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FOUNDATION INVESTIGATION AND DESIGN REPORT

Culvert Replacement At Station 18+515 Highway 400 Northbound Rehabilitation Highway 11 to Highway 93 Simcoe County, Ontario, GWP 2179-10-00

Submitted to:

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REPORT



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**FOUNDATION REPORT - TRENCHLESS CULVERT
INSTALLATION, HIGHWAY 400 NBL REHABILITATION**

PART A

**FOUNDATION INVESTIGATION REPORT
CULVERT REPLACEMENT AT STATION 18+515
HIGHWAY 400 NORTHBOUND REHABILITATION
HIGHWAY 11 TO HIGHWAY 93
SIMCOE COUNTY, ONTARIO, G.W.P. 2039-06-00**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services in support of the Highway 400 northbound rehabilitation from Highway 11 to Highway 93 in Simcoe County, Ontario.

The terms of reference and scope of work for the foundation investigation are outlined in MTO's Request for Proposal (RFP) dated May 2008; in Section 6.8 of MH's *Technical Proposal* for this assignment and in Golder's scope change letter of May 10, 2011.

This report provides factual data on the subsurface conditions encountered at the site (Highway 400 Northbound, Station 18+515) where a new culvert will be installed to replace the existing skewed corrugated steel pipe (CSP) culvert located at Station 18+508.

2.0 SITE DESCRIPTION

The site is located at the Highway 400 and Highway 11 split at Station 18+515 on Highway 400 Northbound. Highway 400 NBL in this area is a two lane freeway that rises up on an embankment and crosses above the Highway 11 freeway.

The topography across the site adjacent to the Highway 400 and Highway 11 split slopes gently to the west towards Little Lake. Vegetation within the right of way is sparse consisting of grass and small shrubs with densely treed areas further beyond. The Highway 400 NBL embankment is about 3.5 m high and its side slope geometry is approximately 2 horizontal to 1 vertical (2H:1V). The ground surface at the embankment toe varies from approximately Elevation 230.5 m to 231.5 m, referenced to Geodetic datum.

There is an existing skewed CSP culvert located under the embankment at approximately Station 18+508 that facilitates drainage of the Hwy 11/Hwy 400 median to the east property line.

3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out on December 20 and 21, 2011, and consisted of drilling and sampling a total of three (3) boreholes to depths ranging from 11.1 m to 15.8 m below ground surface. The boreholes were numbered 11-C1-01, 11-C1-02 and 11-C1-03 and their locations are shown on Drawing 1.

The field investigation was carried out using a track mounted D50 drill rig supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. The boreholes were advanced through the overburden using 108 mm inside diameter (I.D.) hollow-stem augers. Soil samples were obtained at intervals of depth of 0.75 m and 1.5 m, using a 50 mm outside diameter split-spoon sampler driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedures, as specified in ASTM D1586 (Standard Test Method for Standard Penetration Test).

In addition to the testing outlined above, Dynamic Cone Penetration Tests (DCPT) were conducted in Borehole 11-C1-01. This test consists of continuously driving into undisturbed ground a 50 mm diameter cone (60° vertex angle) attached to a drill rod, with a driving energy of 475 J per blow (63.5 kg hammer dropping freely



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a vertical distance of 0.76 m). The number of blows for each 300 mm of penetration is recorded and this provides an indication of the relative changes in the soil density/consistency with depth.

Groundwater conditions were observed in the open boreholes during and immediately following the drilling operations. All boreholes were backfilled to ground surface using bentonite pellets in accordance with Ontario Regulation 903 (as amended).

The field work was supervised on a full-time basis by a member of Golder's staff who located the boreholes in the field, directed the drilling, sampling and in situ testing operations, and logged the boreholes. At this site the embankment slopes are relatively steep and it was necessary to undertake the field investigations with minimal traffic disruptions. Therefore, the borehole locations were selected to be as close as feasible to the desired location while allowing for safe operation of the drill rig and minimal traffic disruptions.

The recovered soil samples were subjected to Visual Identification (VI) and select samples were also subjected to a laboratory testing programme consisting of natural moisture content and grain size distribution analyses in accordance with MTO and/or ASTM Standards as appropriate. The results of this testing program are shown on the Record of Borehole sheets in Appendix A and the laboratory figures in Appendix B.

The borehole locations were staked in the field by Golder personnel relative to the on-site features shown on the digital terrain model provided by MH. The ground surface elevations at the borehole locations were also determined from this digital terrain model. The borehole locations in MTM NAD83 northing and easting coordinates, the ground surface elevations referenced to geodetic datum and the depths drilled, are summarized below.

Culvert Location Station	Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
Hwy. 400 NBL Station 18+515	11-C1-01	4920690.3	292743.7	231.0	15.8 m
	11-C1-02	4920671.2	292762.0	233.8	14.2 m
	11-C1-03	4920650.2	292772.6	230.9	11.1 m

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This section of Highway 400 is located within the physiographic region known as the Simcoe Uplands (Chapman and Putnam 1984). The general topography within the Simcoe Uplands consists of broad, gently rolling till or moraine plains divided by deep valleys. The till within the Uplands is often overlain by glaciofluvial deposits consisting of sandy silt to sand and gravel. These deposits can present a wide range of grain sizes including large boulders, till lenses and silt.

Surficial deposits of glaciolacustrine materials formed by the wave action at the shores of glacial lakes or along glacial melt water streams are also commonly found within the site area overlaying the till. These deposits consist primarily of coarse-grained sediments of fine to medium grained sand or silt and minor clay deposits (Ontario Geological Survey, 1994). Surficial deposits of clayey silt to silty clay are also present adjacent to current and former streams.



4.2 Subsurface Conditions

Reference is made to the Record of Borehole sheets in Appendix A. Details of the encountered subsurface conditions and the results of in-situ and laboratory tests are presented in this appendix and on the "Borehole Locations and Soil Strata" drawing. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions.

The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic section (Drawing 1) are inferred from non-continuous sampling and therefore represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In general, the subsurface soils at this site consist of a surficial layer of topsoil and loose to compact silty sand to sand and silt embankment fill material. These soils are further underlain by very loose to compact sand and silt to silt deposits, a loose surficial layer of sand and very loose to very dense sand to silty sand soils.

4.2.1 Topsoil

A 700 mm thick surficial layer of topsoil was encountered below the existing ground surface in Boreholes 11-C1-01 and 11-C1-03. Topsoil thickness may vary between and beyond the boreholes.

4.2.2 Asphalt

Borehole 11-C1-02 was drilled through the paved shoulder of Highway 400 NBL. An approximately 100 mm thick layer of asphalt was encountered at this location.

