



Suncor Energy Products Partnership

Foundation Investigation and Design Report

Project Name

Sanitary Forcemain - Highway 401 Crossing

Project Name

2435 South Service Road, Clarington, ON

Project Number

BRM-00605520-A0

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Legal Notification

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Drawing 1 Borehole Location Plan at Highway 401
Drawing 2 Cross Section

Appendix B – Borehole Logs

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**Appendix D – Guidelines for Foundation Engineering for Tunneling Speciality-
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Appendix E – OPSS 450

1. Introduction

1.1 Project Description

This report presents the results of a subsurface investigation carried out for the installation of a new two proposed 75mm sanitary forcemain lines crossing Highway 401 (in a single 300 mm diameter steel casing) from the south end of Martin Road to South Service Road in Clarington, Ontario. The portion of the project to be constructed within the Highway 401 right-of-way will be constructed using a trenchless installation.

The crossing length at Highway 401 is not available at this time but the distance between the furthest boreholes is about 115 m in length.

This report summarizes the results of the current investigation, and provides geotechnical engineering guidelines to support the design and construction of the underground highway crossing.

1.2 Terms of Reference

The purpose of the investigation was to examine the subsoil and groundwater conditions along the proposed sanitary forcemain crossing alignment at the site, by advancing four (4) sampled boreholes at the locations illustrated on the attached Borehole and Tunnel Location Plan (Drawing 1), and to provide geotechnical comments and recommendations for the design and construction of the steel casing crossing under HWY 401.

Based on an interpretation of the factual test hole data currently completed, exp has provided engineering guidelines for the geotechnical design and construction for this project.

In preparing this report, **exp** has reviewed the “Guidelines for Foundation Engineering for Tunneling Speciality- Tunnelling Specialty For Corridor Encroachment Permit Application”, prepared by MTO, in order to meet the requirements for the Ministry of Transportation Encroachment Permit Application for the proposed trenchless installations.

This report is provided on the basis of the terms of reference presented above and on the assumption that the design will be in accordance with applicable codes and standards. If there are any changes in the design features relevant to the geotechnical analyses, or if any questions arise concerning geotechnical aspects of the codes and standards, this office should be contacted to review the design.

The information in this report in no way reflects on the environmental aspects of the soil. Should specific information in this regard be needed, additional testing may be required.

2. Procedure

The fieldwork for the geotechnical investigation was carried out between May 26th and 30th, 2016. The investigation included four (4) boreholes (numbered BH1 to BH4, inclusive) which were advanced to a depth of 6.5 metres¹ (21.3 feet) at the locations indicated on the attached Drawing 1 in **Appendix A**. Boreholes were advanced across the Site in the proposed footprint of the sanitary forcemain.

The boreholes located on Highway 401 (BH2 and BH3) were advanced using a truck mounted drill rig equipped with continuous flight, hollow/solid stem augering equipment and standard soil sampling equipment. The boreholes at each end of the alignment (BH1 and BH4) were advanced using a portable drill rig “Dynamic Ram Sounder” using a continuous sampling procedure. All drilling equipment was owned and operated by specialist drilling contractors.

The field work was conducted under the supervision of a qualified member of our geotechnical engineering staff. The field engineer examined and classified characteristics of the soils encountered in the boreholes, including the presence of fill materials, made groundwater observations during and upon completion of the drilling, recorded observations of borehole construction, and processed the recovered samples. Representative samples of the overburden were recovered at frequent depth intervals for identification purposes using a conventional split spoon sampler. Standard penetration tests were carried out simultaneously with the sampling operations to assess the strength characteristics of the substrate.

Groundwater levels were closely monitored during the course of the fieldwork. Piezometers were installed in Borehole BH1 and BH4 to monitor the groundwater levels. “MW” was suffixed to BH1 & BH4 where monitoring wells are installed. All recovered soil were logged in the field, carefully packaged and transported to the laboratory for more detailed examination and classification. In the laboratory, the samples were classified as to their olfactory, visual and textural characteristics.

The locations of the boreholes were determined by **exp** prior to the drilling process. The horizontal locations were laid out in the field by **exp** prior to the drilling operations. Final survey (horizontal and vertical) was undertaken using GPS survey equipment.

¹ Unless otherwise indicated all depths are noted as metres below existing grade.

3. Laboratory Testing

The laboratory-testing program consisted of the following:

- Natural moisture content tests on all recovered samples, with results presented on the Borehole Logs found in **Appendix B**.
- Standard characterization tests (grain-size, Atterberg Limits) were performed on samples:
 - BH1 – SA3 & SA9
 - BH2 – SA2, SA5 & SA8
 - BH3 – SA4 & SA6
 - BH4 – SA2 & SA7

The results of these test are presented on the Borehole Logs and the results are presented in **Appendix C**.

4. Summarized Conditions

4.1 Site Description

The Site is located west of Waverly Road on Highway 401. The proposed tunnel will be located to the east of the alignment of Martin Road, and will provide a sanitary connection from the subject site. The topography in the area is relatively flat. At the tunnel crossing location, Highway 401 consists of three east-bound lanes (EBLs), three west-bound lanes (WBLs), an off-ramp from the EBLs to Energy Drive, an on-ramp from Waverly Road north-bound to the WLBs and an on-ramp from Waverly Road south-bound to the WBLs. There is a paved median between the EBLs and the WLBs with a concrete barrier wall. The two on-ramps to the WBLs are separated by a paved median. Drainage ditches line both sides of the highway in this area.

4.2 Soil Stratigraphy

The detailed soil profile encountered in the boreholes and the results of laboratory moisture content testing are indicated on the attached borehole logs in **Appendix B**. They include textural descriptions of the subsoil at each location along with the other results of the field-testing program.

It should be noted that the soil boundaries indicated on the borehole logs are inferred from non-continuous sampling and observations during drilling. These boundaries are intended to reflect transition zones for the purpose of geotechnical design and should not be interpreted as exact planes of geological change. Notes on Sample Descriptions found in **Appendix B** are an integral part of and should be read in conjunction with this report.

The stratigraphy at the site, as revealed in the sampling completed within the boreholes, is generally comprised of initial topsoil, pavement, or clayey silt fill overlaying a native silty clay/clayey silt deposit. The boreholes all are terminated in a sandy silt/silty sand/gravelly deposits.

A brief description of the soil profile, in general order of depth (listed in metres below grade, unless otherwise noted), follows:

4.2.1 TOPSOIL

An initial layer of topsoil was encountered in Borehole BH1. The topsoil layer was approximately 1.5 meters thick at this location.

4.2.2 PAVEMENT STRUCTURE

Boreholes BH2 and BH3 were advanced through the paved portion of the road platform for Highway 401.

The pavement structure consisted of asphaltic concrete placed over granular base course(s). The asphaltic concrete layer(s) thickness from drilling was found to be from 150 mm (BH2) to 280 mm (BH3). Granular base was encountered beneath the asphalt and extended to a depth of 0.8 m below the ground surface at each location. The granular fill consisted of sand and gravel and in BH3, contained concrete fragments.

4.2.3 FILL

In Borehole BH2, a layer of earth fill was encountered beneath the pavement structure. The fill was predominantly a silty sand, some clay, some gravel. Trace amount of topsoil inclusions were also present in the fill samples.

Grain size distribution analysis and Atterberg Limits were carried out on fill sample. The results of the tests are summarized in the following table, and the detailed laboratory test results are provided in **Appendix C**.

Sample ID	% Gravel	% Sand	% Silt	% Clay	Atterberg Limits		
					Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)
BH2 SA2 0.8 m depth	12	38	29	21	27.9	13.6	14.3

4.2.4 CLAYEY SILT/SILTY CLAY

The predominant soil encountered in the boreholes is a clayey silt/silty clay deposit. This material was encountered beneath the topsoil, pavement structure and fill materials in Boreholes BH1 through BH3 and at the surface in Borehole BH4. The clayey silt/silty clay extended to depths of 5.3 to 6.1 m in the boreholes. In BH4, occasional sandy seams were noted between 3 and 4 m depth.

The clayey silt/silty clay deposit is a mottled brown/grey in color. The deposit generally contains trace to some sand, and trace to none gravel.

Grain size distribution analyses and Atterberg Limits were carried out on native soil samples. The results of the tests are summarized in the following table, and the detailed laboratory test results are provided in **Appendix C**.

Sample ID	% Gravel	% Sand	% Silt	% Clay	Atterberg Limits		
					Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)
BH1 SA3 1.5 m depth	0	9	51	40	36.7	20.7	15.9
BH2 SA5 3.0 m depth	0	10	52	38	35.4	16.3	19.0
BH3 SA4 2.3 m depth	0	8	55	37	36.4	17.3	19.0
BH3 SA6 4.5 m depth	0	7	50	43	35.1	16.0	19.1
BH4 SA2 0.5 m depth	5	16	52	27	24.9	16.9	8.0
BH4 SA7 4.5 m depth	0	8	35	57	43.6	16.9	26.7

Based on the grain size results, the hydraulic conductivity (k) of the deposit is expected to be in the order of 10^{-6} cm/sec and lesser.

Based on the Atterberg results, the deposit is lean clay with low to medium plasticity.

Based on Standard Penetration Test (SPT) N-Values recorded during the drilling, the deposit was typically in firm to soft consistency except the upper layer in BH3 where the clay was in stiff consistency. The clayey silt/silty clay was typically very moist to wet.

4.2.5 GRAVELLY SAND/SILTY SAND/SANDY SILT

The terminal deposits in all four boreholes are gravelly sand/silty sand/sandy silt. Those materials were encountered at depths of 5.3 to 6.1 m and extended to the limit of our explorations at 6.6 to 6.7 m. The deposits contained trace to some clay and were grey in colour. With Standard Penetration Test (SPT) “N” values ranging from 3 to greater than 50, the compactness condition of the deposit varied from very loose to very dense. The moisture conditions encountered were moist to saturated, and the natural moisture contents of the recovered samples ranged from 8 to 25%.

Grain size distribution analyses and Atterberg Limits were carried out on native soil samples. The results of the tests are summarized in the following table, and the detailed laboratory test results are provided in **Appendix C**.

Grain Size Distribution

Sample ID	% Gravel	% Sand	% Silt	% Clay	Atterberg Limits		
					Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)
BH1 SA9 6.1 m depth	25	54	15	6	12.4	10.4	2 (non plastic)
BH2 SA8 5.3 m depth	8	42	31	19	18.1	9.9	8.2

4.3 Groundwater Condition

Groundwater conditions were observed in the open augered boreholes during the course of the fieldwork. Piezometers were installed in the continuous push boreholes to allow for on-going monitoring of the groundwater table.

Upon completion of drilling BH2 and BH3, the groundwater was at 4.1 and 3.4 m, respectively. The groundwater in the piezometers installed in BH1 and BH4 was at 1.3 and 0.6 m, respectively, on July 7, 2016. It is believed that the measured groundwater is perched water trapped within occasional wet sand seams encountered within the clay deposit.

Seasonal variations and localized fluctuations in the groundwater level should be anticipated with high levels occurring during periods of wet weather.

5. Discussion and Recommendation

The project involves the installation of two buried 75mm diameter HDPE sanitary force mains enclosed in a single 300mm steel casing pipe underneath Highway 401. Within the Highway 401 corridor, trenchless methods such as jack and bore, directional drilling, pipe jacking will be required to cross the highway. The crossing length at Highway 401 is not available at the time of writing this report but it is anticipated to be about 115 m (distance between BH1 to BH4).

Based upon the MTO requirements, it is recommended that the invert level of the liner pipe for this crossing will be at a depth of approximately 5.0 m below grade at the centreline of the highway (the invert of the casing is to be at an elevation of 78.9 m). The soil conditions at the tunnel horizon consist of clayey silt/silty clay. No groundwater is anticipated within the depth of the proposed tunnel except a perched groundwater.

The details of the highway crossing are subject to review and approval of the Ministry of Transportation.

The field program to identify and characterize the subgrade soil and groundwater conditions at the Highway crossing is considered reasonable to provide geotechnical comments and recommendations for the proposed trenchless installation of the sanitary force main steel casing. Due to the consistent nature of the subgrade soils in the boreholes which were drilled at each end of the proposed crossing and at the pavement, additional boreholes within the highway medians have not been carried out as part of this investigation.

5.1 Tunneling Methods (Trenchless Technology)

In order to minimize the impact and effects of the proposed crossing on the structural integrity of the roadway and the traffic flows along Highway 401, it was determined that trenchless pipe installation for the sanitary force main would be required.

Regardless of the method used, it is recommended that the contractor prepare a plan in advance of construction outlining the details of the installation to provide instructions for the construction crew. The plan should also be reviewed by the proponent and the MTO prior to construction. Upon request, **exp** can assist in reviewing the plan to check that assumptions regarding soil condition are appropriate.

It should be noted that the stratigraphy between boreholes may vary and areas of weaker or denser soil may be present along the planned route.

It should further be noted that the tunnelling operations should take into account the presence of existing infrastructure, if any, at the site. If the underground utility pipes are available at the site, the appropriate cover between the invert of a pipe and the crown of the proposed casing(s) should be provided to avoid disturbance to the pipe bedding materials.

Reference is also given to Ontario Provincial Standards Specifications (OPSS 415), Construction Specifications for Pipeline and Utility Installation by Tunnelling.

A general description of the possible tunneling methods is presented below.

5.1.1 Pipe Ramming

Pipe ramming installation is analogous to driving an open ended tube pile directed horizontally. Impact force from a percussive hammer is used to advance the casing from an entry pit to a receiving pit. During the advance, most of the soil being penetrated fills the conduit rather than being excavated. The rammed conduit is advanced to a receiving pit at which point the soil contained in the pipe is removed.

Minimal groundwater control should be needed along the installation path because the soil within the pipe is not removed until after the crossing has been completed. The retained soil will tend to act as a plug, reducing the potential for ground water seepage and running of soil into the pipe.

Reference is given to the excavation section for recommendations pertaining to of the construction of entry and receiving pits. At the time of drilling, no significant groundwater was observed at the site except perched groundwater; therefore, it is expected that low to moderate dewatering measures will be required at the entry and receiving pits.

5.1.2 Jack and Bore

Jack and bore typically involves the simultaneous advancement of continuous flight auger and conduit pipe. The auger is used to excavate soil in advance of casing and transport cuttings back to the receiving pit where they are removed. Rotary power to auger and pushing force is provided by a drill rig located within a jacking pit. Jack and bore is a common method of trenchless installation and in appropriate site and soil conditions may be preferable from a cost perspective.

Jack and bore installation(s) should be conducted in accordance with OPSS 416, construction Specifications for Pipe Line and Utility Installation by Jacking and Boring.

There is no free groundwater was observed at the site except perched groundwater, but in general, in wet soils there is potential for ground surface subsidence due to running of wet sandy soils into the bore, which could result in voids.

From geotechnical perspective, a jack and bore method is considered feasible for the proposed crossing.

5.1.3 Directional Drilling

The typical technique for installing pipe by directional drilling uses a surface mounted drill rig that launches drill rods creating a string of rods (called the drill string) below the ground guided by a drill head that is directionally controlled by the drill operator. The direction of the drill is along a pre-determined path (called the drill path) based upon the above ground and below ground, pre-construction investigations of the site. A locating device is used during the drill to track the location of the drill head so that the operator may make adjustments as necessary.

A small diameter pilot hole is drilled from the entrance point (typically in a sending pit) to the desired exit point (receiving pit). It is necessary to use a drilling fluid during drilling to lubricate and protect the pipe, and to maintain the size of the hole being opened. Following the exit of the pilot drill bit, the hole is then enlarged by the use of a

backreamer attached to the end of the drill string which is pulled back through the pilot hole. As the backreaming takes place, the pipe being installed is also pulled into the hole.

Directional drilling may require the use of a casing pipe to protect the carrier pipe where required and/or dictated by an outside agency.

From geotechnical perspective, Horizontal Directional Drilling Method is also considered feasible for the proposed crossing. However, both Horizontal Directional Drilling and Jack and Bore Methods are rated as #2 in section below “assessment of tunneling method” compared to pipe ramming method.

5.1.4 Assessment of Tunnelling Methods

At the time of writing this report, limited design details are available. However, the crossing pipes should be installed with at least 1 m of cover below the lowest elevation of the ditches exist at the site. In addition, the installation depth for the pipes will also be dictated by the minimum specified depth requirements from the Ministry of Transportation, for the crossings below Highway 401.

