-cohesive zones of the deposit could be less than one minute.



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**Clayey gravel:** The deposit is predominantly very dense clayey gravel with the bottom of the deposit at about Elevation 166.2 m in the one borehole where the deposit was encountered. Although the fines portion of the deposit is described as silty clay the bulk behavior of the deposit should be considered as non-cohesive and therefore sloughing and bore wall instability are expected within this deposit. The tunneling conditions can be described as flowing to cohesive running within the deposit. Stand up time for the unsupported excavation face within the deposit is expected to be less than 5 minutes.

**Shale Bedrock:** During the HDD installation through the bedrock some deviation of the pilot hole alignment may occur at the bedrock surface and at harder rock (limestone/dolostone) layers within the shale bedrock. A number of zones of broken core and lost core, which could indicate soft seams, voids or vugs in the bedrock, were noted in the drillhole logs. These zones could result in uneven drilling pressure which can result in difficulties in maintaining proper alignment and can cause problems during reaming. The contractor should select equipment such that the pilot hole and reamers can accommodate and make their way through such material. The Georgian Bay shale can be generally excavated with proper cutters to excavate the harder limestone interbeds. Rock swelling and slaking during and after construction due to the friable nature of the Georgian Bay shale should be expected and considered in the design. The HDD unit must have sufficient thrust to overcome high soil and rock resistance.

### 5.2 Hydraulic Fracturing / Drilling Fluid Pressures

Latorre et al (2002)<sup>1</sup> provides some the following recommendations for minimum cover depth for various pipe diameters (to reduce the potential for drilling fluid release) as below:

**Recommended Minimum Depth of Cover for Various Pipe Diameters (Latorre et al.)**

Diameter	Depth of Cover
50 mm (2 in.) to 150 mm (6 in.)	1.2 m (4 ft.)
200 mm (8 in.) to 350 mm (14 in.)	1.8 m (6 ft.)
375 mm (15 in.) to 600 mm (24 in.)	3.0 m (10 ft.)
625 mm (25 in.) to 1,200 mm (48 in.)	4.5 m (15 ft.)

The above assessment of minimum depth of soil cover assumes that a clean, engineered HDD bore will be constructed in accordance with good industry practice. This includes monitoring of variables including but not limited to drilling fluid pressures, qualities, fluid and solids return rates and advance rates. Advancing the pilot bore drill bit with insufficient drilling fluid flow rates or unsuitable properties, for example, may lead to insufficient cuttings removal and increased downhole drilling fluid pressures. Selection and monitoring of these parameters, including design of the drilling fluid (with additives, if needed), is the responsibility of the HDD contractor. It is recommended that the HDD contractor utilize downhole measurement devices to monitor drilling fluid pressures during pilot drilling. It is understood that the details of the HDD crossing plan such as work space requirements, pipe layout, pilot bore tracking details and excavations are being completed by others, and therefore are not discussed in this report.

<sup>1</sup> Latorre, Carlos, A., Wakeley, Lillian D., Conroy, Patrick J., 2002. Guidelines for Installation of Utilities Beneath Corp of Engineers Levees Using Horizontal Directional Drilling. US Army Corp of Engineers – Engineer Research and Development Center ERDC/GSL TR-02-9. 43 pgs.





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## **DRAFT GEOTECHNICAL INVESTIGATION REPORT TRANSCANADA KNC PROJECT PROPOSED HDD CROSSING UNDER RUTHERFORD ROAD**

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The potential for hydraulic fracturing (frac-out) to occur during a directional drill is influenced by several factors including the depth of cover below ground surface, the ground conditions (including fractured or high permeability materials), the hydrostatic head acting in the drill hole and the dynamic drilling fluid pressures that occur during the drilling process.

The drilling fluid pressures that will develop within the drillhole must not be allowed to exceed the static confining stresses in soil encountered below the roadways. Once initiated, hydraulic fractures occurring in soil will lead to fluid loss and may continue to spread vertically causing fluid movement towards the surface (frac-out). Therefore, the mud pressure in the drillhole should be carefully monitored and controlled while drilling.

The HDD contractor should complete a hydraulic fracture analysis before finalizing the drill path. This evaluation should incorporate the specific equipment, materials, drill path geometry and drill plan that will be used. Deeper burial depths, shorter bore lengths, or a combination of these modifications may be considered to reduce frac-out potential. As part of the mitigation measures to prevent frac-out from occurring during drilling, pressure relief pits (or “burp” holes) should be installed on either side of the roadways to dissipate high fluid pressures that may develop during drilling. The installation of pressure relief pits will also minimize the potential for “hydrolock”, which is a condition where circulation from the bore is lost due to cuttings inhibiting mud circulation which then allows pressure build-up ahead of the advancing pipe, creating a hydraulic cylinder in the ground. The maximum drilling fluid pressures and static confining stresses should be confirmed once the alignment has been finalized.

The properties of the drilling fluid should provide long-term support of the bore to minimize the potential for development of post-construction voids/settlements. Therefore, the annulus should be grouted during pullback with a bentonite or cement based slurry. If the annulus is to be grouted during pullback, consideration should be given to using a series of tremie pipes or grout lines pulled in during pullback. There is a high potential for inadequate grout or unsuccessful grout placement if a single grout line or tremie pipe is utilized. Reaming and pullback rates should be carefully controlled so that the annulus is properly prepared and cuttings are effectively mixed with the slurry. The final ream and pullback operation should be carried out continuously to minimize the risks associated with closure of the bore and/or ground losses when personnel are not on site.

Drilling fluid and cutting return to the rig should be monitored as well as visually inspecting the condition of the ground surface for fluid release. In addition, a drilling fluid management plan assessing the properties of the drilling mud should be implemented to control loss of drilling fluid into higher permeable zones. A properly designed drill plan that minimizes excessive drilling pressure and stationary circulation within high permeable zones is also recommended to prevent scoured zones with an increased borehole annulus. The potential for formation of mud rings, poor cutting clearance and difficulty pulling the pipe should be monitored during the drilling process to ensure a clean, well-engineered bore is maintained. If reduced cutting returns or pressure spikes are recorded at the rig occur, then drilling should be stopped and mitigative measures considered and incorporated.

Environmental monitoring of the crossing locations should be carried out during construction. In addition, contingency plans for drilling fluid containment should be implemented in the event of unexpected fluid release to the ground surface. Maintaining the minimum recommended depths of cover below the crossings should reduce the possibility of fluid release by confining the drill path within more consolidated materials due to the confining stress of the overlying soil and lower expected permeability of the clayey materials.





## **DRAFT GEOTECHNICAL INVESTIGATION REPORT TRANSCANADA KNC PROJECT PROPOSED HDD CROSSING UNDER RUTHERFORD ROAD**

Uncontrolled build-up of downhole pressures could lead to hydraulic fracturing of the soil resulting in drilling fluid release at the surface. Corrective measures such as the use of drilling fluid additives capable of inhibiting the swelling potential of these materials, as well as minimizing the time between the completion of drilling and pulling of the pipe may be required. Prior to the initiation of the directional drill, a plan should be developed with the drilling contractor to establish alarm criteria in relation to downhole pressures and cutting and fluid return to the rig.

There is also a potential for deviation in the alignment when making the transition between the deposits. The contractor should select equipment such that the pilot hole and reamers can accommodate and make their way through such material if such mixed faces are encountered.

Sloughing and bore wall instability may occur within granular/non-cohesive deposits/lenses (i.e., silts of slight plasticity or non-cohesive pockets in glacial deposits) during installation of pipe using trenchless methods. Bore instabilities may be mitigated to some extent through appropriate equipment and drilling fluid selection.

Golder has not carried out specific analyses to estimate downhole pressures and estimate the resistance of the in situ soil to hydraulic fracture. These analyses will be carried out by others prior to construction.

### **5.3 Entry and Exit Pits**

Excavations will be constructed at the HDD entry and exit points to assist with drilling fluid management. It is understood the depth of the exit and entry pits for the proposed pipeline installation will be about 4.2 m below existing ground surface and as such will be extended through the surficial stiff silty clay deposit and will be terminated within the underlying firm to very stiff silty clay till. All temporary excavations should be carried out in accordance with current Ontario Occupational Health and Safety Act and Regulations for Construction Projects (OHSA). Based on the results of the boreholes and the current OHSA criteria, the firm to very stiff silty clay would be classified as Type 3 soils. Temporary excavations should be cut at slope angles not steeper than 1 horizontal to 1 vertical (1H:1V). However, depending upon the construction and groundwater control procedures adopted by the contractor and weather conditions at the time of construction, some local flattening of the slopes may be required. Care is required to ensure that adequate support is provided for all existing utilities and portions of the roadway which are located in the zone of influence of the excavation, as defined by a line drawn from the base of the excavation upward at an inclination of 1H:1V. Properly designed temporary support systems could be used to limit the extent of the excavations and reduce potential impacts on adjacent services.

Stockpiling or storage of excavation spoils, construction materials or heavy equipment should not be permitted within 2 m of the crest of temporary excavation slopes to reduce the potential risk for slope instability.

The groundwater level is expected to be at or above the base of the pits, however, due to the clayey nature of the soils forming the excavation sides and base it is expected that the amount of groundwater seepage entering the pits can be handled by appropriately filtered sumps installed in the base of the excavations. Surface water should be directed away from the excavations.

### **5.4 Other Considerations**

All trenchless works should be carried out by an experienced specialist contractor employing only qualified workers skilled in their trade under the direction of an experienced foreman. The contractor's work plan should include a provision for compensation grouting should the need arise. It is recommended that the geotechnical aspects of the contractor's work plan for the undercrossing be reviewed by this office prior to construction.



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## **DRAFT GEOTECHNICAL INVESTIGATION REPORT TRANSCANADA KNC PROJECT PROPOSED HDD CROSSING UNDER RUTHERFORD ROAD**

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Before excavation begins at the proposed crossing location, hand digging or hydro-vacuum methods should be used to expose any underground utilities in the vicinity of the proposed crossings, if present, to determine the exact locations and depths.

It is emphasized that the resulting performance of the completed undercrossing largely be dependent upon the contractor's construction procedures and techniques. Ground movements (heave or settlement) associated with the work should be monitored and, if necessary, the construction method should be changed to control ground movements and minimize disturbance to the overlying roads. Where adequate provisions are not included to ensure excavation stability, detrimental surface settlement could occur, adversely impacting the road and any existing underground services in the vicinity of the HDD installation which would then require remedial measures to be undertaken. If the settlement monitoring program indicates settlement is occurring, monitoring of the situation will be required until all movement has stabilized.

Should remedial works be required for roads due to settlement/heave, further monitoring of the situation will be required until all movement has stabilized.

Prior to the construction, the contractor should be required to submit their proposed construction method and monitoring program (identifying the risks and methods of control for possible problems that could cause interference to the roads, such as lifting/settlement/changes of alignment) for the review and approval from TransCanada and the relevant municipalities (i.e., City of Vaughan and Region of York).

### **5.5 Settlement and Settlement Monitoring Program**

As mentioned in previous sections, the final profile of the proposed HDD was not known at the time of preparation of this report. The estimated ground surface settlement where the proposed pipeline crosses existing roadway will be provided once the HDD profile is final.

Provision should be made in the contract documents for a settlement monitoring program implemented to measure ground settlement at the existing roadway prior to, during and following the proposed HDD installation. A monitoring program utilizing a combination of surface and subsurface settlement monitoring points is recommended. All monitoring should be carried out in accordance with relevant Municipalities and a detailed monitoring plan can be prepared once the pipe alignment at the roadway crossing is finalized.

The installations would be carried out by Golder and the subsequent survey monitoring would be done by the Contract Administrator with the results being promptly reviewed by Golder on an ongoing basis.

### **5.6 Monitoring Well Decommissioning**

As noted, monitoring wells were installed in Boreholes BH-11, BH-14 (deep and shallow) and BH-15 to permit monitoring of the groundwater levels at the site. Ontario Regulation (O.Reg.) 903, as amended, of the Ontario Water Resources Act requires that monitoring wells/piezometers are properly abandoned/decommissioned by qualified personnel. Further measurements of the wells/piezometers should be taken before decommissioning and that a final measurement should be taken as close to construction start as possible. Decommissioning of the monitoring wells should be carried out prior to the construction activities. If requested, Golder could provide assistance to TransCanada for the decommissioning of the wells by a licensed water well drilling contractor.



## **6.0 GEOTECHNICAL INSPECTION AND TESTING**

Due to the complexity of this project and the variable subsurface conditions, it is recommended that geotechnical input continue throughout the design and construction of the project.

A program of geotechnical inspection and monitoring will be required during construction of the undercrossing to ensure that the intent of the design recommendations provided is being met and that the various project criteria are being achieved.

## **7.0 CLOSURE**

This report is intended to summarize available data on subsurface soil and groundwater conditions and provide preliminary design recommendations for the subject site.

We trust this report is sufficient for your immediate requirements. Should you have any comments or questions, please do not hesitate to contact us.