4.2.3 Silty Sand to Sand and Silt (Fill)

Fill material ranging in composition from silty sand to sand and silt; trace to some clay, trace to some gravel with occasional cobbles was encountered below the asphalt layer in Borehole 11-C1-02. The fill material is approximately 3.6 m thick and extends to a depth of 3.7 m below ground surface (Elevation 230.1 m).

The measured SPT „N" values within the fill material range from 9 blows to 29 blows per 0.3 m of penetration, indicating a loose to compact relative density.

Two (2) samples of the silty sand to sand and silt fill were subjected to a grain size distribution test and the results are shown on Figure B1 in Appendix B. These results show a grain size distribution consisting of 6 % and 11 % gravel, 39 % and 54 % sand, 23 % and 41 % silt and 12 % and 14 % clay sized particles. The presence of cobbles is also inferred from increased resistance to augering during the drilling operations.

The natural water content measured on two (2) samples of the fill material is 9% and 27 %. The higher moisture content was recorded where occasional topsoil inclusions were found within the fill.



4.2.4 Sand

An approximately 700 mm thick sand layer was encountered below the topsoil in Borehole 11-C1-03. The sand deposit extends to a depth of 1.4 m below ground surface corresponding to Elevation 229.5 m.

One SPT „N“ value measured in the sand layer is 8 blows per 0.3 m of penetration, indicating a loose relative density.

4.2.5 Sand and Silt to Silt

A native granular deposit ranging in composition from sand and silt to sandy silt to silt and containing trace to some clay and trace gravel was encountered in all three boreholes. The sand and silt to silt deposit is 3.0 m to 3.8 m thick, and extends to depths ranging from 4.2 m to 7.5 m below ground surface (Elevations 226.8 m to 226.3 m).

The SPT „N“ values measured within this deposit range from 2 blows to 22 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

Grain size distribution tests were conducted on three (3) samples of the sand and silt portion of this deposit and on two (2) samples of the sandy silt to silt portion of this deposit. The results are shown on Figures B2 and B3, respectively, in Appendix B. These results show a grain size distribution consisting of 0 % to 4 % gravel, 10 % to 59 % sand, 35 % to 82 % silt and 2 % to 10 % clay sized particles.

The natural water content measured on seven (7) samples of this deposit ranges from about 18% to 25 %.

4.2.6 Sand to Silty Sand

A granular deposit consisting of sand to silty sand, trace to some silt, trace clay, trace to some gravel was encountered in all three boreholes extending to borehole termination depths ranging from 11.1 m to 14.2 m below ground surface (Elevation 219.8 m to 218.4 m).

The SPT „N“ values measured within this deposit range from 3 blows to 66 blows per 0.3 m of penetration. Based on these values the relative density of the deposit is described as very loose to very dense.

In Borehole 11-C1-01 DCPT tests were performed from 14.2 m to 15.8 m below ground surface corresponding to Elevations 218.4 m to 215.2 m. Based on these results, the subsurface soils below the sand to silty sand are inferred to have a very loose to compact relative density.

Two (2) samples of the sand to silty sand deposit were subjected to a grain size distribution test and the results are shown on Figure B4 in Appendix B. These results show a grain size distribution consisting of 0 % gravel, 66 % and 86 % sand, 9 % and 29 % silt and 5 % clay sized particles.

The natural water content measured on nine (9) samples of this deposit ranges from about 17% to 27 %.



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4.3 Groundwater Conditions

The recorded depths to the groundwater level and corresponding elevations upon completion of drilling are summarized as follows:

Borehole No.	Date	Groundwater Level	
		Depth (m)	Elevation (m)
11-C1-01	December 21, 2011	4.6	226.4 ¹
11-C1-02	December 20, 2011	3.7	230.1 ¹
11-C1-03	December 21, 2011	3.0	227.9 ¹

1. Recorded unstabilized water level.

In Borehole 11-C1-02, hydrostatic uplift was encountered at a depth of 7.6 m when drilling in the sand deposit, suggesting that excess hydrostatic pressure exists in this water bearing and relatively permeable deposit.

The groundwater level elevation at this site has been estimated based on the unstabilized water levels observed during and following completion of drilling, soil moisture conditions, and changes in soil colour from brown to grey. Based on these observations, the estimated groundwater level at this site is approximately 230.3± m. All groundwater observations at this site are short term and the levels are expected to fluctuate seasonally and are expected to rise during wet periods of the year.

5.0 CLOSURE

Mr. Daniel Demmings supervised the drilling, sampling and in situ testing operations, logged the boreholes and processed the recovered soil samples for transport to Golder's laboratory in Whitby for further examination and laboratory testing.

This Foundation Investigation Report was prepared by Ms. T. Veronica Ayetan, P.Eng., a geotechnical engineer, under the technical direction of Mr. Rehman Abdul, P.Eng., a senior geotechnical engineer. Mr. Fintan J. Heffernan, P.Eng., Golder's MTO's Designated Contact for this project conducted an independent quality control review and audit of the report.



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Report Signature Page

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PART B

**FOUNDATION DESIGN REPORT
CULVERT REPLACEMENT AT STATION 18+515
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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report presents interpretation of the geotechnical data in the factual report and provides geotechnical design recommendations for the installation of the new culvert. The discussion and recommendations presented in this report are based on our understanding of the project and our interpretation of the factual data obtained from the subsurface investigations.

Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project, and for which special provisions or operational constraints may be required in the Contract Documents. Those requiring information on these aspects of construction should make their own interpretation of the factual information provided, as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

We understand that a new culvert will be installed below the existing Highway 400 NBL and its widened embankment footprint at approximately Station 18+515 to replace an existing skewed corrugated steel pipe (CSP) culvert located under Highway 400 NBL at about Station 18+508. The new culvert will be 900 mm in diameter and its length will be approximately 42 m. The design inlet and outlet elevations of the pipe invert are 230.3 m and 229.9 m respectively.

6.2 Installation Methods

We understand that it may be necessary to install the culvert under the Highway 400 NBL by a trenchless method in order to minimize traffic disruptions and ultimately reduce user delay costs during construction and realignment of the Highway 400 NBL. Nevertheless, it is also necessary to consider Open Cut Excavations as an option especially if the construction could be staged to permit the installation to be completed using this technique. Furthermore, trenchless alternatives will also present a greater risk compared to open cut excavations because the alignment passes through granular soils and the groundwater table is located within the zone of tunnelling. Therefore, viable installation methods include:

- Open Cut Excavation;
- Pipe Ramming;
- Pilot Tube Micro Tunnelling (PTMT); and
- Micro Tunnelling.

Each method considered has advantages, disadvantages or limitations and these are discussed further in Sections 6.3 and 6.4. The diameter, length and anticipated subsurface conditions limit the number of trenchless installation techniques that would be economically viable at this site. However, the choice of equipment and the method of tunnelling is the Contractor's responsibility.