The complexity ratings of Foundations Engineering services (tunnel excavation diameter, pipe size and minimum overburden cover) recommended by MTO are defined in Table 1 of “Guidelines for Foundation Engineering for Tunneling Speciality-Tunnelling Specialty For Corridor Encroachment Permit Application” included in **Appendix D** attached. Based on the diameter of the proposed trenchless drill crossing, and anticipated installation depth, this project has a Medium Complexity rating, for Foundation Engineering Services.

The following table summarizes some of the possible alternatives for the pipe installation:

Installation Method	Advantages	Disadvantages	Rating
Pipe Ramming	<ul style="list-style-type: none"> Well suited for steel pipes and casings over distances usually up to 45m (150 ft) up long and up to 1,500mm (60-inches) in diameter Suitable for a wide variety of soil conditions (soils containing cobbles and boulders) Minimal groundwater control required along the installation route Can be driven at almost any angle Accommodates obstructions well No traffic interruption and requirement for detour route Little surface settlement Moderate Cost 	<ul style="list-style-type: none"> Installation utilizes pneumatic percussive blows to advance the pipe, creating a lot of noise Pipe can be difficult to steer/direct. Requires staging pits Groundwater control is required for staging pits Contractors not available locally, would require utilizing a contractor from out-of-town, which would increase transportation costs. Ground heave Slower than other techniques Vibrations may cause settlement of highway 	2
Jack and Bore	<ul style="list-style-type: none"> Handles wide variety of ground conditions No dewatering Minimal surface disruption Very accurate (slopes of 0.2% easily achieved) Relative simple operation 	<ul style="list-style-type: none"> Requires large area for jacking shaft and support equipment Relatively high construction cost Obstructions problematic Short and long term settlement Fluid to support annular space 	2

	<ul style="list-style-type: none"> • Common use in Ontario • Short mobilization time • No requirement for detour • Suitable for steel pipes up to 1.8 m in diameter • Low Cost 	<ul style="list-style-type: none"> • Pipe can be difficult to steer/direct 	
Directional Drilling	<ul style="list-style-type: none"> • Handles wide variety of ground conditions • Steerable all horizontally and vertically to maintain and adjust alignment • Does not require staging pits • Minimal groundwater control required • Alignment can be adjusted to avoid obstruction • Local contractors available • Short mobilization • Ramped drilling • Small settlement, if fluid well controlled • Suitable for installation of pipe up to 1.2 m in diameter and longer length • Moderate Cost 	<ul style="list-style-type: none"> • Potential for inadvertent drilling returns • Requires drilling fluid to maintain the bore which could allow subsidence • Site grades may require longer bore or staging pits • Annual space filling (fluid or grouting) 	1

Regardless of the method chosen, the proposed tunnel alignment will go through the clayey silt/silty clay soils. These soils have a firm to stiff consistency and their moisture contents are quite high (ranging from very moist to wet). There were some fine sand seams noted in Borehole BH4 at the proposed tunnel horizon. Depending on the size and prevalence of these seams, groundwater inflow into the tunneling may be significant. This could result in a loss of soil from around the leading edge of the liner installation, which could result in surface settlements.

From a geotechnical standpoint, based on a review of the subgrade soil and groundwater conditions, crossing length, pipe diameters, and minimum installation depths, the site is well suited for all noted trenchless methods at the Highway 401 crossing.

The following sections provide, in general, geotechnical comments and recommendations for excavations and groundwater control, pipe installation, and recommendations for inspection and testing during trenchless construction.

5.1.5 Recommended Minimum Installation Depth

Regardless of the method chosen, in selection of the minimum installation depth consideration has been given to requirements from the Ministry of Transportation for service crossings below provincial highways, and the soil and groundwater conditions encountered in the boreholes.

The soil condition at the recommended installation depth is described as mottled brown/grey clayey silt/silty clay soils, with a firm to stiff consistency. Cross Section (in **Appendix A**) shows the soil conditions at the site.

At the time of writing this report, there is no detailed design plan available. However, it should be noted that the alignment of the crossing should avoid any conflict with existing utilities, if any. If utility services exist, the trenchless drill installation of the forcemain should go below the services. Prior to construction, it is imperative that the

utility services be exposed if possible and that the servicing depths are confirmed. A minimum vertical separation distance of $\geq \phi$ (or 1.5 m whichever is greater) is recommended between the new forcemain and the existing services, if any.

5.1.6 Trenchless Installation

It is recommended that the forcemain crossing below Highway 401 be carried out using one of the noted trenchless methods. An encroachment permit from the Ministry of Transportation will be required to work under Highway 401.

Based on the results of the investigation, the site supports the construction of the forcemain crossing below Highway 401 using trenchless techniques, in accordance with the following discussion and recommendations. The procedures should follow OPSS 450 and industrial standards. For reference, a copy of OPSS 450 is provided in **Appendix E**.

The sending and receiving pits for the trenchless equipment are expected to be located outside of the MTO Encroachment Limit.

It is anticipated that the invert levels will be set into the natural clayey silt/silty clay. Minor to moderate groundwater seepage is anticipated. The rate of infiltration through the clayey silt/silty clay soils are expected to be very low but will be high for fill and sand seams. The base of the sending and receiving pits are expected to be set at clay soil.

The trenchless work should be carried out by a specialist contractor experienced in the area, and should be continually monitored for levelness and alignment. If the work is carried out properly, and no significant obstructions are encountered, only nominal settlement would be expected in the overlying soils.

Excavation recommendations for the sending and receiving pits are discussed in the following section.

5.1.7 Settlement Monitoring

Monitoring of settlement points will be a crucial part of the fieldwork monitoring program. The purpose of the settlement monitoring is to identify potential movements which could indicate damage to utilities or road structures along the tunnel alignment. The Ministry of Transportation has guidelines for the installation and placement of settlement monitoring points. The following comments are provided regarding the settlement monitoring point installation and observations:

- Monitoring points should be located above the tunnel alignment, at a spacing of less than 5 m. In this regard, it is anticipated that monitoring points could be installed at the lowest ditch inverts, at the edges of pavement, and within the paved lane and median area.
- Surface monitoring points on the existing pavement can be painted on the ground surface. It is understood that the works may be carried out during winter months. Therefore, the monitoring points on the unpaved right-of-way should be founded below frost penetration depth. The monitoring points installed below

frost depth would reduce the occurrence of shifting or tilting which could result from surface activities or disturbance in the area.

- At least 2 sets of readings are required prior to commencement of the directional drilling to establish baseline conditions. During the site work, a minimum of 3 sets of readings are required daily, provided that movements are within anticipated levels (refer to comments below). When the work in progress, daily readings are also required during periods of work stoppages.
- The following criteria are recommended for assessing the monitoring point data:
 - Review Level: A maximum value of 8 mm relative to the baseline readings is recommended for this project. If this level is reached, the method, rate, sequence of construction and mitigation measures should be reviewed, with changes implemented to mitigate further ground movements.
 - Alert Level: A maximum value of 12 mm relative to the baseline readings is recommended for this project. If this level is reached, the Contractor will be required to cease construction operations to secure the site and to mitigate further movements.

A pavement condition survey is also required prior to construction on Highway 401 at the alignment location. The condition of the pavement should be thoroughly documented, including identification of cracks, distortions, depressions, etc.

It is imperative that suitable traffic control (in accordance with MTO Book 7) be provided for the installation, monitoring and decommissioning of the settlement monitoring points. A traffic control plan should be prepared and provided to MTO for their review and consideration.

5.2 Excavations

The base of the sending and receiving pits is expected to be set at clay soil. Temporary excavations to conventional depths for installation and connections of underground servicing lines, and the sending and receiving pits at this site should comply with Regulation 213/91 (Construction Projects) under the Ontario Occupational Health and Safety Act. The predominant clayey silt/silty clay deposits encountered in all boreholes would be classified as Type 3 soils and temporary side slopes terminated in this material may be cut near vertical in the bottom 1.2 m and trimmed back at about 3 horizontal to 1 vertical above this level.

Underground utilities may exist in proximity to the pipe alignment and/or sending and receiving pits. To ensure stability, it is suggested that any exposed services be supported in open excavations, or that consideration be given to adjusting the location of the excavations to incorporate adequate separation from existing services where possible.

Recommendations for excavation dewatering are further discussed in Section 5.3.

5.2.1 Support of Excavations

In areas adjacent to existing structures and services, if any, that are located above the base of the excavations, side slopes may require support to prevent possible disturbance to these structures. This concept also applies to connection to existing services. In granular soils above the groundwater and in cohesive natural soils, bracing will not normally be required if the structures are behind a 45 degree line drawn up from the near edge of the excavation.

For support of excavations, shoring utilizing a prefabricated system may be available depending on the required depths. The prefabricated trench box system, if utilized, must be designed by a professional engineer to withstand the soil and hydrostatic loading. The design and use of the support system should conform to the requirements set out in the most recent version of the Occupational Health and Safety Act for Construction Projects and approved by the Ministry of Labour. Excavations should conform to the guidelines set out in the proceeding section and the Safety Act.

Where applicable, the lateral earth pressure acting on the excavation support may be calculated from the following equation:

$$P = K (\gamma h + q)$$

where,

- p = lateral earth pressure in kPa acting at depth h;
- γ = natural unit weight, a value of 21 kN/m³ (average of lab test results);
- h = depth of point of interest in m;
- q = equivalent value of any surcharge on the ground surface in kPa.

The earth pressure coefficient (K) may be taken as

- 0.25, where small movements are acceptable and movement sensitive services are not above a line extending at 45 degrees from the bottom edge of the excavation;
- 0.35, where utilities, roads must be protected from significant movement; and,
- 0.45, where adjacent sensitive services (gas and water mains), if any, are above a line 60 degrees from the horizontal extending from the bottom edge of the excavation.

The above expression assumes that no hydrostatic pressure will be applied against the shoring system.

5.2.2 Base Stability

Where the excavation terminates in the competent clayey silt/silty clay encountered in all boreholes, it is anticipated that the base will remain stable for the short construction period and no base stability concerns.

5.3 Groundwater Control

Upon completion of drilling boreholes BH2 and BH3 on May 26, 2016, the groundwater was at 4.1 and 3.4 m, respectively. The groundwater in the piezometers installed in BH1 and BH4 was at 1.3 and 0.6 m, respectively, on July 7, 2016. It is believed that the measured water is perched water within occasional wet sand seams encountered within the clay deposit.

The groundwater table at the site is expected to be below exploration depth of the boreholes. Any seepage of perched water should be controllable using conventional dewatering techniques which incorporate sump pits and pumps.

The sending and receiving pits for the trenchless drill installation should be located such that surface water which collects and flows along the existing drainage ditches exists at the site, do not drain towards the pits. Some soil berm around the perimeter of the pits may be required to help redirect surface water flow away from the open excavations.

Although not anticipated for this project, any dewatering effort, with a daily volume of over 50,000 litres, will require a Permit to Take Water (PTTW) from the Ministry of the Environment (MOE). PTTW applications will need to be approved by the Ministry of Environment according to Sections 34 and 98 of the Ontario Water Resources Act R.S.O. 1990 and the Water Taking and Transfer Regulation O. Reg. 387/04. It is noted that a standard geotechnical investigation will not determine all the groundwater parameters which may be required to support the application.

5.4 Backfilling

It is anticipated that backfilling work will be required where forcemain installed by trenchless techniques are tied in with services installed with conventional open cut installation methods. In addition, at the completion of the trenchless drill installations, the sending and receiving pits will require backfilling to return site conditions to pre-construction grades. The following comments and recommendations are provided for backfilling such excavations.

Based on the available borehole information, and the laboratory tests, the excavated soils will generally consist of clayey silt/silty clay. The trenches above the forcemain services and open excavations should be backfilled with inorganic on-site soils placed in maximum 300 mm thick lifts and compacted to at least 95 percent Standard Proctor Maximum Dry Density (SPMDD).

The natural on-site excavated soil can be used as trench backfill, provided the material is within 3 percent of the optimum moisture as determined in the standard proctor test. Stockpiling of excavated material for prolonged periods of time should be avoided. This is particularly important if construction is attempted in wet, adverse weather. Materials which have high in-situ moisture content may require drying or blending if used in areas which cannot tolerate settlements. More specifically, portions of the silt and clay may require some drying prior to use as trench backfill or be limited for use in non-settlement sensitive areas.

Organic matter has to be avoided within the backfill material. Alternatively, imported fill material meeting backfill specifications may be used.

5.5 Inspection and Testing Recommendations

Full-time inspection by **exp**'s geotechnical personnel should be carried out during placement and compaction of trench/open pit backfill to examine and approve potential sources of fill material, and to carefully monitor the placement and verify the compaction by in situ density testing.

Monitoring drilling fluid returns is an important QA/QC procedure during directional drill installations. Full-time monitoring by a geotechnical engineer is recommended. Generally, drilling fluid, which carries soils from down-hole, should exit the hole at the entry or exit end of the installation. Drilling fluid flow provides visual verification that the hole is open and that the fluids are not inadvertently escaping.

Monitoring of settlement points will be a crucial part of the fieldwork monitoring program. Full-time monitoring by a geotechnical engineer is recommended.

6. Closure

The comments given in this report are intended only for the guidance of design engineers. The number of boreholes required to determine the localized underground conditions between boreholes affecting construction costs, techniques, sequencing, equipment, scheduling, etc. would be much greater than has been carried out for design purposes.

More specific information with respect to the conditions between samples, or the lateral and vertical extent of materials may become apparent during excavation operations. The interpretation of the borehole information must, therefore, be validated during excavation operations. Consequently, during the future development of the property, conditions not observed during this investigation may become apparent; should this occur, **exp** Services Inc. should be contacted to assess the situation and additional testing and reporting may be required.

Contractors bidding on or undertaking the works should in this light, decide on their own investigations, as well as their own interpretations of the factual borehole results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

Exp should be retained for a general review of the final design and specifications to verify that this report has been properly interpreted and implemented. If not afforded the privilege of conducting this review, **exp** will assume no responsibility for interpretation of the recommendations in this report.

This report was prepared by Jodi Fountain, technologist and Leigh Knegt, Senior Geotechnical Engineer. Technical review was provided by Idib Sadoun – Designated MTO Foundation Contact.

We trust this report is complete within our terms of reference, and the information presented is sufficient for your present purposes. If you have any questions, or when we may be of further assistance, please do not hesitate to contact our office.

Yours truly,
Exp Services Inc.