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**DRAFT GEOTECHNICAL INVESTIGATION REPORT  
TRANSCANADA KNC PROJECT  
PROPOSED HDD CROSSING UNDER RUTHERFORD ROAD**

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## Report Signature Page

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## IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

**Standard of Care:** Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

**Basis and Use of the Report:** This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

**Soil, Rock and Groundwater Conditions:** Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.



## IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report. The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

**Sample Disposal:** Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

**Follow-Up and Construction Services:** All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

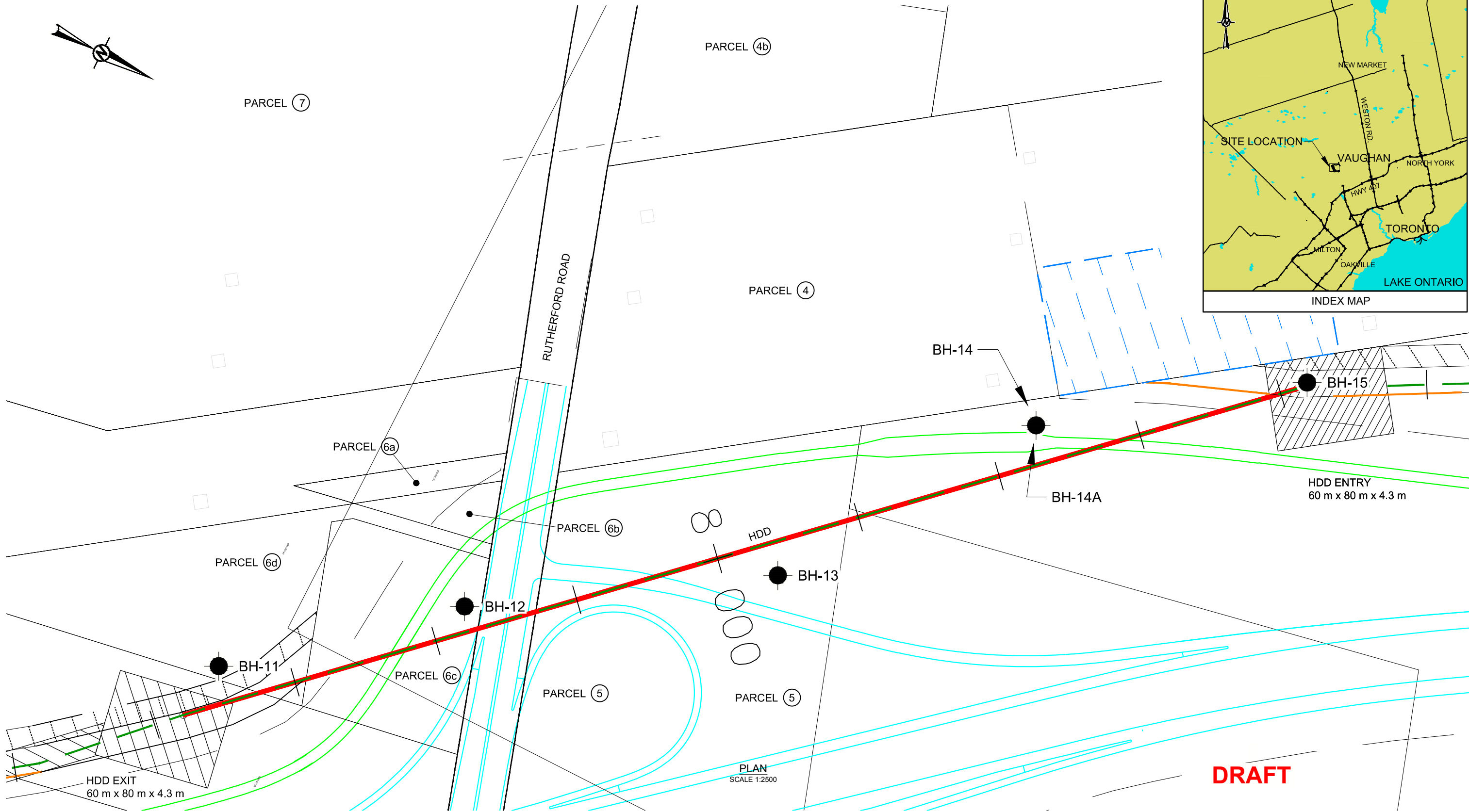
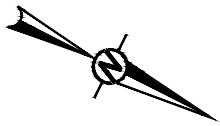
During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

**Changed Conditions and Drainage:** Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.



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PLAN  
SCALE 1:2500

**DRAFT**

**REFERENCE**

BASE MAP OBTAINED IN A DIGITAL FORMAT FROM JDBARNES, FILE TITLED KNC Profile - Golder.dwg, RECEIVED SEPTEMBER 20, 2014.

**LEGEND**

- PROPOSED HDD ALIGNMENT
- PROPOSED TRANSIT INFRASTRUCTURE
- PROPOSED HIGHWAY 427 EXTENSION
- PARCEL NUMBER

CLIENT  
TRANSCANADA PIPELINES LIMITED



CONSULTANT



YYYY-MM-DD	2014-09-22
PREPARED	JFC
DESIGN	MM
REVIEW	MM
APPROVED	-

PROJECT  
KING'S NORTH CONNECTION  
(KNC) GEOTECHNICAL INVESTIGATION

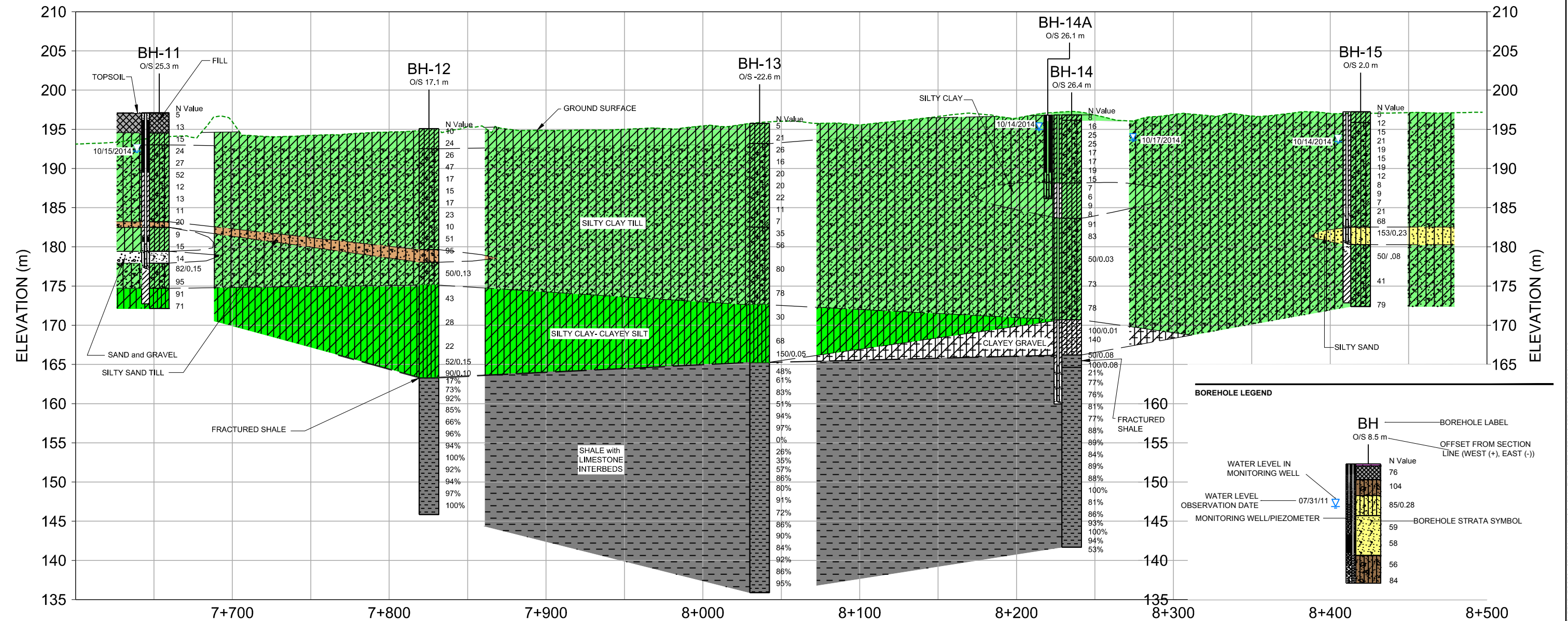
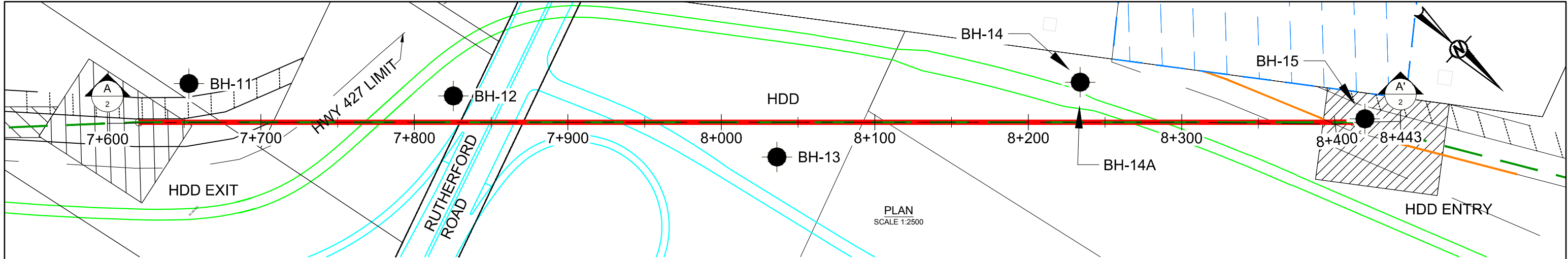
TITLE  
**HDD CROSSING UNDER RUTHERFORD ROAD PLAN**

PROJECT No. 1404378	CONTROL 0002	Rev. A	FIGURE <b>1</b>
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

28 mm





STRATIGRAPHY LEGEND	
	TOPSOIL
	FILL
	SILTY CLAY
	SILTY CLAY TILL
	SILTY CLAY-CLAYEY SILT
	SILTY SAND
	CLAYEY GRAVEL
	SAND and GRAVEL
	SANDY SILT TILL
	SHALES

HORIZONTAL SCALE 1:2500  
VERTICAL SCALE 1:500  
A-A' HDD CENTRLINE PROFILE

REFERENCE  
BASE MAP OBTAINED IN A DIGITAL FORMAT FROM JDBARNES, FILE TITLED KNC Profile - Golder.dwg, RECEIVED SEPTEMBER 20, 2014.

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CLIENT  
TRANSCANADA PIPELINES LIMITED

CONSULTANT



YYYY-MM-DD	2014-09-22
PREPARED	JFC
DESIGN	ARV
REVIEW	MM
APPROVED	-

PROJECT  
KING'S NORTH CONNECTION  
(KNC) GEOTECHNICAL INVESTIGATION

TITLE  
HDD CROSSING UNDER RUTHERFORD ROAD PLAN AND PROFILE

PROJECT No.	CONTROL	Rev.	FIGURE
1404378	0002	A	2

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# **APPENDIX A**

## **Record of Borehole Sheets**

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## LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

### I. SAMPLE TYPE

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

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

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

#### Dynamic Cone Penetration Resistance; $N_d$ :

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

<b>PH:</b>	Sampler advanced by hydraulic pressure
<b>PM:</b>	Sampler advanced by manual pressure
<b>WH:</b>	Sampler advanced by static weight of hammer
<b>WR:</b>	Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance ( $Q_t$ ), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

### III. SOIL DESCRIPTION

#### (a) Cohesionless Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) Cohesive Soils Consistency

	$C_u, S_u$	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

### IV. SOIL TESTS

w	water content
$w_p$	plastic limit
$w_l$	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	relative density (specific gravity, $G_s$ )
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
$SO_4$	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
$\gamma$	unit weight

**Note:** 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.



## LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

### I. GENERAL

$\pi$	3.1416
$\ln x$ ,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

### III. SOIL PROPERTIES

#### (a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )
e	void ratio
n	porosity
S	degree of saturation

#### (a) Index Properties (continued)

w	water content
$w_l$ or LL	liquid limit
$w_p$ or PL	plastic limit
$I_p$ or PI	plasticity index = $(w_l - w_p)$
$w_s$	shrinkage limit
$I_L$	liquidity index = $(w - w_p) / I_p$
$I_C$	consistency index = $(w_l - w) / I_p$
$e_{max}$	void ratio in loosest state
$e_{min}$	void ratio in densest state
$I_D$	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

#### (b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

#### (c) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_\alpha$	secondary compression index
$m_v$	coefficient of volume change
$c_v$	coefficient of consolidation (vertical direction)
$c_h$	coefficient of consolidation (horizontal direction)
$T_v$	time factor (vertical direction)
U	degree of consolidation
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$

#### (d) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	coefficient of friction = $\tan \delta$
$c'$	effective cohesion
$c_u, s_u$	undrained shear strength ( $\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
$p'$	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
$q_u$	compressive strength $(\sigma_1 - \sigma_3)$
$S_t$	sensitivity

\* Density symbol is  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1  
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$



## LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

### WEATHERINGS STATE

**Fresh:** no visible sign of weathering

**Faintly weathered:** weathering limited to the surface of major discontinuities.

**Slightly weathered:** penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

**Moderately weathered:** weathering extends throughout the rock mass but the rock material is not friable.

**Highly weathered:** weathering extends throughout rock mass and the rock material is partly friable.

**Completely weathered:** rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

### BEDDING THICKNESS

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

### JOINT OR FOLIATION SPACING

<u>Description</u>	<u>Spacing</u>
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

### GRAIN SIZE

<u>Term</u>	<u>Size*</u>
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: \* Grains greater than 60 microns diameter are visible to the naked eye.