Ground behaviour will be, in part, dependent on the installation method adopted and this report provides guidance on the influence of ground behaviour on some possible installation methods. It should not be construed that the Contractor is restricted to the particular methods considered herein, and in the event of



alternative methods, the Contractor must make his own interpretation of the anticipated ground behaviour, based on the factual information provided in Part A, Foundation Investigation Report.

6.3 Open Cut Excavation

Open cut excavation across the active highway requires cutting and removing the existing pavement, trench excavation and excavation sidewall support, pipe installation, trench backfilling and pavement restoration. The open cut method offers the best control of gradient and alignment of the culvert and the least risk of unanticipated damage to the active highway. If the construction cannot be staged to allow uninterrupted traffic flow, the major disadvantages with an open cut installation would be traffic disruption due to lane closures, excavations near the centreline of the highway, pavement reconstruction and the potential for post construction settlement of the backfill materials. The open cut excavation method is feasible at this site and pipe installation should be undertaken in accordance with OPSS 421.

6.3.1 Pipe Bedding

The bedding for the culvert should conform to the requirements of OPSD 802.032 (Rigid Pipe Bedding - Earth Excavation). The subsurface conditions at this site are considered suitable to provide adequate pipe support and therefore Class "B" bedding will suffice. Additional bedding requirements that may be imposed by the pipe supplier must also be followed.

Granular "A" material meeting Ontario Provincial Standard Specification (OPSS) 1010 should be used as pipe bedding. Prior to placing the pipe bedding, any accumulation of water at the base of the excavation should be removed and any soft/loose soils should be subexcavated and replaced with compacted granular fill or pipe bedding material. Placement of the pipe bedding must be done in the dry. Where wet conditions are encountered, clear stone may be used as a bedding material provided that the clear stone is fully enclosed in a Class II non-woven geotextile with a filtration opening size of 90 microns or less.

The bedding and cover material should be placed in 150 mm thick loose lifts and uniformly compacted to at least 95 percent of the materials Standard Proctor Maximum Dry Density (SPMDD) using suitable vibratory compaction equipment.

6.3.2 Trench Backfill

Beyond the shoulder of the highway, the majority of fill and native site soils are generally considered suitable for reuse as trench backfill provided they are free of significant amounts of topsoil, organic material or other deleterious material. The trench backfill material should be placed in maximum 300 mm loose lifts and uniformly compacted to at least 95 percent of SPMDD.

To achieve the specified compaction, soils must neither be too wet nor too dry of their optimum moisture content. Soils that are too wet cannot be used immediately because the material will have to be dried to a moisture content of $\pm 2\%$ of optimum. If the construction operations are time sensitive, the use of imported granular



material may be considered. Soils that are dry of optimum can be used immediately provided that the material is moisture conditioned (i.e. water added) to achieve a moisture content of $\pm 2\%$ of optimum.

Normal post-construction settlement of the compacted backfill equivalent to 1% of the backfill height should be anticipated. The majority of this settlement will take place within about six months following the completion of the backfilling operations. If this post-construction settlement cannot be tolerated (for example below the roadway), it is recommended that the trench be backfilled with Granular "B" Type I compacted to a minimum of 98 percent of the materials Standard Proctor Maximum Dry Density (SPMDD) at a moisture content within $\pm 2\%$ of the optimum value.

6.4 Trenchless Installation Methods

6.4.1 Pipe Options

Installation of a culvert by tunnelling will require installing an over-size steel casing that will accommodate a smaller diameter carrier pipe installed to line and grade within the casing. To accommodate the carrier pipe installation and allow for potential misalignment during casing advance, it is understood that steel casings are typically chosen to be about 1.5 times the diameter of the carrier pipe with the option of upsizing the casing pipe to a larger pipe diameter that may be more readily available. It is envisaged that a 1500 mm diameter casing pipe will be selected for this 900 mm culvert.

The selected pipe must be capable of supporting overburden and highway loads, hydrostatic pressures (if present) and must be able to withstand the installation forces and the pressure from grout used to fill the annulus between the carrier pipe and the casing.

6.4.2 Pipe Ramming

Pipe ramming is a trenchless method that uses a pneumatic tool to hammer up to 1500 mm diameter steel pipes or casings into the ground over distances up to about 60 m. The leading edge of the pipe is almost always open and its shape has to allow a small overcut (to reduce friction between the carrier pipe and soil and improve load conditions on the pipe) to direct the soil into the pipe interior instead of compacting it outside the pipe. Soil/pipe friction reduction is typically achieved with lubrication, and different types of bentonite and/or polymers can be used for this purpose. Depending on the length of the installation the soils inside the pipe can be removed either during or after the installation by augering, compressed air or water jetting.

Pipe ramming is not-steerable; meaning that once the bore has begun there is little control of the line and grade of the installation. Installation accuracy (vertically and horizontally) is usually about $\pm 1\%$ of the length of the bore, but subsurface obstructions or improperly aligned pipes may result in significant deviations from the desired line and grade. Another drawback is the possibility of significant soil disturbance and the potential for heave at the surface if a blockage is created at the end of the installed pipe below the travelled right of way. Vibrations from a pipe ramming operation can also cause settlement of loose materials in the immediate vicinity of the installation which could cause deformation at the ground surface.



Although pipe ramming can be applied in a wide variety of soils, some soils are better suited for this method than others. The most suitable soil conditions are soft to very soft clays, silts and organic deposits, and sands above the water table. Pipe ramming is more difficult in very dense or hard soils and soils containing obstructions such as cobbles and boulders.

6.4.3 Pilot Tube Micro Tunnelling (PTMT)

PTMT employs augers for excavation and soil removal and a jacking system for advancing the drill pipes, casings and product pipes. The guidance system comprises a target with LEDs mounted in the steering head of the equipment that is monitored through a TV monitor. The PTMT operation includes pilot boring and reaming and since this technique is used for smaller size pipes, the equipment and space required for this operation is smaller than what is normally required for pipe jacking, and microtunneling.

PTMT can obtain an accuracy of 6 mm per 90 m of pipe length; however, the accuracy depends on the ground conditions, the accuracy of the guidance system and the operator's skill. PTMT can be applied in different soil conditions but soils with large cobbles and boulders are problematic and high ground losses are experienced in running and flowing sands and in squeezing clay, unless the operation is adapted to provide a counter-balancing fluid pressure during the drilling and reaming operations. The "pilot tube" is advanced in a similar fashion to horizontal directional drilling with a guidance system used to control alignment and grade.

In this method, a bore hole is drilled with a steering head connected to pilot tubes whose size is smaller than the required casing size. A slanted steering head is used for pilot boring and adjustment of alignment and grade and the bore hole is subsequently enlarged by a reamer with a casing following behind the reamer, with an auger string inside the casing used to remove cuttings. The product pipes follow the casing to be installed in the ground. A typical PTMT construction sequence is as follows.