Jodi Fountain
Technologist

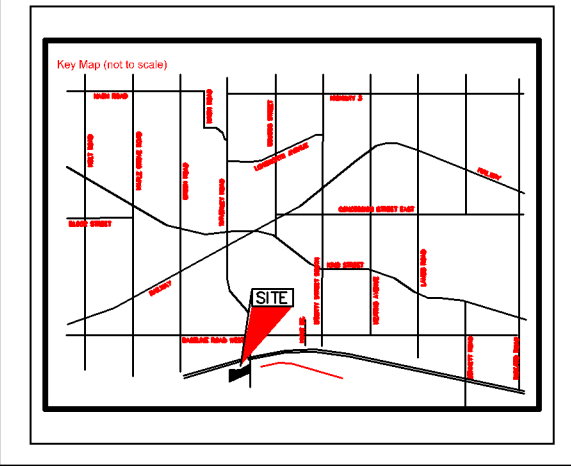
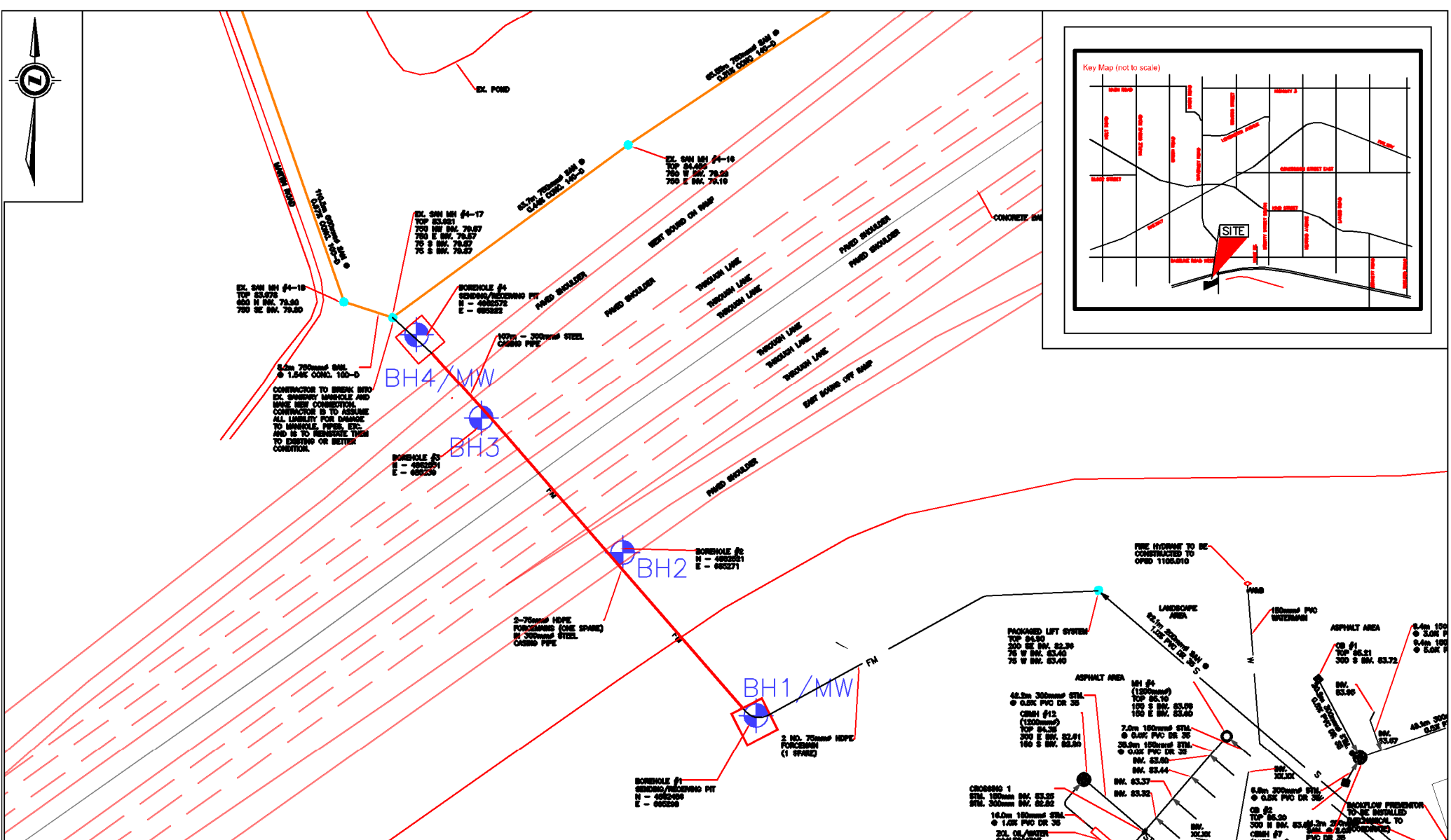




Leigh Knecht, P.Eng.
Head, Geotechnical Services

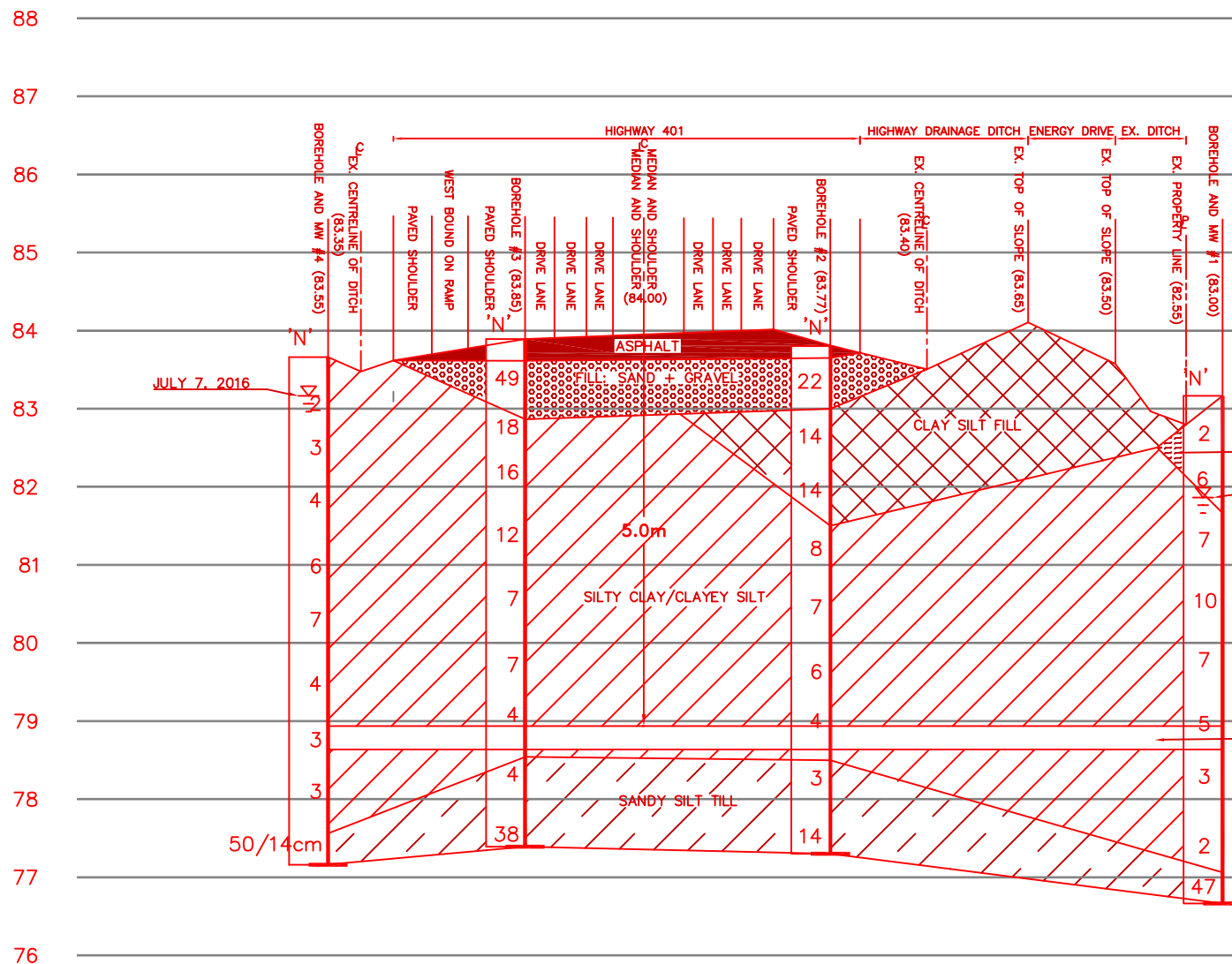



Idib Sadoun, M. Sc., P.Eng.
Designated MTO Foundation Contact

Appendix A – Drawings



Legend:		 BH4 Approximate Borehole Location	(83.6 m)	Ground Elevation (m)	MW	Denotes Monitoring Well
<div>-NOTES-</div> <div>1. THIS BOREHOLE LOCATION PLAN SHOULD BE READ IN CONJUNCTION WITH EXP REPORT BRM-00605520-AO.</div> <div>2. THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.</div> <div>3. CO-ORDINATES FOR EXP BOREHOLES WERE ESTABLISHED WITH GPS AND ARE ACCURATE TO ± 0.05m.</div>			<div>Foundation Investigation & Design Report</div> <div>Sanitary Forcemain - HWY 401 Crossing</div> <div>2435 SOUTH SERVICE ROAD, CLRINGTON, ONTARIO</div>			<div>CLIENT</div> <div>SUNCOR ENERGY PRODUCT PARTNERSHIP</div> <div>TITLE</div> <div>BOREHOLE AND TUNNEL LOCATION PLAN</div> <div><div>exp Services Inc. 15701 Robin's Hill Road London, ON, N5V 0A5</div><div><div>PREPARED BY</div><div>R.C.</div><div>CHECKED BY</div><div>L.K.</div></div></div> <div><div>DATE</div><div>JULY. 2016</div><div>SCALE</div><div>NTS</div><div>PROJECT NO.</div><div>BRM-00605520-AO</div><div>DWG.</div><div>1</div></div>



Legend:  BH4 Approximate Borehole Location (83.6 m) Ground Elevation (m) MW Denotes Monitoring Well

-NOTES-

1. THIS BOREHOLE LOCATION PLAN SHOULD BE READ IN CONJUNCTION WITH EXP REPORT BRM-00605520-AO.
2. THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
3. CO-ORDINATES FOR EXP BOREHOLES WERE ESTABLISHED WITH GPS AND ARE ACCURATE TO $\pm 0.05\text{m}$.


Foundation Investigation & Design Report

Sanitary Forcemain - HWY 401 Crossing

2435 SOUTH SERVICE ROAD,
CLRINGTON, ONTARIO

CLIENT
SUNCOR ENERGY PRODUCT PARTNERSHIP

TITLE
SOIL STRATA AND TUNNEL SECTION

 **exp Services Inc.**
15701 Robin's Hill Road
London, ON, N5V 0A5

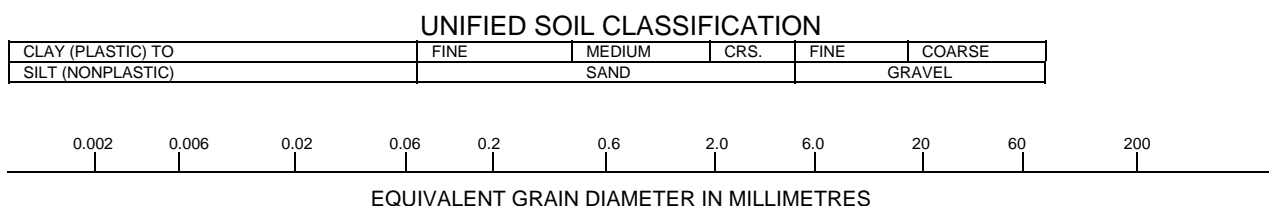
PREPARED BY
R.C.
CHECKED BY
L.K.

DATE
JULY. 2016
SCALE
NTS
PROJECT NO.
BRM-00605520-AO
DWG.
2

**Appendix B –
Borehole Logs & Notes on Sample Descriptions**

Notes On Sample Descriptions

1. All sample descriptions included in this report follow the Unified Soil Classification System (USCS) as outlined by the Ministry of Transportation. Different classification systems may be used by others; one such system is the International Society for Soil Mechanics and Foundation Engineering (ISSMFE), as outlined in the Canadian Foundation Engineering Manual. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually. Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems.



ISSMFE SOIL CLASSIFICATION

CLAY	SILT			SAND			GRAVEL			COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE		

2. **Fill:** Where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc., none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.
3. **Till:** The term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (75 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

Figure 1A

Notes On Sample Descriptions

4. The following table gives a description of the soil based on particle sizes. With the exception of those samples where grain size analyses have been performed, all samples are classified visually. The accuracy of visual examination is not sufficient to differentiate between this classification system or exact grain size.

Soil Classification		Terminology	Proportion
Clay and Silt	<0.075 mm		
Sand	0.075 to 4.75 mm	"trace" (e.g. Trace sand)	0% to 10%
Gravel	4.75 to 75 mm	"some" (e.g. Some sand)	10% to 20%
Cobbles	75 to 200 mm	with (e.g. with sand)	20% to 35%
Boulders	>200 mm	and (e.g. and sand)	35% to 50%

For a given material listed as an adjective (e.g. silty sand) means the predominant grain size is sand sized with 30 to 40% silt sized particles.

The compactness of Cohesionless soils and the consistency of the cohesive soils are defined by the following:

Cohesionless Soil		Cohesive Soil		
Compactness	Standard Penetration Resistance "N" value Blows/ 0.3 m	Consistency	Undrained Shear Strength (kPa)	'N' Values
Very Loose	0 to 4	Very soft	<12	<2
Loose	4 to 10	Soft	12 to 25	2 to 4
Compact	10 to 30	Firm	25 to 50	4 to 8
Dense	30 to 50	Stiff	50 to 100	8 to 15
Very Dense	Over 50	Very Stiff	100 to 200	15 to 30
		Hard	>200	>30

5. ROCK CORING

Where rock drilling was carried out, the term RQD (Rock Quality Designation) is used. The RQD is an indirect measure of the number of fractures and soundness of the rock mass. It is obtained from the rock cores by summing the length of the core covered, counting only those pieces of sound core that are 100 mm or more length. The RQD value is expressed as a percentage and is the ratio of the summed core lengths to the total length of core run. The classification based on the RQD value is given below.

RQD Classification	RQD (%)
Very Poor Quality	<25
Poor Quality	25 to 50
Fair Quality	50 to 75
Good Quality	75 to 90
Excellent Quality	90 to 100

$$\text{Recovery Designation:} \quad \% \text{ Recovery} = \frac{\text{Length of Core Per Run}}{\text{Total Length of Run}} \times 100$$

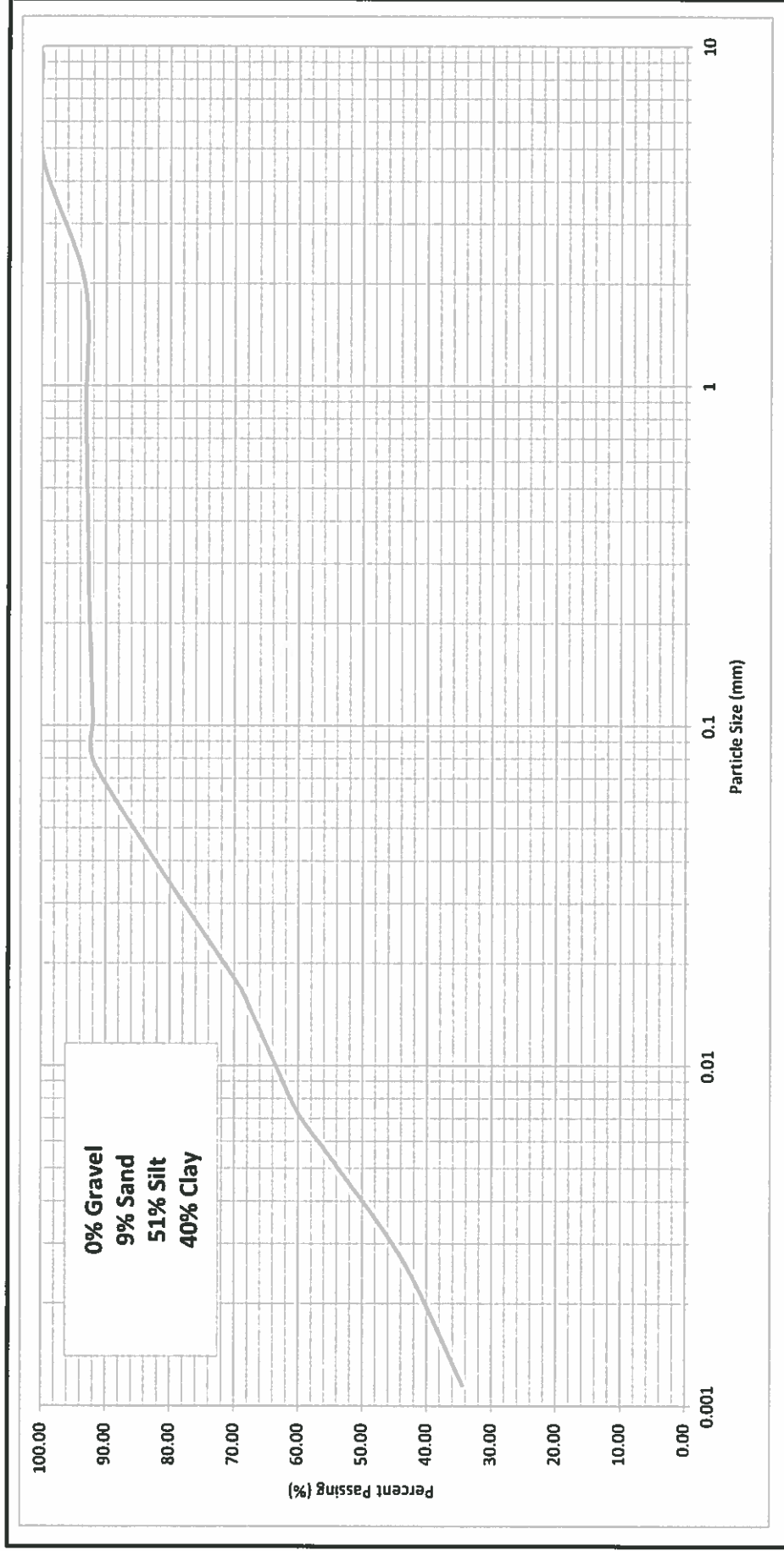
Figure 1B

Appendix C – Laboratory Test Results



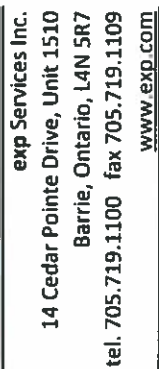
exp Services Inc.
14 Cedar Pointe Drive, Unit 1510
Barrie, Ontario, L4N 5R7
tel. 705.719.1100 fax 705.719.1109
www.exp.com

