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DRAFT GEOTECHNICAL INVESTIGATION REPORT

TransCanada King's North Connection (KNC) Proposed Undercrossing of McGillivray Road, CP Rail and Major McKenzie Drive West in Vaughan, Ontario

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DRAFT REPORT



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TRANSCANADA KNC PROJECT
PROPOSED UNDERCROSSING OF MCGILLIVRAY ROAD, CP
RAIL AND MAJOR MCKENZIE DRIVE WEST
VAUGHAN, ONTARIO**

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Figure 1: HDD Crossing under Mc Gillivray Rd., CP, Huntington Rd. and Major McKenzie Dr. Plan

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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 13 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 (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 850 m length undercrossing of McGillivray Road, Canadian Pacific (CP) Rail and Major McKenzie Drive West, parallel and adjacent to Huntington Road in the City of Vaughan, Ontario as shown in the attached 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 McGillivray Road, CP Rail and Major McKenzie Drive West at Huntington Road by means of Horizontal Directional Drilling (HDD) method of installation. Land use in the area of the site is primarily agricultural with the exception of the CP Land north of McGillivray Road and east of Huntington Road.

The terrain in the area adjacent to the site is slightly sloping southward, varying from approximately Elevations 205.8 m to 206.4 m.

3.0 GEOTECHNICAL INVESTIGATION

3.1 Investigation Procedure

A subsurface investigation was carried out by Golder for the proposed HDD crossing between August 5 and September 5, 2014 during which time a total of four (4) boreholes (designated as Boreholes BH-24, BH-25,



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BH-27 and BH-28) were advanced at the location of the proposed entry and exit pits and along the proposed route, as set out by Entec and staked out by J.D. Barnes Ltd., Ontario Land Surveyors.

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 24.8 m to 60.7 m below ground surface as directed by Entec. The boreholes were advanced through the overburden using HQ casing and/or 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, using a 50 mm O.D. split-spoon sampler driven by an automatic hammer in accordance with Standard Penetration Test (SPT) procedures.¹ Samples of the bedrock were obtained in Boreholes BH-24 and BH-25 using an 'NQ' size rock core barrel with core lengths between about 3.1 m and 5.9 m, respectively.

The groundwater conditions in the open boreholes were observed during and upon completion of drilling, and monitoring wells were installed in Boreholes BH-24 and BH-28 to permit monitoring of the water levels at these locations. The wells consist of 50 mm diameter PVC pipes, with slotted screens surrounded with sand seals at selected depths within the boreholes. The boreholes and annulus surrounding the well pipes above the screen were backfilled to the surface with bentonite pellets. Well installation details and water level readings are presented on the Record of Borehole sheets BH-24 and BH-28 in Appendix A. All open boreholes were backfilled with bentonite pellets and soil cutting 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 utility services, directed the sampling and in situ testing operations, logged the boreholes and cared for the soil and rock 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 core upon extraction from the core barrel. The bedrock was sequentially photographed and selected samples were properly packed and transported to Golder's Mississauga lab for strength testing (uniaxial (unconfined) compression and point load index). The results of the laboratory testing are included in Appendix B.

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:

¹¹ ASTM D1586 – Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils



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Borehole Designation	Location (UTM NAD 83)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m)	Easting (m)		
BH-24	4,852,79.0	607,935.8	202.2	60.7
BH-25	4,853,150.8	607,743.4	204.5	59.6
BH-27	4,853,3290	607,703.0	205.0	59.5
BH-28	4,853,520.5	607,538.1	205.8	24.5

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 deposit of silty clay underlain by deposits of cohesive and non-cohesive till. The till deposit is underlain by a deposit which ranges from a silt of slight plasticity to a silty clay – clayey silt of low plasticity. These deposits are underlain by a deposit of silty sand and/or sandy gravel to sand and gravel which is in turn underlain by shale bedrock.

4.2.1 Topsoil

A 280 mm thick layer of topsoil was encountered at the ground surface in Borehole BH-28 at about Elevation 205.8 m.

4.2.2 Upper Silty Clay (CL to CI)

An upper deposit of cohesive soils comprised of brown to grey silty clay was encountered at the ground surface in Boreholes BH-24, BH-25 and BH-27 and underlying the topsoil layer in Borehole BH-28. The upper portion of the deposit up to a depth of about 1.1 m contains trace quantities of organic matter, roots and rootlets and these are anticipated to be related to the existing agricultural land use. The deposit also generally contains trace to some sand, trace gravel. The top of the upper cohesive deposit ranges from about Elevations 205.5 m to 202.2 m and its thickness varies between about 5.8 m and 11.7 m as encountered in the boreholes.



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The SPT 'N'-values measured within the upper silty clay ranges from 7 blows to 27 blows per 0.3 m of penetration, suggesting a firm to very stiff consistency.

The grain size distribution test results for two (2) samples of the silty clay are shown on Figure B1 in Appendix B.

Atterberg limits tests were carried out on four (4) samples of the deposit, and measured liquid limits ranging from about 28 per cent to 36 per cent, plastic limits ranging from about 15 per cent to 18 per cent and plasticity indices from about 13 per cent to 18 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure B2 in Appendix B and indicate that the material is classified as silty clay of low to intermediate plasticity.

4.2.3 Silt and Sand Pocket (ML/SM)

Borehole BH-28 penetrated an approximately 2.6 m thick pocket of grey silt and sand, some gravel, some clay underlying the upper silty clay in Borehole BH-28 at about Elevation 199.7 m.

The grain size distribution test result for a sample of silt and sand pocket is shown on Figure B3 in Appendix B.

An Atterberg limits test was carried out on the fines portions of a sample of silt and sand and measured a liquid limit of about 16 per cent, a plastic limit of about 12 per cent and a corresponding plasticity index of about 4 per cent. The result of the Atterberg limits test is shown on the plasticity chart on Figure B4 in Appendix B and indicates that the fines portion of the material is classified as a silt of slight plasticity.

4.2.4 Cohesive Till (CL to ML)

A deposit of cohesive till comprised of sandy silty clay - clayey silt to sandy silty clay was encountered underlying the upper silty clay in Boreholes BH-24, BH-25 and BH-27 and underlying the silt and sand pocket in Borehole BH-28. The deposit generally contains variable percentages of sand and trace to some gravel. The presence of cobbles and boulders is inferred from auger grinding noted within the till deposit; auger grinding was noted at depths ranging from 12.2 m to 14.6 m depth in all of the boreholes. Lenses of sandy silt were encountered within the cohesive till in Borehole BH-25. The top of the cohesive till ranges from about Elevations 197.1 m to 193.3 m. Borehole BH-28 was terminated within this deposit at a depth of about 24.8 m penetrating it for about 16.2 m; where the deposit was fully penetrated, its thickness varies between about 5.4 m and 16.2 m. A 3.0 m thick layer of silty sand till was also encountered within the cohesive till deposit.

The SPT 'N'-values measured within the cohesive till range from 10 blows per 0.3 m of penetration to 152 blows per 0.2 m of penetration and an in situ field vane test carried out within this deposit measured natural undrained shear strength of greater than 96 kPa (i.e. it was not possible to turn the shear vane apparatus) and a remoulded shear strength of about 64 kPa. The SPT 'N'-values suggest that the cohesive till deposit has a stiff to hard consistency.

The grain size distribution test results for six (6) samples of the cohesive till are shown on Figure B5 in Appendix B.

Atterberg limits tests were carried out on five (5) samples of the till deposit, and measured liquid limits ranging from about 18 per cent to 26 per cent, plastic limits ranging from about 12 per cent to 15 per cent and plasticity indices ranging from about 5 per cent to 11 per cent. The results of the Atterberg limits are shown on the



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plasticity chart on Figure B6 in Appendix B and indicate that the material is classified as silty clay-clayey silt to silty clay of low plasticity.

4.2.5 Silty Sand Till (SM)

Borehole BH-27 encountered an approximately 3.0 m thick layer of non-cohesive till comprised of grey silty sand, some gravel, trace clay size particles at about Elevation 187.9 m within the cohesive till.

One SPT 'N'-value of 50 blows per 0.08 m of penetration was recorded within the silty sand till deposit, indicating a very dense compactness.

A grain size distribution test result for a sample of this layer is shown on Figure B7 in Appendix B.

4.2.6 Silt to Silty Clay – Clayey Silt (ML to CL-ML)

A deposit of non-cohesive silt (silt of slight plasticity) to silty clay-clayey silt of low plasticity was encountered in Boreholes BH-24, BH-25 and BH-27 underlying the cohesive till. The deposit was predominantly non-cohesive in Borehole BH-27 and ranged from a non-cohesive silt to low plasticity silty clay-clayey silt in Boreholes BH-24 and BH-25. The top of the deposit ranges from about Elevations 179.0 m (Borehole BH-24) to 178.3 m (Borehole BH-25) and the thickness of the deposit varies between about 18.3 m and 24.4 m. Varying quantities of sand (trace sand to sandy) and trace quantities of gravel were also noted within the deposit.

The SPT 'N'-values measured within the non-cohesive zones (silt) of the deposit range from 13 blows to 58 blows per 0.3 m of penetration indicating the material is compact to very dense; however, the 'N' values were predominantly less than 20 blows per 0.3 m of penetration indicating a generally compact material.

The SPT 'N'-values measured within the cohesive zones of the deposit (silty clay-clayey silt) range from 14 per 0.3 m of penetration to 50 blows per 0.13 m of penetration indicating stiff to hard consistency; however, the 'N' values were predominantly less between 15 blows and 30 blows per 0.3 m indicating a predominantly very stiff consistency.

The grain size distribution test results for two (2) samples of the silty clay-clayey silt deposit are shown on Figure B8 in Appendix B.

Atterberg limits tests were carried out on two (2) samples of the silty clay-clayey silt deposit and measured liquid limits of about 23 per cent, plastic limits of about 16 per cent and 18 per cent and corresponding plasticity indices of about 5 per cent and 7 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure B9 in Appendix B and indicate that the material is classified as a silty clay - clayey silt of low plasticity.

The grain size distribution test results for three (3) samples of the silt deposit are shown on Figure B10 in Appendix B.

Atterberg limits tests were carried out on three (3) samples of the silt deposit and measured liquid limits ranging from about 18 per cent to 20 per cent, plastic limits of between 16 per cent and 18 per cent and corresponding plasticity indices between about 2 per cent and 4 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure B11 in Appendix B and indicate that the material is classified as a silt of slight plasticity.



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4.2.7 Silty Sand (SM)

A non-cohesive deposit of silty sand was encountered underlying the silt to silty clay-clayey silt in Boreholes BH-24, BH-25 and BH-27. The top of the silty sand deposit ranges from about Elevations 160.4 m to 154.6 m and the thickness of the deposit varies between about 3.0 m to 12.2 m.

The SPT 'N'-values measured within the silt sand range from 40 blows per 0.3 m of penetration to 50 blows per 0.1 m of penetration indicating a dense to very dense material. The grain size distributions of three (3) samples of the silty sand deposit are shown on Figure B12 in Appendix B.

4.2.8 Sandy Gravel to Sand and Gravel with Shale Fragments

A layer of sandy gravel to sand and gravel was encountered underlying the silty sand deposit in Boreholes BH-25 and BH-27 at about Elevations 151.1 m and 148.3 m in the respective boreholes. Borehole BH-27 was terminated at about Elevation 145.5 m upon split-spoon refusal on inferred shale bedrock. Coring operations were undertaken in Borehole BH-25 within this layer and cobbles, boulder and shale fragments were recovered in the core samples. Auger grinding was also noted in Borehole BH-27 within this layer.

SPT 'N'-values of 50 blows per 0.10 m of penetration, 50 blows per 0.02 m of penetration and 100 blows per 0.05 m of penetration were measured within this deposit, indicating a very dense material.

4.2.9 Shale Bedrock

Bedrock was encountered and core samples were recovered from Boreholes BH-24 and BH-25. Based on the review of the bedrock core samples, the bedrock consists of shale of Georgian Bay Formation and is generally described as slightly weathered, very thinly bedded, dark grey, non-porous, weak to medium strong, as presented on the Record of Drillhole sheets BH-24 and BH-25. The degree of weathering of the bedrock samples (i.e. slightly weathered), and the strength classification of intact rock mass based on field identification (i.e. weak to medium strong) are described in accordance with the International Society of Rock Mechanics (ISRM¹) standard classification system.

The Rock Quality Designation (RQD) measured on the core samples ranges generally from about 30 per cent to 93 per cent, indicating a rock mass of poor to excellent quality as per Table 3.10 of Canadian Foundation Engineering Manual (CFEM).² However, a portion of core recovered from Borehole BH-24 contains fractured rock with RQD value of about 13 per cent indicating a rock mass of very poor quality. The Total Core Recovery (TCR) and Solid Core Recovery (SCR) of samples recovered are between 91 per cent and 100 per cent and between 46 per cent and 68 per cent, respectively.

One Unconfined Compression (UC) test (ASTM D7012³) was carried out on a selected sample of rock core in Borehole BH-24 and measured Uniaxial Compressive Strength (UCS) of about 20 MPa as detailed in Table B1.

Point load strength index tests (ASTM D5731⁴) were carried out on core samples of the shale with limestone interbeds bedrock obtained in Borehole BH-24. The axial and diametral point load strength index values are

¹ 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.

² Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition.

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

⁴ 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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shown on the Record of Drillhole sheet BH-24 and are presented in Table B2 in Appendix B. The two (2) axial tests measured I_{s50} values of about 11.0 MPa and 6.1 MPa and two (2) diametral tests measured I_{s50} values of about 3.2 MPa and 1.4 MPa.

Based on the laboratory UC test results along with Point load test results and in accordance with Table 3.5 in CFEM (2006), the shale bedrock interbedded with limestone is classified as weak to medium strength rock.