- Excavate and prepare the entrance and exit working platforms for the equipment including an entry headwall;
- Set up the thrust frame and the guidance system including the steering head and target at the entrance working platform;
- Install the pilot tube behind the steering head. The boring process proceeds with the rotation and thrust of the pilot tube. Deviations are continuously adjusted through video monitor surveillance of the illuminated target; and
- When the steering head exits the tunnel reach, the reamer and casing with auger inside are connected to the last segment of pilot tube. The reamer and auger enlarge the pilot bore hole by rotating and thrusting the reamer and casing. The steering head and the pilot tubes are then retrieved at the entrance working platform.



6.4.4 Micro Tunnelling (MT)

Micro tunnelling is a method of installing pipes behind a steerable remote controlled shield that is pressurized with a bentonitic fluid to minimize ground losses. The process is essentially remote controlled pipe jacking where all operations are controlled from the surface, cuttings are removed by the circulating slurry and the necessity for personnel to enter the bore is eliminated. Micro tunnelling is a precise method of tunnelling and there is relatively little settlement with this method, if the face pressure and cutting tools are appropriate for the ground and are maintained over the length of the drive.

Micro tunnelling can be applied to a wide range of ground conditions from saturated sands and gravels, through to soft or stiff, dry or saturated clays and mudstones, to solid rock. Specialist advice on machine selection should be sought and recommendations regarding the machine design for the given ground conditions should be supported by the manufacturer. Appropriate machine design refinements may be used to extend the application range of the machine to cover more adverse soil conditions, including handling of obstructions such as cobbles and boulders.

6.4.5 Assessment of Tunnelling Alternatives

To reduce the risk of subsidence or heave, tunnelling installations require a minimum depth of overburden cover over the tunnel crown. As the depth of overburden cover decreases the risk of concentrated subsidence or heave increases, as does the risk of extreme events such as sinkholes forming at the ground surface. In Ontario the general practice is to maintain a depth of cover equivalent to 2 to 3 tunnel diameters or at least a minimum of 1.5 m for pipe ramming operations.

The Contractor must be aware of the inherent risks and consequences involved with trenchless installations that could include some or all the following:

- Obstructions within the tunnel reach that could increase the level of construction effort. The contractor should have on site adequate equipment such as mandrels, pneumatic breakers or chisels, and augers to break and remove these obstructions. If these efforts prove futile, an open cut excavation will be required to remove the obstruction and complete the remainder of the installation.
- Inability to correct for line and grade within the design tolerances. If misalignment occurs, the Contractor should be prepared to abandon the pipes in the ground and grout the excavation. Alternatively, an open cut excavation could be the most efficient way of completing the installation and salvaging any misaligned casings.

Table 1 summarizes the casing inverts, the pipe dimensions, the depth of overburden cover to the casing pipe (assuming a 1500 mm diameter casing pipe) and the Depth of Cover to Tunnel Diameter Ratio. The table also includes a summary of the subsurface conditions encountered in the boreholes from ground surface to the steel casing inverts.

The SPT „N“ values and the coefficient of uniformity (which indicates the extent to which the soil is well graded, and that is expressed as the ratio of the particle size at which 60 percent of the particles are finer than to the particle size at which 10 percent are finer than), assist in classifying the soil behaviour according to the Tunnelman's Ground Classification System (Terzaghi, 1950). This system is commonly used to describe the



potential behaviour of an unsupported tunnel face during excavation and it uses qualitative “stand-up time” criteria to classify the ground at and above the tunnel face into the following principal categories: firm, slow ravelling, rapid ravelling, squeezing, cohesive running, running, flowing and swelling. Efforts to predict soil behaviour must also be tempered by experience and engineering judgement.

The soil conditions within the tunnel horizon are classified in Table 2 following the text of this report and the conditions generally range from “running” to “flowing”. The tunnelling alternatives that are considered to be feasible and practical for this site are also included in Table 2.

Tunnelling should be undertaken in accordance with the non-standard special provision *Pipe Installation by Trenchless Method*, included in Appendix C. The choice of equipment and the method of tunnelling is the Contractor’s responsibility.

6.4.6 Tunnel Support

The casing must be designed to accommodate hoop stress and sufficient nominal wall thickness must be provided to meet this design requirement. The casing should conform to OPSS 1802 (Smooth Walled Steel Pipe) and the least nominal wall thickness provided in Table 1 of this specification will apply.

6.4.7 Grouting

It is necessary to check the amount of spoil removed during tunnelling to determine whether there is over excavation and if there are any possible voids outside of the casing. Where settlement monitoring indicates that the ground has settled, or where signs of ground loss are observed, provision should be made for a program of compensation grouting using appropriate grouting materials and approved methods. In addition, it is recommended that once the permanent pipe is installed within the casing, the annular space between the casing and the pipe should also be grouted with a grout that is compatible with the casing and pipe material.

6.4.8 Instrumentation and Monitoring

The Contract Documents should require the Contractor to monitor the roadway surface before, during and after construction. A precondition survey is also required to document the existing conditions of the existing roadway and nearby structures. An instrumentation and monitoring program is recommended in order to:

- Document the effects of the installation on the overlying roadways,
- Obtain prior warning of ground movements that could occur due to the construction methods and equipment or unforeseen ground condition;
- Verify the Contractor’s compliance with the settlement limits imposed in the Contract; and
- Allow adjustments to be made to the installation method such that the settlement limits established are not exceeded.



FOUNDATION REPORT - TRENCHLESS CULVERT INSTALLATION, HIGHWAY 400 NBL REHABILITATION

The overburden soils above the tunnel alignment should be monitored for movement during construction by using in-ground monitoring points and surface settlement points. The in-ground monitoring points provide the best advance indicators of subsurface disturbance and the potential for settlement/heave at the ground surface.

The Monitoring Plan presented in Appendix D illustrates the approximate locations of the monitoring instruments for a trenchless installation and provide typical instrument details. The monitoring point locations are approximate and take into consideration the need to minimize traffic disruption during their installation as well as reading during construction. These locations must be confirmed by the Contractor in consultation with the Geotechnical Engineer prior to installation and construction, and may have to be adjusted in the field to suit local conditions and constraints.

Monitoring points should be installed under the supervision of a geotechnical engineer at least seven days prior to any excavation. All monitoring points should be surveyed for elevation at least three (3) times on two (2) separate days to establish a pre-construction baseline prior to commencing culvert installation. All points behind the face of the excavation and those within 10 m of the front of the face should be surveyed for elevation every four hours over the duration of the tunnel drive.

Monitoring of surface monitoring points on this project is constrained by the continuous and high traffic volume and the limited periods during which access to the highway can be obtained and this aspect must be taken into consideration.