GRAIN SIZE ANALYSIS



Sample ID: BH1 SA3 (1.5m depth) Sample Location: Highway 401
Sample Date: 30-May-16 Project Number: BRM-00605520-A0
Client: Suncor

Figure #: 1



25% Gravel
54% Sand
15% Silt
6% Clay

Particle Size (mm)	Percent Passing (%)
0.075	100
0.15	85
0.3	75
0.6	65
1.18	45
2.0	35
3.75	25
7.5	15
15	6

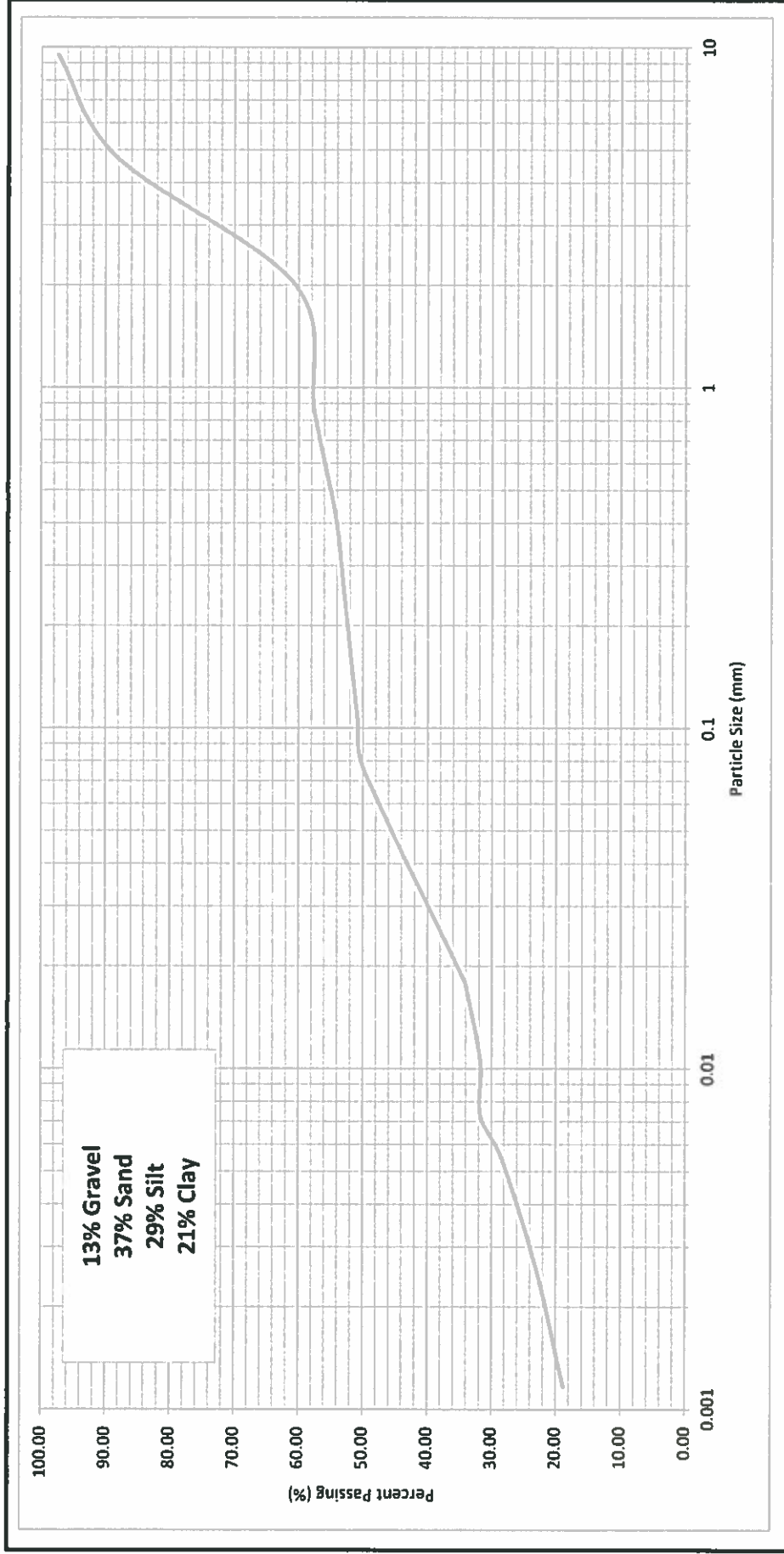
Sample ID:	BH1 SA9 (6.1 m depth)	Sample Location:	Highway 401
Sample Date:	30-May-16	Project Number:	BRM-00605520-A0
Client:	Suncor		

Figure #: 2



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GRAIN SIZE ANALYSIS

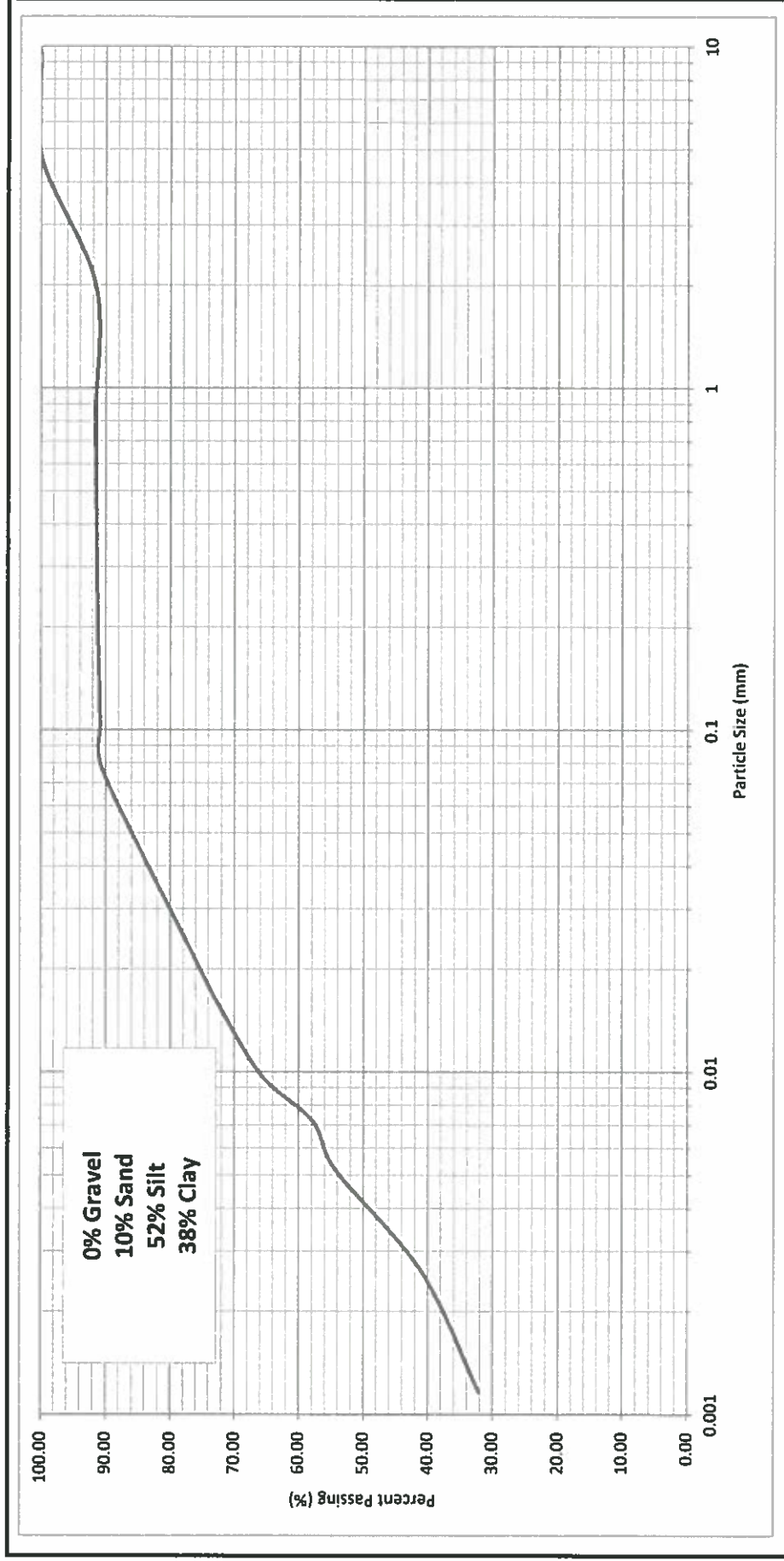


Sample ID: BH2 SA2 (0.8 m depth) Sample Location: Highway 401
Sample Date: 26-May-16 Project Number: BRM-00605520-A0
Client: Suncor



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GRAIN SIZE ANALYSIS



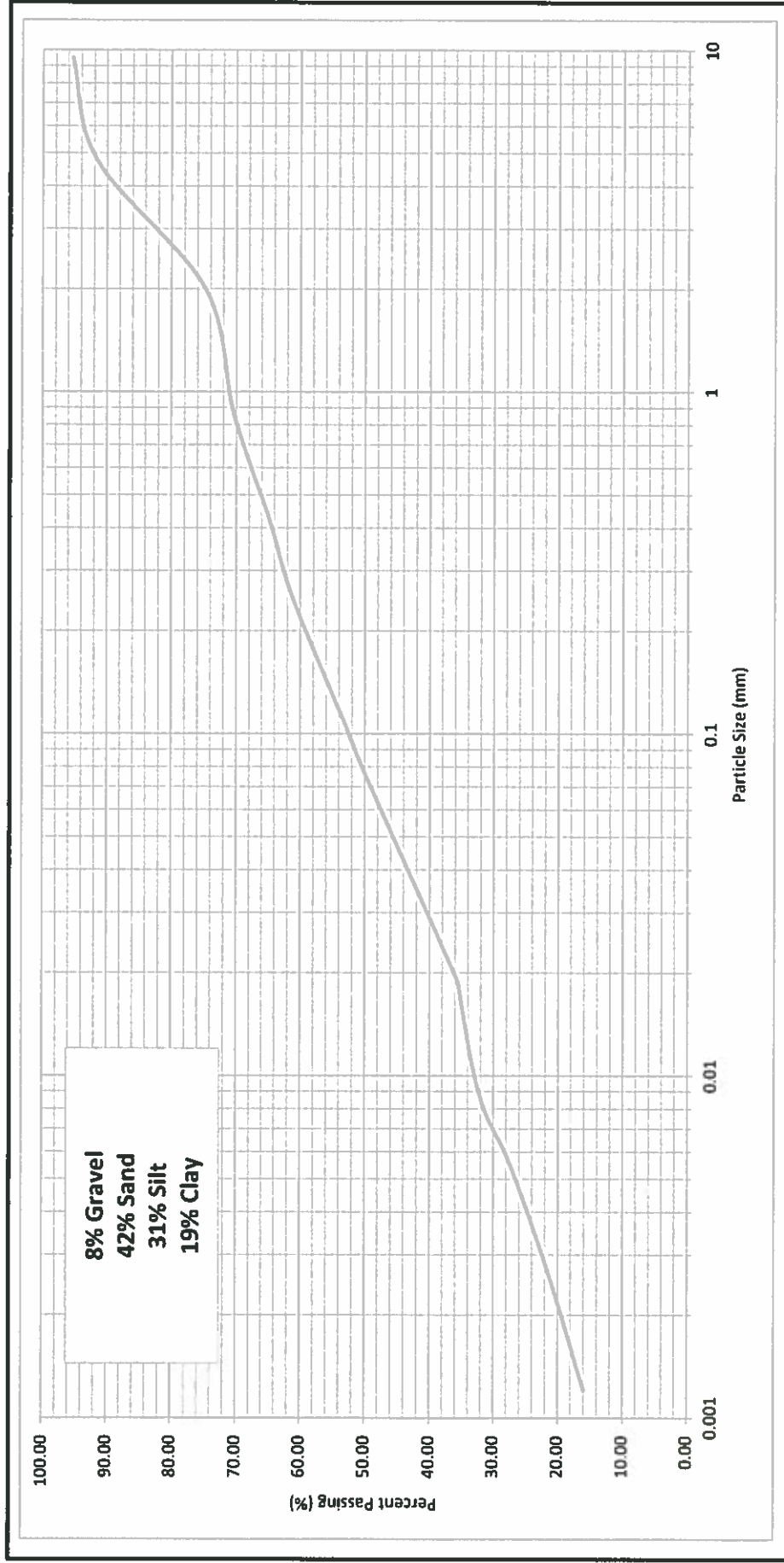
Sample ID: BH2 SA5 (3.0 m depth) Sample Location: Highway 401
Sample Date: 26-May-16 Project Number: BRM-00605520-A0
Client: Suncor

Figure #: 4



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GRAIN SIZE ANALYSIS



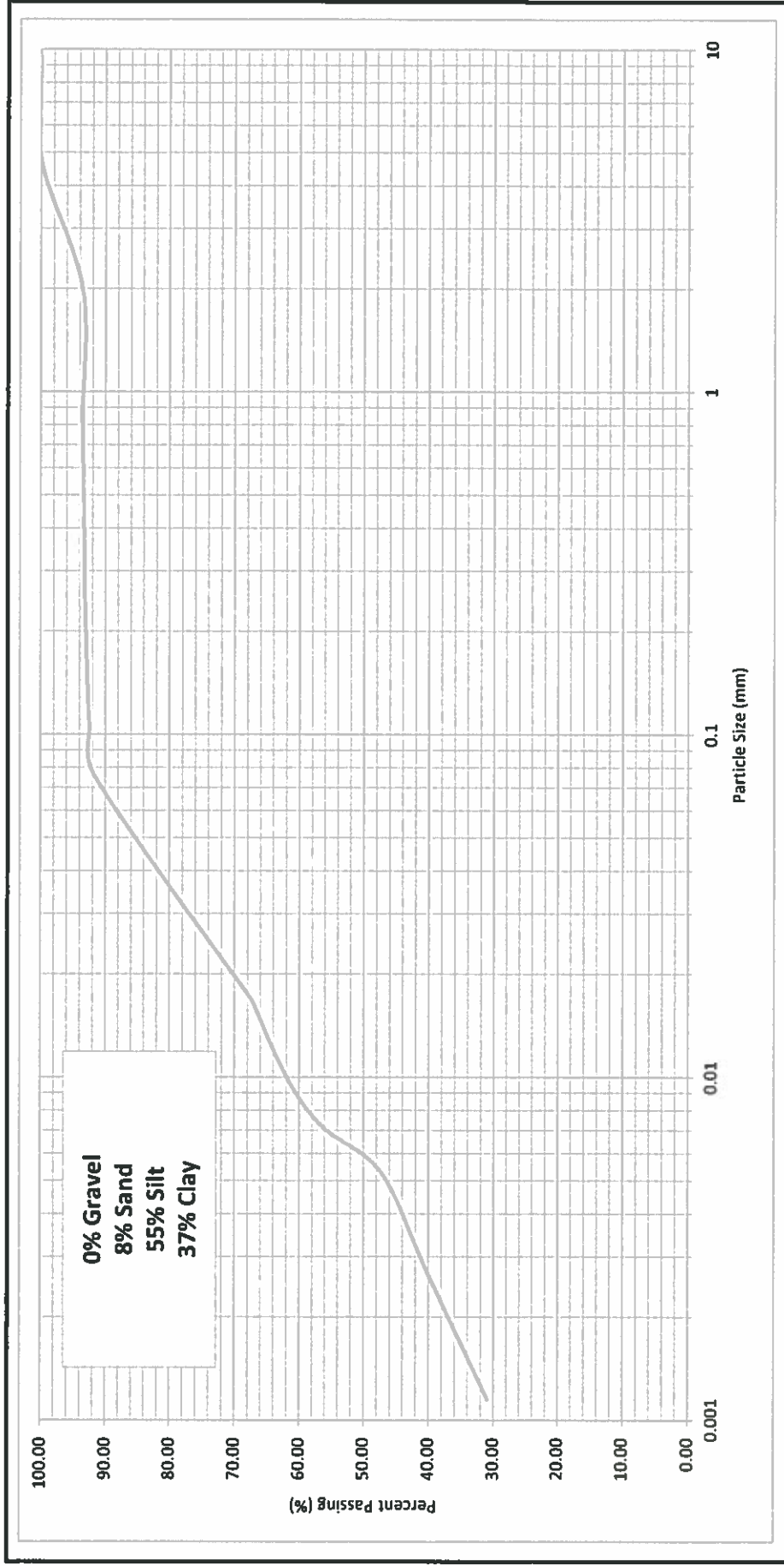
Sample ID: BH2 SA8 (5.3 m depth) Sample Location: Highway 401
Sample Date: 26-May-16 Project Number: BRM-00605520-A0
Client: Suncor