4.3 Groundwater Conditions

Monitoring wells were installed in Boreholes BH-24 and BH-28 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:

Borehole	Ground Surface Elevation (m)	Depth to Water (m)	Groundwater Elevation (m)	Screened Depths (m)	Screened Deposit	Date Measured
BH-24	202.2	23.3	178.9	45.7 to 51.8	Silty Sand	September 12, 2014
		22.5	179.7			September 22, 2014
BH-28	205.8	9.1	196.7	15.8 to 18.9	Sandy Silty Clay Till	August 14, 2014
		9.2	196.6			September 22, 2014

The relatively shallow groundwater level measured at a depth of 9.2 m (Elevation 196.6 m) is likely reflecting a perched water table within the silty clay till deposit. The groundwater level associated with the silty sand layer is at a lower Elevation of 179.9 m (approximately 16.7 m lower) reflecting a downward gradient within the till.

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.



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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 McGillivray Road, CP Rail, Huntington Road and Major Mc Kenzie Drive West.

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

Crossing Length	853.1 m
Approximate Ground Elevation at Entry Pit (South of McGillivray Road)	202.2 m
Approximate Track Elevation at CP Crossing	202.7 m
Approximate Ground Elevation at Major McKenzie Drive West	204.0
Approximate Ground Elevation at Huntington Road	203.0
Approximate Ground Elevation at McGillivray Road	202.5
Approximate Ground Elevation at Exit Pit (North of Major McKenzie Drive West)	206.5
Approximate Invert Elevation	172.0 m

For an HDD alignment that would be at Elevation 172 m and above, the strata that the installation would extend through are summarized below beginning with the uppermost stratum. In general, the subsoil conditions are



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considered suitable for HDD installation methods although there will be challenges to be overcome through proper equipment selection and fluid pressures within the glacial till deposit and careful consideration should be given to nature of the silt to silty clay-clayey silt deposit with respect to anticipated stand up time within the non-cohesive portions of the deposit.

Silty Clay: The stratum generally consists of firm to very stiff silty clay with compact silt and sand pockets. The bottom elevation of the deposit ranges from about Elevation 197.1 m in Borehole BH-28 to Elevation 192.0 m in Borehole BH-24. Due to the firm to hard consistency of the deposit and its low to intermediate plasticity, it appears that these materials might be readily penetrated during directional drilling. However, this material is generally susceptible to hydraulic fracturing with increased fluid pressures. Correlating the soil classification with a modified version of Terzaghi's Tunnelman's Classification¹, the tunnelling conditions can be described as firm within the stiff to very stiff silty clay materials. Stand up time for the unsupported excavation face within this deposit is expected to be about 30 hours.

Glacial Till Deposit: The till deposit is generally very stiff to hard, , cohesive till with cobbles/boulders and non-cohesive pockets of silty sand till. The bottom of the deposit ranges from about Elevation 179.0 m to 176.3 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.

The specific presence of cobbles and boulders can significantly affect the selection of equipment and progress of construction works in trenchless excavations, if the bore horizon is selected to extend through till. . 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 tunnelling 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 silty clay-clayey silt of low plasticity with the bottom of the deposit ranging from about Elevation 160.4 m to 154.6 m. The silt is expected to become sandier with depth, as encountered in Borehole BH-25. The groundwater level as measured within the underlying granular deposit is near the surface of this silt/silty clay-clayey silt deposit and

¹ Heuer, Ronald E.: "Important Ground Parameters in Soft Ground Tunnelling", Proceedings Specialty Conference on Subsurface Explorations for Underground Excavations and Heavy Construction, ASCE, NY, 1974.



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therefore the HDD installation within this deposit is expected to be below the groundwater table. Based on the preliminary alignment provided, approximately 650 m out of the total 850 m length of the proposed crossing will be within this deposit. 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 tunnelling 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.

5.2 Hydraulic Fracturing / Drilling Fluid Pressures

Latorre et al (2002)¹ provides some guidance relating to the recommended minimum depth of cover for various pipe diameters (to reduce the potential for drilling fluid release) as reproduced 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.

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.

¹ 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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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 and the CP railway. 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 and the CP railway 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.

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



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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 up to 5 m below existing ground surface and as such will be extended within the upper silty clay deposit. 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 will be 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 prevailing groundwater level is expected to be below the base of the pits. Dry conditions were encountered during drilling at relatively shallow depths within the upper silty clay deposit. Due to the clayey nature of the upper silty clay deposit on site small amounts of seepage are expected into the excavations. Such seepage and removal of precipitation that enters the shafts/pits can be handled by appropriately filtered sumps installed in the excavation base.

5.4 Other Considerations

The proposed undercrossing must be constructed in accordance with CP and municipal regulations/requirements. 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



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recommended that the geotechnical aspects of the contractor's work plan for the undercrossing be reviewed by this office prior to construction.

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 railway tracks and roads. Where adequate provisions are not included to ensure excavation stability, detrimental surface settlement could occur, adversely impacting the railway tracks and any associated existing underground services present.

Should remedial works be required of the tracks and/or 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 railway track and/or roads, such as lifting/settlement/changes of alignment) for the review and approval from TransCanada, CP and the relevant municipalities (i.e., City of Vaughan and Region of York).

6.0 SETTLEMENT AND SETTLEMENT MONITORING

6.1 CP Rail Crossing

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 under the existing CP track will be provided once the HDD profile is final. With HDD installation method, long-term settlement can occur after the pipeline installation is completed due to consolidation of the mud slurry and progressive collapse of the oversized drillhole between the ground and the pipe. Therefore, grouting of the annulus between the product pipe and the HDD drillhole should be specified and carried out following the installation of the pipeline below the CP railway. The material used for grouting the annulus between the sidewall of the drill hole and pipe could consist of either cementitious materials such as portland cement or a bentonite grout of sufficient solids content that the grout will "set-up" within the full annular space between the pipe and the wall of the directionally drilled hole.

A settlement monitoring program should be implemented to measure ground settlement at the CP tracks crossing site. Therefore, provision for settlement monitoring should be made in the contract documents for monitoring the response of the railway tracks to the trenchless operations prior to, during and after completion of 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 Municipal and CP guidelines. In addition, it would be prudent to have the undercrossing construction monitored by Golder.



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The **surface** settlement monitoring points would consist of settlement plates installed at subballast level with steel riser rods at the end of the ties. An array/row of monitoring points should be installed on the south and north sides of each track. Each row would have one surface settlement monitoring point installed above the pipe centerline with additional monitoring points offset at intervals of 2 metres to a distance of 16 m east and west of the proposed pipeline crossing centerline. With this monitoring point configuration, the requirement for surface monitoring points installed at 9.45 m east and west of the crossing centerline in accordance with CPR's Track Movement Monitoring Guidelines for Pipe Installation by Trenchless Method (July 23, 2010) is met with the proposed points at 10 m distance from the centerline and additional points should not be required.

Two sets of **subsurface** monitoring points (for a total of four monitoring points) should be installed adjacent to the proposed HDD crossing. The subsurface monitoring points should be installed approximately 10 m and 20 m north and south of the centerline of the tracks above the proposed pipeline centreline. Each subsurface settlement monitoring points would consist of a steel rod installed within a drilled hole to a depth of about 2.0 metres above the crown of the final HDD reamed hole and grouted in place.

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 submitted to Golder for review on an ongoing basis. A baseline survey should be carried out at least twice per day for two days prior to construction with the points referenced to two independent benchmarks. Anomalous readings should be rechecked and discarded, if necessary. As a minimum, the party responsible for surveying monitoring should:

- assign each monitor a unique identifier and note the location;
- note the date and elevation of baseline readings and all subsequent readings; and
- note differences in elevation.

Monitoring should be carried out at the following frequencies:

- Daily: Two times a day during construction and once a day during the week after completion of the crossings
- Weekly: Up to three months after completion of the crossings

The frequency of monitoring at any stage can be adjusted based on the magnitude of movements observed during construction. The survey data should be reviewed two months after construction to determine if further monitoring is warranted.

The elevation of the top of the monitoring points should be read using conventional precision levelling equipment. A specialist surveying firm should be retained to confirm the set-up and to carry out the monitoring during construction; their equipment and procedures must be capable of surveying the settlement point elevation to within ± 1 mm of the actual elevation and ± 2 mm of the track alignments.

The acceptable settlement should be specified by CP according to the train traffic. The following procedure should be followed if the settlement reaches half of the allowable settlement (Level 1 - Warning) and the full allowable settlement (Level 2 - Critical):



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- If Level 1 is reached a survey is to be conducted. If no movement is measured, work may continue. If movement is measured, monitoring will continue and tunnel excavation will not continue until this movement has stopped.
- If Level 2 is reached, a survey is to be conducted. If no movement is measured, work may continue. If movement is measured, monitoring will continue and tunnel excavation will not continue until this movement has stopped. A new pipe installation procedure is to be submitted by the contractor and approved by CP prior to tunnelling work continuing.

In addition to ground movement monitoring, as noted above, the track alignment (line and grade) should be carefully monitored using a total station during installation.

6.2 Roadway Crossings

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 roadways 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 roadways 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 completed once the pipe alignment at the roadway crossings 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.

6.3 Monitoring Well Decommissioning

As noted, monitoring wells were installed in Boreholes BH-24 and BH-28 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. It is recommended that the decommissioning of the monitoring well be carried out as part of the construction activities at the site so that water level measurements can be taken immediately prior to construction. If requested, Golder could provide assistance to TransCanada for the decommissioning of the wells by a licensed water well drilling contractor.

7.0 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.



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8.0 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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Report Signature Page

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REFERENCE
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DRAFT

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 PROJECT

TITLE

**HDD CROSSING UNDER MCGILLIVRAY RD., CP, HUNTINGTON
RD. AND MAJOR MCKENZIE DR. PLAN**

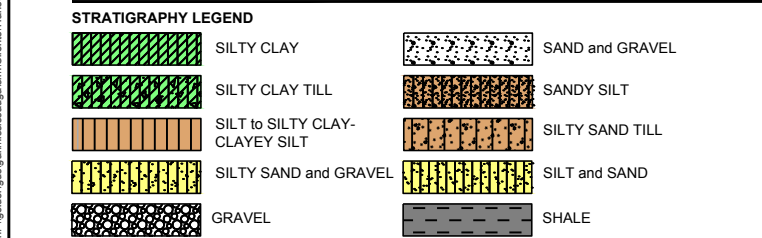
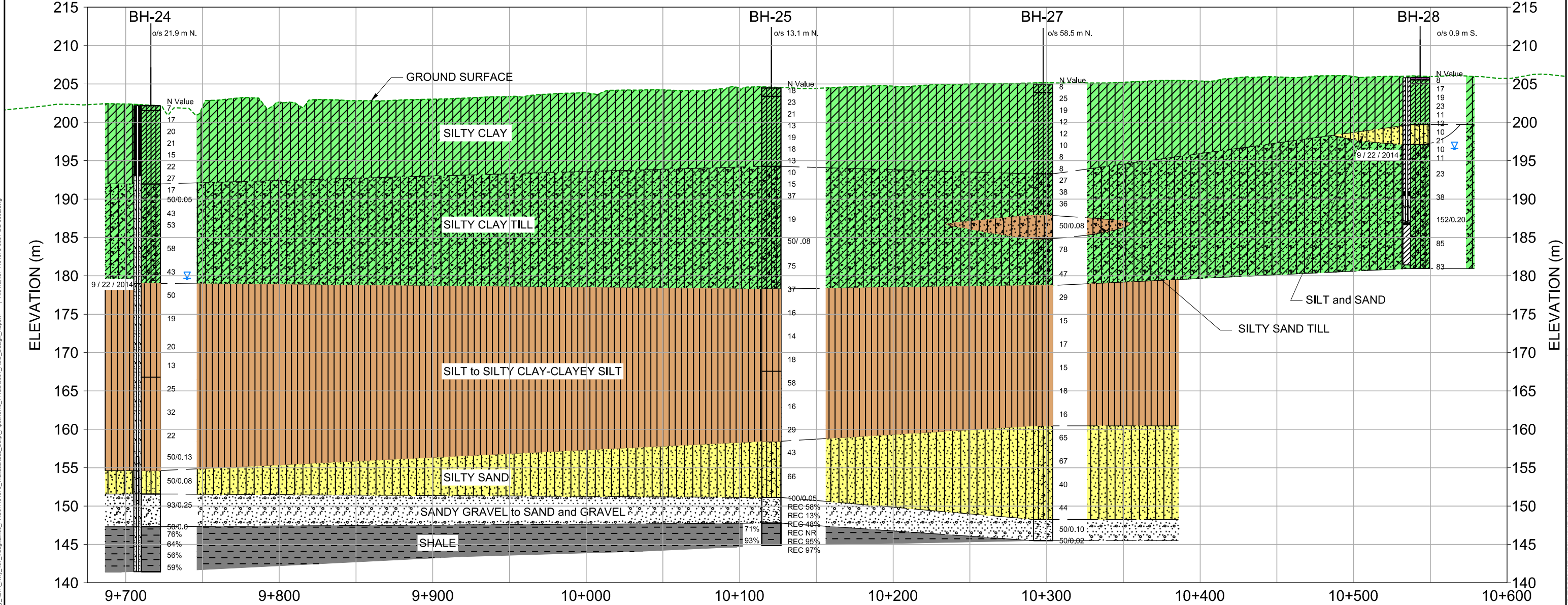
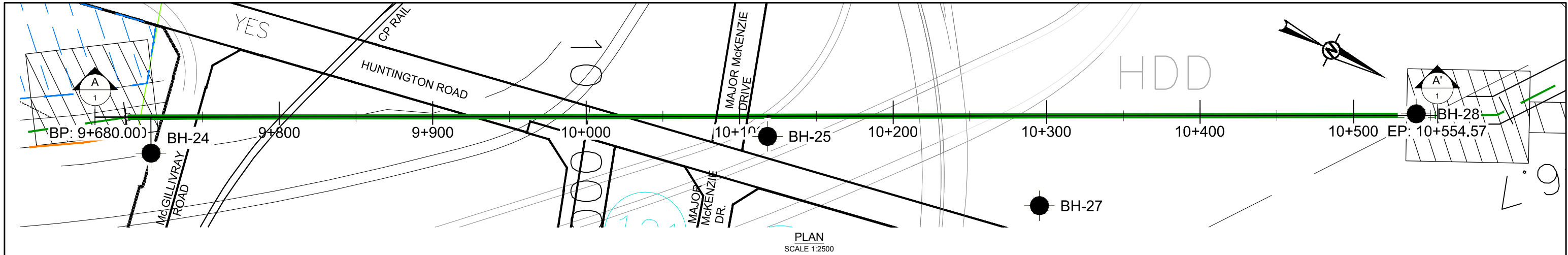
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FIGURE
1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



HORIZONTAL SCALE 1:2500
VERTICAL SCALE 1:500
A-A' HDD CENTRLINE PROFILE
2

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

DRAFT

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 PROJECT

TITLE
HDD CROSSING UNDER MCGILLIVRAY RD., CP, HUNTINGTON RD. AND MAJOR MCKENZIE DR. PLAN AND PROFILE

PROJECT No.
1404378

CONTROL
0001

Rev.
A

FIGURE
2



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 Ground water 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.