### CORE CONDITION

#### Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

#### Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

#### Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

### DISCONTINUITY DATA

#### Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

#### Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

#### Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

#### Abbreviations

JN Joint	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	

LOCATION: N 4851062.91; E 608908.89

SHEET 1 OF 3

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

[illegible]

1 : 50



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PROJECT: 1404378  
LOCATION: N 4851062.91; E 608908.89

# RECORD OF BOREHOLE: BH-11

SHEET 2 OF 3

BORING DATE: September 22 and 23, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION  GRAIN SIZE DISTRIBUTION (%)			
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	20		40		60					80	
								SHEAR STRENGTH Cu, kPa		nat V. + rem V. ⊕		Q - U -					10 <sup>-5</sup>	
								20	40	60	80	WATER CONTENT PERCENT Wp ———— W ———— WI 10 20 30 40						
10	Power Auger 108 mm Inner Diameter Hollow Stem Augers	--- CONTINUED FROM PREVIOUS PAGE --- (CL) SILTY CLAY, some sand, trace gravel; brown (TILL); cohesive, stiff to hard													GR SA SI CL			
11				8	SS	13												
12																		
13					9	SS	11											
14		sandy (SW) SILTY SAND, some gravel, some clay; grey (TILL); non-cohesive, wet, compact		183.20 13.92	10A 10B	SS	20										12 52 29 7	
15		(CI) SILTY CLAY, trace sand; grey; cohesive, stiff		182.49 14.63														
16						11	SS	9										
17		containing silt lenses				12	SS	15										
18		SAND and GRAVEL, trace to some silt, trace clay; grey; non-cohesive, wet, compact		179.44 17.68														
19		(CL) Sandy SILTY CLAY, trace to some gravel; grey (TILL); cohesive, hard		177.92 19.20														
20		- Split-spoon sampler bouncing.				14	SS	82/ 0.15									6 25 50 19	
				CONTINUED NEXT PAGE														

DEPTH SCALE

1 : 50



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PROJECT: 1404378  
LOCATION: N 4851062.91; E 608908.89

## RECORD OF BOREHOLE: BH-11

SHEET 3 OF 3

BORING DATE: September 22 and 23, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa		WATER CONTENT PERCENT						
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>			
		--- CONTINUED FROM PREVIOUS PAGE ---													GR SA SI CL	
20	Power Auger 108 mm Inner Diameter Hollow Stem Augers	(CL) Sandy SILTY CLAY, trace to some gravel; grey (TILL); cohesive, hard														
21																
22		- Split-spoon sampler bouncing.			15	SS	95									2 16 59 23
23		(CL-ML) SILTY CLAY - CLAYEY SILT, trace sand; grey; cohesive, hard		174.72 22.40												
24		- Split-spoon sampler bouncing.			16	SS	91									
25		END OF BOREHOLE		172.13 24.99	17	SS	71									
26		NOTE:  1. Water level measurements in monitoring well:  Date      Depth (m)      Elevation (m) 09/23/2014      6.2      192.2 10/15/2014      4.9      192.2														
27																
28																
29																
30																

DEPTH SCALE

1 : 50



LOGGED: OS

CHECKED: ARV

LOCATION: N 4851193.66; E 608796.38

**RECORD OF BOREHOLE: BH-12**

SHEET 1 OF 5

BORING DATE: August 26 to 28, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

[illegible]

DEPTH SCALE

1 : 50



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PROJECT: 1404378

## RECORD OF BOREHOLE: BH-12

SHEET 2 OF 5

LOCATION: N 4851193.66; E 608796.38

BORING DATE: August 26 to 28, 2014

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION  GRAIN SIZE DISTRIBUTION (%)		
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa		nat V. + Q - rem V. ⊕ U - ⊙		WATER CONTENT PERCENT						
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>	10 <sup>-4</sup>			10 <sup>-3</sup>	
								20	40	60	80	10	20	30	40			
10	Tricone HQ Casing	--- CONTINUED FROM PREVIOUS PAGE --- (CL/CI) SILTY CLAY, some sand to sandy, trace gravel; brown (TILL); cohesive, stiff to hard														GR SA SI CL		
11					8	SS	23											
12																		
13					9	SS	10											
14					10	SS	51										0 22 63 15	
15																		
16				(SM) SILTY SAND, some gravel, trace clay; grey (TILL); non-cohesive, very dense		179.64 15.44	11A 11B	SS	95									
17				(CI) SILTY CLAY, some sand; trace gravel; grey (TILL); cohesive, hard		178.04 17.04												
18				- Cobbles inferred below a depth of 18.3 m.			12	SS	50/ 0.13									1 12 54 33
20						175.12												
		CONTINUED NEXT PAGE																

DEPTH SCALE

1 : 50



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PROJECT: 1404378  
LOCATION: N 4851193.66; E 608796.38

## RECORD OF BOREHOLE: BH-12

SHEET 3 OF 5

BORING DATE: August 26 to 28, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	GRAIN SIZE DISTRIBUTION (%)	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa		nat V. + Q - rem V. ⊕ U -		WATER CONTENT PERCENT Wp — W — Wi					
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>				10 <sup>-4</sup>
20	Tricone HQ Casing	--- CONTINUED FROM PREVIOUS PAGE --- (CL-ML) SILTY CLAY - CLAYEY SILT, trace to some sand, containing shale; grey; cohesive, hard		19.96												GR SA SI CL	
21																	
22				13	SS	43											
23																	
24																	
25					14	SS	28										
26																	
27																	
28					15	SS	22										0 0 86 14
29																	
30		- Shale fragments below a depth of 29.6 m.		16	SS	52/ 0.15											
		CONTINUED NEXT PAGE															

DEPTH SCALE

1 : 50



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CHECKED: ARV

PROJECT: 1404378  
LOCATION: N 4851193.66; E 608796.38

## RECORD OF BOREHOLE: BH-12

SHEET 4 OF 5

BORING DATE: August 26 to 28, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION  GRAIN SIZE DISTRIBUTION (%)
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa		nat V. + Q - rem V. ⊕ U - ○		WATER CONTENT PERCENT Wp — W — WI			
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>		
30	Tricone HQ Casing	--- CONTINUED FROM PREVIOUS PAGE --- - Auger grinding below a depth of 29.9 m. (CL-ML) SILTY CLAY - CLAYEY SILT, trace to some sand, containing shale; grey; cohesive, hard													GR SA SI CL
31															
32	Rock Coring NQ	Fractured Shale (BEDROCK) Shale (BEDROCK)  Bedrock cored from depths of 31.80 m to 49.22 m.  For bedrock coring details refer to Record of Drillhole BH-12.		163.38 31.70 31.80	17	SS	90/ 0.10								RQD = 17%
33															RQD = 73%
34															RQD = 92%
35															
36															RQD = 85%
37															RQD = 66%
38															
39															RQD = 96%
40															

DEPTH SCALE

1 : 50



LOGGED: SP

CHECKED: ARV

PROJECT: 1404378  
LOCATION: N 4851193.66; E 608796.38

## RECORD OF BOREHOLE: BH-12

BORING DATE: August 26 to 28, 2014

SHEET 5 OF 5

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION									
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	20 40 60 80				10 <sup>-6</sup> 10 <sup>-5</sup> 10 <sup>-4</sup> 10 <sup>-3</sup>					GRAIN SIZE DISTRIBUTION (%)									
								SHEAR STRENGTH Cu, kPa		nat V. + Q - rem V. ⊕ U - ⊙		WATER CONTENT PERCENT														
								20 40 60 80				Wp  -----  W  -----  WI														
40	Rock Coring NQ	--- CONTINUED FROM PREVIOUS PAGE --- Shale (BEDROCK)													GR SA SI CL											
41		Bedrock cored from depths of 31.80 m to 49.22 m.																					RQD = 94%			
42		For bedrock coring details refer to Record of Drillhole BH-12.																								
43																										
44																							RQD = 92%			
45																										
46																							RQD = 94%			
47																										
48																							RQD = 97%			
49																										
50		END OF BOREHOLE		145.86 49.22																						

DEPTH SCALE

1 : 50



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PROJECT: 1404378

## RECORD OF DRILLHOLE: BH-12

SHEET 1 OF 2

LOCATION: N 4851193.7 ; E 608796.4

DRILLING DATE: August 27 and 28, 2014

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55 High Torque

DRILLING CONTRACTOR: Davis Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY												FEATURES	PIEZOMETER		
						FLUSH RETURN	RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t. CORE AXIS	DISCONTINUITY DATA			WEATH- ERING INDEX	Diameter Point Load Index (MPa)					
							TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr	Ja						Jn	
							용용용용용	용용용용용													
		Continued from Record of Borehole BH-12		163.28 31.80																	
32	HQ Casing	Slightly weathered, thinly laminated to laminated, grey to dark grey, very fine grained, non-porous, weak to medium strong, SHALE with very thin to thin interbeds of grey, very fine grained, medium strong to strong LIMESTONE (Georgian Bay Formation)			1																
					2																
					3																
					4																
					5																
			6																		
			7																		
			8																		

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DEPTH SCALE

1 : 50



LOGGED: SP

CHECKED: ARV

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PROJECT: 1404378

## RECORD OF DRILLHOLE: BH-12

SHEET 2 OF 2

LOCATION: N 4851193.7 ; E 608796.4

DRILLING DATE: August 27 and 28, 2014

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55 High Torque

DRILLING CONTRACTOR: Davis Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY																				FEATURES	PIEZOMETER																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
						RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t. CORE AXIS	DISCONTINUITY DATA						WEATH- ERING INDEX						Diametral Point Load Index (MPa)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
						TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION						Jr	Ja	Jn	W1	W2	W3		W4	W5			W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
42	NQRC August 27 and 28, 2014	--- CONTINUED FROM PREVIOUS PAGE --- Slightly weathered, thinly laminated to laminated, grey to dark grey, very fine grained, non-porous, weak to medium strong, SHALE with very thin to thin interbeds of grey, very fine grained, medium strong to strong LIMESTONE (Georgian Bay Formation)			8																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															

PROJECT: 1404378  
LOCATION: N 4851374.14; E 608680.42

## RECORD OF BOREHOLE: BH-13





SHEET 1 OF 7

BORING DATE: August 13, 14 and 16, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES				DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION  GRAIN SIZE DISTRIBUTION (%)							
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa				WATER CONTENT PERCENT													
								20		40		60		80		10 <sup>-6</sup>			10 <sup>-5</sup>		10 <sup>-4</sup>		10 <sup>-3</sup>		
								20		40		60		80		Wp			W		WI				
0		GROUND SURFACE		195.76 0.00													GR SA SI CL								
	Power Auger 108 mm Inner Diameter Hollow Stem Augers	(CI) SILTY CLAY, some sand, trace gravel, trace organics, containing rootlets to a depth of 0.6 m; brown; cohesive, firm																							
1				1	SS	5																			
2																									
3				2	SS	21																			
		(CL) SILTY CLAY, some sand to sandy, trace to some gravel; brown (TILL); cohesive, firm to very stiff																							
3				3	SS	26																			
4																									
5				4	SS	16																			
		- Becoming grey below a depth of 4.6 m																							
6																									
7				5	SS	20																			
8				6	SS	20																			
	Tricone HQ Casing																								
9																									
10				7	SS	22																			
CONTINUED NEXT PAGE																									

DEPTH SCALE

1 : 50



LOGGED: SP/ARV

CHECKED: ARV

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PROJECT: 1404378  
LOCATION: N 4851374.14; E 608680.42

## RECORD OF BOREHOLE: BH-13

SHEET 2 OF 7

BORING DATE: August 13, 14 and 16, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa		nat V. + Q - rem V. ⊕ U - ⊙		WATER CONTENT PERCENT					
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>	10 <sup>-4</sup>			10 <sup>-3</sup>
10	Tricone HQ Casing	--- CONTINUED FROM PREVIOUS PAGE --- (CL) SILTY CLAY, some sand to sandy, trace to some gravel; brown (TILL); cohesive, firm to very stiff													GR SA SI CL		
11					8	SS	11										
12																	
13					9	SS	7										
14		(CL) Sandy SILTY CLAY, some gravel; grey (TILL); cohesive, hard		182.50 13.26	10	SS	35									8 24 54 14	
15																	
16		----- silty sand to sandy silt lenses			11A												
17					11B	SS	56										
18					11C												
19		- Split-spoon sampler bouncing.			12	SS	80										
20																	
		CONTINUED NEXT PAGE															

DEPTH SCALE

1 : 50



LOGGED: SP/ARV

CHECKED: ARV

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PROJECT: 1404378  
LOCATION: N 4851374.14; E 608680.42

## RECORD OF BOREHOLE: BH-13


SHEET 3 OF 7

BORING DATE: August 13, 14 and 16, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION  GRAIN SIZE DISTRIBUTION (%)	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa		nat V. + Q - rem V. ⊕ U -		WATER CONTENT PERCENT Wp — W — Wi				
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>			10 <sup>-4</sup>
20	Tricone HQ Casing	--- CONTINUED FROM PREVIOUS PAGE --- (CL) Sandy SILTY CLAY, some gravel; grey (TILL); cohesive, hard													GR SA SI CL	
21																
22																
23																
24		(CL-ML) SILTY CLAY - CLAYEY SILT; grey; cohesive, hard		172.60 23.16												
25																
26																
27																
28																
29																
30																

DEPTH SCALE

1 : 50



LOGGED: SP/ARV

CHECKED: ARV

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PROJECT: 1404378  
LOCATION: N 4851374.14; E 608680.42

## RECORD OF BOREHOLE: BH-13

BORING DATE: August 13, 14 and 16, 2014

SHEET 4 OF 7

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION		
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	20		60		10 <sup>-5</sup>					
								40		80		10 <sup>-5</sup>				10 <sup>-4</sup>	
								SHEAR STRENGTH Cu, kPa		nat V. + rem V. ⊕		Q - U -				WATER CONTENT PERCENT	
30	Tricone HQ Casing	-- CONTINUED FROM PREVIOUS PAGE --												GR SA SI CL			
		(CL-ML) SILTY CLAY - CLAYEY SILT; grey; cohesive, hard															
		Fractured Shale (BEDROCK) Shale (BEDROCK)												RQD = 0%			
		Bedrock cored from depths of 30.53 m to 59.88 m.															
		For bedrock coring details refer to Record of Drillhole BH-13.															
31	Rock Coring NQ													RQD = 48%			
32																	
33														RQD = 61%			
34																	
35														RQD = 83%			
36																	
37														RQD = 51%			
38																	
39														RQD = 94%			
40														RQD = 97%			
		CONTINUED NEXT PAGE															