A specialist surveying firm should be retained to confirm the set-up and to carry out the monitoring during construction. Their equipment and procedures must be capable of surveying the in-ground monitoring points laterally and vertically to within ± 2 mm. The survey data should be submitted by the surveyor to the Geotechnical Engineer and Contract Administrator on an ongoing basis, for prompt review.

For this project a Review Level of 10 mm and an Alert Level of 15 mm is considered appropriate for horizontal and vertical displacements. The following procedure should be followed if displacements reach the Review and Alert Levels.

- If the Review Level is reached the Contractor should be required to provide a formal plan that clearly states what measures will be taken to ensure that the Alert Level is not reached; and,
- If the Alert Level is reached, the Contractor shall stop all work and the Contract Administrator of the project and MTO would have the authority to order the Contractor to make the face secure and suspend all tunnelling activities until an approved mitigation solution is developed. The Contractor must have an emergency plan in place to ensure public safety.

6.5 Preferred Culvert Installation Alternative

A comparison of the advantages, disadvantages, relative costs and risks associated with the various installation methods is presented in Table 3, following the text of this report. The preferred alternatives for installing the new culvert are ranked in the table below on a numerical scale in order of preference with one (1) being assigned to the most preferred alternative and four (4) being assigned to the least preferred option. The preferred alternative was selected based on installation cost and the availability of construction equipment and local construction knowledge.



FOUNDATION REPORT - TRENCHLESS CULVERT INSTALLATION, HIGHWAY 400 NBL REHABILITATION

Location Station	Ranking of Installation Alternatives			
	Open Cut Excavation	Pipe Ramming	MT	PTMT
Hwy. 400 NBL Station 18+515	1	2	3	4

From a geotechnical perspective installation by the open-cut method is recommended provided that the construction can be staged to accommodate this method.

6.6 Temporary Excavations and Shoring

Excavations will be made through the existing fill and native soils, which typically vary from very loose to compact cohesionless soils. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act and Regulations for Construction Projects (OHSA). For the purposes of the OHSA the existing fill and the upper portion of the native sand and silt to silt soils above the groundwater table can be classified as Type 3 soil. Below the groundwater table the soils at this site should be classified as Type 4 soils. Where space permits, and provided that proper groundwater control is in place, a temporary open-cut excavation through these materials should be made with side slopes formed no steeper than 1H:1V.

Temporary roadway protection may be required at the entry and exit platform areas if sufficient space is not available to permit open cut excavations. The width of open cuts will likely be limited as much as practical and based on the subsurface conditions at the culvert crossing location and the likely excavation geometry, it is envisaged that the launch portal will be supported using a system of close shoring such as soldier piles and lagging. If the culvert is installed by open-cut excavation, a suitably designed trench box may be used to shore the excavation, if unsupported sideslopes with a gradient to 1H:1V or flatter are not used.

The shape of the soil pressure distribution diagram behind a shoring system depends upon the type of soil to be encountered and the amount of movement that can be permitted. The shoring system can be restrained, fixed or flexible. The sequence of work may also alter the shape of the pressure diagram during the various construction phases.

Earth pressure computations must also take into account the groundwater level. Above the groundwater level, earth pressure is computed using the bulk unit weight of the retained soil. Below the groundwater level, the earth pressures are computed using the submerged unit weight of the soil, hydrostatic pressure is added to the earth pressure in this situation.

Flexible shoring should be designed on the basis of the active earth pressure coefficient (K_a). Where limited shoring movement (Performance Level 1A or 1B) is required, the design should be based on the at rest earth pressure coefficient (K_o). For "kick out" design the lateral resistance should be computed on the basis of the passive earth pressure coefficient (K_p).

Decisions regarding shoring methods and sequencing are the responsibility of the Contractor. Temporary shoring should be designed by a licensed Professional Engineer experienced in shoring design. The temporary excavation support system should be designed and constructed in accordance with OPSS 539 to meet Performance Level 2, for 25 mm maximum horizontal displacement.



6.7 Design and Construction Considerations

6.7.1 Surface Water and Groundwater Control

Excavations may extend below the groundwater table and provisions will be required to maintain sufficiently dry excavations. The dewatering system is the Contractor's responsibility and the rate and volume required for dewatering is dependent on the construction methods and staging chosen by the Contractor.

Assuming a groundwater table at Elevation 230.3 m, excavations will be made in the embankment fill material and the native sand and silt to silt material above and below the groundwater table. The sands and silts below the groundwater table are susceptible to disturbance. For an open cut excavation, dewatering ahead of the excavation will be required and the groundwater level should be lowered to below the excavation base in these situations. Even with dewatering works in place, disturbance of the subgrade is possible requiring that care be executed when excavating to subgrade level. Any accumulation of water at the base of the excavation and loose soils must be removed to avoid detrimental settlement of the pipe.

Given the groundwater condition at this site and the soil deposits that will be encountered along the tunnel alignment, it is anticipated that a Permit To Take Water (PTTW) will not be required provided that the installation can be completed expeditiously. The rate and volume required for dewatering will be dependent on the construction methods and staging chosen by the Contractor. A PTTW is required for any water taking if the volume exceeds 50 m³/day.

6.7.2 Erosion Protection

Erosion protection should be provided at the culvert inlets and outlets (including the slopes and sides). At the inlet area a clay seal can be provided such that water flow is channelled through the culvert and does not seep through the backfill around and underneath the structure. Therefore, the clay seal should extend to cover all the granular backfill materials, should be a continuous layer around the culvert, should have a minimum compacted thickness of 0.6 m, and should extend at least 1 m above the high water level. The clay seal should also be protected by a layer of rip-rap. Material used for the clay seal should conform to the requirements stipulated in OPSS 1205 (Clay Seal). Alternatively, concrete cut-off and head walls can be constructed to protect the granular backfill and prevent seepage around the culvert.

Concrete cut-off and head walls can also be used to protect the granular fill around the culvert outlet from erosion. In this case, however, filtered erosion protection such as rip-rap should be provided along the channel and the sides beyond the concrete cut-off and head walls.

Design of an erosion protection scheme for the drainage channel in the inlet and outlet areas will depend on hydrologic and hydraulic parameters and/or other concerns. Typically, rip-rap protection should be provided to these areas. The rip-rap layer should cover all surfaces with which water is likely to be in contact.

We recommend that a qualified Hydraulics Engineer be consulted to design the specifics of the drainage channel, culvert outlet and inlet (i.e. thickness and extent of protection) and scour depth. Footings must also be placed below the scour depth.