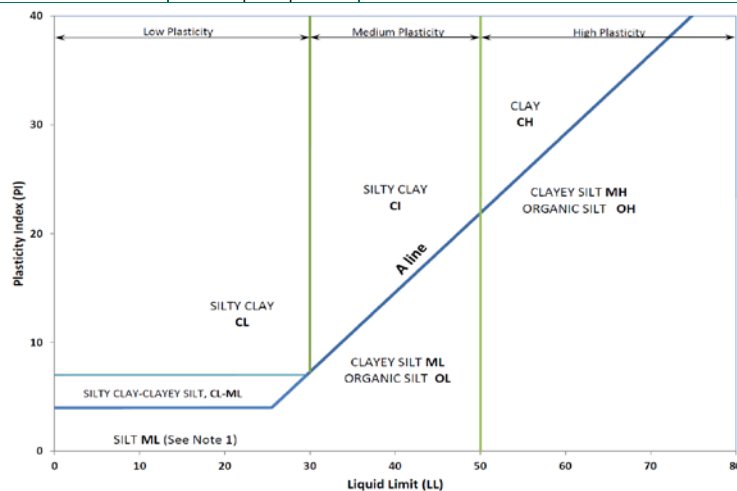
Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed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



METHOD OF SOIL CLASSIFICATION

The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)

Organic or Inorganic	Soil Group	Type of Soil		Gradation or Plasticity	$Cu = \frac{D_{60}}{D_{10}}$		$Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$			Organic Content	USCS Group Symbol	Group Name			
INORGANIC (Organic Content $\leq 30\%$ by mass)	COARSE-GRAINED SOILS ($>50\%$ by mass is larger than 0.075 mm)	GRAVELS ($>50\%$ by mass of coarse fraction is larger than 4.75 mm)	Gravels with $\leq 12\%$ fines (by mass)	Poorly Graded	<4		≤ 1 or ≥ 3			$\leq 30\%$	GP	GRAVEL			
				Well Graded	≥ 4		1 to 3				GW	GRAVEL			
			Gravels with $>12\%$ fines (by mass)	Below A Line	n/a						GM	SILTY GRAVEL			
				Above A Line	n/a						GC	CLAYEY GRAVEL			
		SANDS ($\geq 50\%$ by mass of coarse fraction is smaller than 4.75 mm)	Sands with $\leq 12\%$ fines (by mass)	Poorly Graded	<6		≤ 1 or ≥ 3				SP	SAND			
				Well Graded	≥ 6		1 to 3				SW	SAND			
			Sands with $>12\%$ fines (by mass)	Below A Line	n/a						SM	SILTY SAND			
				Above A Line	n/a						SC	CLAYEY SAND			
			Organic or Inorganic	Soil Group	Type of Soil	Laboratory Tests	Field Indicators					Organic Content	USCS Group Symbol	Primary Name	
							Dilatancy	Dry Strength	Shine Test		Thread Diameter	Toughness (of 3 mm thread)			
INORGANIC (Organic Content $\leq 30\%$ by mass)	FINE-GRAINED SOILS ($\geq 50\%$ by mass is smaller than 0.075 mm)	SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below)	Liquid Limit <50	Rapid	None	None	>6 mm	N/A (can't roll 3 mm thread)	$<5\%$	ML	SILT				
				Slow	None to Low	Dull	3mm to 6 mm	None to low	$<5\%$	ML	CLAYEY SILT				
			Liquid Limit ≥ 50	Slow to very slow	Low to medium	Dull to slight	3mm to 6 mm	Low	5% to 30%	OL	ORGANIC SILT				
				Slow to very slow	Low to medium	Slight	3mm to 6 mm	Low to medium	$<5\%$	MH	CLAYEY SILT				
				None	Medium to high	Dull to slight	1 mm to 3 mm	Medium to high	5% to 30%	OH	ORGANIC SILT				
		CLAYS (PI and LL plot above A-Line on Plasticity Chart below)	Liquid Limit <30	None	Low to medium	Slight to shiny	~ 3 mm	Low to medium	0% to 30%	CL	SILTY CLAY				
			Liquid Limit 30 to 50	None	Medium to high	Slight to shiny	1 mm to 3 mm	Medium	(see Note 2)	CI	SILTY CLAY				
			Liquid Limit ≥ 50	None	High	Shiny	<1 mm	High		CH	CLAY				
		HIGHLY ORGANIC SOILS (Organic Content $>30\%$ by mass)		Peat and mineral soil mixtures							30% to 75%	PT	SILTY PEAT, SANDY PEAT		
				Predominantly peat, may contain some mineral soil, fibrous or amorphous peat							75% to 100%		PEAT		



Note 1 – Fine grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are non-plastic (i.e. a PL cannot be measured) are named SILT.

Note 2 – For soils with $<5\%$ organic content, include the descriptor “trace organics” for soils with between 5% and 30% organic content include the prefix “organic” before the Primary name.

Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML.

For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between “clean” and “dirty” sand or gravel.

For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.

A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to or indicates a range of similar soil types within a stratum.



ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
SILT/CLAY	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

Percentage by Mass	Modifier
>35	Use 'and' to combine major constituents (i.e., SAND and GRAVEL, SAND and CLAY)
> 12 to 35	Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable
> 5 to 12	some
≤ 5	trace

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.) split-spoon sampler for a distance of 300 mm (12 in.).

Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve frictions are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); 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.).

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

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size
TP	Thin-walled, piston – note size
WS	Wash sample

SOIL TESTS

w	water content
PL, w_p	plastic limit
LL, w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
GS	specific gravity
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 (FV)	field vane (LV-laboratory vane test)
Y	unit weight

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

NON-COHESIVE (COHESIONLESS) SOILS

Compactness²

Term	SPT 'N' (blows/0.3m) ¹
Very Loose	0 - 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	>50

- SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects.
- Definition of compactness descriptions based on SPT 'N' ranges from Terzaghi and Peck (1967) and correspond to typical average N_{60} values.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

COHESIVE SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N' ¹ (blows/0.3m)
Very Soft	<12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	>200	>30

- SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

Water Content

Term	Description
$w < PL$	Material is estimated to be drier than the Plastic Limit.
$w \sim PL$	Material is estimated to be close to the Plastic Limit.
$w > PL$	Material is estimated to be wetter than the Plastic Limit.



LIST OF SYMBOLS

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

I. GENERAL

π	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

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	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
γ'	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_α	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
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	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 ρ . Unit weight symbol is γ 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	



**DRAFT GEOTECHNICAL INVESTIGATION REPORT
TRANSCANADA KNC PROJECT
PROPOSED UNDERCROSSING OF MCGILLIVRAY ROAD, CP
RAIL AND MAJOR MCKENZIE DRIVE WEST
VAUGHAN, ONTARIO**

APPENDIX A

Record of Borehole and Drillhole Sheets

PROJECT: 1404378

RECORD OF BOREHOLE: BH-24

SHEET 1 OF 7

LOCATION: N 4852794.98; E 607935.52

BORING DATE: September 2 to 5, 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						
								20	40	60	80	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴	10 ⁻³			
								20	40	60	80	10	20	30	40			
0		GROUND SURFACE		202.17 0.00													GR SA SI CL	
	Mud Rotary HQ Casing	(CL) SILTY CLAY, trace sand, trace gravel, trace organics, containing roots and rootlets; brown to dark brown; cohesive, firm			1	SS	7											
1		(CL/CI) SILTY CLAY, trace sand, trace gravel; brown with oxidation staining; cohesive, stiff to very stiff		201.56 0.61														
2					2	SS	17											
3					3	SS	20											
4																		
5				4	SS	21												
6																		
7				5	SS	15												
8					6	SS	22											
9																		
10					7	SS	27											

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DEPTH SCALE

1 : 50



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PROJECT: 1404378
LOCATION: N 4852794.98; E 607935.52

RECORD OF BOREHOLE: BH-24

SHEET 2 OF 7

BORING DATE: September 2 to 5, 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. + rem V. ⊕		Q - ● U - ○		WATER CONTENT PERCENT								
								20	40	60	80	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴	10 ⁻³		Wp ——— W ——— WI					
								20	40	60	80	10	20	30	40		GR	SA	SI	CL		
10		-- CONTINUED FROM PREVIOUS PAGE --																				
	Mud Rotary HQ Casing			191.97 10.20													7 31 50 12					
		(CL-ML) Sandy SILTY CLAY - CLAYEY SILT, some gravel; grey (TILL); cohesive, very stiff to hard																				
11					8	SS	17															
12			- Auger grinding at a depth of 12.2 m.		9	SS	50/ 0.05															
13																						
14			- Auger grinding at a depth of 14.3 m.		10	SS	43															
15																						
16																						
17																						
18																						
19																						
20																						
		CONTINUED NEXT PAGE																				

DEPTH SCALE

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PROJECT: 1404378
LOCATION: N 4852794.98; E 607935.52

RECORD OF BOREHOLE: BH-24


SHEET 3 OF 7

BORING DATE: September 2 to 5, 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	20	40	60	80	nat V. rem V.			+	Q - U -
20	Mud Rotary HQ Casing	--- CONTINUED FROM PREVIOUS PAGE --- (CL-ML) Sandy SILTY CLAY - CLAYEY SILT, some gravel; grey (TILL); cohesive, very stiff to hard														GR SA SI CL	
21																	
22					13	SS	43										
23																	
24		(ML) SILT, some clay; grey; non-cohesive, wet, compact to dense		179.01 23.16													
25		sandy			14	SS	50										
26																	
27																	
28					15	SS	19										0 0 90 10
29																	
30																	

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DEPTH SCALE

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PROJECT: 1404378
LOCATION: N 4852794.98; E 607935.52

RECORD OF BOREHOLE: BH-24

SHEET 4 OF 7

BORING DATE: September 2 to 5, 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 ⁻⁶	10 ⁻⁵		
30		--- CONTINUED FROM PREVIOUS PAGE --- (ML) SILT, some clay; grey; non-cohesive, wet, compact to dense													GR SA SI CL
31															
32					16	SS	20								
33															
34					17	SS	13								
35	Mud Rotary HQ Casing														
36		(CL-ML) SILTY CLAY - CLAYEY SILT; grey; cohesive, very stiff to hard		166.81 35.36											
37					18	SS	25								
38															
39															
40					19	SS	32								0 0 88 12
		CONTINUED NEXT PAGE													

DEPTH SCALE

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PROJECT: 1404378
LOCATION: N 4852794.98; E 607935.52

RECORD OF BOREHOLE: BH-24

SHEET 5 OF 7

BORING DATE: September 2 to 5, 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					GRAIN SIZE DISTRIBUTION (%)			
								20	40	60	80	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴	10 ⁻³		GR	SA	SI	CL
40	Mud Rotary HQ Casing	— CONTINUED FROM PREVIOUS PAGE — (CL-ML) SILTY CLAY - CLAYEY SILT; grey; cohesive, very stiff to hard			19	SS	32										0	0	88	12
41																				
42																				
43					20	SS	22													
44																				
45																				
46		trace sand, trace gravel			21	SS	50/ 0.13													
47																				
48		(SM) SILTY SAND, some gravel to gravelly, trace to some clay, containing shale fragments; grey; non-cohesive, wet, very dense		154.62 47.55																
49					22	SS	50/ 0.08										14	50	29	7
50		CONTINUED NEXT PAGE																		

DEPTH SCALE

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LOCATION: N 4852794.98: E 607935.52

SHEET 6 OF 7

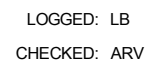
BORING DATE: September 2 to 5, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE
1 : 50



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PROJECT: 1404378

RECORD OF BOREHOLE: BH-24

SHEET 7 OF 7

LOCATION: N 4852794.98; E 607935.52

BORING DATE: September 2 to 5, 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					
								20	40	60	80	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴			10 ⁻³
60	NQ RC NW Casing	-- CONTINUED FROM PREVIOUS PAGE --														GR SA SI CL	
61		END OF BOREHOLE		141.45 60.72													
62		NOTE: 1. Water level measurements in piezometer:															
63		Date Depth (m) Elevation (m)															
64		9/12/2014 23.3 178.9															
65		9/22/2014 22.5 179.7															
66																	
67																	
68																	
69																	
70																	

DEPTH SCALE

1 : 50



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CHECKED: ARV

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PROJECT: 1404378

RECORD OF DRILLHOLE: BH-24

SHEET 1 OF 1

LOCATION: N 4852795.0 ;E 607935.5

DRILLING DATE: September 5, 2014

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 55 HT

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/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		2 4 6		
						80 60 40 20	80 60 40 20												
55	NQRC September 5, 2014	Continued from Record of Borehole BH-24 Slightly weathered, thinly laminated to laminated, dark grey, fine grained, non-porous, weak to medium strong SHALE (BEDROCK) - Shale bedrock is interbedded with limestone.		147.31 54.86	1													LC BC UC = 20.8 MPa	
56																			
57		2																	
58		3																11.0 MPa Axial	
59																			
60					4												6.1 MPa Axial		
61		END OF DRILLHOLE		141.45 60.72															
62																			
63																			
64																			