DEPTH SCALE

1 : 50



LOGGED: SP/ARV

CHECKED: ARV

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LOCATION: N 4851374.14; E 608680.42

**RECORD OF BOREHOLE: BH-13**

SHEET 5 OF 7

BORING DATE: August 13, 14 and 16, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

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DEPTH SCALE

1 : 50



LOGGED: SP/ARV

CHECKED: ARV

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PROJECT: 1404378  
LOCATION: N 4851374.14; E 608680.42

## RECORD OF BOREHOLE: BH-13

BORING DATE: August 13, 14 and 16, 2014

SHEET 6 OF 7

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION  GRAIN SIZE DISTRIBUTION (%)													
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa		WATER CONTENT PERCENT Wp — W — Wi																		
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>			10 <sup>-4</sup>	10 <sup>-3</sup>											
50	Rock Coring NQ	--- CONTINUED FROM PREVIOUS PAGE --- Shale (BEDROCK)													GR SA SI CL													
		Bedrock cored from depths of 30.53 m to 59.88 m.  For bedrock coring details refer to Record of Drillhole BH-13.																							RQD = 72%			
51																											RQD = 86%	
52																												RQD = 90%
53																												RQD = 84%
54																												RQD = 92%
55																												RQD = 86%
56																												RQD = 95%
57																												
58																												
59																												
60		END OF BOREHOLE		135.88	59.88																							
		CONTINUED NEXT PAGE																										

DEPTH SCALE

1 : 50



LOGGED: SP/ARV

CHECKED: ARV

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PROJECT: 1404378  
LOCATION: N 4851374.14; E 608680.42

## RECORD OF BOREHOLE: BH-13

BORING DATE: August 13, 14 and 16, 2014

SHEET 7 OF 7

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION  GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa		nat V. + Q - rem V. ⊕ U - ○		WATER CONTENT PERCENT Wp — W — WI				
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>	10 <sup>-4</sup>		
60		--- CONTINUED FROM PREVIOUS PAGE ---														
		NOTE:														
		1. Borehole was backfilled with Portland cement grout upon completion of drilling.														
61																
62																
63																
64																
65																
66																
67																
68																
69																
70																

DEPTH SCALE

1 : 50



LOGGED: SP/ARV

CHECKED: ARV

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PROJECT: 1404378

## RECORD OF DRILLHOLE: BH-13

SHEET 1 OF 3

LOCATION: N 4851374.1 ; E 608680.4

DRILLING DATE: August 14 and 16, 2014

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55 High Torque

DRILLING CONTRACTOR: Davis Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY															FEATURES	PIEZOMETER			
						RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t. CORE AXIS	DISCONTINUITY DATA			WEATH- ERING INDEX			Diametral Point Load Index (MPa)								
						TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	W1	W2		W3	W4	W5			W6		
						용용용용용	용용용용용																		
		Continued from Record of Borehole BH-13		165.23																					
	NW casing	Highly weathered shale, containing sand lenses		30.53 165.00	1																				
31		Moderately weathered to fresh, thinly laminated to laminated, grey to dark grey, very fine grained, non-porous, weak to medium strong SHALE with very thin to thin interbeds of grey, very fine grained, medium strong to strong LIMESTONE (Georgian Bay Formation)		30.76																					
					2																				
32																									
33					3																				
34																									
35					4																				
36					5																				
37																									
					6																				
38																									
39					7																				
40		* At a depth of 40.0 m; core tube did not lock into the core barrel properly; rock core sample was lost.			8*																				
		CONTINUED NEXT PAGE																							

DEPTH SCALE

1 : 50



LOGGED: SP/ARV

CHECKED: ARV

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PROJECT: 1404378

## RECORD OF DRILLHOLE: BH-13

SHEET 2 OF 3

LOCATION: N 4851374.1 ; E 608680.4

DRILLING DATE: August 14 and 16, 2014

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55 High Torque

DRILLING CONTRACTOR: Davis Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY																		FEATURES	PIEZOMETER																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
						FLUSH RETURN	RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t CORE AXIS	DISCONTINUITY DATA			WEATH- ERING INDEX			Diametral Point Load Index (MPa)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
							TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	W1	W2	W3	W4	W5	W6	W7	W8			W9	W10																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
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SHEET 3 OF 3

DATUM: Geodetic

DRILLING CONTRACTOR: Davis Drilling

[illegible]

DEPTH SCALE

1 : 50

LOGGED: SP/ARV

CHECKED: ARV

PROJECT: 1404378

## RECORD OF BOREHOLE: BH-14

SHEET 1 OF 6

LOCATION: N 4851485.02; E 608508.09

BORING DATE: August 15 to 21 and 25, 2014

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION		
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH				WATER CONTENT PERCENT						
								Cu, kPa		nat V. + Q - ● rem V. ⊕ U - ○		Wp   — W —   WI						
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>	10 <sup>-4</sup>	10 <sup>-3</sup>			
								20	40	60	80	10	20	30	40			
0		GROUND SURFACE		196.83 0.00													GR SA SI CL	
	Power Auger 110 mm Inner Diameter Hollow Stem Augers	(CL) SILTY CLAY, trace sand, trace gravel, trace organics, containing rootlets; brown to dark brown; cohesive, firm			1	SS	8						○					
		(CL) SILTY CLAY, some sand, trace gravel; brown with oxidation staining (TILL); cohesive, stiff to very stiff		196.15 0.68									○					
1				2	SS	16												
				3	SS	25												
2																		
														○				
3			- Becoming grey below a depth of 3.1 m.			5	SS	17						○				
4						6	SS	17										
5		Auger grinding below a depth of 5.0 m.			7	SS	19						○ —					
6					8	SS	15											
7		(CI) SILTY CLAY, trace sand, trace gravel; grey; cohesive, firm to stiff		189.82 7.01														
8					9	SS	7											
9					10	SS	6											
10																		
		CONTINUED NEXT PAGE																

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DEPTH SCALE

1 : 50



LOGGED: OS/SP

CHECKED: ARV

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PROJECT: 1404378

## RECORD OF BOREHOLE: BH-14

SHEET 2 OF 6

LOCATION: N 4851485.02; E 608508.09

BORING DATE: August 15 to 21 and 25, 2014

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION								
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa				WATER CONTENT PERCENT												
								20		40		60		80		10 <sup>-6</sup>		10 <sup>-5</sup>		10 <sup>-4</sup>		10 <sup>-3</sup>		
								nat V. $\oplus$ rem V. $\ominus$		Q - $\bullet$ U - $\circ$		Wp		W		Wi								
10	Power Auger 110 mm Inner Diameter Hollow Stem Augers	--- CONTINUED FROM PREVIOUS PAGE --- (Cl) SILTY CLAY, trace sand, trace gravel; grey; cohesive, firm to stiff		183.65 13.18											GR SA SI CL									
11					11	SS	9																	
12																								
13																								
14		(CL) Sandy SILTY CLAY, trace gravel; grey (TILL); cohesive, hard  - Auger grinding at a depth of 13.7 m.				13	SS	91																
15																								
16																								
17																								
18					- Auger grinding at a depth of 17.4 m.																			
19		Wash Boring Mud Rotary NW Casing																			0 25 67 18			
20				15											SS	50/ 0.03								
		CONTINUED NEXT PAGE																						

DEPTH SCALE

1 : 50



LOGGED: OS/SP

CHECKED: ARV

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LOCATION: N 4851485.02; E 608508.09

**RECORD OF BOREHOLE: BH-14**

SHEET 3 OF 6

BORING DATE: August 15 to 21 and 25, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

[illegible]

DEPTH SCALE

1 : 50



LOGGED: OS/SP

CHECKED: ARV

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PROJECT: 1404378  
LOCATION: N 4851485.02; E 608508.09

## RECORD OF BOREHOLE: BH-14

SHEET 4 OF 6

BORING DATE: August 15 to 21 and 25, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa		WATER CONTENT PERCENT						
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>			
30	Wash Boring Mud Rotary NW Casing	--- CONTINUED FROM PREVIOUS PAGE --- (GC) Sandy Silty CLAYEY GRAVEL (RESIDUAL SOIL); grey; non-cohesive, very dense		166.22	20	SS	50/ 0.08									GR SA SI CL
		Fractured Shale (BEDROCK)		30.61												
31																
32																
		Shale (BEDROCK)  Bedrock cored from depths of 32.21 m to 55.14 m.  For bedrock coring details refer to Record of Drillhole BH-14.		164.62 32.21	21	SS	100/ 0.08									
33																RQD = 21%
34																RQD = 77%
35																RQD = 76%
36																RQD = 81%
37																RQD = 77%
38																
39																
40																
		CONTINUED NEXT PAGE														

DEPTH SCALE

1 : 50



LOGGED: OS/SP

CHECKED: ARV

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PROJECT: 1404378  
LOCATION: N 4851485.02; E 608508.09

## RECORD OF BOREHOLE: BH-14

BORING DATE: August 15 to 21 and 25, 2014

SHEET 5 OF 6

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION  GRAIN SIZE DISTRIBUTION (%)
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa		WATER CONTENT PERCENT Wp — W — Wi					
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>		
40		--- CONTINUED FROM PREVIOUS PAGE --- Shale (BEDROCK)													GR SA SI CL
41		Bedrock cored from depths of 32.21 m to 55.14 m.  For bedrock coring details refer to Record of Drillhole BH-14.													RQD = 88%
42															RQD = 89%
43															RQD = 84%
44															RQD = 89%
45															RQD = 88%
46															RQD = 100%
47															RQD = 81%
48															
49															
50															

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DEPTH SCALE

1 : 50



LOGGED: OS/SP

CHECKED: ARV

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PROJECT: 1404378

## RECORD OF BOREHOLE: BH-14

SHEET 6 OF 6

LOCATION: N 4851485.02; E 608508.09

BORING DATE: August 15 to 21 and 25, 2014

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa		nat V. + Q - ● rem V. ⊕ U - ○		WATER CONTENT PERCENT Wp — W — Wi			
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>		
50		--- CONTINUED FROM PREVIOUS PAGE --- Shale (BEDROCK)													GR SA SI CL
51		Bedrock cored from depths of 32.21 m to 55.14 m.  For bedrock coring details refer to Record of Drillhole BH-14.													RQD = 86%
52															RQD = 93%
53															RQD = 100%
54															RQD = 94%
55															RQD = 53%
56		END OF BOREHOLE		141.69 55.14											
57		NOTE:  1. Water level measurements in monitoring well:													
58		Date      Depth (m)      Elevation (m)													
59		08/26/2014      4.4      192.4													
60		09/22/2014      3.5      193.3													
		10/17/2014      3.2      193.6													

DEPTH SCALE

1 : 50



LOGGED: OS/SP

CHECKED: ARV

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PROJECT: 1404378

## RECORD OF DRILLHOLE: BH-14

SHEET 1 OF 3

LOCATION: N 4851485.0 ;E 608508.1

DRILLING DATE: August 20 to 22, 2014

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 75 - Rubber Tire

DRILLING CONTRACTOR: At Cost Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY												FEATURES	PIEZOMETER																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
							RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP W/L CORE AXIS	DISCONTINUITY DATA			WEATH- ERING INDEX	Diametral Point Load Index (MPa)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
							TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr	Ja		Jn	W1	W2			W3	W4	W5	W6	W7	W8	W9	W10																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
		Continued from Record of Borehole BH-14		164.62																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												

[illegible]

SHEET 3 OF 3

DATUM: Geodetic

DRILLING CONTRACTOR: At Cost Drilling

[illegible]

DEPTH SCALE

1 : 50

LOGGED: OS/SP

CHECKED: ARV

PROJECT: 1404378  
LOCATION: N 4851484.32; E 608509.29

# RECORD OF BOREHOLE: BH-14A

BORING DATE: August 26, 2014

SHEET 1 OF 2  
DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION  GRAIN SIZE DISTRIBUTION (%)
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa		nat V. + Q - ● rem V. ⊕ U - ○		WATER CONTENT PERCENT Wp — W — WI			
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>		
0		GROUND SURFACE		196.82											GR SA SI CL
		No sample taken; for soil description refer to Record of Borehole BH-14.		0.00											
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															

CONTINUED NEXT PAGE

DEPTH SCALE  
1 : 50



LOGGED: OS  
CHECKED: ARV

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PROJECT: 1404378  
LOCATION: N 4851484.32; E 608509.29

## RECORD OF BOREHOLE: BH-14A

BORING DATE: August 26, 2014

SHEET 2 OF 2  
DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION  GRAIN SIZE DISTRIBUTION (%)
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa		nat V. + Q - ● rem V. ⊕ U - ○		WATER CONTENT PERCENT Wp — W — WI			
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>		
10	Power Auger	--- CONTINUED FROM PREVIOUS PAGE --- No sample taken; for soil description refer to Record of Borehole BH-14.													GR SA SI CL
11		END OF BOREHOLE		186.15											
		NOTE:  1. Water level measurements in monitoring well:  Date      Depth (m)      Elevation (m) 09/22/2014      3.5      194.3 10/14/2014      1.8      195.0		10.67											
12															
13															
14															
15															
16															
17															
18															
19															
20															

DEPTH SCALE

1 : 50



LOGGED: OS  
CHECKED: ARV

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PROJECT: 1404378  
LOCATION: N 4851635.52; E 608399.25