Figure #: 5



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GRAIN SIZE ANALYSIS



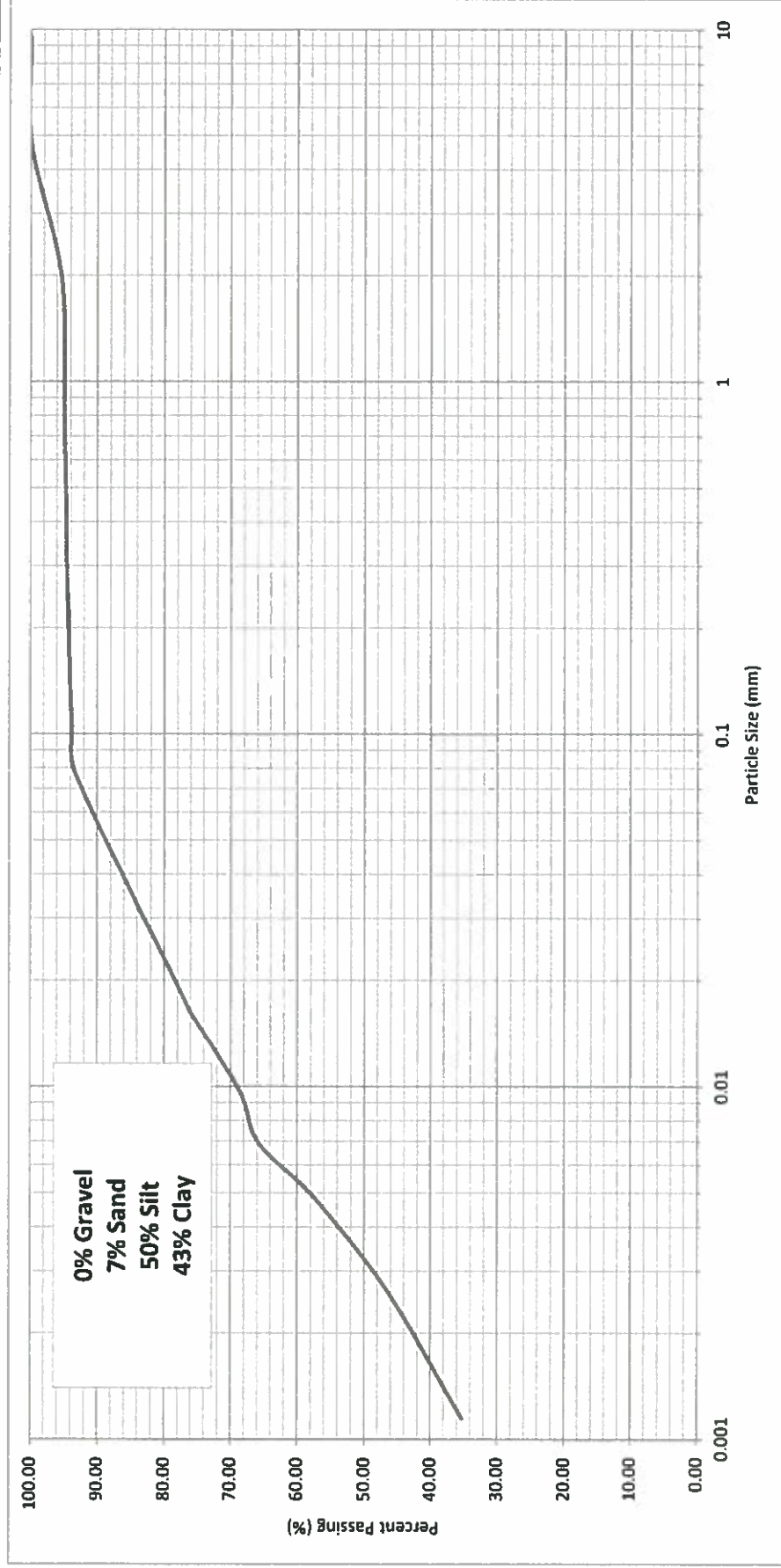
Sample ID: BH3 SA4 (2.3 m depth) Sample Location: Highway 401
Sample Date: 26-May-16 Project Number: BRM-00605520-A0
Client: Suncor

Figure #: 6



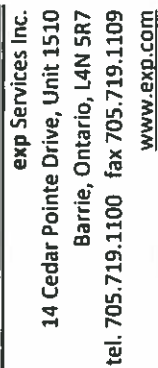
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GRAIN SIZE ANALYSIS

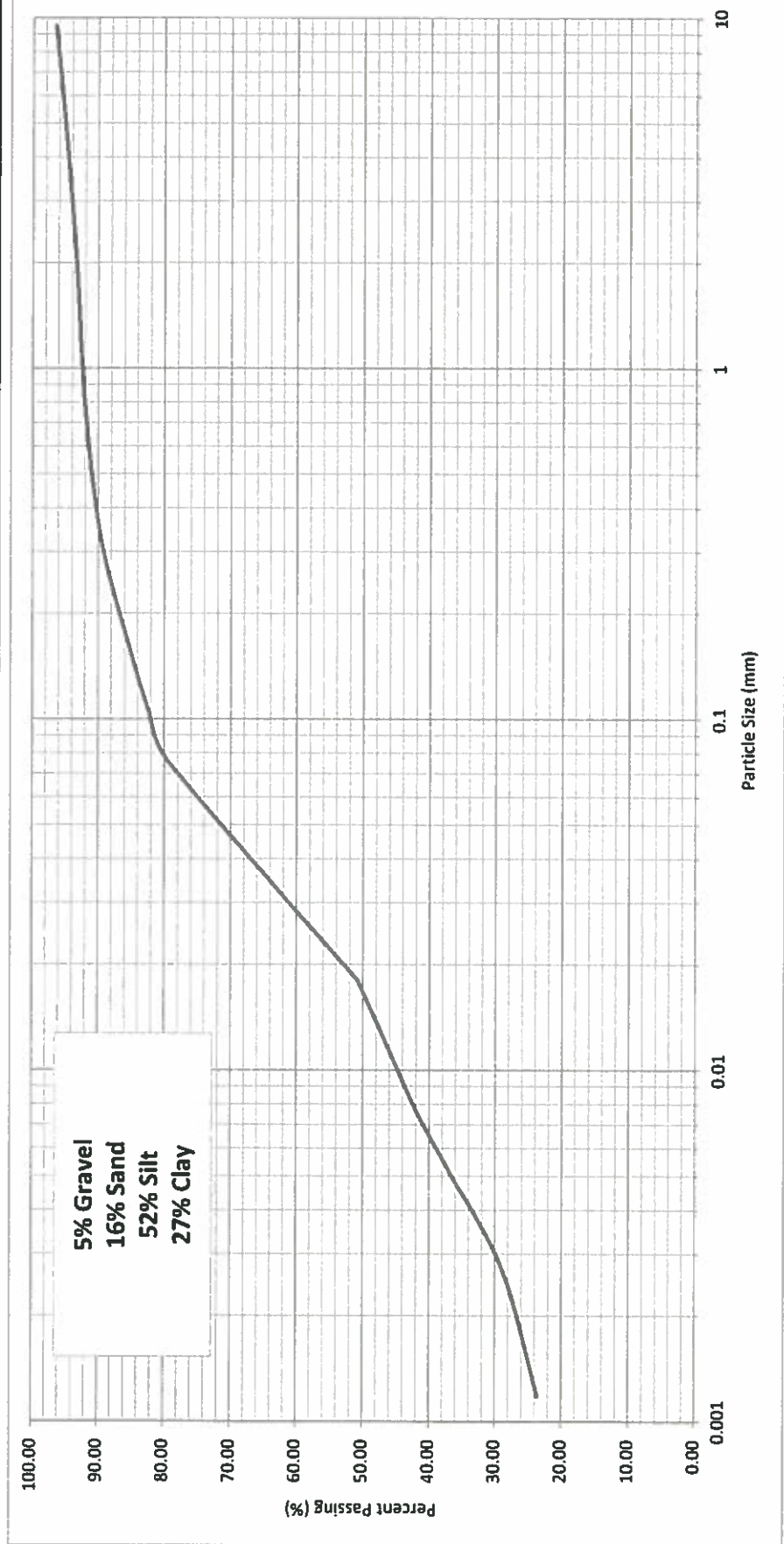


Sample ID: BH3 SA6 (4.5 m depth)
Sample Date: 26-May-16
Client: Suncor

Sample Location: Highway 401
Project Number: BRM-00605520-A0



GRAIN SIZE ANALYSIS



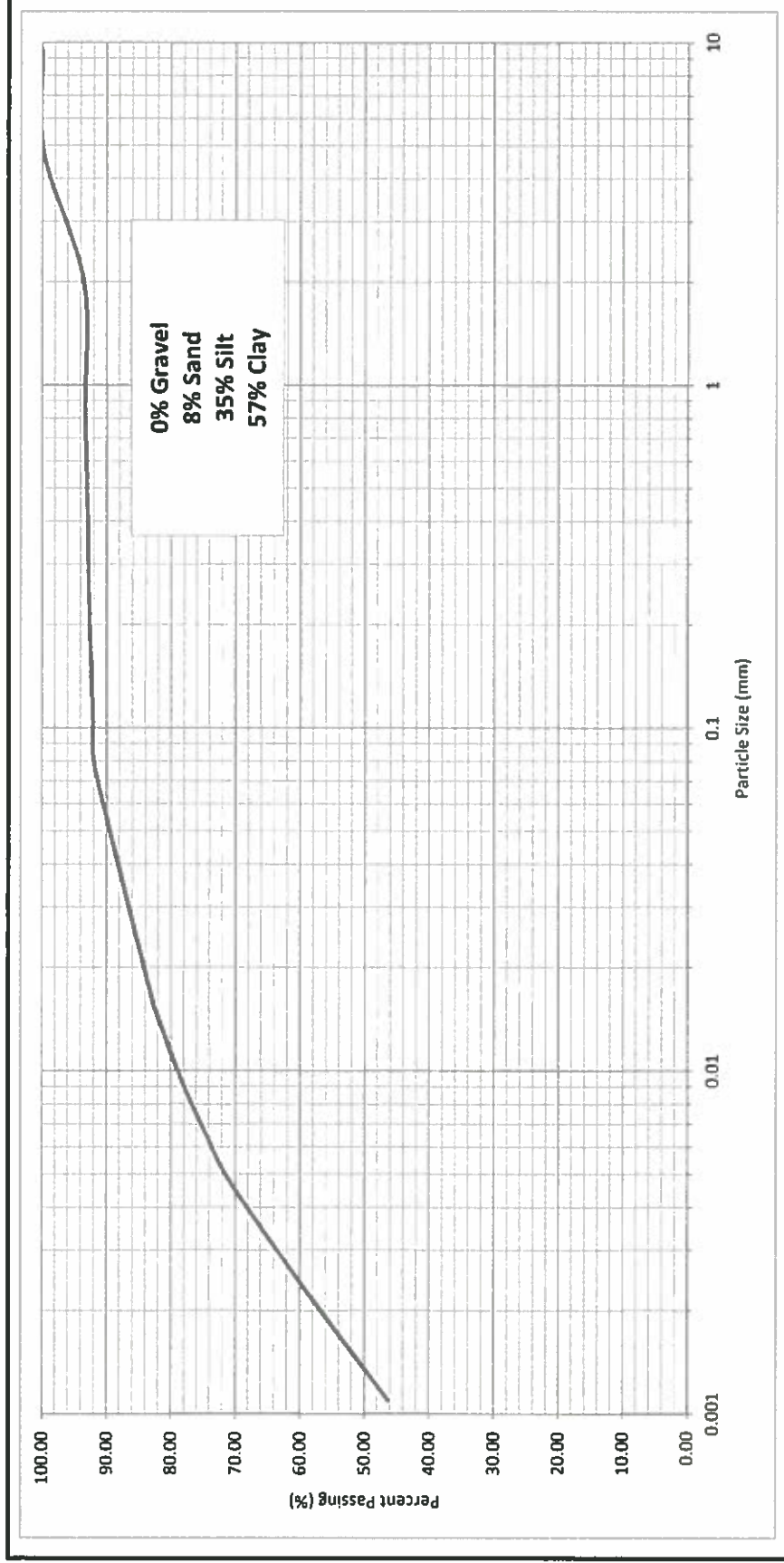
Sample ID:	BH4 SA2 (0.8 m depth)	Sample Location:	Highway 401
Sample Date:	30-May-16	Project Number:	BRM-00605520-A0
Client:	Suncor		

Figure #: 8



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GRAIN SIZE ANALYSIS



Sample ID: BH4 SA7 (4.5 m depth)
Sample Date: 30-May-16
Client: Suncor

Sample Location: Highway 401
Project Number: BRM-00605520-A0



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Atterberg Limits Report

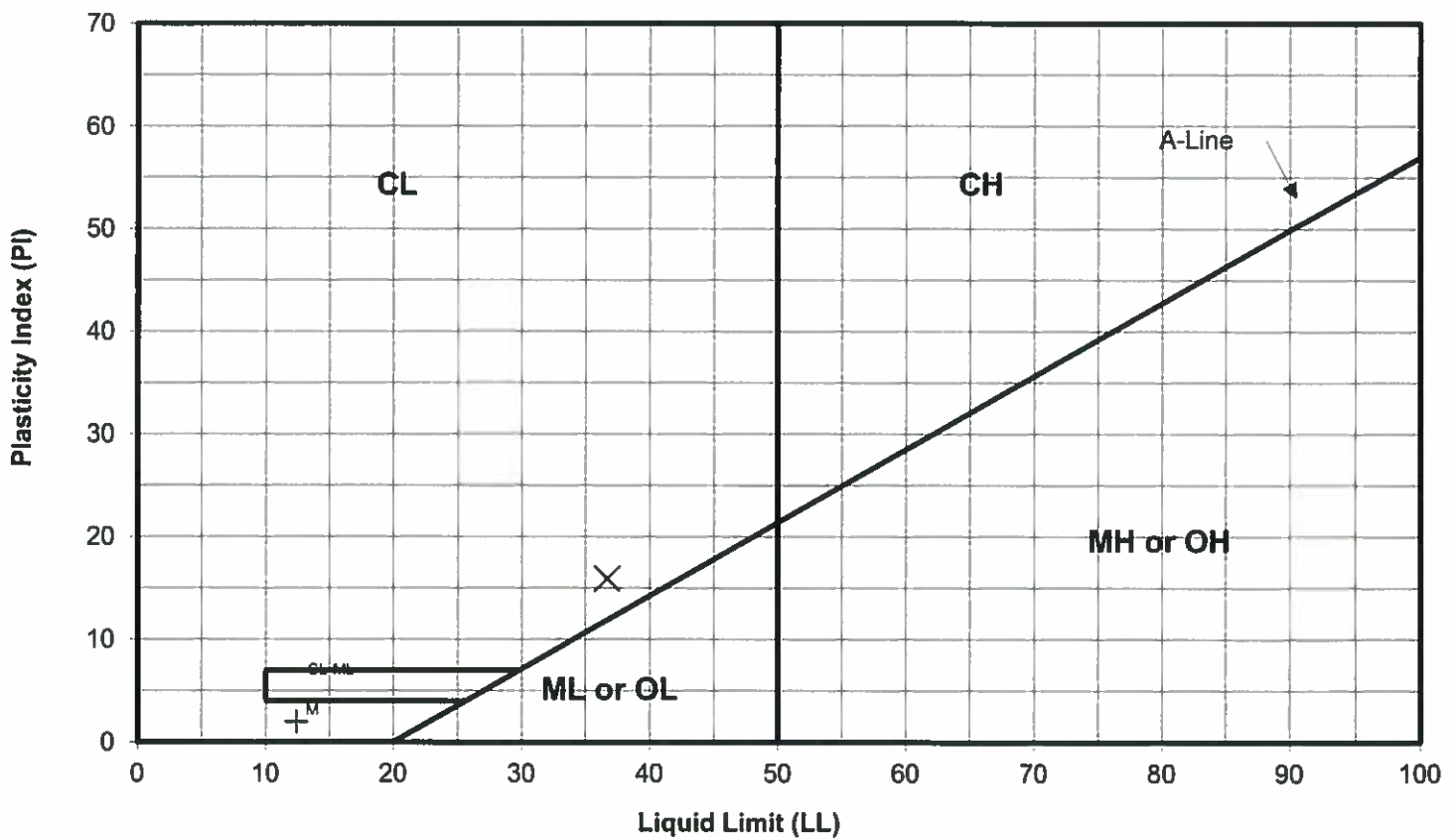
Project Name: Hwy 401 Bowmanville
Project No.: BRM-00605520-A0
Client: Suncor Energy

Figure No.: 10
Date Tested: June 9, 2016
Date Sampled: May 30, 2016

SAMPLE INFORMATION

SAMPLE ID	BH1 SA3	LIQUID LIMIT (LL):	36.7	PLASTIC LIMIT (PL)	20.7	PLASTIC INDEX (PI)	15.9	X
SAMPLE ID	BH1 SA9	LIQUID LIMIT (LL):	12.4	PLASTIC LIMIT (PL)	10.4	PLASTIC INDEX (PI)	2.0	+

Plasticity Chart



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Prepared By:

Jodi Fountain

Checked By:

Leigh Kregt P. Eng.