DEPTH SCALE

1 : 50



LOGGED: LB

CHECKED: ARV

LOCATION: N 4853150.78; E 607743.38

RECORD OF BOREHOLE: BH-25

SHEET 1 OF 7

BORING DATE: August 11 to 14, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

[illegible]

DEPTH SCALE

1 : 50



LOGGED: MCK

CHECKED: ARV

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PROJECT: 1404378

RECORD OF BOREHOLE: BH-25

SHEET 2 OF 7

LOCATION: N 4853150.78; E 607743.38

BORING DATE: August 11 to 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 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	nat V. rem V.	+ ⊕	Q - U -			● ○
10		-- CONTINUED FROM PREVIOUS PAGE --													GR SA SI CL		
	Power Auger 108 mm Inner Diameter Hollow Stem Augers	(CL) SILTY CLAY, some sand to sandy, trace gravel; grey (TILL); cohesive, stiff to hard		194.26 10.20													
11				8	SS	10									3 19 52 26		
12		- Auger grinding at a depth of 12.2 m.															
13				9	SS	15											
14		- Auger grinding at a depth of 14.6 m.			10	SS	37										
15																	
16																	
17		sandy silt lenses			11	SS	19										
18																	
19																	
20					12	SS	50/ .08										
			CONTINUED NEXT PAGE														

DEPTH SCALE

1 : 50



LOGGED: MCK

CHECKED: ARV

BHS001 S:\CLIENTS\TRANSCANADAHWY 427N HWY 407 VAUGHAN\02_DATA\GINT\1404378.GPJ GAL-MIS.GDT 10/06/14 MK AUG. 2014

PROJECT: 1404378

RECORD OF BOREHOLE: BH-25

SHEET 3 OF 7

LOCATION: N 4853150.78; E 607743.38

BORING DATE: August 11 to 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	RESISTANCE, BLOWS/0.3m				CONDUCTIVITY, k, cm/s					
								SHEAR STRENGTH Cu, kPa		nat V. + Q - rem V. ⊕ U - ●		WATER CONTENT PERCENT					
								20	40	60	80	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴			10 ⁻³
20	Power Auger 108 mm Inner Diameter Hollow Stem Augers	— CONTINUED FROM PREVIOUS PAGE — (CL) SILTY CLAY, some sand to sandy, trace gravel; grey (TILL); cohesive, stiff to hard - Auger grinding at a depth of 20.4 m.													GR SA SI CL		
21																	
22																	
23					13	SS	75									0 9 73 18	
24																	
25																	
26					178.26 26.20	14A 14B	SS	87									
27				(CL-ML) SILTY CLAY - CLAYEY SILT, some sand to a depth of 29.6 m; grey; cohesive, stiff to very stiff													
28																	
29							15	SS	16								
30																	
		CONTINUED NEXT PAGE															

DEPTH SCALE

1 : 50



LOGGED: MCK

CHECKED: ARV

BHS001 S:\CLIENTS\TRANSCANADAHWY 427N HWY 407 VAUGHAN\02 DATA\GINT\1404378.GPJ GAL-MIS.GDT 10/06/14 MK AUG. 2014

PROJECT: 1404378
LOCATION: N 4853150.78; E 607743.38

RECORD OF BOREHOLE: BH-25

SHEET 4 OF 7

BORING DATE: August 11 to 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		WATER CONTENT PERCENT				
								20	40	60	80	10 ⁻⁶	10 ⁻⁵			10 ⁻⁴
30	Power Auger 108 mm Inner Diameter Hollow Stem Augers	--- CONTINUED FROM PREVIOUS PAGE --- (CL-ML) SILTY CLAY - CLAYEY SILT, some sand to a depth of 29.6 m; grey; cohesive, stiff to very stiff													GR SA SI CL	
31																
32																
33	Wash Boring HQ Casing			16	SS	14										
34																
35																
36																
37		(ML) Sandy SILT, trace clay; grey; non-cohesive, wet, very dense		17	SS	18									0 0 91 9	
38																
39																
40																

DEPTH SCALE

1 : 50



LOGGED: MCK

CHECKED: ARV

LOCATION: N 4853150.78; E 607743.38

SHEET 5 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	20 40 60 80		10 ⁻⁶ 10 ⁻⁵ 10 ⁻⁴ 10 ⁻³					
								SHEAR STRENGTH Cu, kPa		nat V. + rem V. Q - U -				WATER CONTENT PERCENT Wp W Wi	
								20 40 60 80		10 20 30 40					
40	Wash Boring H.Q. Casing	— CONTINUED FROM PREVIOUS PAGE —										GR SA SI CL			
41		(ML) Sandy SILT, trace clay; grey; non-cohesive, wet, very dense													
42			19	SS	16										
43															
44															
45															
46		(SM) SILTY SAND; grey; non-cohesive, wet, dense to very dense	158.44 46.02									0 34 62 4			
47															
48															
49															
50															
CONTINUED NEXT PAGE															

1 : 50



CHECKED: ARV

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PROJECT: 1404378
LOCATION: N 4853150.78; E 607743.38

RECORD OF BOREHOLE: BH-25

SHEET 6 OF 7

BORING DATE: August 11 to 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	RESISTANCE, BLOWS/0.3m				WATER CONTENT PERCENT							
								SHEAR STRENGTH Cu, kPa		nat V. + rem V. ⊕		Q - ● U - ○		Wp — W — WI					
								20	40	60	80	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴			10 ⁻³		
50	Wash Boring HQ Casing	— CONTINUED FROM PREVIOUS PAGE — (SM) SILTY SAND; grey; non-cohesive, wet, dense to very dense													GR SA SI CL				
51					22	SS	66									0 78 21 1			
52																			
53																			
54				(GP) Sandy GRAVEL, containing cobbles, boulder and shale fragments; grey; non-cohesive, wet, very dense		151.12 53.34	23	SS	100/ 0.05										
55						24	SC	REC 58%											
56						25	SC	REC 13%											
57		Shale (BEDROCK) Bedrock cored from depths of 56.7 m to 59.6 m. For bedrock coring details refer to Record of Drillhole BH-25.		147.77 56.69	26	SC	REC 48%												
						27	SC	REC NR											
58						1	RC	REC 95%							RQD = 71%				
59						2	RC	REC 97%							RQD = 93%				
60		END OF BOREHOLE		144.85 59.61															
		NOTES:																	
		CONTINUED NEXT PAGE																	

DEPTH SCALE

1 : 50



LOGGED: MCK

CHECKED: ARV

PROJECT: 1404378
LOCATION: N 4853150.78; E 607743.38

RECORD OF BOREHOLE: BH-25

SHEET 7 OF 7

BORING DATE: August 11 to 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 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 ⁻⁶	10 ⁻⁵	10 ⁻⁴			10 ⁻³
60		— CONTINUED FROM PREVIOUS PAGE — 1. NR Not Recorded. 2. Borehole backfilled with portland cement grout upon completion of drilling.															
61																	
62																	
63																	
64																	
65																	
66																	
67																	
68																	
69																	
70																	

DEPTH SCALE

1 : 50



LOGGED: MCK

CHECKED: ARV

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PROJECT: 1404378

RECORD OF DRILLHOLE: BH-25

SHEET 1 OF 1

LOCATION: N 4853150.8 ;E 607743.4

DRILLING DATE: August 11, 2014

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 55 HT

DRILLING CONTRACTOR: Geo-Environmental Drilling Inc

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.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																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
							80 60 40 20	80 60 40 20																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
57	HQ Casing	Continued from Record of Borehole BH-25		147.88																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	

DEPTH SCALE

1 : 50



LOGGED: MCK

CHECKED: ARV

LOCATION: N 4853329.02: E 607703.00

SHEET 1 OF 7

BORING DATE: August 5 to 8, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

1 : 50



PROJECT: 1404378
LOCATION: N 4853329.02; E 607703.00

RECORD OF BOREHOLE: BH-27

SHEET 2 OF 7

BORING DATE: August 5 to 8, 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					
								nat V. + Q - rem V. ⊕ U - ○				Wp — W — Wi					
								20	40	60	80	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴	10 ⁻³		
10	Power Auger 108 mm Inner Diameter Hollow Stem Augers	— CONTINUED FROM PREVIOUS PAGE — (CL) SILTY CLAY, trace to some sand, trace gravel; brown; cohesive, firm to very stiff													GR SA SI CL		
11				8	SS	8											
12		(CL) Sandy SILTY CLAY, trace gravel; grey (TILL); cohesive, very stiff to hard		193.29 11.66													
13					9	SS	27										4 27 49 20
14				- Auger grinding at a depth of 13.1 m.													
15																	
16																	
17				(SM) SILTY SAND, some gravel, trace clay; grey (TILL); non-cohesive, moist to wet, very dense	187.88 17.07												
18																	
19																	
20																	
				CONTINUED NEXT PAGE													

DEPTH SCALE

1 : 50



LOGGED: JH

CHECKED: ARV

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LOCATION: N 4853329.02: E 607703.00

SHEET 3 OF 7

BORING DATE: August 5 to 8, 2014

DATUM: Geodetic

HAMMER TYPE: AUTOMATIC

SAMPLER HAMMER, 64kg; DROP, 760mm

DEPTH SCALE
1 : 50



LOGGED: JH
CHECKED: ARV

PROJECT: 1404378

RECORD OF BOREHOLE: BH-27

SHEET 4 OF 7

LOCATION: N 4853329.02; E 607703.00

BORING DATE: August 5 to 8, 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		Wp	W			Wi
								20	40	60	80					
30	Power Auger 108 mm Inner Diameter Hollow Stem Augers	--- CONTINUED FROM PREVIOUS PAGE --- (ML) SILT, some clay, trace sand; grey; non-cohesive, wet, compact													GR SA SI CL	
31																
32																
33																
34																
35																
36																
37																
38																
39																
40																

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50



LOGGED: JH

CHECKED: ARV

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PROJECT: 1404378
LOCATION: N 4853329.02; E 607703.00

RECORD OF BOREHOLE: BH-27

SHEET 5 OF 7

BORING DATE: August 5 to 8, 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	RESISTANCE, BLOWS/0.3m				WATER CONTENT PERCENT							
								SHEAR STRENGTH Cu, kPa		nat V. + rem V. ⊕		Q - U - ⊙		Wp ——— W ——— WI					
								20	40	60	80	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴	10 ⁻³				
40	Power Auger 108 mm Inner Diameter Hollow Stem Augers	— CONTINUED FROM PREVIOUS PAGE — (ML) SILT, some clay, trace sand; grey; non-cohesive, wet, compact			19	SS	18									GR SA SI CL			
41																			
42																			
43					20	SS	16												
44																			
45		(SM) SILTY SAND, trace clay; grey; non-cohesive, wet, dense to very dense		160.45 44.50															
46					21	SS	65												
47																			
48																			
49					22	SS	67												
50		CONTINUED NEXT PAGE																	

DEPTH SCALE

1 : 50



LOGGED: JH

CHECKED: ARV

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PROJECT: 1404378

RECORD OF BOREHOLE: BH-27

SHEET 6 OF 7

LOCATION: N 4853329.02; E 607703.00

BORING DATE: August 5 to 8, 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. + rem V. ⊕		Q - ● U - ○				WATER CONTENT PERCENT Wp — W — Wi	
							20	40	60	80		10 ⁻⁶	10 ⁻⁵	10 ⁻⁴	10 ⁻³		
							20	40	60	80		10	20	30	40		
50	Power Auger 108 mm Inner Diameter Hollow Stem Augers	— CONTINUED FROM PREVIOUS PAGE — (SM) SILTY SAND, trace clay; grey; non-cohesive, wet, dense to very dense														GR SA SI CL	
51																	
52					23	SS	40									0 82 15 3	
53																	
54																	
55					24	SS	44										
56																	
57			(SP/GP) SAND and GRAVEL, some silt, trace clay; grey; non-cohesive, very dense		148.26 56.69												
58			- Auger grinding below a depth of 58.2 m.			25	SS	50/ 0.10									
59																	
60		SPLIT-SPOON SAMPLER REFUSAL END OF BOREHOLE		145.49 59.46	26	SS	50/ 0.02										
		NOTE:															
		CONTINUED NEXT PAGE															

DEPTH SCALE

1 : 50



LOGGED: JH

CHECKED: ARV

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PROJECT: 1404378

RECORD OF BOREHOLE: BH-27

SHEET 7 OF 7

LOCATION: N 4853329.02; E 607703.00

BORING DATE: August 5 to 8, 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					
								20	40	60	80	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴			10 ⁻³
60		-- CONTINUED FROM PREVIOUS PAGE -- 1. Borehole backfilled with portland cement grout upon completion of drilling.														GR SA SI CL	
61																	
62																	
63																	
64																	
65																	
66																	
67																	
68																	
69																	
70																	