6.7.3 Settlement

The existing Highway 400 NBL will be widened and the underlying soils will experience a vertical stress increase due to approximately 2.8 m of new fill placed in the widening area. The settlement analysis was carried out using elastic deformation moduli established from predictions/empirical correlations using SPT “N” values, tempered with engineering judgement from our experience with similar soils in this region of Ontario. It is estimated that this new fill will induce approximately 50 mm of settlement in the foundation soils at the interface between the existing embankment and the widening area. It needs to be emphasized that this settlement will translate into differential settlement between the new culvert installed under the existing embankment and the new culvert located in the widening area. Therefore, the connection joint must be designed to accommodate this settlement.

6.7.4 Construction Concerns

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

- Potential for groundwater levels to be higher at the time of construction than those recorded in this report;
- Possibility of encountering unforeseen subsurface conditions along the length of the proposed alignment i.e. more extensive fills, etc.; and
- Possibility of encountering obstructions during tunnelling.

7.0 CLOSURE

This Foundation Design Report was prepared by Ms. T. Veronica Ayetan, P.Eng., a geotechnical engineer, under the technical direction of Mr. Rehman Abdul, P.Eng., a senior geotechnical engineer. The report was reviewed by Mr. John Westland, a principal with Golder and Mr. Fintan J. Heffernan, P.Eng., Golder’s MTO’s Designated Contact for this project conducted an independent quality control review and audit of the report.



FOUNDATION REPORT - TRENCHLESS CULVERT INSTALLATION, HIGHWAY 400 NBL REHABILITATION

Report Signature Page

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TV/RA/JW/FJH/jl

n:\active\2009\1111\09-1111-0022 mh - hwy 400 nbl - vespra twp\6 - reports\7 - culvert at crown hill ramp\final report\fidr\09-1111-0022 rpt07 2012september27 trenchless culvert installation.docx



FOUNDATION REPORT - TRENCHLESS CULVERT INSTALLATION, HIGHWAY 400 NBL REHABILITATION

REFERENCES

Chapman, L.J., and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.

Ontario Geological Survey 1994. *Aggregate Resources Inventory of Ting, Tay and Medonte Townships, Simcoe County*. Paper 79, Ontario Geological Survey.

Terzaghi, K. 1950. *Geologic Aspects of Soft Ground Tunnelling*. John Wiley & Sons, New York.

Ontario Provincial Standard Specifications (OPSS)

- OPSS 421 Construction Specification for Pipe Culvert Installation in Open Cut
- OPSS 539 Construction Specification for Temporary Protection Systems
- OPSS 1010 Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
- OPSS 1205 Material Specification for Clay Seal
- OPSS 1802 Material specification of Smooth Walled Steel Pipe

Ontario Provincial Standard Drawings (OPSD)

- OPSD 802.032 Rigid Pipe Bedding, Cover and Backfill, Type 4 Soil - Earth Excavation



FOUNDATION REPORT - TRENCHLESS CULVERT INSTALLATION, HIGHWAY 400 NBL REHABILITATION

TABLE 1
CONSTRUCTIBILITY REVIEW OF TUNNELLING ALTERNATIVES

Location Station	Existing Dimensions/Type	Casing Pipe Invert Elevations*		Depth of Overburden Cover (m)	Depth of Cover to Tunnel Diameter Ratio	Anticipated Subsurface Conditions Within The Zone of Tunnelling	Estimated Groundwater Depth Relative to Casing Pipe Invert
		Inlet (m)	Outlet (m)				
Hwy. 400 NBL Station 18+515	900 mm x 42 m CSP	230.0±	229.6±	2.7**	1.8	Loose Silty Sand to Sand and Silt Fill, Loose Sand, Very Loose to Compact Sand and Silt.	0.3 m± to 0.6 m± above. Subject to seasonal changes.

* Elevations based on a 1500 mm diameter casing.

** Maximum overburden cover measured within embankment footprint

Prepared by: T. Veronica Ayetan, P.Eng.

Checked by: R. Abdul, P.Eng.

Reviewed by: J. Westland, P.Eng.



FOUNDATION REPORT - TRENCHLESS CULVERT INSTALLATION, HIGHWAY 400 NBL REHABILITATION

**TABLE 2
FEASIBILITY OF TUNNELLING METHODOLOGIES**

Culvert Location	Proposed Diameter	Depth of Overburden Cover ⁵ (m)	Borehole Number	Soil Conditions ¹ (Ground surface to casing pipe invert)	Fines ² Content	SPT "N" Values	Coefficient of Uniformity ³	Soil Behaviour ⁴	Pipe Ramming	PTMT	MT
Hwy 400 NBL 18+515	900 mm	2.7	11-C1-01	Sand and Silt to Sandy Silt *	51*, 73*	11, 12, 5	>50	Running to flowing.	Yes	Yes	Yes
			11-C1-02	Silty Sand to Sand and Silt Fill *, Sand and Silt to Silt **	35*, 55*, 41**	15, 29, 9, 3	9 to >50	Running to flowing.			
			11-C1-03	Sand *, Sand and Silt*	43*	7, 8, 14	7	Running to flowing.			

1. Soil conditions from ground surface to pipe invert, bold soil conditions indicate soil conditions within tunnel horizon.
2. Fines content is defined as the percentage by weight of soil particles passing the No. 200 Sieve and * denotes fines content for respective soil type.
3. Coefficient of uniformity of soil within and immediately surrounding the tunnel horizon.
4. Critically dependent on the groundwater level at the time of construction.
5. Maximum overburden cover measured within existing embankment footprint.

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FOUNDATION REPORT - TRENCHLESS CULVERT INSTALLATION, HIGHWAY 400 NBL REHABILITATION

**TABLE 3
EVALUATION OF INSTALLATION METHODS**

Installation Method	Ranking*	Advantages	Disadvantages	Risk/Consequences	Estimated Costs/m of Pipe Installation
Open Cut Installations (OPSS 421)	1	<p>Best control of gradient and alignment of culvert;</p> <p>Reduced potential for delays due to obstructions;</p> <p>Least risk of unanticipated damage to active highway; and</p> <p>Equipment and skilled construction workforce readily available.</p>	<p>Requires lane closures and pavement restoration unless the construction is staged; and</p> <p>Relatively large and deep excavation required.</p>	Increased traffic disruption.	\$650 per metre
Pipe Ramming	2	<p>Minimal traffic disruption;</p> <p>Better suited for penetrating through potential obstructions such as cobbles and boulders; and</p> <p>Equipment and skilled construction workforce available.</p>	<p>Large obstructions can deflect casing; and</p> <p>Unable to correct for line and grade during installation.</p>	<p>Obstructions can cause deflection of casing resulting in misalignment;</p> <p>Risk of heaving increases with decreasing cover;</p> <p>Nests of cobbles and/or boulders can stop penetration of casing requiring hand mining; and</p> <p>Vibration from pipe ramming may be experienced by highway users.</p>	\$4,800 per metre
MT	3	<p>Minimal traffic disruption; and</p> <p>Does not require groundwater lowering since machine can counterbalance earth and water pressures, thereby reducing the risk of ground losses during tunnelling.</p>	<p>Lack of availability of machines with the suitable diameter bore;</p> <p>Relatively expensive compared to other methods;</p> <p>High mobilization cost for short crossings; and</p> <p>Requires a skilled construction workforce.</p>	Time delay in obtaining a suitable diameter machine is likely.	\$5,000 per metre