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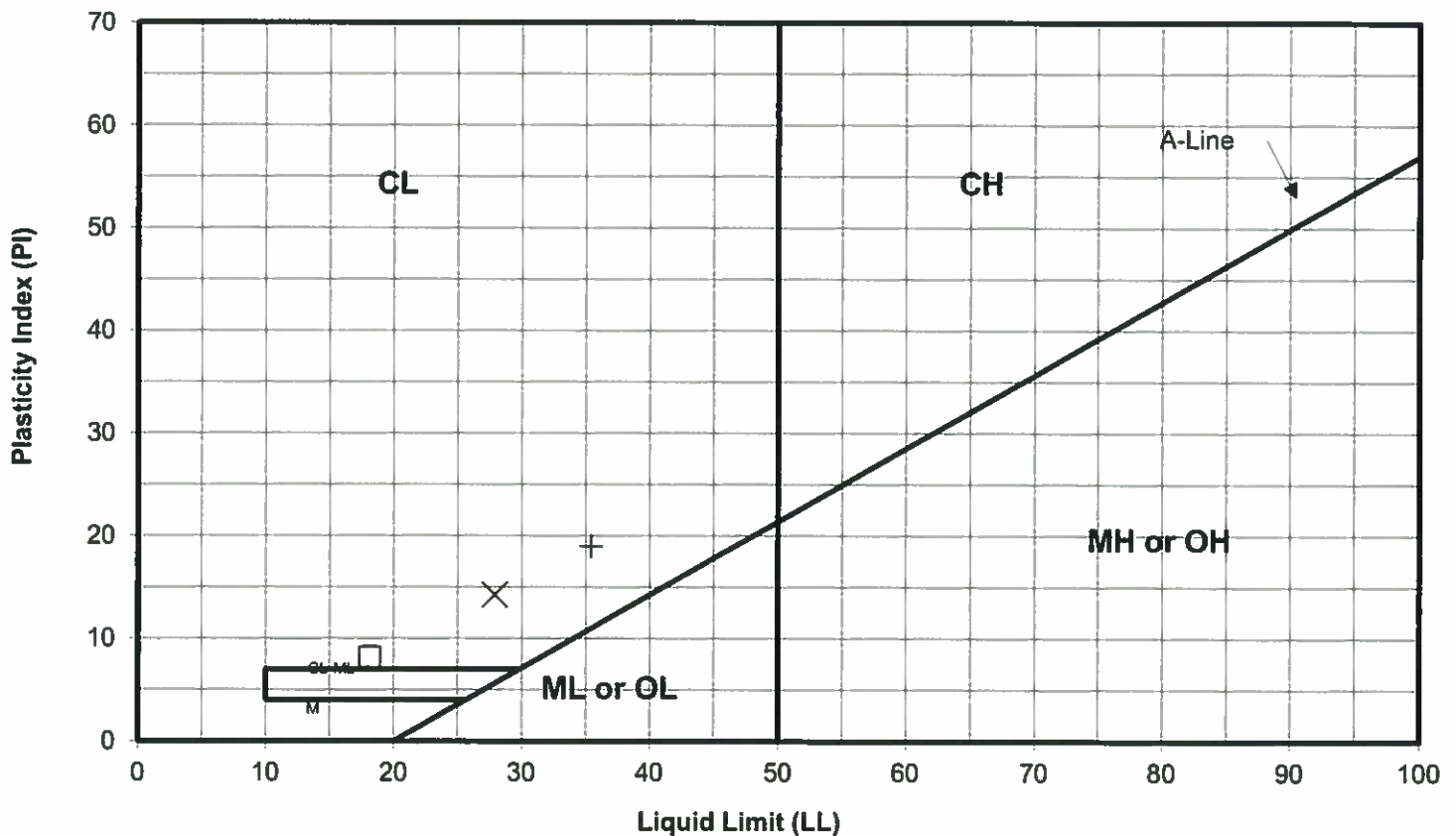
Project Name: Hwy 401 Bowmanville
Project No.: BRM-00605520-A0
Client: Suncor

Figure No.: 11
Date Tested: June 7, 2016
Date Sampled: May 30, 2016

SAMPLE INFORMATION

SAMPLE ID	BH2 SA2	LIQUID LIMIT (LL):	27.9	PLASTIC LIMIT (PL)	13.6	PLASTIC INDEX (PI)	14.3	X
SAMPLE ID	BH2 SA5	LIQUID LIMIT (LL):	35.4	PLASTIC LIMIT (PL)	16.3	PLASTIC INDEX (PI)	19.0	+
SAMPLE ID	BH2 SA8	LIQUID LIMIT (LL):	18.1	PLASTIC LIMIT (PL)	9.9	PLASTIC INDEX (PI)	8.2	□

Plasticity Chart



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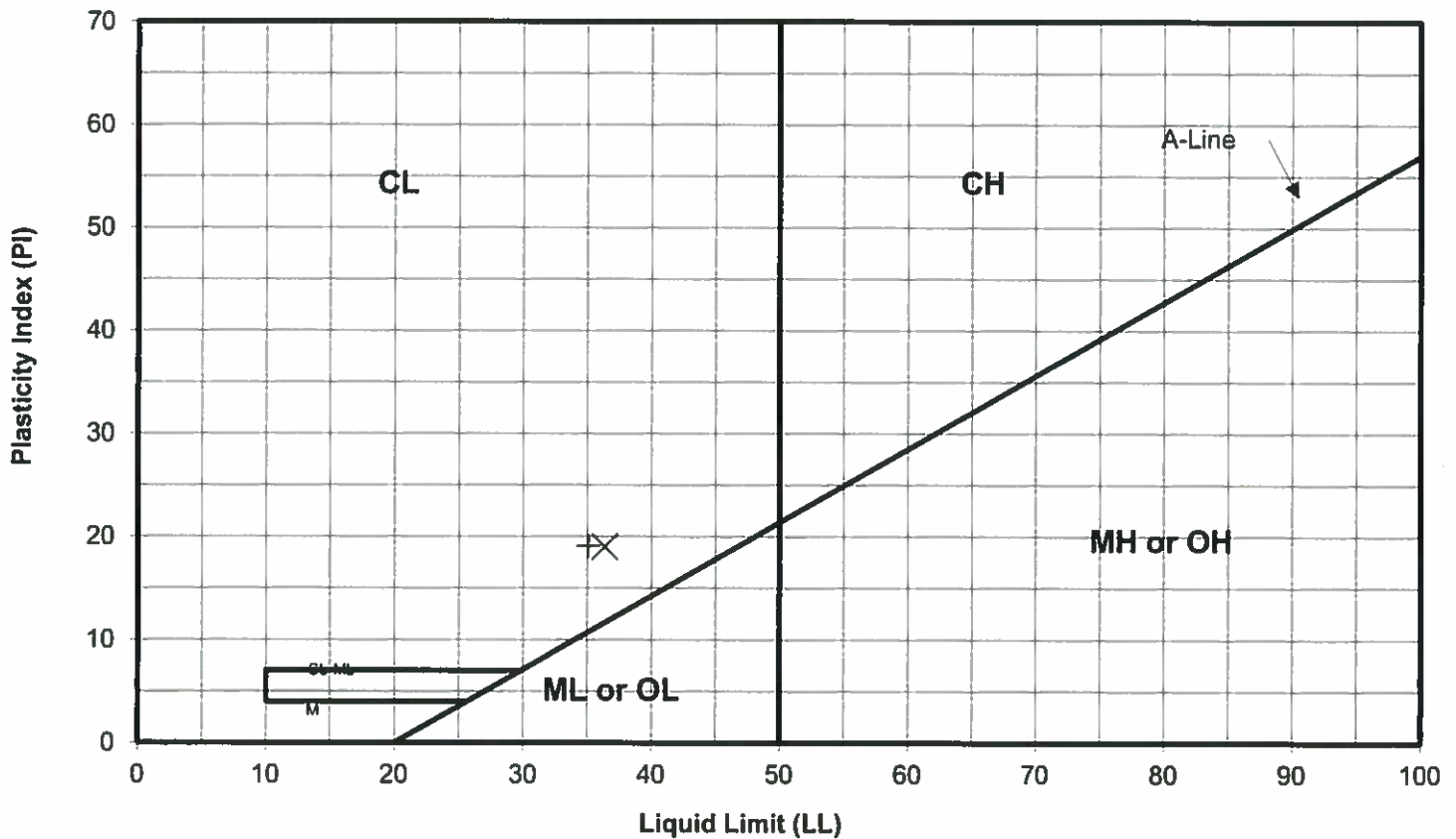
Project Name: Hwy 401 Bowmanville
Project No.: BRM-00605520-A0
Client: Suncor

Figure No.: 12
Date Tested: June 9, 2016
Date Sampled: May 30, 2016

SAMPLE INFORMATION

SAMPLE ID	BH3 SA4	LIQUID LIMIT (LL):	36.4	PLASTIC LIMIT (PL)	17.3	PLASTIC INDEX (PI)	19.0	X
SAMPLE ID	BH3 SA6	LIQUID LIMIT (LL):	35.1	PLASTIC LIMIT (PL)	16.0	PLASTIC INDEX (PI)	19.1	+

Plasticity Chart



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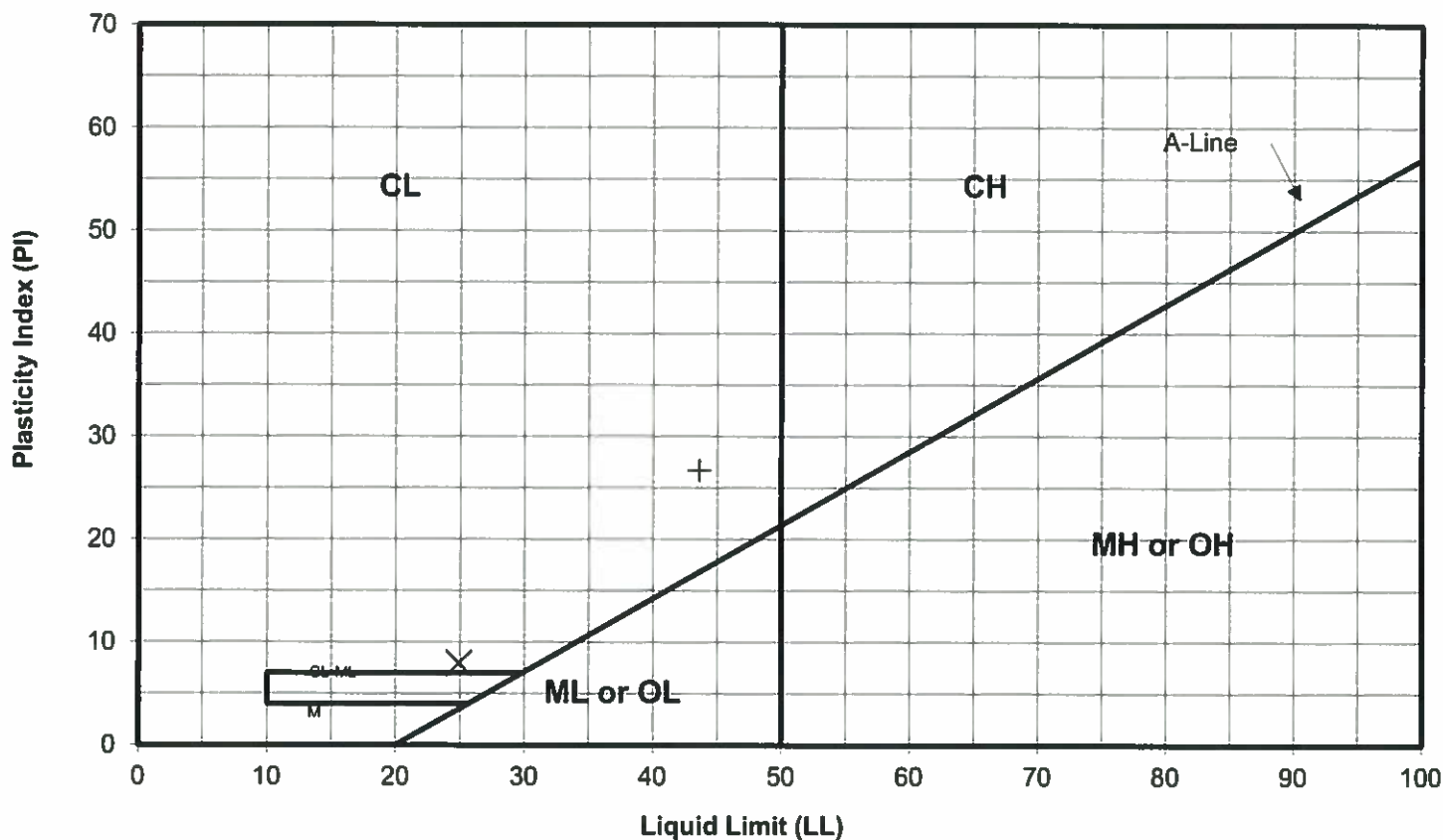
Project Name: Hwy 401 Bowmanville
Project No.: BRM-00605520-A0
Client: Suncor

Figure No.: 13
Date Tested: June 10, 2016
Date Sampled: May 30, 2016

SAMPLE INFORMATION

SAMPLE ID	BH4 SA2	LIQUID LIMIT (LL):	24.9	PLASTIC LIMIT (PL)	16.9	PLASTIC INDEX (PI)	8.0	X
SAMPLE ID	BH4 SA7	LIQUID LIMIT (LL):	43.6	PLASTIC LIMIT (PL)	16.9	PLASTIC INDEX (PI)	26.7	+

Plasticity Chart



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**Appendix D –
Guidelines for Foundation Engineering for Tunneling
Specialty – Tunneling Specialty for Corridor
Encroachment Permit Application**

Guidelines For Foundation Engineering – Tunnelling Specialty For Corridor Encroachment Permit Application

These guidelines specify MTO's minimum requirements for the Foundation Engineering – Tunnelling Specialty component of submissions from proponents of development within the Ministry of Transportation's (MTO) corridor permit control area. The Foundation Engineering – Tunnelling Specialty component of submissions is a requirement for the permit application only and do not cover all the design requirements.

The complexity ratings of Foundations Engineering services are defined in Table 1.

Table 1: Complexity ratings for tunnelling specialty services

Highway Classification	Tunnel Excavation Diameter (ϕ)					
	$\leq 1\text{ m}$		$>1\text{ m} \ \& \ \leq 2\text{ m}$		$>2\text{ m}$	
	Minimum Overburden Cover * (m)					
	$\geq 3\ \phi$ (or 1.5 m whichever is greater)	$< 3\ \phi$ (or 1.5 m whichever is greater)	$\geq 3\ \phi$	$< 3\ \phi$ (or 1.5 m whichever is greater)	$\geq 3\ \phi$	$< 3\ \phi$ (or 1.5 m whichever is greater)
Kings Highway	Low	Medium	Medium	High	High	High
400 Series Freeway	Medium	High	High	High	High	High

*Minimum overburden cover is the vertical distance measured from the lowest ground elevation to the crown of the tunnel.