DEPTH SCALE

1 : 50



LOGGED: JH

CHECKED: ARV

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PROJECT: 1404378

RECORD OF BOREHOLE: BH-28

SHEET 1 OF 3






LOCATION: N 4853520.50; E 607538.10

BORING DATE: August 6, 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 ⁻⁶	10 ⁻⁵	10 ⁻⁴	10 ⁻³			
								nat V. + Q - ● rem V. ⊕ U - ○				Wp — W — Wi						
								20	40	60	80	10	20	30	40			
0		GROUND SURFACE		205.80													GR SA SI CL	
	Power Auger 108 mm Inner Diameter Hollow Stem Augers	TOPSOIL		0.00	1A													
		(CL) SILTY CLAY, trace sand, trace organics, containing rootlets; brown; cohesive, firm		205.52		SS	8											
				0.28	1B													
1		(CL) SILTY CLAY, some sand to sandy, trace gravel; brown with oxidation staining; cohesive, very stiff		205.04														
				0.76														
					2		17											
2																		
					3		19											
					4		23											
3			- Becoming grey below a depth of 3.0 m.															
					5		11											
4																		
					6		12											
5																		
				7		10												
6		(SM/ML) SILT and SAND, some clay, some gravel; grey; non-cohesive, wet, compact		199.70														
				6.10	8		21											
7																		
8		no recovery in split-spoon sampler																
9		(CL) Sandy SILTY CLAY; grey (TILL); cohesive, stiff to hard		197.11														
				8.69														
					10		11											
10																		
		CONTINUED NEXT PAGE																

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DEPTH SCALE

1 : 50



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CHECKED: ARV

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PROJECT: 1404378
LOCATION: N 4853520.50; E 607538.10

RECORD OF BOREHOLE: BH-28

SHEET 2 OF 3

BORING DATE: August 6, 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 ⁻⁶	10 ⁻⁵	10 ⁻⁴				10 ⁻³
												Wp ———— W ———— WI						
10	Power Auger 108 mm Inner Diameter Hollow Stem Augers	— CONTINUED FROM PREVIOUS PAGE — (CL) Sandy SILTY CLAY; grey (TILL); cohesive, stiff to hard													GR SA SI CL			
11																		
12																		
13					11		23											
14																		
15				- Auger grinding at a depth of 14.5 m.														
16					12		38											
17																		
18																		
19				- Split-spoon sampler bouncing at a depth of 18.6 m.		13		152/ 0.20										
20																		
CONTINUED NEXT PAGE																		

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DEPTH SCALE

1 : 50



LOGGED: OS

CHECKED: ARV

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PROJECT: 1404378

RECORD OF BOREHOLE: BH-28

SHEET 3 OF 3

LOCATION: N 4853520.50; E 607538.10

BORING DATE: August 6, 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					
								20	40	60	80	10 ⁻⁶	10 ⁻⁵			10 ⁻⁴	10 ⁻³
20	Power Auger 108 mm Inner Diameter Hollow Stem Augers	— CONTINUED FROM PREVIOUS PAGE — (CL) Sandy SILTY CLAY; grey (TILL); cohesive, stiff to hard													GR SA SI CL 1 9 67 23		
21																	
22																	
23																	
24																	
25		END OF BOREHOLE		180.96 24.84													
26		NOTE: 1. Water level measurements in piezometer: Date Depth (m) Elevation (m) 8/14/2014 9.1 196.7 9/22/2014 9.2 196.6															
27																	
28																	
29																	
30																	

DEPTH SCALE

1 : 50



LOGGED: OS

CHECKED: ARV

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**DRAFT GEOTECHNICAL INVESTIGATION REPORT
TRANSCANADA KNC PROJECT
PROPOSED UNDERCROSSING OF MCGILLIVRAY ROAD, CP
RAIL AND MAJOR MCKENZIE DRIVE WEST
VAUGHAN, ONTARIO**

APPENDIX B

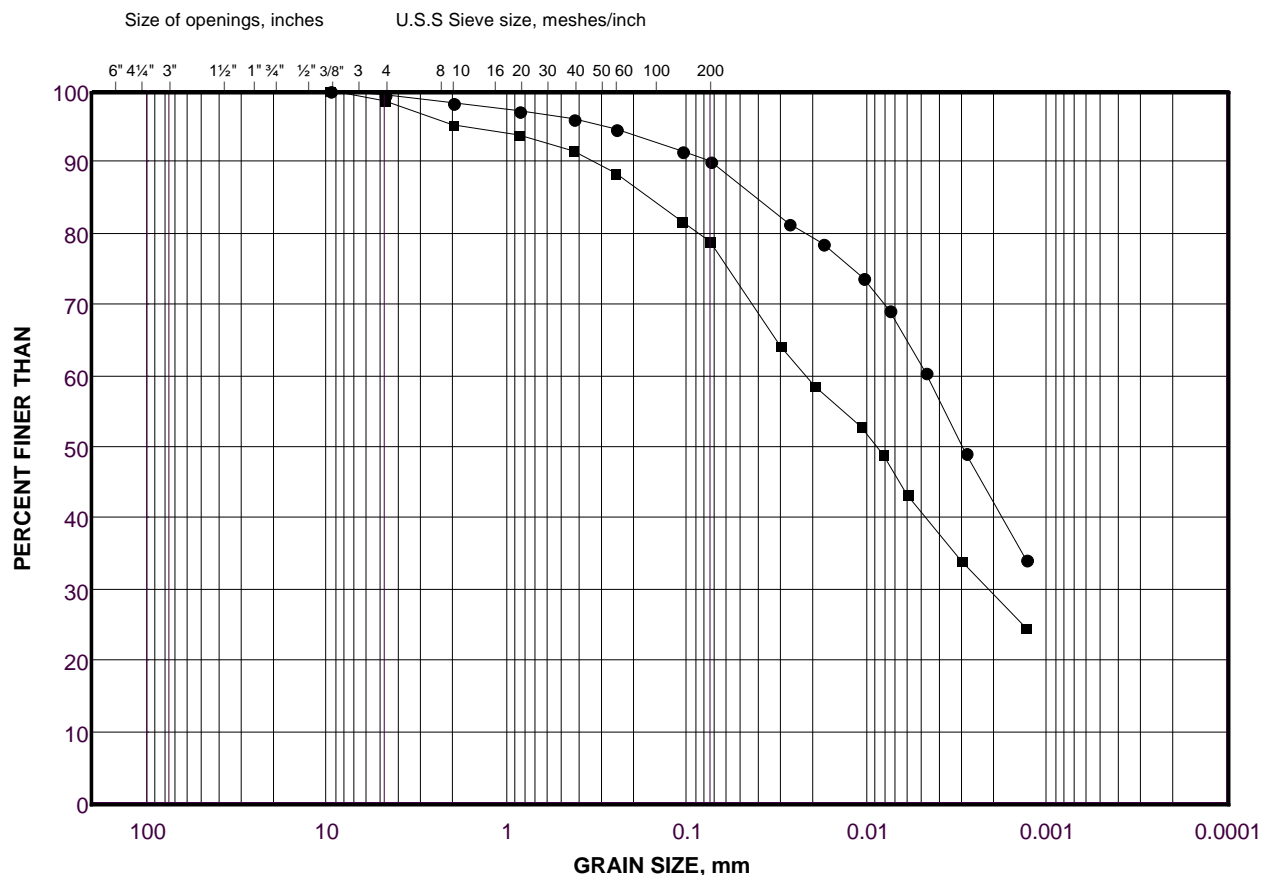
Laboratory Test Results

GRAIN SIZE DISTRIBUTION

Upper Silty Clay

HDD under McGillivray Road, CP Rail and Major McKenzie Drive

FIGURE B1



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

LEGEND

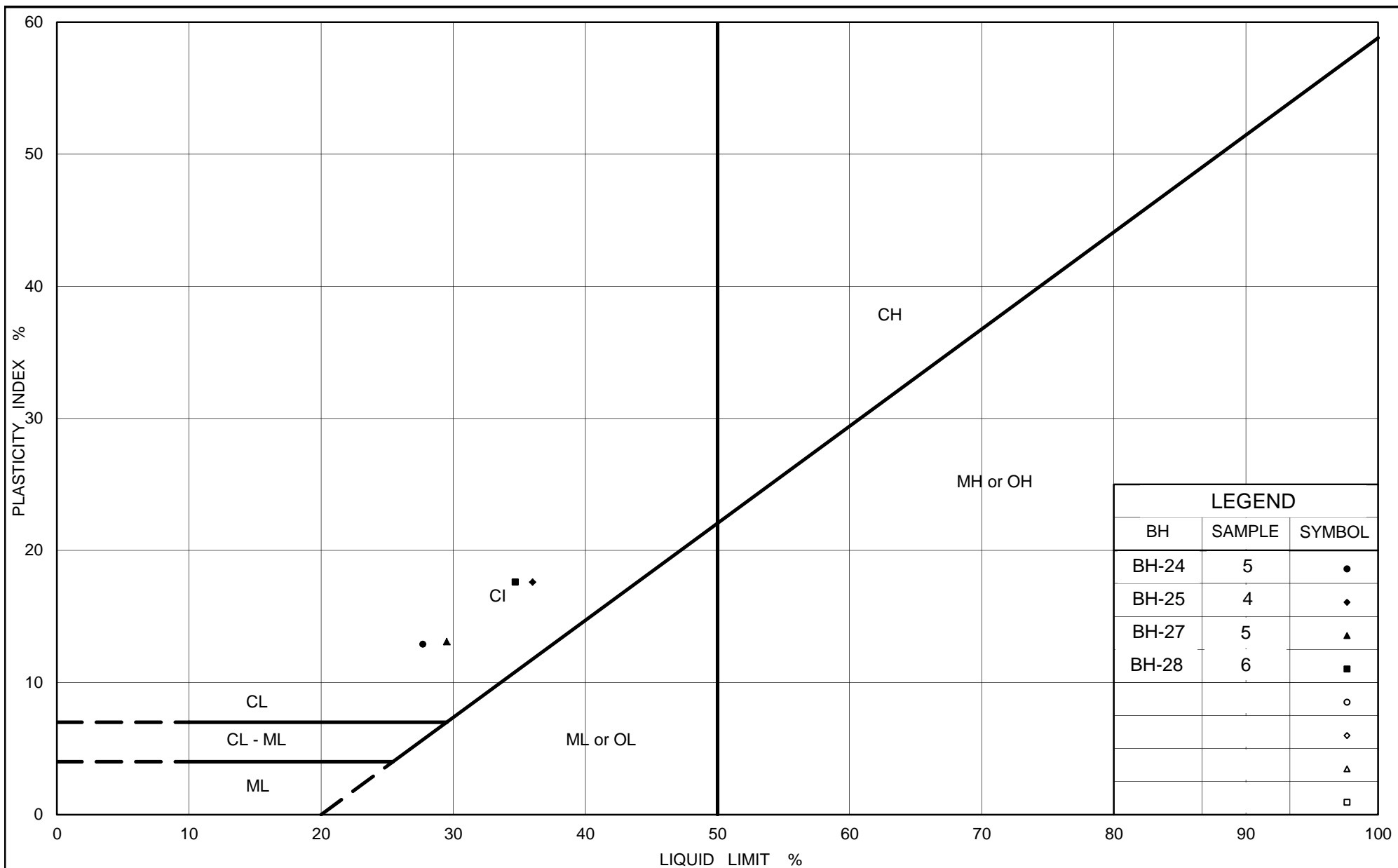
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BH-25	4	199.6
■	BH-28	4	203.2

Project Number: 1404378

Checked By: ARV

Golder Associates

Date: 17-Sep-14



PLASTICITY CHART
Upper Silty Clay
HDD under McGillivray Road, CP Rail and Major McKenzie Drive