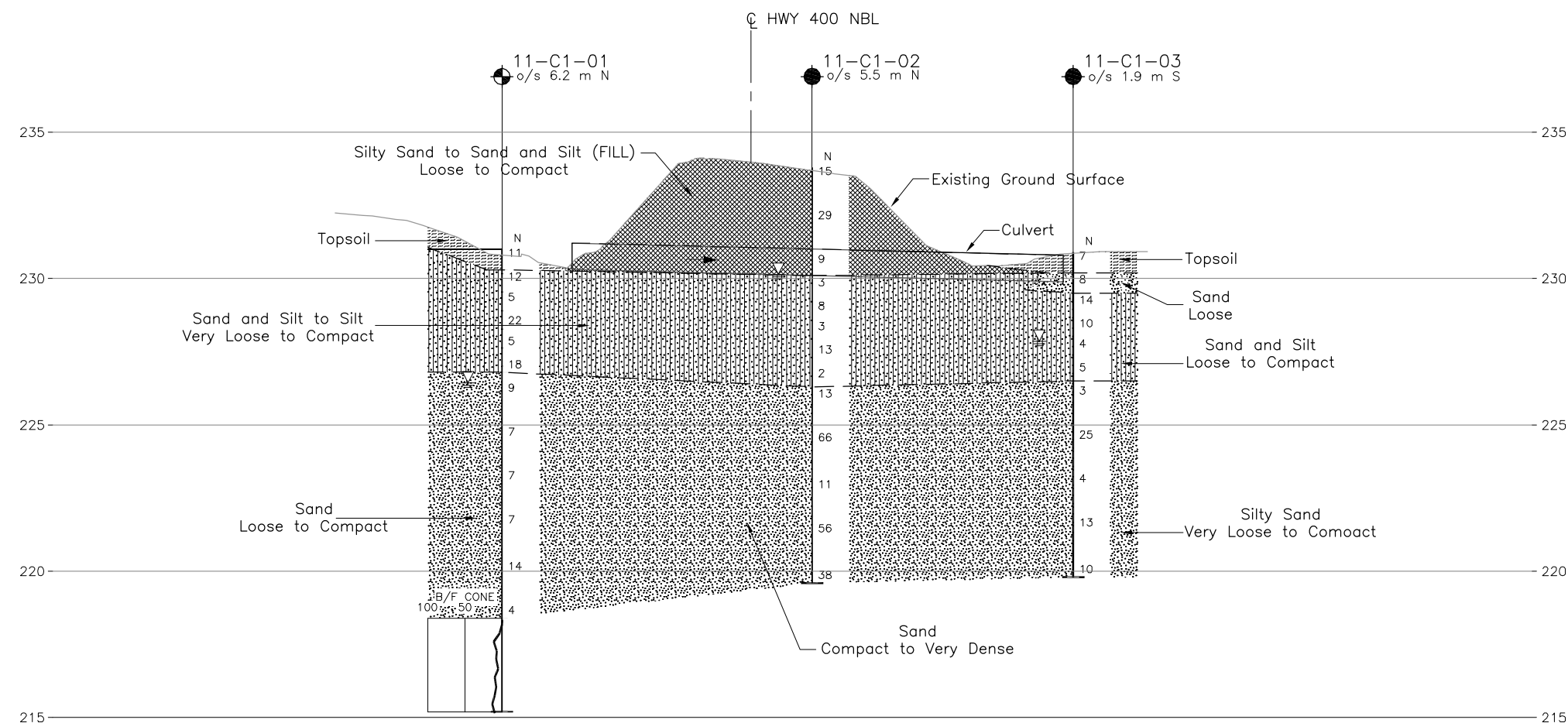


FOUNDATION REPORT - TRENCHLESS CULVERT INSTALLATION, HIGHWAY 400 NBL REHABILITATION

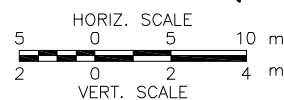
Installation Method	Ranking*	Advantages	Disadvantages	Risk/Consequences	Estimated Costs/m of Pipe Installation
PTMT	4	Minimal traffic disruption; Does not require groundwater lowering; and Relatively small working area required compared to other methods.	Relatively expensive compared to other methods; Lack of availability of machines; and Requires skilled construction workforce.	Time delay in sourcing a machine; and Hydraulic fracture (frac-out) could occur at sites where relatively shallow overburden cover exists.	\$5,000 to \$7,000 per metre

* Ranking considered from a foundation perspective.

Prepared by: T. Veronica Ayetan, P.Eng.
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SECTION A-A' CULVERT AT STATION 18+515
HIGHWAY 400 (NBL)



METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

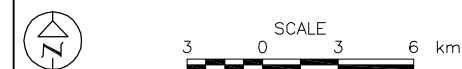
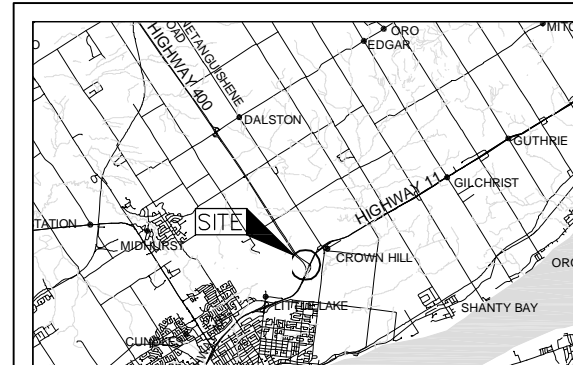
CONT No. 2012-2034
GWP No. 2179-10-00

CULVERT REPLACEMENT
STATION 18+515
BOREHOLE LOCATIONS AND SOIL STRATA





SHEET
62



Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



LEGEND

- | | |
|---|---|
|  | Borehole – Current Investigation (Golder, 2011) |
|  | Borehole and DCPT – Current Investigation (Golder, 2011) |
| N | Standard Penetration Test Value |
| 16 | Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow) |
|  | WL upon completion of drilling |
|  | Flow direction |

BOREHOLE CO—ORDINATES			
No.	ELEVATION	NORTHING	EASTING
11—C1—01	231.0	4920690.3	292743.7
11—C1—02	233.8	4920671.2	292762.0
11—C1—03	230.9	4920650.2	292772.6

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

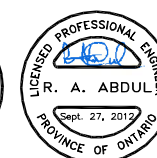
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by MH, drawing files
x84117Align.dwg, x84117Base.dwg and x84117design.dwg received May 2-
2012 and X094197Contours.dwg, received July 18, 2011. Culvert section
obtained from drawing file no. 60% Sections May 2 2012.dwg, received
June 4, 2012.