## RECORD OF BOREHOLE: BH-15

SHEET 1 OF 3

BORING DATE: August 13 and 14, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION				
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH				WATER CONTENT PERCENT								
								Cu, kPa		nat V. + rem V. ⊕		Q - U - ⊙		Wp ——— W ——— WI						
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>	10 <sup>-4</sup>				10 <sup>-3</sup>		
0		GROUND SURFACE		197.23											GR SA SI CL					
	Power Auger 110 mm Inner Diameter 190 mm Outside Diameter Solid Stem Augers	(CI) SILTY CLAY, trace to some sand, trace gravel, trace organics; brown to dark brown, containing rootlets; cohesive, firm to stiff		0.00	1	SS	5													
1					2	SS	12													
		(CL) SILTY CLAY, trace to some sand, trace gravel; brown with oxidation staining (TILL); cohesive, firm to very stiff		195.86																
				1.37	3	SS	15													
2																				
					4	SS	21													
3			- Becoming grey below a depth of 2.8 m.																	
					5	SS	19													
4																				
				6	SS	15														
5																				
				7	SS	19														
6																				
				8	SS	12														
7																				
				9	SS	8														
8																				
9																				
				10	SS	9														
10																				
		CONTINUED NEXT PAGE																		

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50



LOGGED: OS

CHECKED: ARV

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PROJECT: 1404378

## RECORD OF BOREHOLE: BH-15

SHEET 2 OF 3


LOCATION: N 4851635.52; E 608399.25

BORING DATE: August 13 and 14, 2014

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa				WATER CONTENT PERCENT						
								20 40 60 80				10 <sup>-6</sup> 10 <sup>-5</sup> 10 <sup>-4</sup> 10 <sup>-3</sup>						
								nat V. + Q - ● rem V. ⊕ U - ○				Wp   — W —   WI						
								20	40	60	80	10	20	30	40			
10		--- CONTINUED FROM PREVIOUS PAGE ---															GR SA SI CL	
11	Power Auger 110 mm Inner Diameter 190 mm Outside Diameter Solid Stem Augers	(CL) SILTY CLAY, trace to some sand, trace gravel; brown with oxidation staining (TILL); cohesive, firm to very stiff			11	SS	7											
12																		
13																		
14		containing very dense silt lenses			13	SS	68											
15		(SM) SILTY SAND, some gravel; grey; non-cohesive, moist to wet, very dense		182.52 14.71		14	SS	153/ 0.23										
16		- Augers grinding below a depth of 15.8 m.																
17		(CL) Sandy SILTY CLAY, trace gravel; grey (TILL); cohesive, hard		180.29 16.94														
18						15	SS	50/ .08										
19																		
20																		
		CONTINUED NEXT PAGE																

DEPTH SCALE

1 : 50



LOGGED: OS

CHECKED: ARV

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PROJECT: 1404378  
LOCATION: N 4851635.52; E 608399.25

## RECORD OF BOREHOLE: BH-15



SHEET 3 OF 3

BORING DATE: August 13 and 14, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION  GRAIN SIZE DISTRIBUTION (%)	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa		nat V. + Q - ● rem V. ⊕ U - ○		WATER CONTENT PERCENT Wp — W — WI				
								20	40	60	80	10 <sup>-6</sup>	10 <sup>-5</sup>			10 <sup>-4</sup>
20	Power Auger 110 mm Inner Diameter 190 mm Outside Diameter Solid Stem Augers	--- CONTINUED FROM PREVIOUS PAGE --- (CL) Sandy SILTY CLAY, trace gravel; grey (TILL); cohesive, hard														
21																
22																
23																
24																
25		END OF BOREHOLE		172.39 24.84												
26		NOTE:  1. Water level measurements in monitoring well:  Date      Depth (m)      Elevation (m) 08/14/2014      3.5      193.7 09/22/2014      3.8      193.4 10/17/2014      4.1      193.1														
27																
28																
29																
30																

DEPTH SCALE

1 : 50



LOGGED: OS

CHECKED: ARV

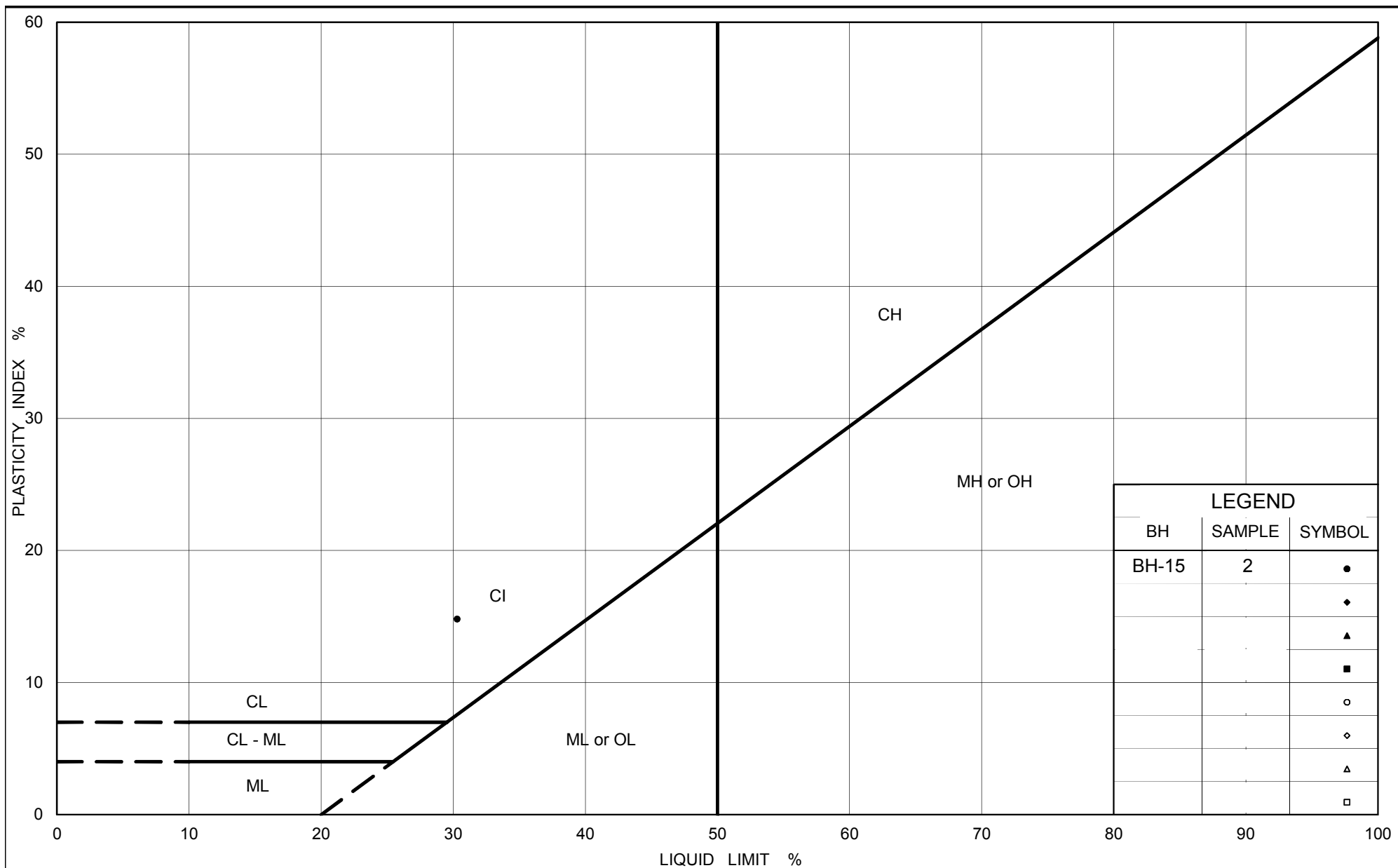
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## **APPENDIX B**

### **Laboratory Test Results**

DRAFT



PLASTICITY CHART  
Silty Clay  
HDD Under Rutherford Road

Figure No. B1

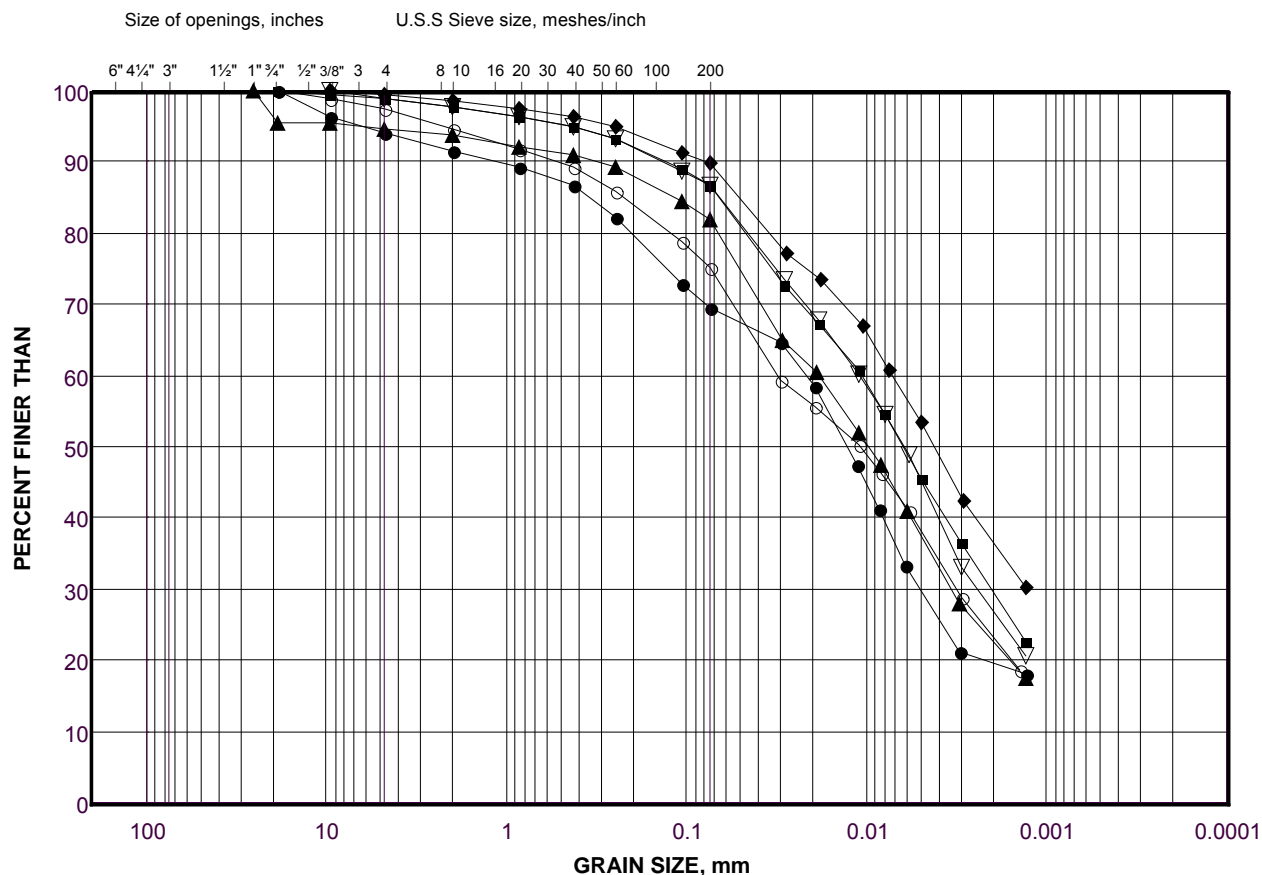
Project No. 1404378

Checked By: ARV

# GRAIN SIZE DISTRIBUTION

Silty Clay Till to Sandy Silty Clay Till  
HDD Under Rutherford Road

FIGURE B2-A



## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BH-11	14	177.2
■	BH-12	3	191.7
◆	BH-14	4	194.3
▲	BH-13	5	189.4
▽	BH-11	7	187.7
○	BH-14	7	192.0