Figure No. B2

Project No. 1404378

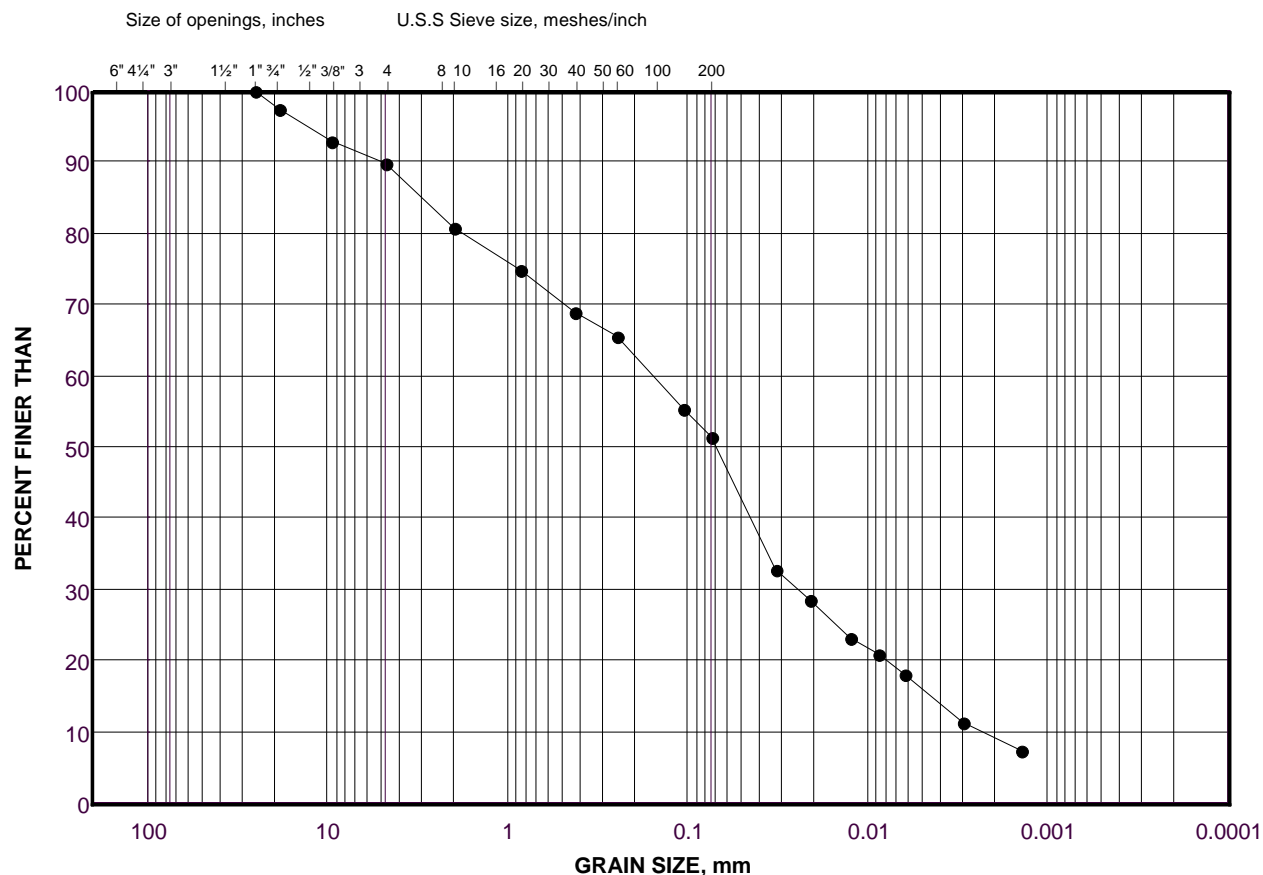
Checked By: ARV

GRAIN SIZE DISTRIBUTION

Silt and Sand Pocket

HDD under McGillivray Road, CP Rail and Major McKenzie Drive

FIGURE B3



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

LEGEND

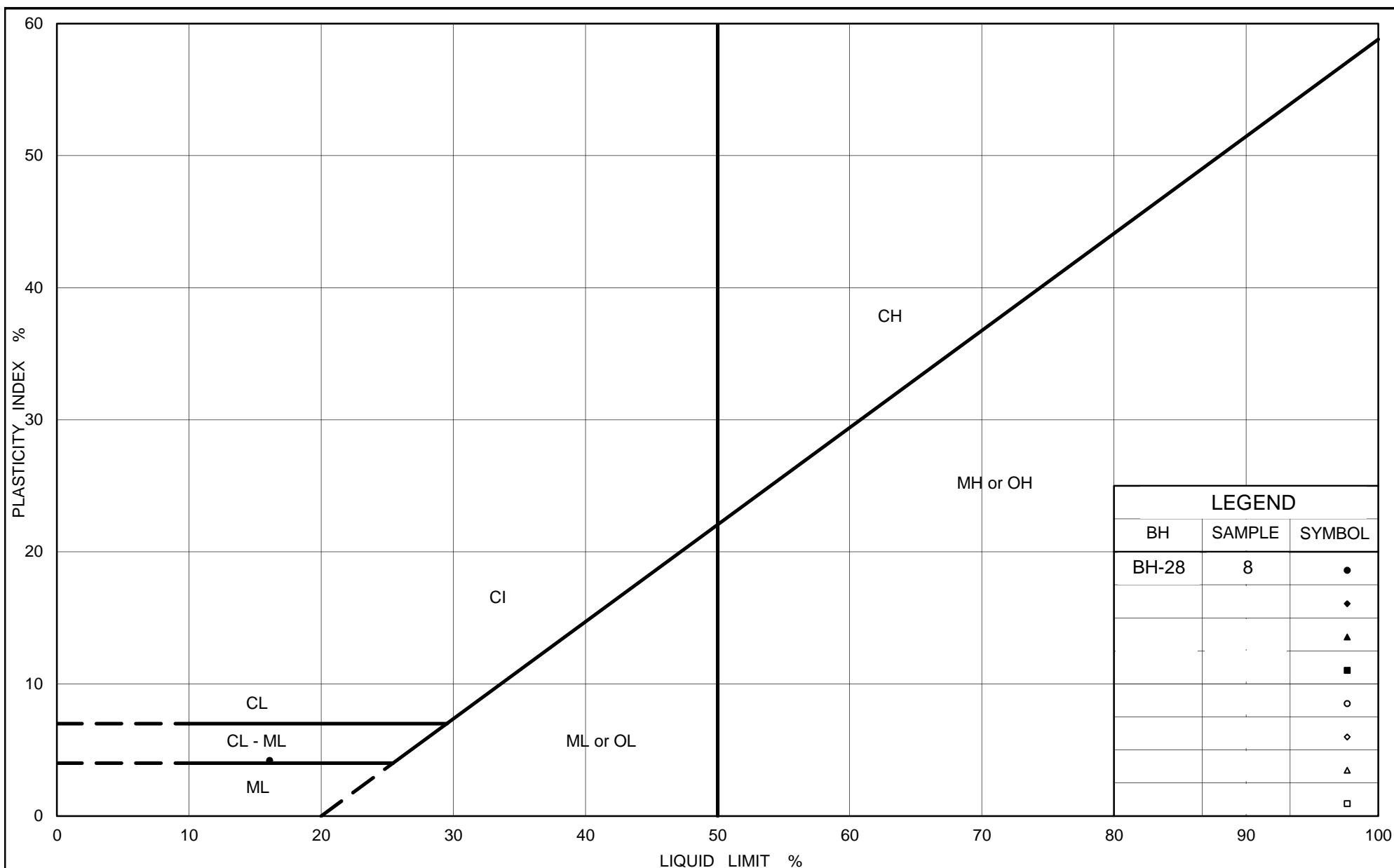
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	28	8	199.4

Project Number: 1404378

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PLASTICITY CHART
Silt and Sand Pocket
HDD under McGillivray Road, CP Rail and Major McKenzie Drive

Figure No. B4

Project No. 1404378

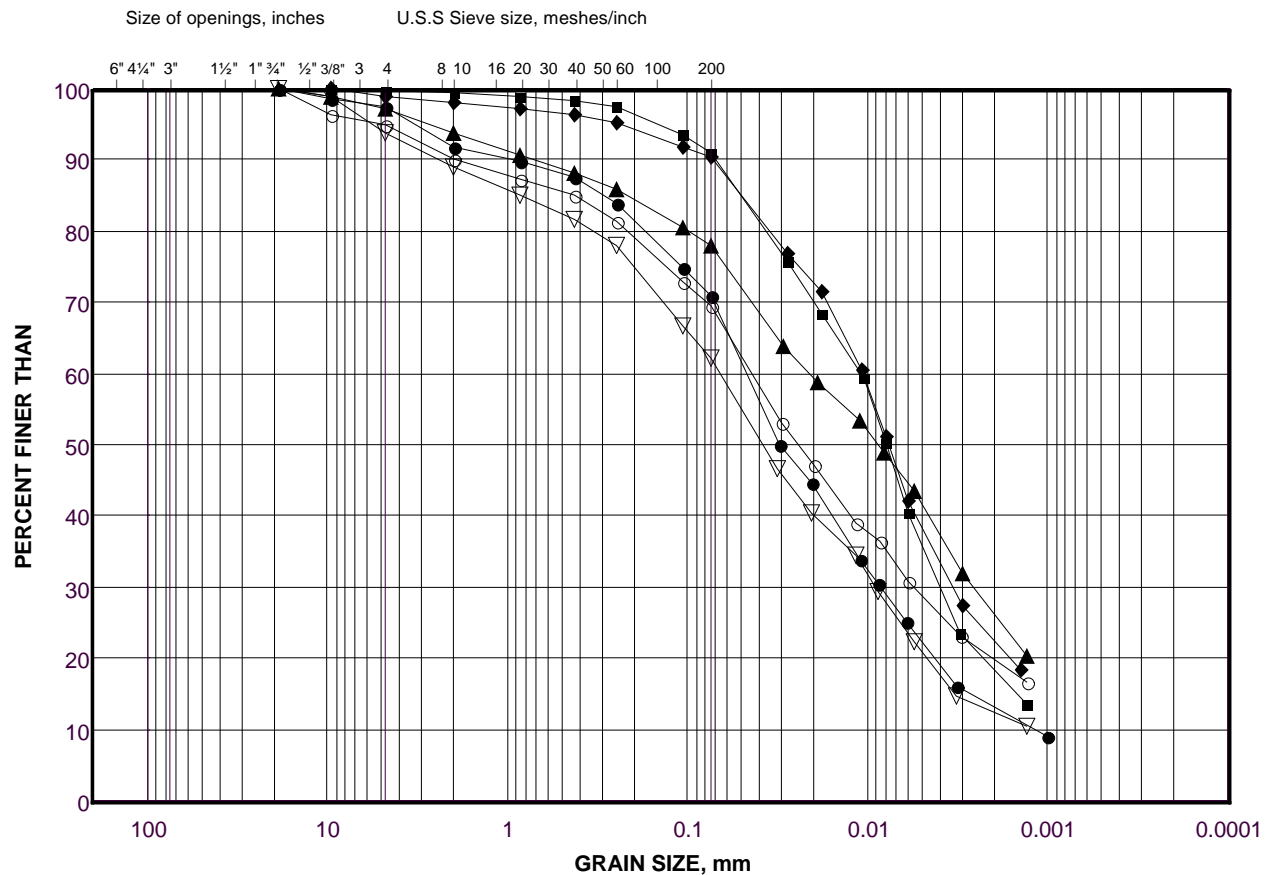
Checked By: ARV

GRAIN SIZE DISTRIBUTION

Cohesive Till

HDD under McGillivray Road, CP Rail and Major McKenzie Drive

FIGURE B5



LEGEND

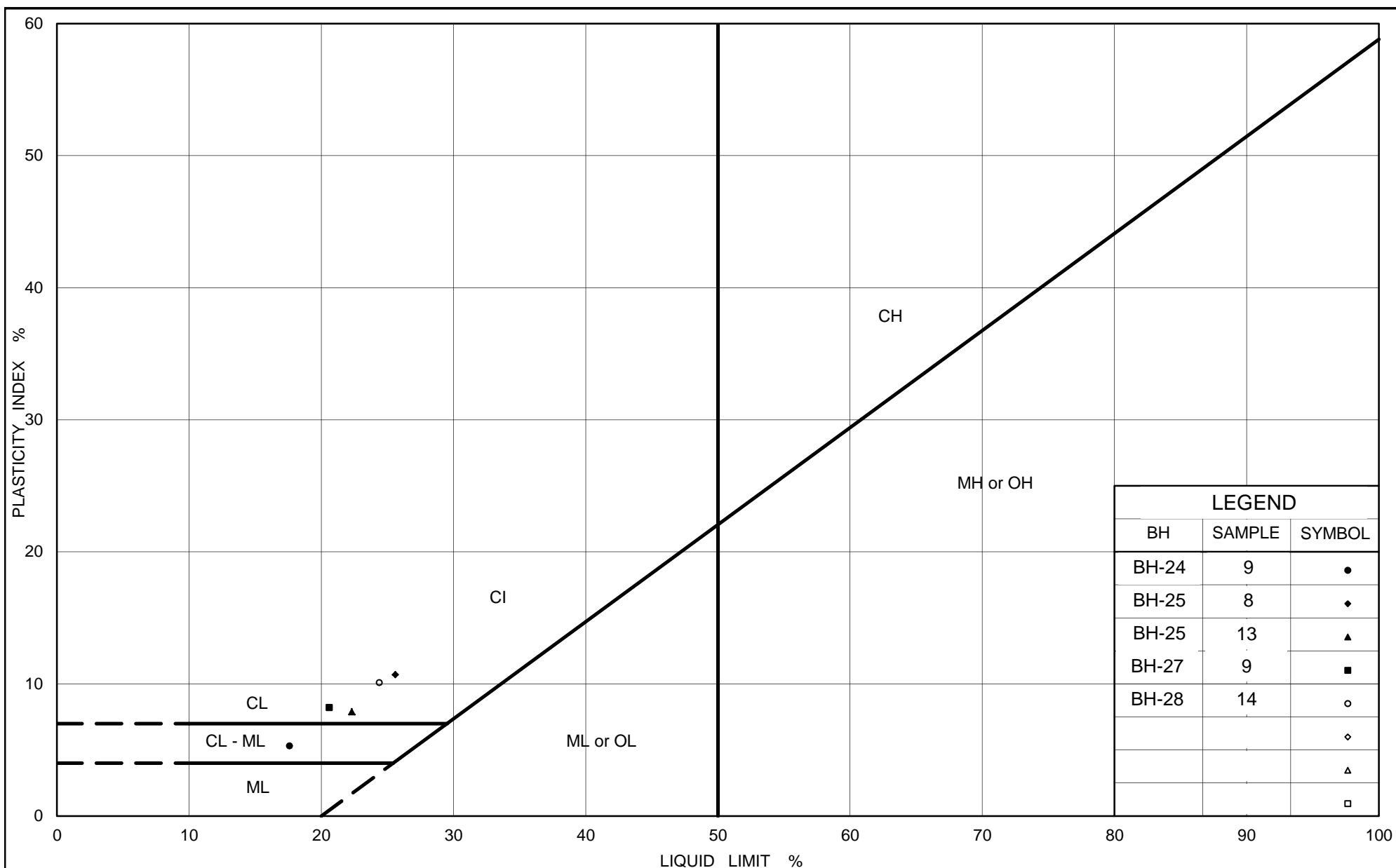
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BH-28	12	190.3
■	BH-25	13	181.3
◆	BH-28	14	184.2
▲	BH-25	8	193.5
▽	BH-24	9	190.0
○	BH-27	9	192.5

Project Number: 1404378

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Date: 23-Sep-14



PLASTICITY CHART
 Silty Clay - Clayey Silt to Silty Clay Till
 HDD under McGillivray Road, CP Rail and Major McKenzie Drive