Foundations Engineering consultants that are registered in the MTO consultant acquisition system (RAQS) at complexity ratings identified in Table 1 are eligible to provide Foundations Engineering services for this project. Alternatively, the proponents may propose a Foundations Engineering consultant that is not registered in RAQS, in which case, the proponent must submit sufficient documentation to demonstrate that the consultant's qualifications meet or exceed the RAQS complexity requirements.

For Engineering Materials Testing and Evaluation, the consultant shall be qualified for Soil and Rock testing of complexity level at least equal to that identified for this project.

Consultant services shall be provided in accordance with the most recent editions of the Canadian Highway Bridge Design Code (CHBDC), and the 'Guideline for Professional Engineers Providing Geotechnical Engineering Services' published by the Professional Engineers of Ontario.

The designated principal contact identified for Foundations Engineering services by MTO shall sign, and where required, seal, all submissions and correspondence that are submitted to MTO.

Services include, but are not restricted to, conducting a site investigation that shall be of sufficient scope to verify design assumptions and to provide the contractor with adequate subsurface information for design and construction planning.

Sufficient subsurface (factual) information is required to determine the vertical and horizontal extent of subsurface materials (including both soil and rock) and their pertinent engineering properties and groundwater conditions.

Subsurface information is usually acquired by advancing boreholes, laboratory testing of soil samples and rock core samples, performing in-situ tests such as standard penetration tests, dynamic cone tests, and piezocone tests (CPTU) and test pits.

Minimum requirements for Subsurface Investigation and Recommendations

A minimum of one borehole shall be advanced at each end of tunnel crossing. The boreholes shall be located outside but within 2 m of the tunnel's excavated footprint.

Spacing between the boreholes shall not exceed 50 m. In case of larger spacing between the boreholes, additional boreholes shall be advanced except where significant traffic disruptions might occur and where consistent conditions are evident.

Boreholes shall be advanced to 3 tunnel diameters (excavated diameters) below invert. If bedrock is encountered earlier, the borehole shall advance to at least 3 m below the invert of tunnel into the bedrock.

The investigations, if required, shall be supplemented with additional and deeper boreholes to verify consistent conditions and existence of boulders within critical foundation zones.

Sampling and testing, consisting of Standard Penetration Test, thin wall tube sample, rock cores, and MTO Field Vane Test where appropriate, shall be conducted to develop a comprehensive subsurface model. Semi-continuous sampling at 0.75m (2.5ft) intervals is required within overburden; whereas, sampling interval of 1.5m (5.0ft) is required below the tunnel invert.

Where encountered, the bedrock-soil interface shall be determined by geological definition and not the by the material properties.

All aspects of implementation of means of subsurface investigations including, but not limited to, planning, licensing, construction, maintenance, abandonment, and reporting, shall be in accordance with Ministry of the Environment Regulation 903 and its amendments (the water well regulation under the OWRA).

Boreholes and piezometer tubes shall be backfilled with a suitable bentonite/cement mixture. Test pits shall be backfilled with suitable material and either re-vegetated or otherwise protected from erosion. Temporary open holes shall be adequately covered.

Holes in roads shall be backfilled as required to prevent future settlement and acceptably patched where pavement surfaces have been damaged. Backfilling requirements shall be described in the Foundation Investigation and Design Report.

Where encountered, artesian groundwater conditions shall be sealed. Details of the artesian condition and the sealing operation shall be included in the Foundation Investigation Report.

Fieldwork shall be carried out in accordance with the Occupational Health and Safety Act.

Traffic protection in accordance with MTO requirements shall be provided during the course of any field investigations. However, where significant traffic disruptions might occur, boreholes may be relocated or numbers reduced with MTO's approval.

The locations and ground surface elevations of all boreholes, test pits and soundings shall be surveyed and referred to fixed reference points and data. Locations are to be identified by co-ordinates (Northing and Easting). The vertical accuracy of survey readings shall be within 0.1m; whereas, horizontal accuracy shall be within 0.5m.

Minimum Laboratory Testing Requirements:

Laboratory testing shall consist of routine testing of 25% of samples. One routine lab test is defined as natural water content plus Atterberg Limit plus grain size distribution tests. Complex laboratory testing is defined by all other tests including compressive strength, shear strength, consolidation, permeability and triaxial testing. Laboratory testing requirements shall be supplemented with additional routine and complex tests if required to verify strata boundaries and properties and behaviour of critical subsurface zones.

Borehole Log Preparation and Foundation Drawing:

Borehole log sheets, figures and drawings shall be prepared in accordance with MTO standards. The Foundation Drawing shall consist of a plan showing the locations of all borings, test pits and soundings and various stratigraphical longitudinal profiles and stratigraphical cross-sections at each tunnel structure foundation element and groundwater levels.

Minimum Requirements for the Foundation Investigation and Design Report:

A Foundation Investigation and Design Report shall consist of the factual subsurface information (including the field and laboratory test information) and the recommendations required for foundation design.

The report shall be signed and sealed by two professional engineers, registered with the Professional Engineers of Ontario, representing the consulting firm; one of them shall be the firm's designated principal contact for MTO's Foundations Engineering projects.

- The Foundation Investigation component of the report shall contain:
- Site Description - including topography, vegetation, drainage, existing land use, and structures.
- Investigation Procedures - including site investigation and lab testing procedures.
- Description of Subsurface Conditions - including soil, boulders, rock and groundwater conditions.
- Miscellaneous Section - that identifies the name of the drilling company, the laboratory where testing was performed, the persons who carried out the field supervision, and those who wrote and reviewed the report.

The Foundation Design component of the report shall present discussion and recommendations for design. The consultant shall analyse field data and test results and make comprehensive and practical recommendations pertaining to temporary, interim and permanent conditions at the Project.

The consultant shall identify and evaluate all reasonable and appropriate alternatives for the proposed tunnel crossing. Alternatives may include, but not limited to, jack & bore, pipe jacking using TBM, pipe ramming, micro-tunnelling (if economically feasible), utility tunnelling using TBM (two pass system), Horizontal Directional Drilling (HDD) and cut and cover methods.

The consultant shall identify and present overview assessments of the advantages, disadvantages, costs and risks/consequences of alternative tunnelling methods in a table. The report should conclude a preferred alternative from foundation engineering and cost effectiveness perspective.

In the development and design of the preferred alternative, the Consultant shall, as applicable, address:

- impacts on the land use and property, traffic and transportation, and environment,
- length and diameter constraints
- control of face stability
- capability of boulder excavation
- evaluation of temporary and permanent support
- alignment control
- estimated settlements and heave and management of these deformations
- special access and egress requirements for TBM's and other similar equipment such as those used for the Jack & Bore method including recommendations for vertical shafts and jacking pits;
- shored and un-shored alternatives for open-cut excavation;
- groundwater control & dewatering;
- the long-term stability of the tunnel;

- relative costs; and
- traffic management and contractor access for each alternative.

If borehole logs available from previous projects are included to meet the requirements of field investigations then the accuracy of subsurface information from these boreholes remains the responsibility of consultant except in situations where MTO specify the use of previous boreholes. Borehole logs from previous studies that are appended to the report shall be reformatted to meet the MTO's requirements.

The final foundation recommendations shall detail the geometric, material and strength properties of the new tunnel crossing plus the liner, bedding and backfill requirements, and slope and embankment restoration requirements. The invert elevation should be assessed in view of the subsurface conditions and the anticipated open face stability control.

The consultant is responsible for developing contract documents sufficient to implement the design. This typically includes:

- Contract specifications for materials and specialized construction activities, and
- Recommendations for methods of overcoming anticipated construction problems, in particular, those relating to dewatering, boulder excavation, alignment control and the stability of excavations and embankments. .

The consultant shall develop a detailed instrumentation and monitoring program that meets the requirements of these guidelines. (see Appendix for typical settlement monitoring guidelines).

The consultant is responsible for preparing Traffic Control Plans and to obtain approvals and an Encroachment Permit from the Ministry, which are required for lane closures necessary to install the settlement monitoring points.

The tunnelling consultant shall ensure that the foundations engineering component of the project is adequately reflected in the design drawings, specifications and related contract documents.

Written confirmation is required from the Proponent and the tunnelling consultant that the design package submitted to MTO have been reviewed by the tunnelling consultant and that all recommendations have been satisfactorily incorporated in the contract package.

APPENDIX: SETTLEMENT MONITORING GUIDELINES - TUNNELING

The purpose of settlement monitoring is to prevent damage to existing utilities and highway structures along the tunnel alignment. Ground settlement include settlement due to lost ground and dewatering/drainage.

Instrumentation Arrays

All measurement points shall be installed and surveyed before the start of excavation to establish benchmarks/baseline.

Surface Monitoring Points

Surface monitoring points will be installed to cover the whole length of the tunnel with in the right of way under the jurisdiction of MTO (Figure 1).

Surface monitoring points will be located at not greater than 5m intervals along the tunnel alignment. The surface monitoring will be identified using paint marks on the pavement. Surface monitoring points installed on the unpaved right of way shall be founded below frost penetration depths. The interval and/or marking of the points should be changed with MTO's approval where traffic disruptions might occur.

The final instrumentation plan should be finalised when Contractor's proposed construction method is available.

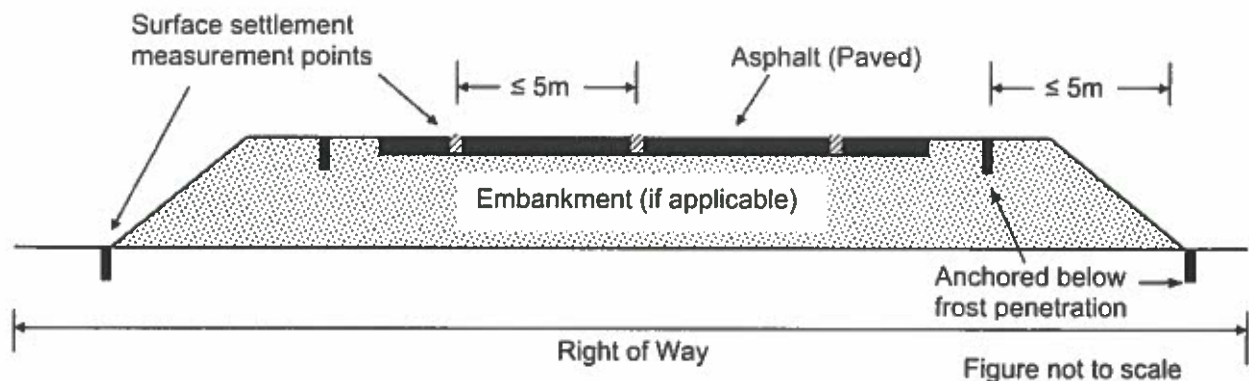


Figure 1: Typical configuration of surface settlement monitoring points along the tunnel alignment.

Condition Survey

A condition survey for the pavement will be carried out prior to commencement of construction and documented for the purpose of requirement of restoration. The condition survey shall document visible flaws such as cracks, distortions and deviations, heaves, and depressions. This surface survey will be completed during the installation of the monitors and again once the tunnel has been completed.

Reading Frequency

An average of at least two readings shall be taken to establish the initial conditions.

The reading and collection of data from the surface monitoring points shall be read and recorded by the Contractor during the construction period and after construction for period of at least 2 weeks provided that further settlement has stopped.

A minimum of three (3) sets of reading be taken daily, provided that movements are within anticipated limits. Otherwise, the frequencies should increase according to a pre-planned interval.

Monitoring of movements is required during work stoppages, such as during non-operation period (off-shifts) or weekends. A minimum of three (3) sets of readings should be taken daily.

Measurements of the monitoring points shall be reported promptly to MTO for review.

Data Collection and Data Transfer

A procedure is required to be established in consultation with MTO so that the monitoring data and the interpreted data will reach all parties as soon as necessary. The contract administrator/consultant and the Contractor should interpret monitoring data as needed for the purpose of on-going construction. The Foundation Engineer should be contacted for technical support to the prime Consultant in the interpretation of ground movements and review of the Contractor's response when Review and Alert Levels are reached.

Criteria for Assessment

The acceptable surface settlement (or heave) will be according to criteria as specified below.

Baseline Reading – A baseline reading of the instrumentation shall be taken prior to commencement of the work. An average of at least two initial readings shall be recorded as baseline reading.

Review Level – A maximum value of 10 mm relative to the baseline readings is suggested for this project. If this level is reached, the method, rate or sequence of construction, or ground stabilization measures should be reviewed or modified to mitigate further ground displacements.

Alert Level – A maximum value of 15mm relative to the baseline readings is suggested for this project. If this level is reached, the Contractor shall cease construction operations and to execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

Review of Contractor's Proposed Method

MTO, the Proponent's prime consultant and Foundation Engineer should review the Contractor's proposed method of construction. The proposed method should include a description of the potential loss of ground, and calculation of the maximum settlement in relation to the Contractor's procedure and equipment, alternative/remedial measures when review level of measurement is reached; and contingency/remedial measures when alert level of measurement is reached.

Contractor's Responsibility For Restoration and Warranty Provision

In addition to the monitoring program to assess the adequacy of the construction method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving) should movements or other surface distress occur, and provide a reasonable warranty period acceptable to MTO. Remedial measures shall be approved by MTO; however, MTO maintains the right to perform the maintenance at the proponent's expense.

Construction Monitoring

The Proponent shall retain a qualified Geotechnical Consultant to supervise the installation of surface settlement points on site and to provide direction, technical input and field inspection on this project.

Appendix E – OPSS



**CONSTRUCTION SPECIFICATION FOR
PIPELINE AND UTILITY INSTALLATION IN SOIL
BY HORIZONTAL DIRECTIONAL DRILLING**

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450-A	Commentary
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450.01	SCOPE
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This specification covers the requirements for the installation of underground pipelines, conduits, cable, or ducts using the trenchless technology known as horizontal directional drilling.

450.01.01 Significance and Use of Appendices

This specification has been developed for use in provincial- and municipal-oriented Contracts. The administration, testing, and payment policies, procedures, and practices reflected in this specification correspond to those used by many municipalities and the Ontario Ministry of Transportation.

Use of this specification or any other specification shall be according to the Contract Documents.

450.01.02 Appendices Significance and Use

Appendices are not for use in provincial contracts as they are developed for municipal use, and then, only when invoked by the Owner.

Appendices are developed for the Owner's use only.

Inclusion of an appendix as part of the Contract Documents is solely at the discretion of the Owner. Appendices are not a mandatory part of this specification and only become part of the Contract Documents as the Owner invokes them.

Invoking a particular appendix does not obligate an Owner to use all available appendices. Only invoked appendices form part of the Contract Documents.

The decision to use any appendix is determined by an Owner after considering their contract requirements and their administrative, payment, and testing procedures, policies, and practices. Depending on these considerations, an Owner may not wish to invoke some or any of the available appendices.

450.02 REFERENCES

When the Contract Documents indicate that provincial-oriented specifications are to be used and there is a provincial-oriented specification of the same number as those listed below, references within this specification to an OPSS shall be deemed to mean OPSS.PROV, unless use of a municipal-oriented specification is specified in the Contract Documents. When there is not a corresponding provincial-oriented specification, the references below shall be considered to be to the OPSS listed, unless use of a municipal-oriented specification is specified in the Contract Documents.

When the Contract Documents indicate that municipal-oriented specifications are to be used and there is a municipal-oriented specification of the same number as those listed below, references within this specification to an OPSS shall be deemed to mean OPSS.MUNI, unless use of a provincial-oriented specification is specified in the Contract Documents. When there is not a corresponding municipal-oriented specification, the references below shall be considered to be the OPSS listed, unless use of a provincial-oriented specification is specified in the Contract Documents.

This specification refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, Construction

OPSS 401	Trenching, Backfilling, and Compacting
OPSS 404	Support Systems
OPSS 409	Closed-Circuit Television Inspection of Pipelines
OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 539	Temporary Protection Systems

450.03 DEFINITIONS

For the purpose of this specification, the following definitions apply:

Active Interference means electrical interference created by magnetic fields and radio frequencies such as power lines.

Backreamer means a cutting head designed for the soil conditions and is attached to the leading end of a drill string to enlarge the pilot bore during a pullback operation to enable installation of the product.

Bore Path means a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

Drilling Fluid Fracture or Frac Out means a condition when the drilling fluid's pressure in the bore is sufficient to overcome the in situ vertical confining stress, thereby fracturing the soil and allowing the drilling fluids to migrate to the surface at an unplanned location.