Project Number: 1404378

Checked By: ARV

**Golder Associates**

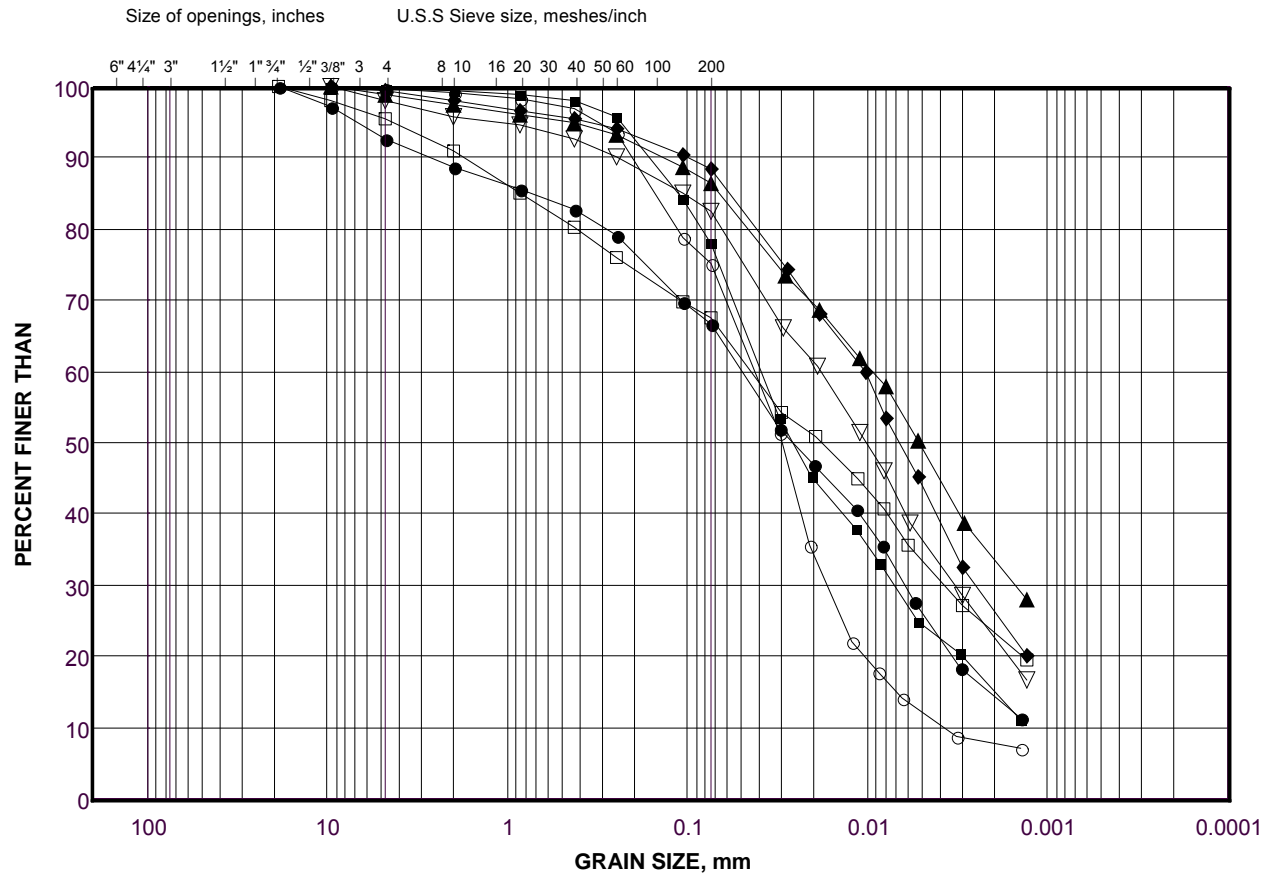
Date: 23-Oct-14

# GRAIN SIZE DISTRIBUTION

Silty Clay Till

HDD Under Rutherford Road

FIGURE B2-B



## LEGEND

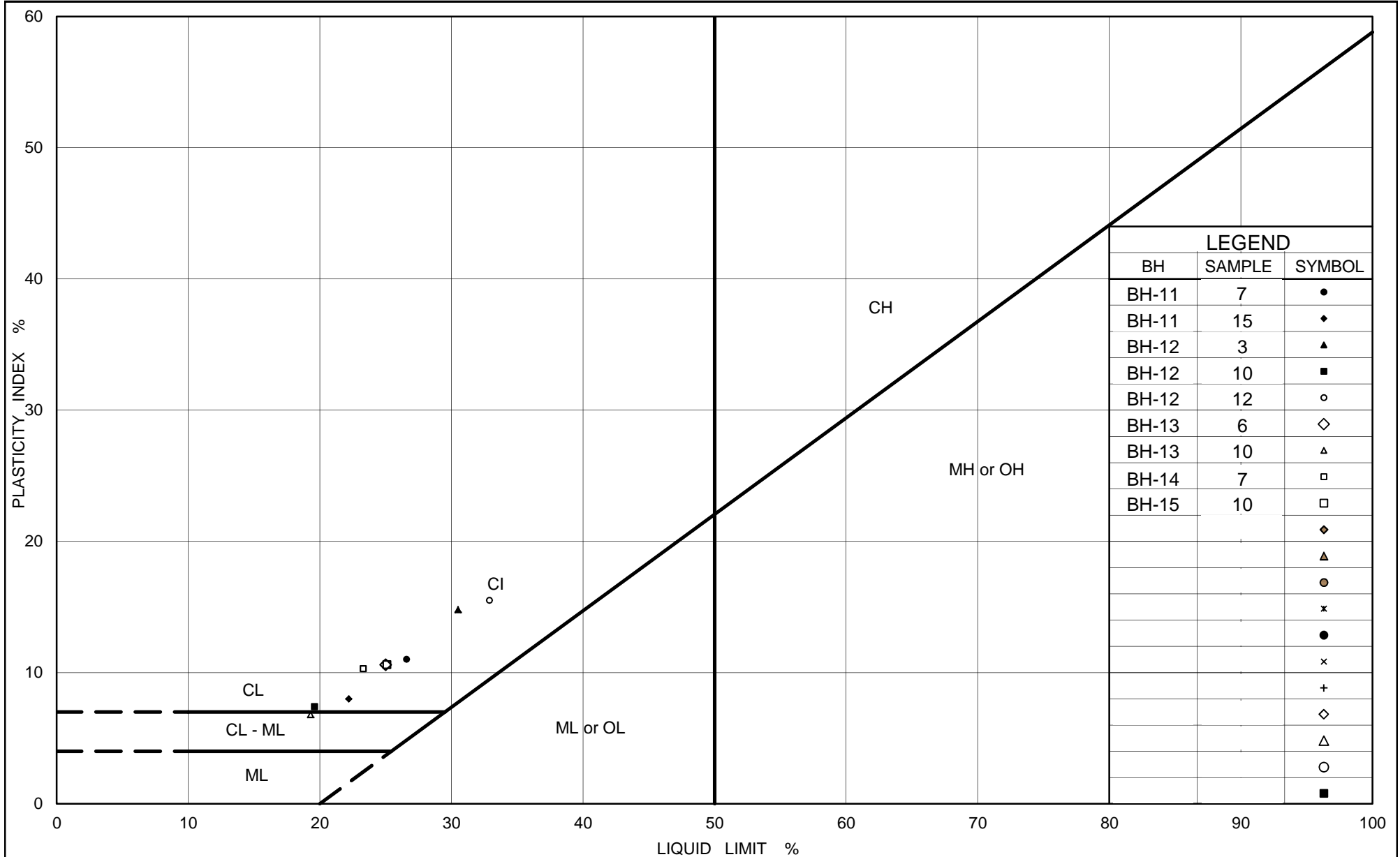
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BH-13	10	181.7
■	BH-12	10	181.1
◆	BH-15	10	187.8
▲	BH-12	12	176.6
▽	BH-11	15	175.6
○	BH-14	15	178.5
□	BH-15	17	172.2

Project Number: 1404378

Checked By: ARV

**Golder Associates**

Date: 08-Oct-14



PLASTICITY CHART  
Silty Clay Till  
HDD Under Rutherford Road

Figure No. B3

Project No. 1404378

Checked By: ARV

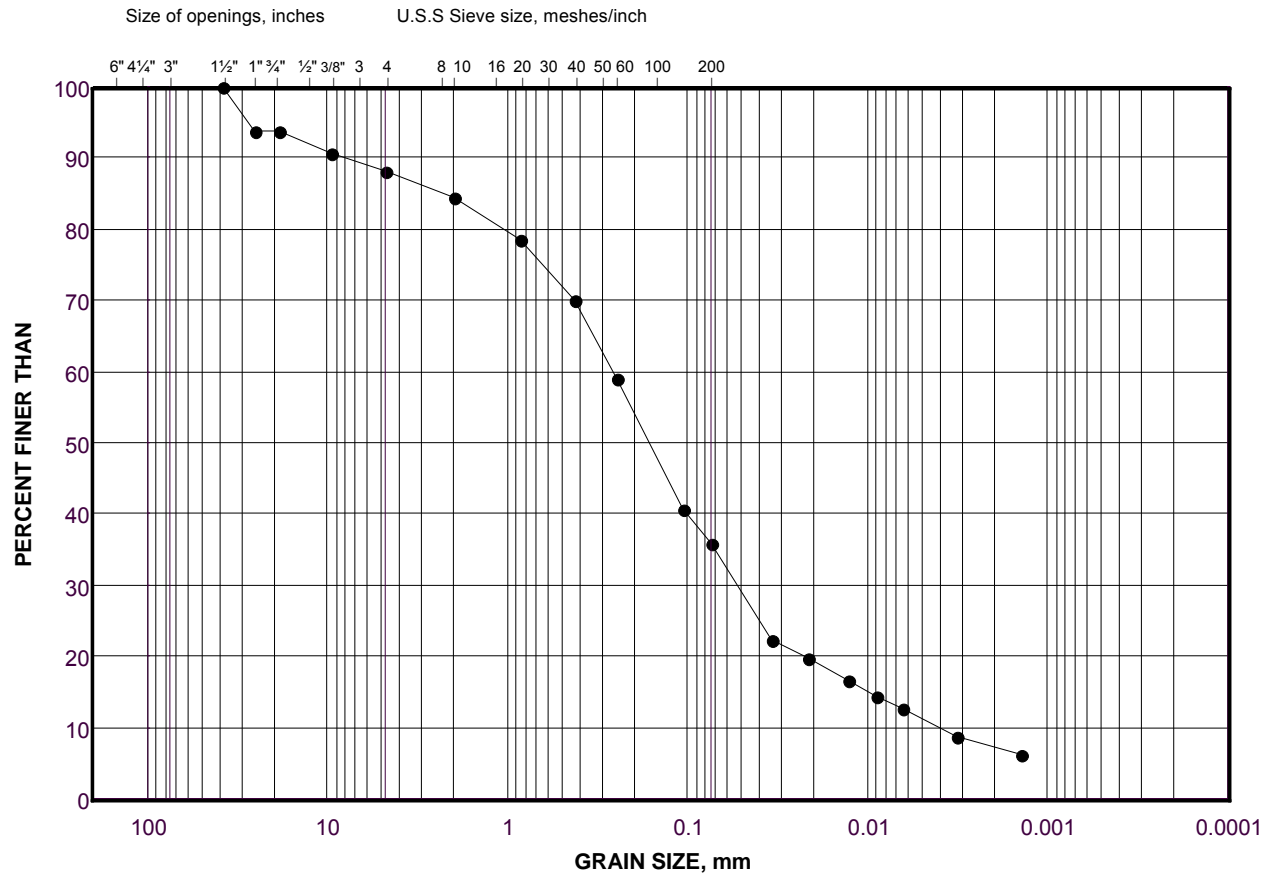


# GRAIN SIZE DISTRIBUTION

Silty Sand Till

HDD Under Rutherford Road

FIGURE B4



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
	GRAVEL SIZE		SAND SIZE			FINE GRAINED

## LEGEND

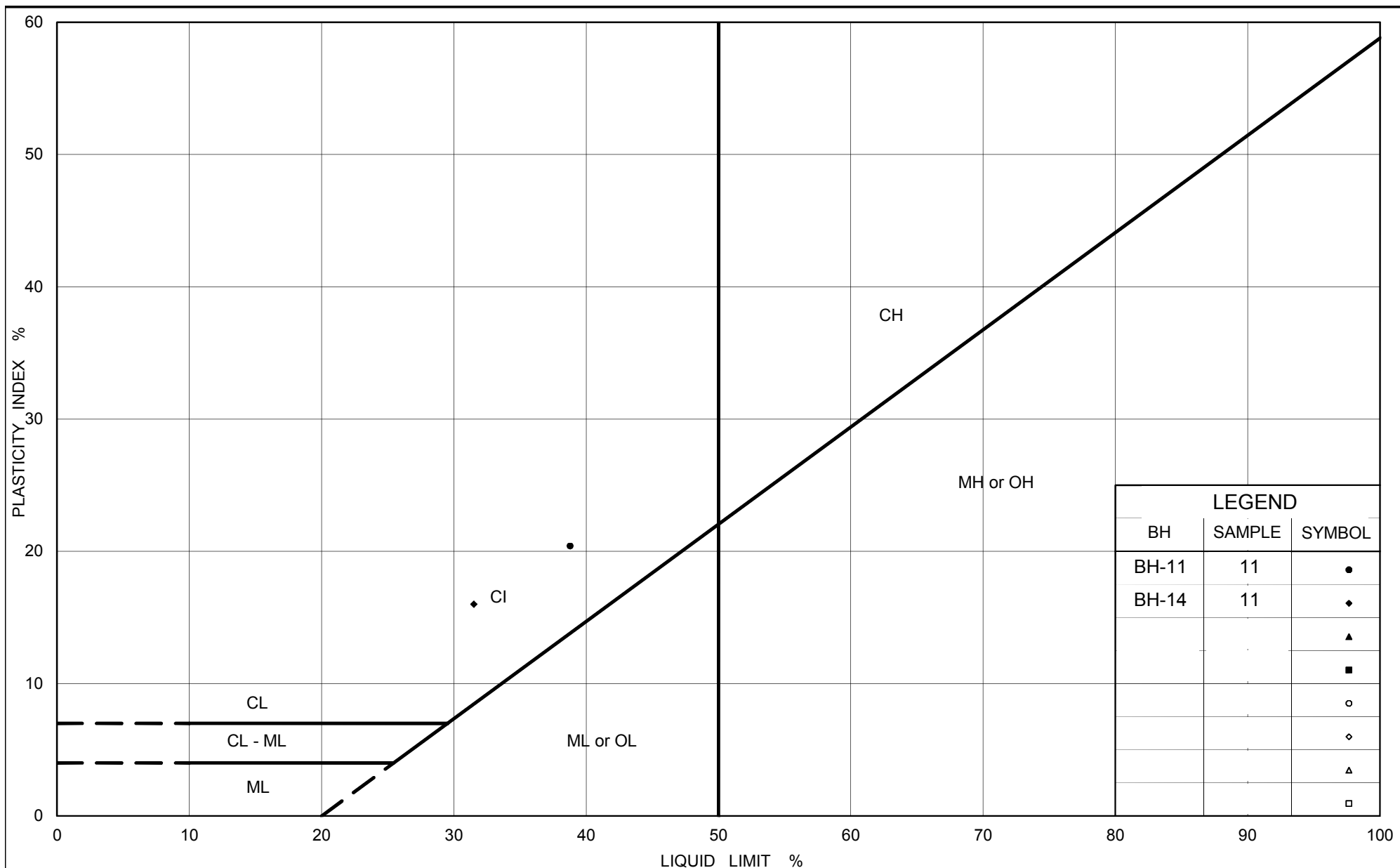
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	BH-11	10B	183.0