Figure No. B6

Project No. 1404378

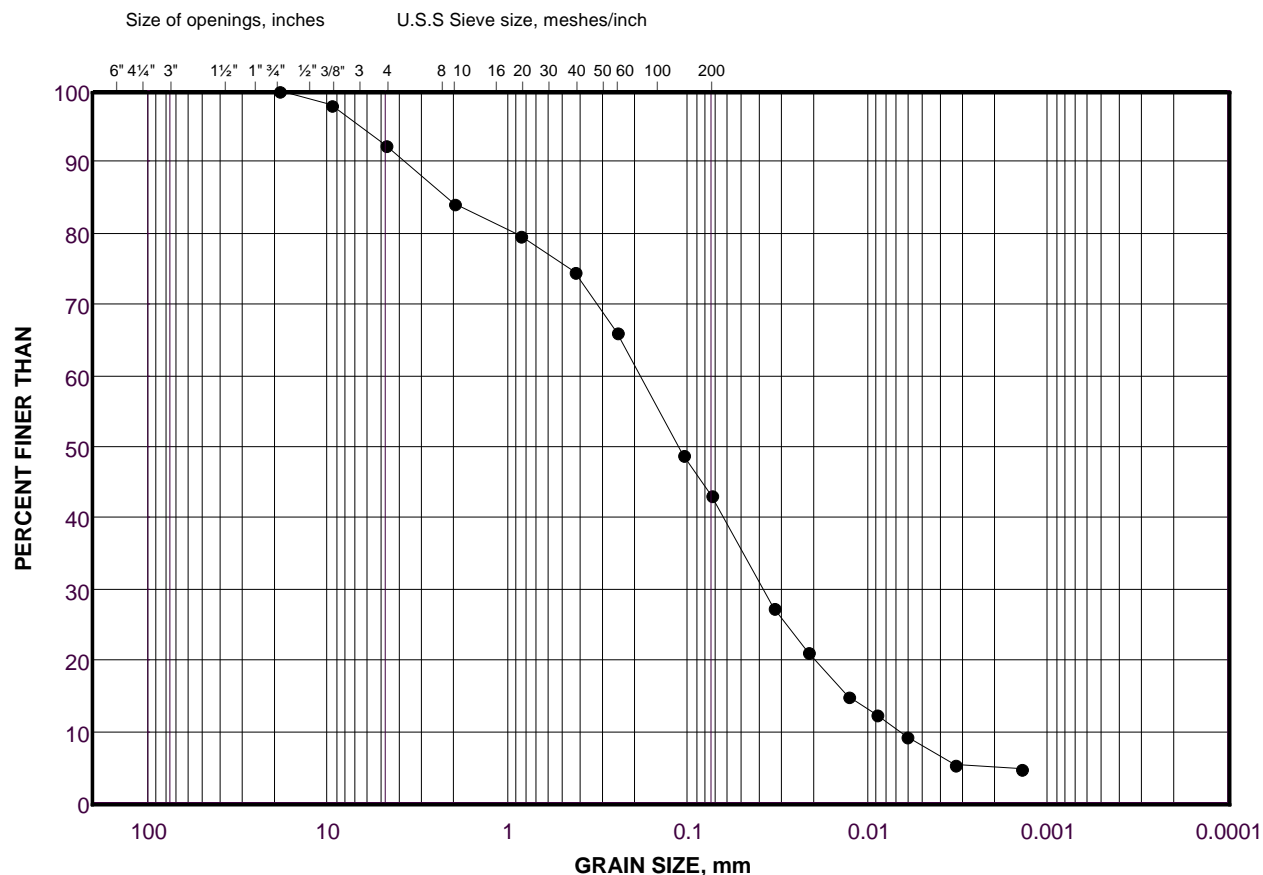
Checked By: ARV

GRAIN SIZE DISTRIBUTION

Silty Sand Till

HDD under McGillivray Road, CP Rail and Major McKenzie Drive

FIGURE B7



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	BH-27	12	186.5

Project Number: 1404378

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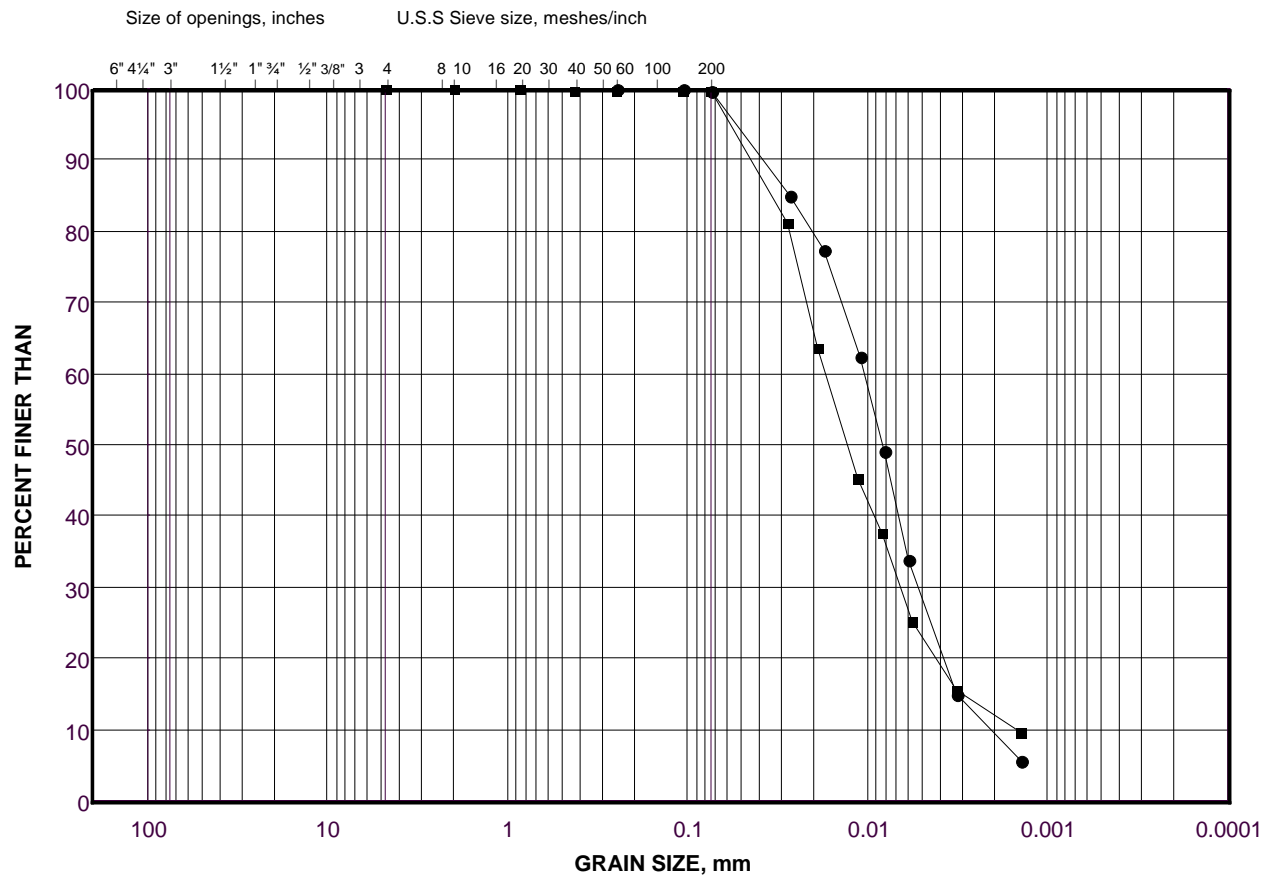
Date: 23-Sep-14

GRAIN SIZE DISTRIBUTION

Silty Clay - Clayey Silt

HDD under McGillivray Road, CP Rail and Major McKenzie Drive

FIGURE B8



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

LEGEND

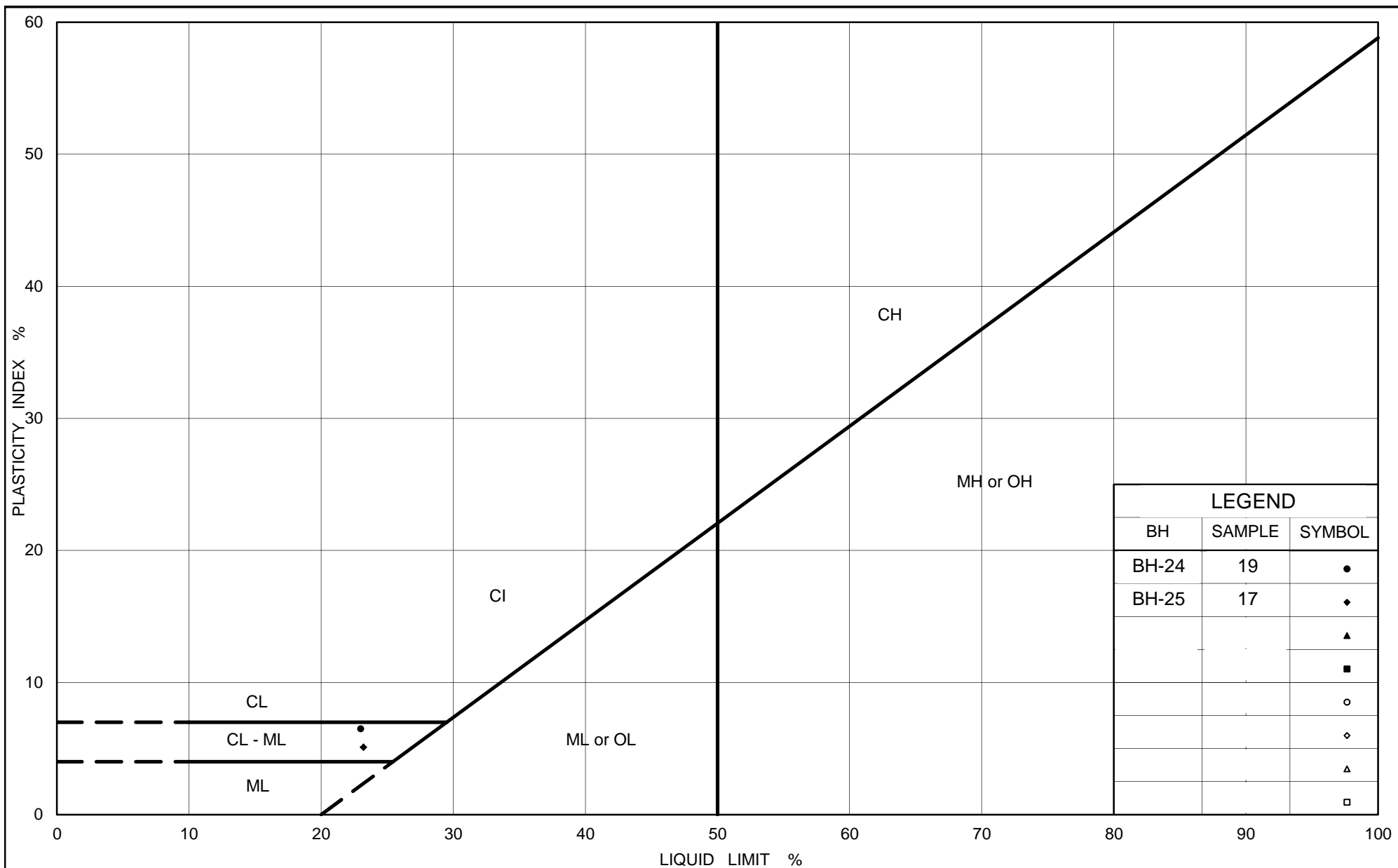
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BH-25	17	169.1
■	BH-24	19	162.3

Project Number: 1404378

Checked By: ARV

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Date: 17-Sep-14



PLASTICITY CHART
Silty Clay - Clayey Silt
HDD under McGillivray Road, CP Rail and Major McKenzie Drive