Drill Fluid Control Points means locations along the bore path when control points are constructed to manage drill fluids.

Drilling Fluids means a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

Entry Point means the location or excavation from which the bore is initiated for the installation of the product.

Exit Point means the location or excavation to which the bore is directed for the installation of the product.

Guidance System means an electronic system capable of indicating the position, depth, and orientation of the drill head during the drilling process.

Horizontal Directional Drilling (HDD) means directional boring or guided horizontal boring.

Inadvertent Returns means the flow of unexpected fluids encountered during the drilling process.

Loss of Circulation means the discontinuation of the flow of slurry in the bore back to the entry or exit point or at drill fluid control points.

Multi Product Installation means two or more products installed in the same bore path. The products may or may not have the same diameters.

Passive Interference means electrical interference created by adjacent structures, buried metal, salt water, and minerals in the soil.

Pilot Bore means the initial bore to set horizontal and vertical alignment between the connecting points.

Product means pipelines, conduits, cable, or ducts.

Pullback means that part of the HDD method in which the drill string is pulled back through the bore path to the entry point, usually installing the product at the same time.

Reamer means a cutting tool specifically designed for in situ ground conditions. It is attached to the leading end of a drill string to enlarge the pilot bore prior to or during a pullback operation to enable installation of the product, and deliver drill fluids into the bore and mix bore cuttings to form flowable slurry.

Reaming means a process for pulling or pushing a tool attached to the end of the drill string through the bore path to enlarge the bore and mix the cuttings with the drilling fluid. This could include multiple passes prior to product pullback.

Rock means natural beds or massive fragments of the hard, stable, cemented part of the earth's crust that are igneous, metamorphic, or sedimentary in origin, that may or may not be weathered and includes boulders having a volume of 0.5 m³ or greater.

Single Product Installation means a single product installed into a bore path. The product may or may not have a tracer wire attached to it.

Slurry means a mixture of soil cuttings and drilling fluid.

Soil means all soils, except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials.

Staging Area means an area set aside for the Contractor's drilling and pipe assembly operations.

Strike Alert means a system, audio or visual or both, that is intended to alert and protect the operator in the case of inadvertently drilling into an electrical Utility cable.

450.04 DESIGN AND SUBMISSION REQUIREMENTS

450.04.01 Submission Requirements

- a) A work plan outlining the procedure and schedule to be used to execute the work.
- b) A list of personnel, including backup personnel, and their qualifications and experience.
- c) A traffic control plan.
- d) A drilling fluid management plan, including source of fresh water and necessary permits or approvals; type of drilling fluids and potential additives and their Material Safety Data Sheets (MSDS); method of drilling fluid containment; method of recycling drilling fluid, as applicable; method of transporting drilling fluids off site; disposal of excess drill fluids according to the Contract Documents; and method to continually monitor fluid properties and pressure throughout the course of drilling and pullback operations to anticipate drilling fluid related problems before they occur; and potential environmental impacts and emergency procedures and associated contingency plans.
- e) A health and safety plan including the company safety manual, emergency procedures, and a list of emergency personnel contact information.
- f) A drilling plan indicating the proposed type and size of directional drilling equipment; location and dimensions of staging areas; diameter of pilot hole and number and size of back reamers; guidance system; field determined elevations of the surface topography along the bore path; field determined elevations and locations of all existing Utilities within 1.5 m of the bore path; rod-by-rod profile data along the bore path; location of drill fluid control points; identification of active and passive interference along with appropriate compensation measures; method to continuously monitor and record product pipe tensile installation forces and down bore fluid pressures; pipe protection procedures; pipe gripping procedures; and temporary protection systems.
- g) A contingency plan in conformance with the Contract Documents, including identifying potential environmental impacts and emergency containment and clean-up procedures.
- h) Work permits required under the authorities having jurisdiction necessary to complete the work.

450.05 MATERIALS

450.05.01 Drilling Fluids

Drilling fluids shall be appropriately mixed for the anticipated in situ ground conditions. Only bentonite and drilling equipment manufacturer-approved polymers shall be permitted for use as drilling fluids. All additives used shall be chemically inert, biodegradable, and non-toxic. No petroleum-based or detergent additives shall be permitted.

Fluid properties shall be continually monitored throughout the course of drilling and pullback operations to ensure that the drill fluid properties remain appropriate for the in situ ground conditions.

450.05.02 Pipe Materials

Pipe and fitting type, class, and size shall be as specified in the Contract Documents.

450.05.03 Tracer Wire

Type and number of tracer wires used shall be as specified in the Contract Documents.

450.06 EQUIPMENT

450.06.01 Directional Drilling Equipment

450.06.01.01 General

The directional drilling equipment shall consist of a directional drill rig and a fluid mixing and delivery system with sufficient capacity to complete the product installation.

The drill rig and all associated equipment shall be in acceptable mechanical working order.

All drill operations and equipment shall be controlled by competent, experienced, and trained personnel.

450.06.01.02 Drilling Rig

The directional drilling rig shall:

- a) consist of a hydraulically powered boring system to rotate, push, and pull the drill rod into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head.
- b) have drill rod that is suitable for both the drill and the product pipe installation.
- c) contain a drill head that is steerable, equipped with the necessary cutting surfaces and fluid jets, and be suitable for the anticipated ground conditions.
- d) have adequate reamers and down-bore tooling equipped with the necessary cutting surfaces and fluid jets to facilitate the product installation and be suitable for the anticipated ground conditions.
- e) support a guidance system to accurately guide boring operations.
- f) be anchored to withstand the pushing and pulling forces required to complete the product installation.
- g) contain an active strike alert system and be properly grounded during all operations.

450.06.01.03 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any active and passive interference that may interfere with the guidance of the system.

The type of guidance system shall be suitable for the design bore path and project specifications. The Contractor shall verify calibration of the guidance system daily prior to use.

450.06.01.04 Drill Fluid Mixing and Delivery System

The drill fluid mixing system shall be of sufficient size to thoroughly and uniformly mix the required drilling fluid.

The delivery system and reamers shall have sufficient flow and capacity to ensure that the slurry volumes are adequate for the length and diameter of the final bore and in situ ground conditions.

450.07 CONSTRUCTION

450.07.01 General

The Contract Administrator shall be notified at least 48 hours in advance of commencement of the drilling operations. Operations shall not begin until proper preparations are made.

When strike alerts are provided on a drilling rig, they shall be activated during drilling and maintained at all times.

The location of all Utilities in the work area shall be identified and located prior to the commencement of the drilling operations. If prior to commencement of drilling operations, a Utility is found to exist that would conflict with the installation of the pipe, the Contractor shall notify the Contract Administrator immediately.

450.07.02 Site Preparation

The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for HDD operations are to be made. All activities shall be confined to designated work areas.

450.07.03 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 491.

Minimum horizontal and vertical clearances to existing facilities shall be maintained as specified in the Contract Documents. Clearances shall be measured from the nearest edge of the largest reamer to the nearest edge of the facility that is parallel to or crossed by the pipeline or Utility being constructed.

Existing underground facilities shall be exposed to verify their horizontal and vertical locations when the bore path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods. The number of exposures required to monitor work progress shall be as specified in the Contract Documents.

Should it become necessary for the Contractor to excavate or disturb existing Utilities to retrieve lost boring equipment, the Contractor shall be responsible for obtaining all relevant approvals.

450.07.04 Transporting, Unloading, Storing, and Handling Materials

Manufacturer's recommendations for transporting, unloading, storing, and handling of materials shall be followed.

450.07.05 Trenching, Backfilling, and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the bore shall be according to OPSS 401.

450.07.06 Support Systems

Support systems shall be according to OPSS 404.

450.07.07 Dewatering

Dewatering shall be in accordance with OPSS 517 or as specified in the Contract Documents.

450.07.08 Temporary Protection Systems

The construction of all temporary protection systems shall be according to OPSS 539. Protection shall be provided when the stability, safety, or function of an existing roadway, railway, watercourse, other works, or proposed works may be impaired. Protection may include sheathing, shoring, and piles necessary to prevent damage to works or proposed works.

450.07.09 Drilling Fluid Management

The Contractor shall employ a containment, collection, and disposal method to manage drilling fluids and to mitigate the development of inadvertent returns. The Contractor shall manage the clean-up and dispose of drilling fluids in accordance with the drilling fluid management plan.

450.07.10 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances specified in the Contract Documents. Drill rod and product bend radius shall be taken into consideration when completing the pilot bore.

In the event the pilot bore does deviate, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback and re-drill from the location along the bore path prior to the deviation. In the event that a drilling fluid fracture, inadvertent returns, or loss of circulation occurs during pilot bore drilling operations, the Contract Administrator shall be advised of the event and of the action taken.

If a drill hole beneath a road shall be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence.

450.07.11 Reaming

The bore shall be reamed to the appropriate size with tooling that is adequate for the in situ ground conditions and the product that is to be installed.

The final staged ream shall not exceed 1.5 times the product pipe largest outside diameter.

The drilling mud in the annular region shall not be removed after installation, but permitted to solidify and provide support for the pipe and surrounding soil.

450.07.12 Product Installation

450.07.12.01 General

The product shall be jointed and installed according to manufacturer's recommendations and shall be protected from damage in the staging area and during pullback.

The minimum allowable bending radius for the product shall not be exceeded during installation at the entry point, exit point, or any other location along the bore path.

The product shall be allowed to recover prior to the connection to a new or existing facility is made. Product recovery time shall be in accordance with the manufacturer's recommendations.

Tracer wire shall be supplied and installed along with the product, as specified in the Contract Documents.

450.07.12.02 Pullback

After completion of reaming the bore to the required diameter, the product shall be pulled into the bore path as soon as possible.

The pullback operation shall be a continuous operation, if possible, until the product pipe is installed.

The product pipe gripping method shall allow the full tensile rating of the product to be developed.

A swivel of sufficient capacity shall be used between the reamer and the product being installed. The swivel shall prevent rotational forces from the reamer being transferred to the product.

When specified in the Contract Documents, a pipe load measuring device shall be used to ensure that the manufacturer's recommended pullback force is not exceeded. (i.e., gauges, down-hole devices, weak links).

When specified in the Contract Documents, a weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product shall be inspected for damage, when visible, at excavation pits and when it exits the bore.

Any damage shall be repaired to the satisfaction of the Contract Administrator.

450.07.13 Product Testing

When required, product testing shall be as specified in the Contract Documents.

450.07.14 Record Keeping

Verification record requirements of the alignment and depth of the installed product shall be as specified in the Contract Documents. A copy of the verification records shall be given to the Contract Administrator at the completion of the HDD operations.

450.07.15 Closed Circuit Television (CCTV) Inspection

When required by the Contract Documents, a CCTV inspection shall be according to OPSS 409.

450.07.16 Site Restoration

When required, site restoration shall be according to OPSS 492.

450.07.17 Management of Excess Material

Management of excess material shall be according to the Contract Documents.

450.09 MEASUREMENT FOR PAYMENT

450.09.01 Actual Measurement

450.09.01.01 Product Installation

Measurement for a product installation shall be in metres along the centreline of the useable product between final connection points or work completed. No additional payment shall be made for end pieces to achieve the design elevation.

450.09.02 Plan Quantity Measurement

When measurement is by Plan Quantity, such measurement shall be based on the units shown in the clauses under Actual Measurement.

450.10 BASIS OF PAYMENT

450.10.01 Product Installation by HDD, "*diameter of product, product material, use of product,*" - Item

Payment at the Contract price for the above tender item shall be full compensation for all labour, Equipment, and Material to do the work.

**Appendix 450-A, November 2012
FOR USE WHILE DESIGNING MUNICIPAL CONTRACTS**

Note: This is a non-mandatory Commentary Appendix intended to provide information to a designer, during the design stage of a contract, on the use of the OPS specification in a municipal contract. This appendix does not form part of the standard specification. Actions and considerations discussed in this appendix are for information purposes only and do not supersede an Owner's design decisions and methodology.

Designer Action/Considerations

The specification was written to encompass the majority of HDD drilling operations for small and medium sized projects with diameters generally up to 914 mm and drill lengths of less than 1,000 m. The basic design considerations should always include: minimum cover to prevent inadvertent drill fluid frac out releases; geology of the area, including future river "scour" or meander projections; site logistics; connection requirements; and site-specific issues (e.g., river crossings, wet lands, and archaeological sites).

Geotechnical and site condition information are required for a successful project design, and to ensure that the Contractor has the proper equipment and materials (i.e., drilling fluid mixtures, methods, or equipment), and pipe design.

The principal safety concern in HDD is ensuring that the drilling equipment does not contact existing underground infrastructure. The risk of contacting other Utilities can be mitigated by knowing the precise locations of all underground Utilities in close proximity to the HDD bore path. Detailed knowledge of all subsurface Utility locations is a critical component of a directional drilling project, and this information should be included in the Tender Documents.

Throughout the commentary, the designer is provided with guidance on the consideration of Quality Assurance and Quality Control (QA/QC) techniques. However, it should be noted that evolving technology and techniques for improved QA/QC are in development and the designer should refer to trade publications to identify the latest available methods. In all cases, the designer should specify the quality assurance acceptance criteria to be used for each specific project.

Subject to the scope of operations, the designer may wish to specify in the Contract Documents a more detailed work plan prior to the commencement of work, particularly for multiple pipe installations, multiple day projects, congested work areas, or environmentally sensitive sites. (450.04)

The designer should give careful consideration, in consultation with the pipe manufacturer, to ensure the installed pipe is suitable to resist all installation and long-term in-service loads, the design shall specify the minimum pipe and fitting type, class, size, maximum bend radius, and safe tensile load. (450.05.02)

The designer should specify the type and number of tracer wires. (450.05.03)

The designer should specify the following elements in the Contract Documents: the minimum horizontal and vertical clearances to existing facilities; and the number of exposures required to monitor the work progress. (450.07.03)

The designer should specify the trenching, backfilling, and compacting requirements for entry and exit points or other locations along the bore, if different than the requirements in OPSS 401. (450.07.05)

The designer may consider special provisions for backfilling and compacting, including the consideration of unshrinkable backfill to ensure proper compaction in critical locations. (450.07.05)

The designer should specify the support systems requirements, if different than the requirements in OPSS 404. (450.07.06)

Appendix 450-A

The designer should specify the dewatering requirements, if different than the requirements in OPSS 517. (450.07.07)

The designer should provide the necessary grade, alignment, and tolerances for the product installation in the Contract Documents. (450.07.10)

The designer may consider a lower reaming diameter than that specified if the ground conditions are suitable. The designer should understand that multiple passes of the reaming operation can be expected and is to be included in the unit cost for the product installation. (450.07.11)

The designer should review product-jointing specifications as provided by manufacturers. Experienced personnel with jointing accreditation may be added as a requirement of the Contract Documents depending on the type of installation. For fusible pipe products, the pipe should be completely jointed prior to the pull back operation to avoid delays during installation. All pipe jointing shall be to manufacturer specifications. (450.07.12.01)

The designer should specify the supply and installation of the tracer wire with the product. (450.07.12.01)

When required, the designer should specify the use of a pipe load measuring device to ensure that the manufacturer's recommended pullback force is not exceeded. (450.07.12.02)

For certain product installations, the designer may wish to consider the requirement of a weak link or breakaway connector or pull load measuring system to prevent excess pulling force from damaging the product. (450.07.12.02)

The designer may consider specifying physical product testing through the use of product coupons from the exit pit. In addition, in situ pressure or vacuum tests can be used to ensure the integrity of the product installation. (450.07.13)

The designer should specify the method of verifying the product installation location. The designer may consider the use of the reporting information available from the drill rig, daylighting, installation of tracer wire with the product, or the use of acoustic/magnetic locating equipment. The designer should consider specifying the required maintenance, submission of a daily drill records, drilling fluid pressures, records of any problems encountered, along with alignment and depth of bore. (450.07.14)

The tender item description for product installation by HDD shall include reference to one or more of the attributes shown (i.e., diameter of product, product material, use of product, to be complete). (450.10.01)

The designer's careful preparation of the project should greatly assist in the success of the installation. However, there may always be a risk of encountering unexpected problems that may require a fair resolution for payment. It is recommended that the designer consider a process regarding payment for failed attempts for inclusion in the Contract Documents. (450.10)

The designer should ensure that the General Conditions of Contract and the 100 Series General Specifications are included in the Contract Documents.

Related Ontario Provincial Standard Drawings

No information provided here.