Project Number: 1404378

Checked By: ARV

**Golder Associates**

Date: 09-Oct-14



LEGEND		
BH	SAMPLE	SYMBOL
BH-11	11	●
BH-14	11	◆
		▲
		■
		○
		◇
		△
		□



PLASTICITY CHART  
Silty Clay Pockets  
HDD Under Rutherford Road

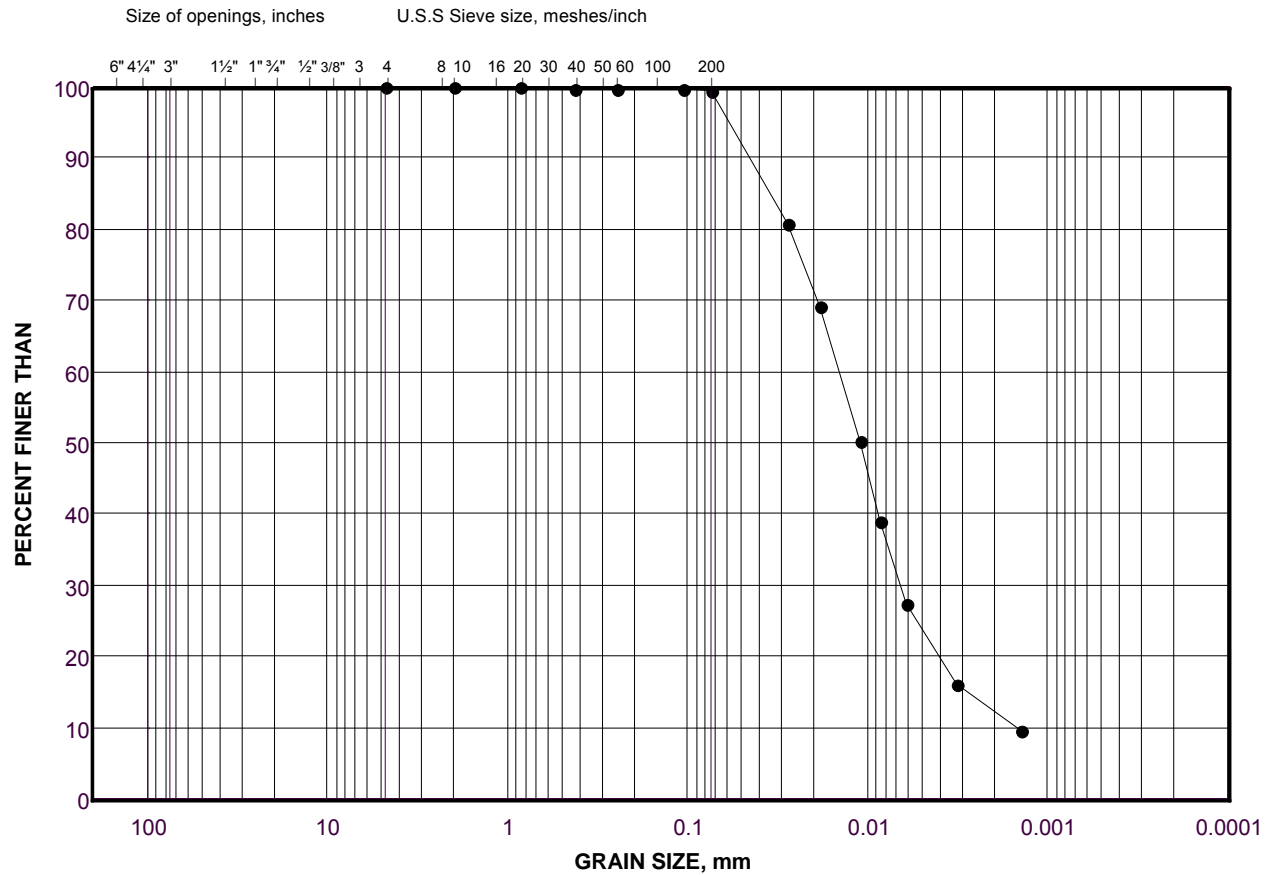
Figure No. B5

Project No. 1404378

Checked By: ARV

Silty Clay - Clayey Silt  
HDD Under Rutherford Road

FIGURE B6



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

## LEGEND

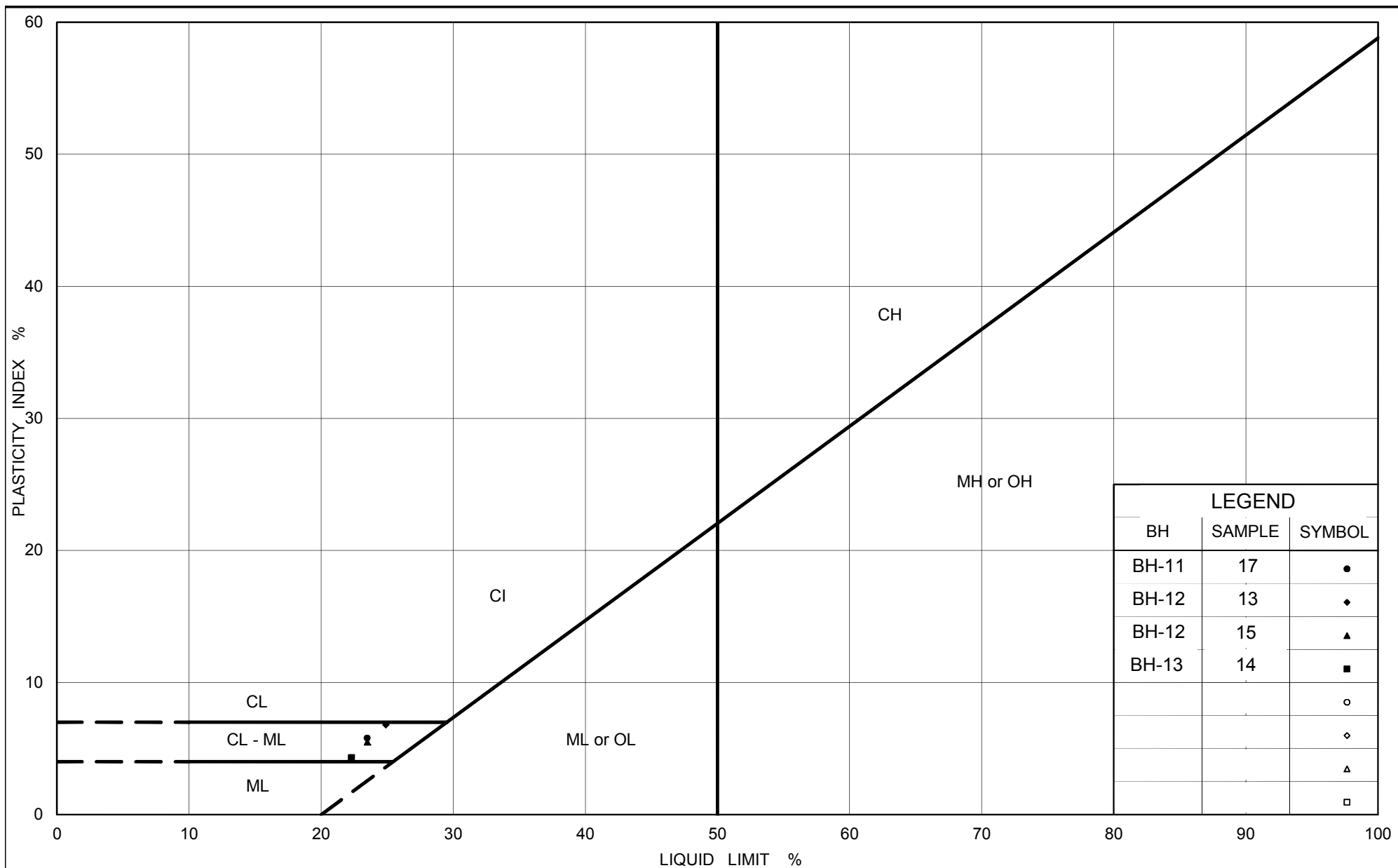
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BH-13	14	170.4

Project Number: 1404378

Checked By: ARV

## Golder Associates

Date: 09-Oct-14



PLASTICITY CHART  
Silty Clay - Clayey Silt  
HDD Under Rutherford Road

Figure No. B7

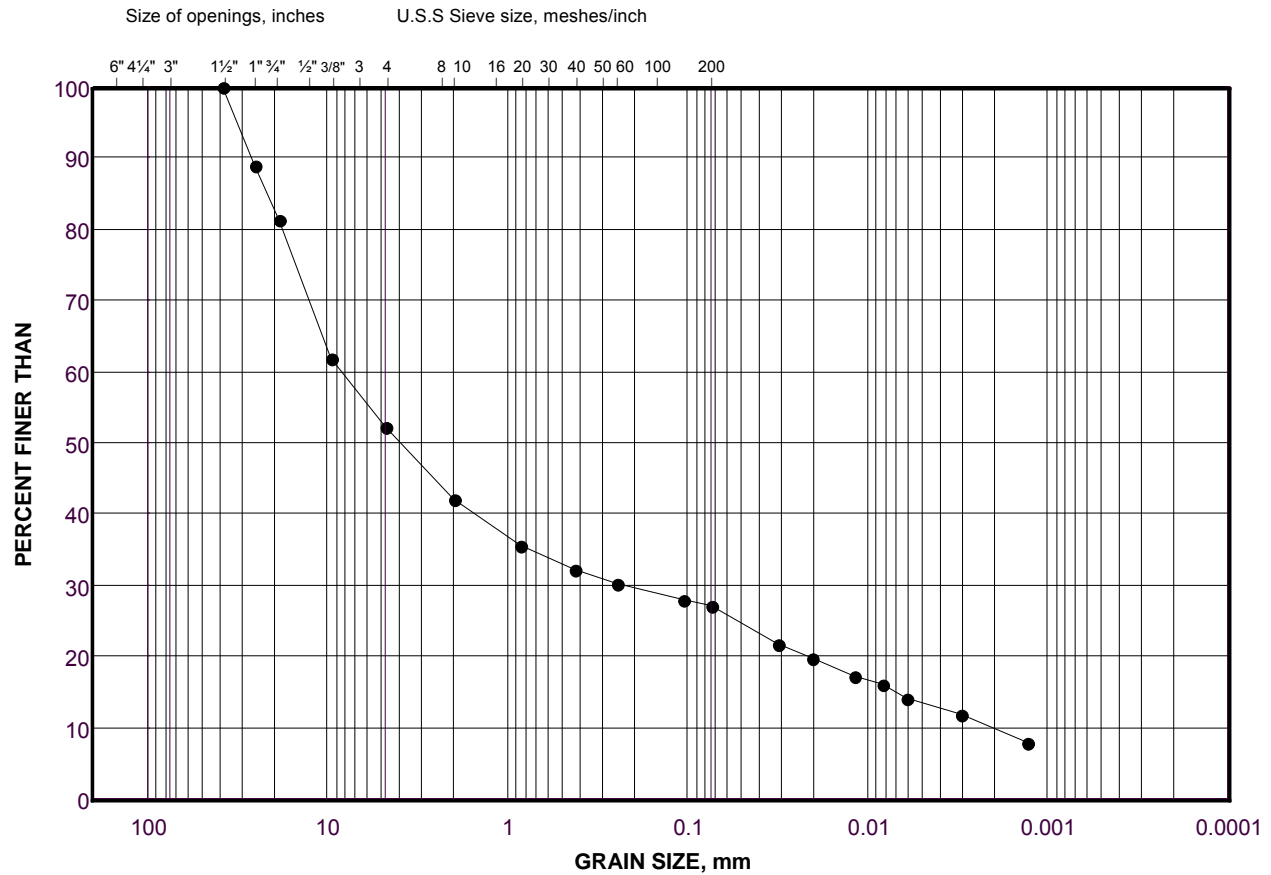
Project No. 1404378

Checked By: ARV

# GRAIN SIZE DISTRIBUTION

Clayey Gravel  
HDD Under Rutherford Road

FIGURE B8



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
	GRAVEL SIZE		SAND SIZE			FINE GRAINED