Figure No. B9

Project No. 1404378

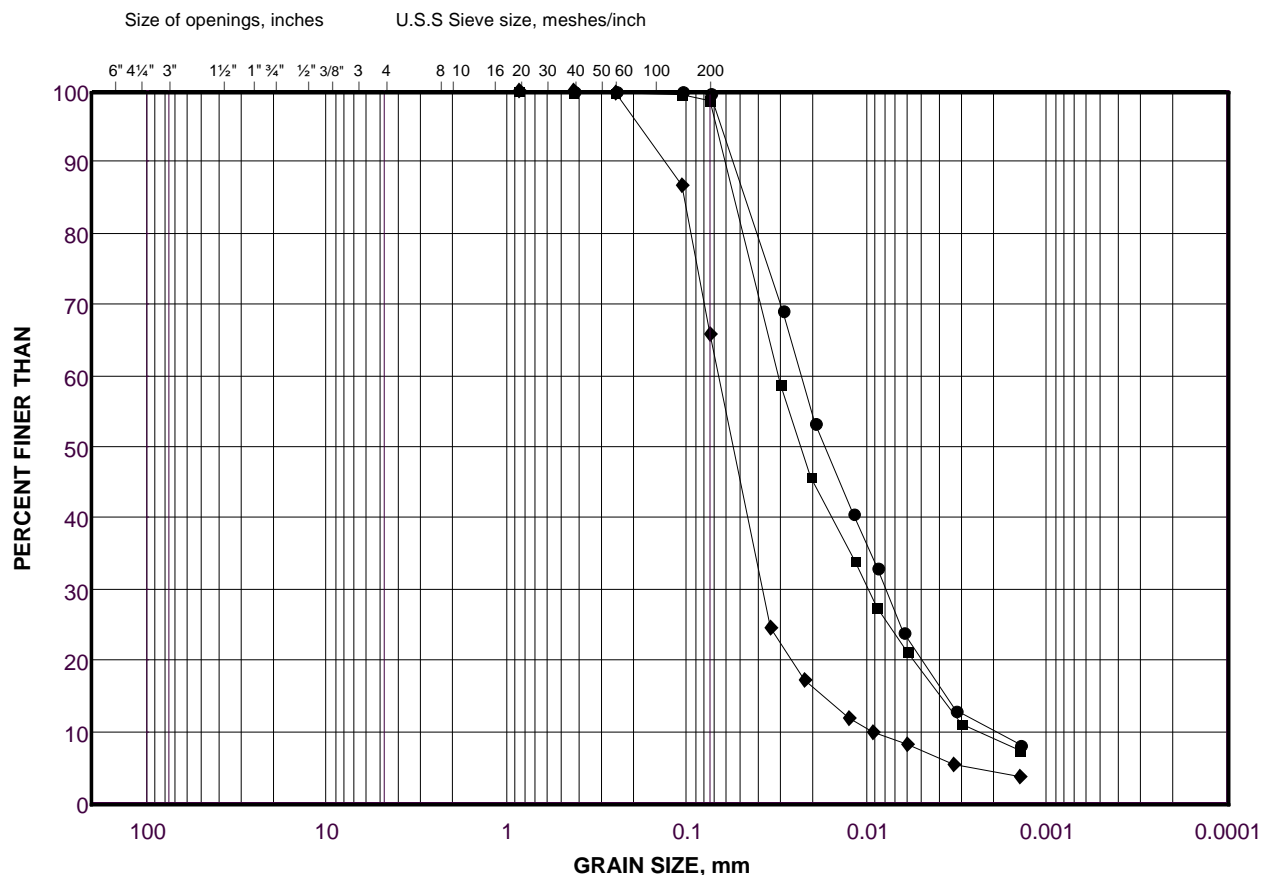
Checked By: ARV

GRAIN SIZE DISTRIBUTION

Silt to Sandy Silt

HDD under McGillivray Road, CP Rail and Major McKenzie Drive

FIGURE B10



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

LEGEND

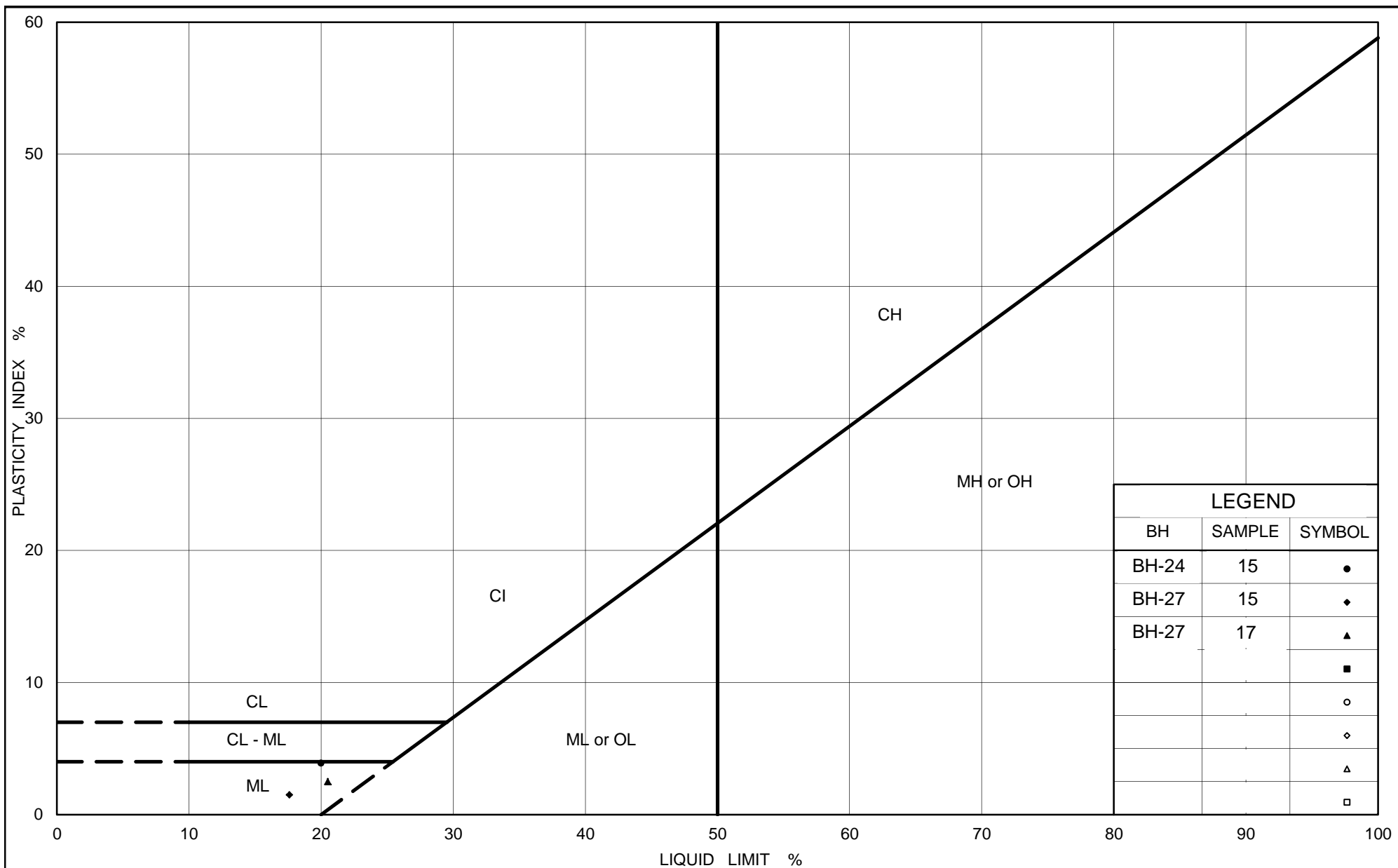
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BH-24	15	174.5
■	BH-27	15	177.2
◆	BH-25	20	160.0

Project Number: 1404378

Checked By: AVR

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Date: 17-Sep-14



PLASTICITY CHART
Silt to Sandy Silt
HDD under McGillivray Road, CP Rail and Major McKenzie Drive

Figure No. B11

Project No. 1404378

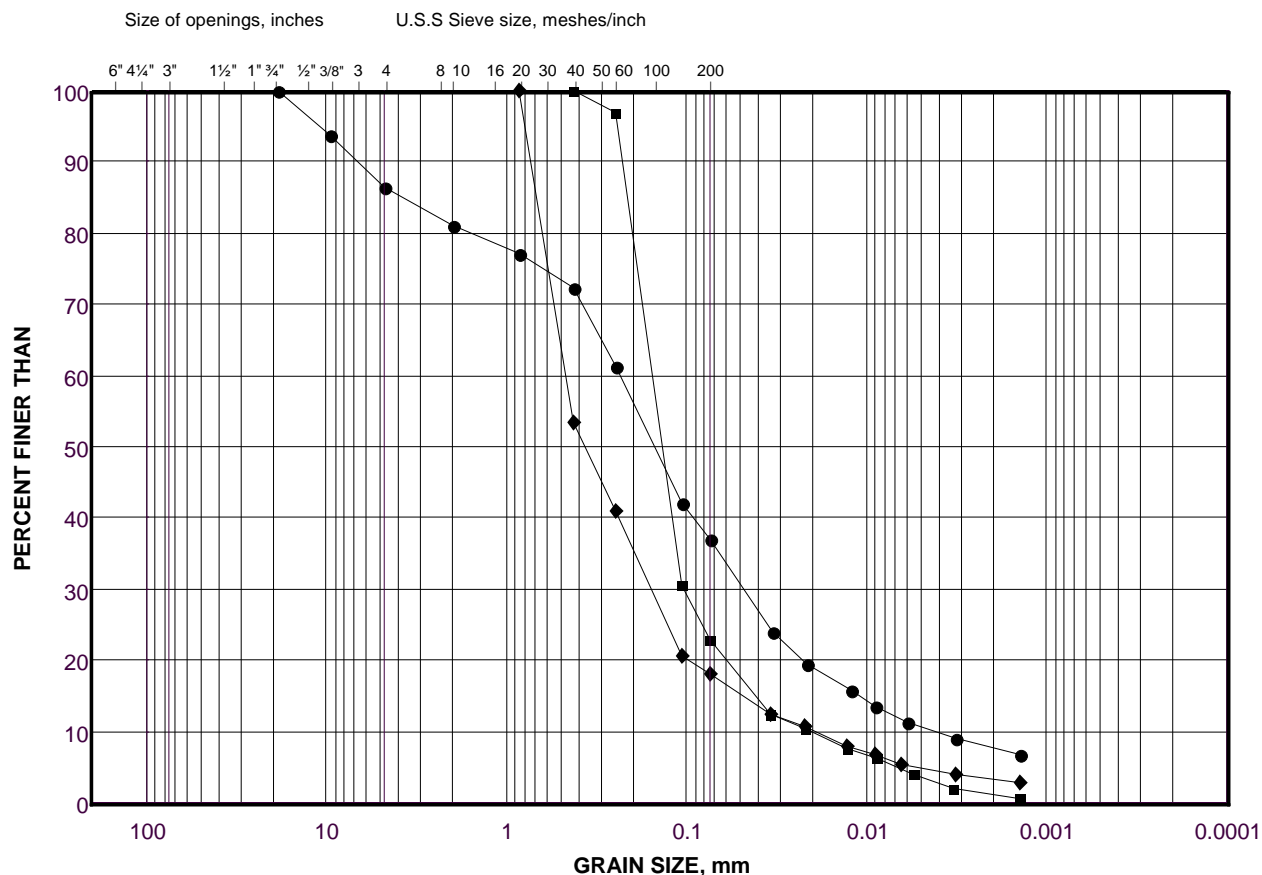
Checked By: ARV

GRAIN SIZE DISTRIBUTION

Silty Sand

HDD under McGillivray Road, CP Rail and Major McKenzie Drive

FIGURE B12

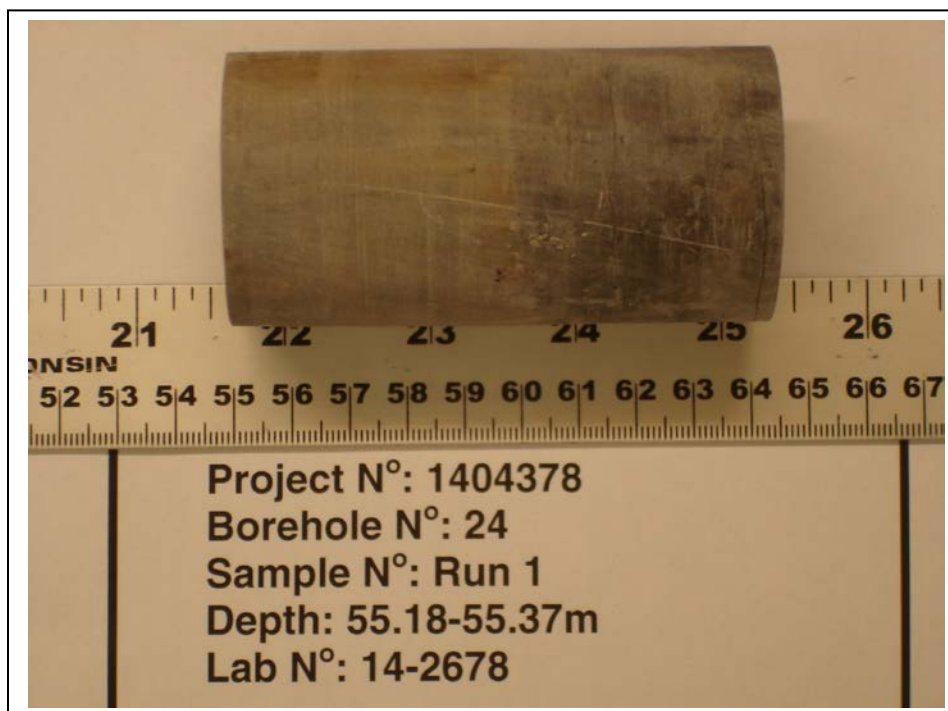


LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BH-24	22	153.1
■	BH-25	22	153.9
◆	BH-27	23	152.9

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

Figure B13



BEFORE COMPRESSION



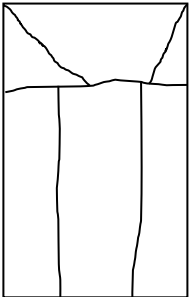
AFTER COMPRESSION

Date 9/12/2014
Project 1404378

Golder Associates

Drawn Frank
Chkd

TABLE B1
UNCONFINED COMPRESSION TEST (UC) OF INTACT ROCK CORE SPECIMENS
ASTM D7012

SAMPLE IDENTIFICATION			
PROJECT NUMBER	1404378	RUN NUMBER	1
BOREHOLE NUMBER	BH-24	SAMPLE DEPTH, m	55.18-55.37
TEST CONDITIONS			
MACHINE SPEED, mm/min	0.00	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	1.92
SPECIMEN INFORMATION			
SAMPLE HEIGHT, cm	9.00	WATER CONTENT, (specimen) %	0.18
SAMPLE DIAMETER, cm	4.70	UNIT WEIGHT, kN/m ³	21.93
SAMPLE AREA, cm ²	17.32	DRY UNIT WT., kN/m ³	21.89
SAMPLE VOLUME, cm ³	155.91	SPECIFIC GRAVITY	-
WET WEIGHT, g	348.84	VOID RATIO	-
DRY WEIGHT, g	294.88		
VISUAL INSPECTION		FAILURE SKETCH	
			

TEST RESULTS			
STRAIN AT FAILURE, %	-	COMPRESSIVE STRENGTH, MPa	20.8
REMARKS:	DATE:		9/12/2014
L/D Ratio not in accordance with ASTM Standard			

Checked By: ARV

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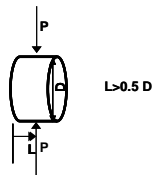
TABLE B2
POINT LOAD TEST RESULTS ON ROCK SAMPLES

Borehole Number	Run Number	Sample Depth (m)	Sample Elevation (m)	Bedrock Description	Test Type	Core Length (mm)	Core ⁽²⁾ Diameter (mm)	Is (50mm) (MPa)	Approx. UCS Value ⁽¹⁾ (MPa)
BH-24	3	58.15	144.0	Shale with Limestone Interbeds	Axial	18.02	47.22	11.01	143
BH-24	3	58.15	144.0	Shale with Limestone Interbeds	Diametral	93.62	39.34	3.19	41
BH-24	4	60.05	142.1	Shale with Limestone Interbeds	Axial	18.68	47.22	6.09	79
BH-24	4	60.05	142.1	Shale with Limestone Interbeds	Diametral	60.84	39.66	1.44	19

⁽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.

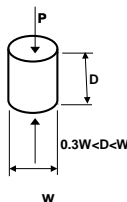
DIAMETRAL SPECIMEN SHAPE REQUIREMENTS

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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