## LEGEND

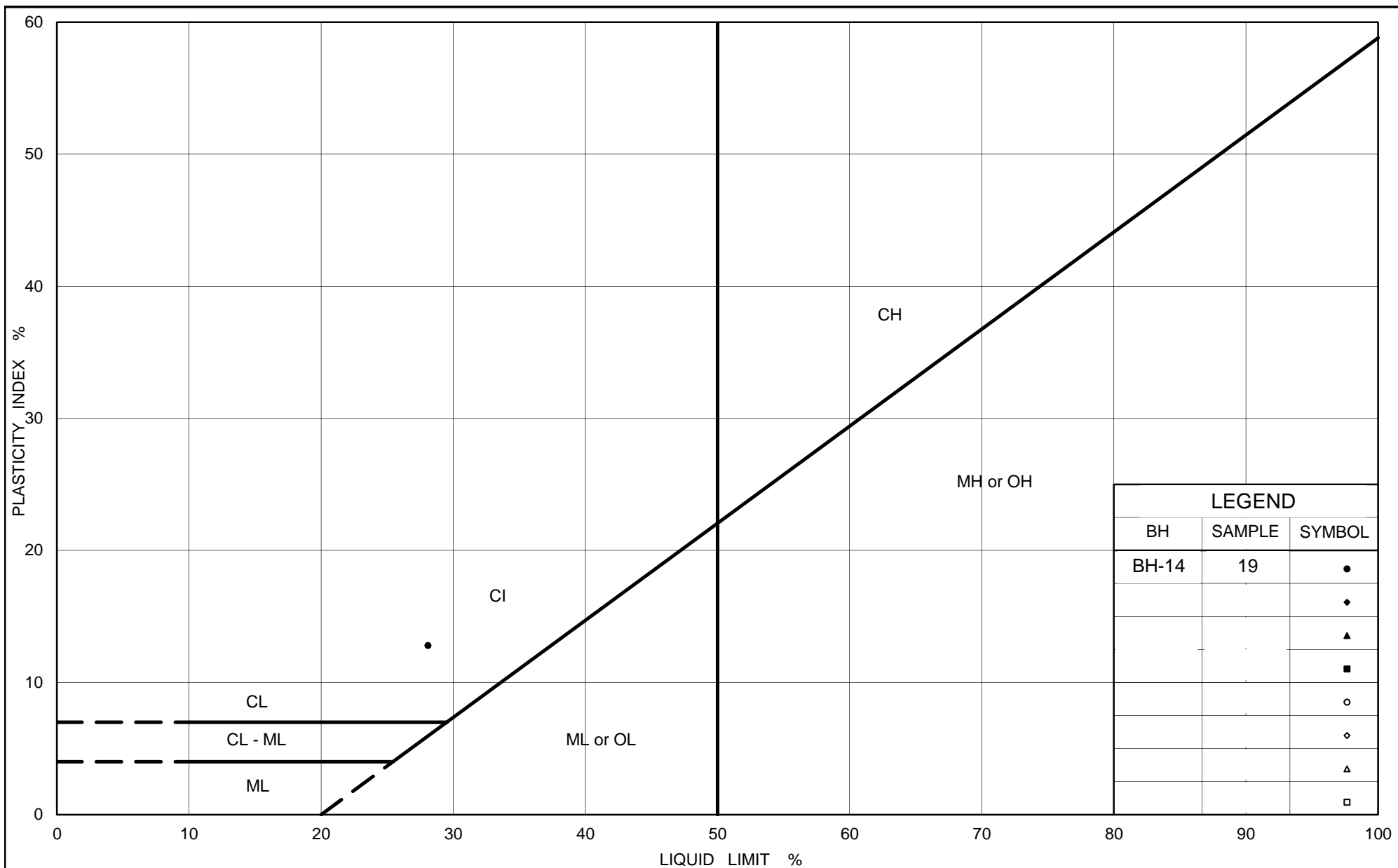
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	BH-14	19	168.9

Project Number: 1404378

Checked By: ARV

**Golder Associates**

Date: 09-Oct-14



PLASTICITY CHART  
Clayey Gravel  
HDD Under Rutherford Road

Figure No. B9

Project No. 1404378

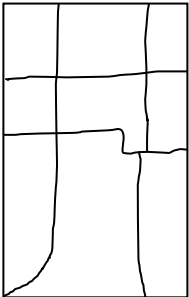
Checked By: ARV

**TABLE B1**  
**SUMMARY OF UNIAXIAL COMPRESSIVE STRENGTH TEST RESULTS**  
**HDD Crossing Under Rutherford Road**

<b>Borehole Number (Core Run)</b>	<b>Sample Depth (m)</b>	<b>Sample Elevation (m)</b>	<b>Rock Type</b>	<b>Core Diameter (mm)</b>	<b>Uniaxial Compressive Strength (MPa)</b>
BH-12	48.3	146.8	Shale	47.1	10.7
BH-13	34.6	161.2	Shale	47.2	14.0
BH-13	50.1	145.7	Limestone	47.2	61.0
BH-14	44.8	152.0	Shale	47.2	11.4

Compiled By: ARVChecked By: MMReviewed By: MM

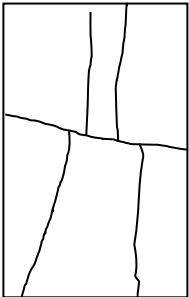
**TABLE B2**  
**UNCONFINED COMPRESSION TEST (UC) OF INTACT ROCK CORE SPECIMENS**  
**ASTM D7012**

SAMPLE IDENTIFICATION			
PROJECT NUMBER	1404378	RUN NUMBER	12
BOREHOLE NUMBER	BH-12	SAMPLE DEPTH, m	48.25-48.41
TEST CONDITIONS			
MACHINE SPEED, mm/min	0.00	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.19
SPECIMEN INFORMATION			
SAMPLE HEIGHT, cm	10.30	WATER CONTENT, (specimen) %	0.03
SAMPLE DIAMETER, cm	4.71	UNIT WEIGHT, kN/m <sup>3</sup>	25.53
SAMPLE AREA, cm <sup>2</sup>	17.42	DRY UNIT WT., kN/m <sup>3</sup>	25.52
SAMPLE VOLUME, cm <sup>3</sup>	179.43	SPECIFIC GRAVITY	-
WET WEIGHT, g	467.25	VOID RATIO	-
DRY WEIGHT, g	454.82		
VISUAL INSPECTION		FAILURE SKETCH	
			

TEST RESULTS			
STRAIN AT FAILURE, %	-	COMPRESSIVE STRENGTH, MPa	10.7
REMARKS:		DATE:	9/12/2014

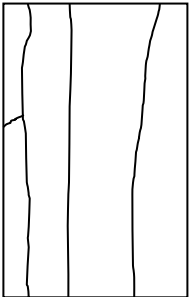


**TABLE B3**  
**UNCONFINED COMPRESSION TEST (UC) OF INTACT ROCK CORE SPECIMENS**  
**ASTM D7012**

SAMPLE IDENTIFICATION			
PROJECT NUMBER	1404378	RUN NUMBER	4
BOREHOLE NUMBER	13	SAMPLE DEPTH, m	34.55-34.73
TEST CONDITIONS			
MACHINE SPEED, mm/min	0.00	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.24
SPECIMEN INFORMATION			
SAMPLE HEIGHT, cm	10.57	WATER CONTENT, (specimen) %	0.06
SAMPLE DIAMETER, cm	4.71	UNIT WEIGHT, kN/m <sup>3</sup>	25.40
SAMPLE AREA, cm <sup>2</sup>	17.44	DRY UNIT WT., kN/m <sup>3</sup>	25.38
SAMPLE VOLUME, cm <sup>3</sup>	184.32	SPECIFIC GRAVITY	-
WET WEIGHT, g	477.50	VOID RATIO	-
DRY WEIGHT, g	451.08		
VISUAL INSPECTION		FAILURE SKETCH	
			

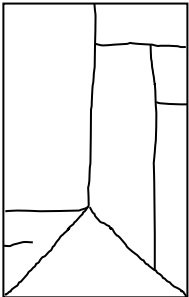
TEST RESULTS			
STRAIN AT FAILURE, %	-	COMPRESSIVE STRENGTH, MPa	14.0
REMARKS:		DATE:	9/3/2014

**TABLE B4**  
**UNCONFINED COMPRESSION TEST (UC) OF INTACT ROCK CORE SPECIMENS**  
**ASTM D7012**

SAMPLE IDENTIFICATION			
PROJECT NUMBER	1404378	RUN NUMBER	15
BOREHOLE NUMBER	BH-13	SAMPLE DEPTH, m	50.00-50.10
TEST CONDITIONS			
MACHINE SPEED, mm/min	0.00	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.08
SPECIMEN INFORMATION			
SAMPLE HEIGHT, cm	9.81	WATER CONTENT, (specimen) %	0.04
SAMPLE DIAMETER, cm	4.72	UNIT WEIGHT, kN/m <sup>3</sup>	25.58
SAMPLE AREA, cm <sup>2</sup>	17.51	DRY UNIT WT., kN/m <sup>3</sup>	25.57
SAMPLE VOLUME, cm <sup>3</sup>	171.83	SPECIFIC GRAVITY	-
WET WEIGHT, g	448.45	VOID RATIO	-
DRY WEIGHT, g	429.63		
VISUAL INSPECTION	FAILURE SKETCH		
			

TEST RESULTS			
STRAIN AT FAILURE, %	-	COMPRESSIVE STRENGTH, MPa	61.0
REMARKS:	DATE:		9/12/2014

**TABLE B5**  
**UNCONFINED COMPRESSION TEST (UC) OF INTACT ROCK CORE SPECIMENS**  
**ASTM D7012**

SAMPLE IDENTIFICATION			
PROJECT NUMBER	1404378	RUN NUMBER	9
BOREHOLE NUMBER	14	SAMPLE DEPTH, m	44.69-44.92
TEST CONDITIONS			
MACHINE SPEED, mm/min	0.00	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.19
SPECIMEN INFORMATION			
SAMPLE HEIGHT, cm	10.35	WATER CONTENT, (specimen) %	0.04
SAMPLE DIAMETER, cm	4.72	UNIT WEIGHT, kN/m <sup>3</sup>	25.41
SAMPLE AREA, cm <sup>2</sup>	17.53	DRY UNIT WT., kN/m <sup>3</sup>	25.40
SAMPLE VOLUME, cm <sup>3</sup>	181.37	SPECIFIC GRAVITY	-
WET WEIGHT, g	470.05	VOID RATIO	-
DRY WEIGHT, g	451.70		
VISUAL INSPECTION	FAILURE SKETCH		
			
TEST RESULTS			
STRAIN AT FAILURE, %	-	COMPRESSIVE STRENGTH, MPa	11.4
REMARKS:	DATE:		9/3/2014

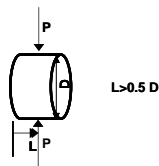
**TABLE B6**  
**POINT LOAD TEST RESULTS ON ROCK SAMPLES**

Borehole Number	Run Number	Sample Depth (m)	Sample Elevation (m)	Bedrock Description	Test Type	Core Length (mm)	Core Diameter <sup>(2)</sup> (mm)	Is (50mm) (MPa)	Approx. UCS Value <sup>(1)</sup> (MPa)
BH-12	2	33.53	161.6	Shale	Diametral	100.0	47.6	0.52	7
BH-12	2	33.95	161.1	Shale	Diametral	55.0	47.6	0.23	3
BH-12	6	40.09	155.0	Shale	Axial	49.0	47.6	0.65	8
BH-12	6	40.11	155.0	Shale	Diametral	85.0	47.6	0.10	1
BH-12	9	44.22	150.9	Shale	Axial	41.0	47.6	0.92	12
BH-12	9	44.24	150.8	Shale	Diametral	84.0	47.6	0.71	9
BH-12	10	44.60	150.5	Shale	Diametral	72.0	47.6	2.48	32
BH-12	12	49.23	145.9	Shale	Diametral	87.0	47.6	1.90	25
BH-12	12	49.25	145.8	Limestone	Axial	48.0	47.6	5.54	72
BH-13	2	30.81	165.0	Limestone	Diametral	61.0	47.6	5.15	67
BH-13	2	32.07	163.7	Shale	Diametral	90.0	47.6	0.18	2
BH-13	3	33.47	162.3	Shale	Diametral	90.0	47.6	0.08	1
BH-13	5	35.96	159.8	Shale	Diametral	72.0	47.6	0.10	1
BH-13	5	35.98	159.8	Shale	Axial	35.0	47.6	0.82	11
BH-13	6	37.54	158.2	Shale	Axial	49.0	47.6	1.23	16
BH-13	6	37.56	158.2	Shale	Diametral	100.0	47.6	0.51	7
BH-13	7	38.78	157.0	Shale	Diametral	87.0	47.6	0.08	1
BH-13	13	46.85	148.9	Limestone	Axial	22.0	47.2	4.47	58
BH-13	17	52.60	143.2	Limestone	Axial	17.5	47.3	7.17	93
BH-13	17	52.60	143.2	Limestone	Diametral	57.9	36.2	4.55	59
BH-13	19	55.41	140.4	Limestone	Axial	16.1	47.4	10.41	135
BH-13	19	55.41	140.4	Limestone	Diametral	54.3	36.9	4.01	52.13
BH-13	21	59.16	136.6	Limestone	Axial	14.7	47.4	7.96	103
BH-13	21	59.16	136.6	Limestone	Diametral	40.3	44.8	2.66	35
BH-14	2	35.16	161.7	Shale	Diametral	79.0	47.6	0.40	5
BH-14	2	35.18	161.7	Shale	Axial	37.0	47.6	0.44	6
BH-14	3	35.92	160.9	Shale	Diametral	66.0	47.6	0.20	3
BH-14	3	36.63	160.2	Limestone	Axial	40.0	47.6	9.40	122
BH-14	4	37.62	159.2	Shale	Axial	37.0	47.6	0.53	7
BH-14	4	37.68	159.2	Shale	Diametral	80.0	47.6	1.19	15

<sup>(1)</sup>  $I_{s50} \times K$ , from ASTM Designation: D 5731 "Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classifications". A value of  $K = 13$  has been used based on a UCS test result.

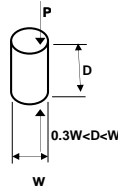
#### DIAMETRAL SPECIMEN SHAPE REQUIREMENTS

note: Diametral tests are perpendicular to core axis (planes of weakness)



#### AXIAL SPECIMEN SHAPE REQUIREMENTS

note: Axial tests are parallel to core axis (planes of weakness)



Compiled By: ARV  
Checked By: MM  
Reviewed By: MM

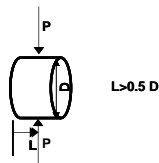
**TABLE B6**  
**POINT LOAD TEST RESULTS ON ROCK SAMPLES**

[illegible]

(1)  $I_{S50} \times K$ , from ASTM Designation: D 5731 "Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classifications". A value of  $K = 13$  has been used based on a UCS test result.

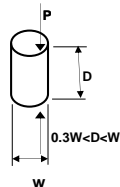
## DIAMETRAL SPECIMEN SHAPE REQUIREMENTS

note: Diametral tests are perpendicular to core axis (planes of weakness)



## AXIAL SPECIMEN SHAPE REQUIREMENTS

note: Axial tests are parallel to core axis  
(planes of weakness)



Compiled By: ARV  
Checked By: MM  
Reviewed By: MM

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