NO.	DATE	BY	REVISION							
Geocres No. 31D-548										
HWY. 400				PROJECT NO. 09-1111-0022				DIST.		
SUBM'D. TVA		CHKD. RAA		DATE: 9/27/2012				SITE:		
DRAWN: CD		CHKD.		APPD. FJH				DWG. 1		





APPENDIX A

Record of Borehole Sheets



LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d :

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

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

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Cohesionless Soils

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

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

V. MINOR SOIL CONSTITUENTS

Percent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (cohesionless) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand



LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
C_u, S_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

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

Notes: 1
2

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

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

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

PROJECT <u>09-1111-0022</u>		RECORD OF BOREHOLE No 11-C1-01				SHEET 2 OF 2		METRIC										
G.W.P. <u>2079-10-00</u>		LOCATION <u>N 4920690.3 ; E 292743.7</u>				ORIGINATED BY <u>DD</u>												
DIST <u>Central</u> HWY <u>400</u>		BOREHOLE TYPE <u>D-50 Track-Mount, 108 mm Diameter Hollow Stem Auger</u>				COMPILED BY <u>NLP</u>												
DATUM <u>Geodetic</u>		DATE <u>December 21, 2011</u>				CHECKED BY <u>TVA/RA</u>												
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)					
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between;"> 20 40 60 80 100 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between;"> ○ UNCONFINED + FIELD VANE </div> <div style="display: flex; justify-content: space-between;"> ● QUICK TRIAXIAL × REMOULDED </div>					<div style="display: flex; justify-content: space-between;"> W_p W W_L </div>						
215.2 15.8	END OF DCPT NOTES: 1. Unstabilized water level measured at a depth of 4.6 m (Elev. 226.4 m) below ground surface upon completion of drilling.																	



PROJECT	09-1111-0022	RECORD OF BOREHOLE No 11-C1-02		SHEET 1 OF 2	METRIC
G.W.P.	2079-10-00	LOCATION	N 4920671.2 ;E 292762.0	ORIGINATED BY	DD
DIST	Central	HWY	400	BOREHOLE TYPE	D-50 Track-Mount, 108 mm Diameter Hollow Stem Auger
DATUM	Geodetic	DATE	December 20, 2011	COMPILED BY	NLP
				CHECKED BY	TVA/RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa									WATER CONTENT (%)			
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED												
							20	40	60	80						100	10	20	30
							20	40	60	80						100			
233.8	GROUND SURFACE					▽													
0.0	ASPHALT (100 mm)		1	SS	15		233												
0.7	Silty sand to sand and silt, trace to some clay, trace to some gravel, occasional cobbles (FILL) Loose to compact Brown Moist to wet		2	SS	29		232						○				11 54 23 12		
							231												
	----- with topsoil dark brown to black		3	SS	9		230							○			6 39 41 14		
230.1	SAND and SILT to SILT, trace to some clay Very loose to compact Grey Wet		4	SS	3		229							○			0 59 35 6		
3.7			5	SS	8		228												
			6	SS	3		227							○			0 10 82 8		
			7	SS	13		226												
			8	SS	2		225												
226.3	SAND, trace silt, trace to some gravel Compact to very dense Brown Wet		9	SS	13		224												
7.5			10	SS	66		223								○				
			11	SS	11		222												
			12	SS	56	221													
	----- silty, trace gravel		13	SS	38	220													
219.6	END OF BOREHOLE																		
14.2																			

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

○ 3% STRAIN AT FAILURE

PROJECT 09-1111-0022		RECORD OF BOREHOLE No 11-C1-02				SHEET 2 OF 2		METRIC													
G.W.P. 2079-10-00		LOCATION N 4920671.2 ; E 292762.0				ORIGINATED BY DD															
DIST Central HWY 400		BOREHOLE TYPE D-50 Track-Mount, 108 mm Diameter Hollow Stem Auger				COMPILED BY NLP															
DATUM Geodetic		DATE December 20, 2011				CHECKED BY TVA/RA															
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa													
--- CONTINUED FROM PREVIOUS PAGE ---							<div style="display: flex; justify-content: space-between;"> 20 40 60 80 100 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between;"> ○ UNCONFINED + FIELD VANE </div> <div style="display: flex; justify-content: space-between;"> ● QUICK TRIAXIAL × REMOULDED </div>					<div style="display: flex; justify-content: space-between;"> 20 40 60 80 100 10 20 30 </div>									
NOTES: 1. Unstabilized water level measured at a depth of 3.7 m (Elev. 230.1 m) below ground surface upon completion of drilling. 2. Increased resistance to augering probably on cobbles/boulders from a depth of 2.0 m to 2.9 m (Elev. 231.8 m to 230.9 m) below ground surface. 3. Hydrostatic uplift encountered at a depth of 7.6 m; sand rose 2.1 m in augers. Auger retracted to 7.6 m and borehole redrilled from 7.6 to 9.1 m.																					

PROJECT		09-1111-0022		RECORD OF BOREHOLE No 11-C1-03		SHEET 1 OF 1		METRIC									
G.W.P.		2079-10-00		LOCATION		N 4920650.2 ; E 292772.6		ORIGINATED BY									
DIST		Central HWY 400		BOREHOLE TYPE		D-50 Track-Mount, 108 mm Diameter Hollow Stem Auger		COMPILED BY									
DATUM		Geodetic		DATE		December 21, 2011		CHECKED BY									
								TVA/RA									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
230.9 0.0	GROUND SURFACE TOPSOIL		1	SS	7	▽	230										0 57 41 2
230.2 0.7	SAND, trace to some silt, containing rootlets Loose Brown Moist		2	SS	8		229										
229.5 1.4	SAND and SILT, trace clay Loose to compact Brown, grey below 2.1 m Wet		3	SS	14		228										
			4	SS	10		227										
			5	SS	4		226										
			6	SS	5		225										
226.5 4.4	Silty SAND, trace clay Very loose to compact Brown to grey Wet		7	SS	3		224										
			8	SS	25		223										
			9	SS	4		222										
			10	SS	13		221										
219.8 11.1	END OF BOREHOLE		11	SS	10		220										
NOTES: 1. Unstabilized water level measured at a depth of 3.0 m (Elev. 227.9 m) below ground surface upon completion of drilling.																	

GTA-MTO 001 09-1111-0022.GPJ GAL-MISS.GDT 6/19/12 DD/SAC



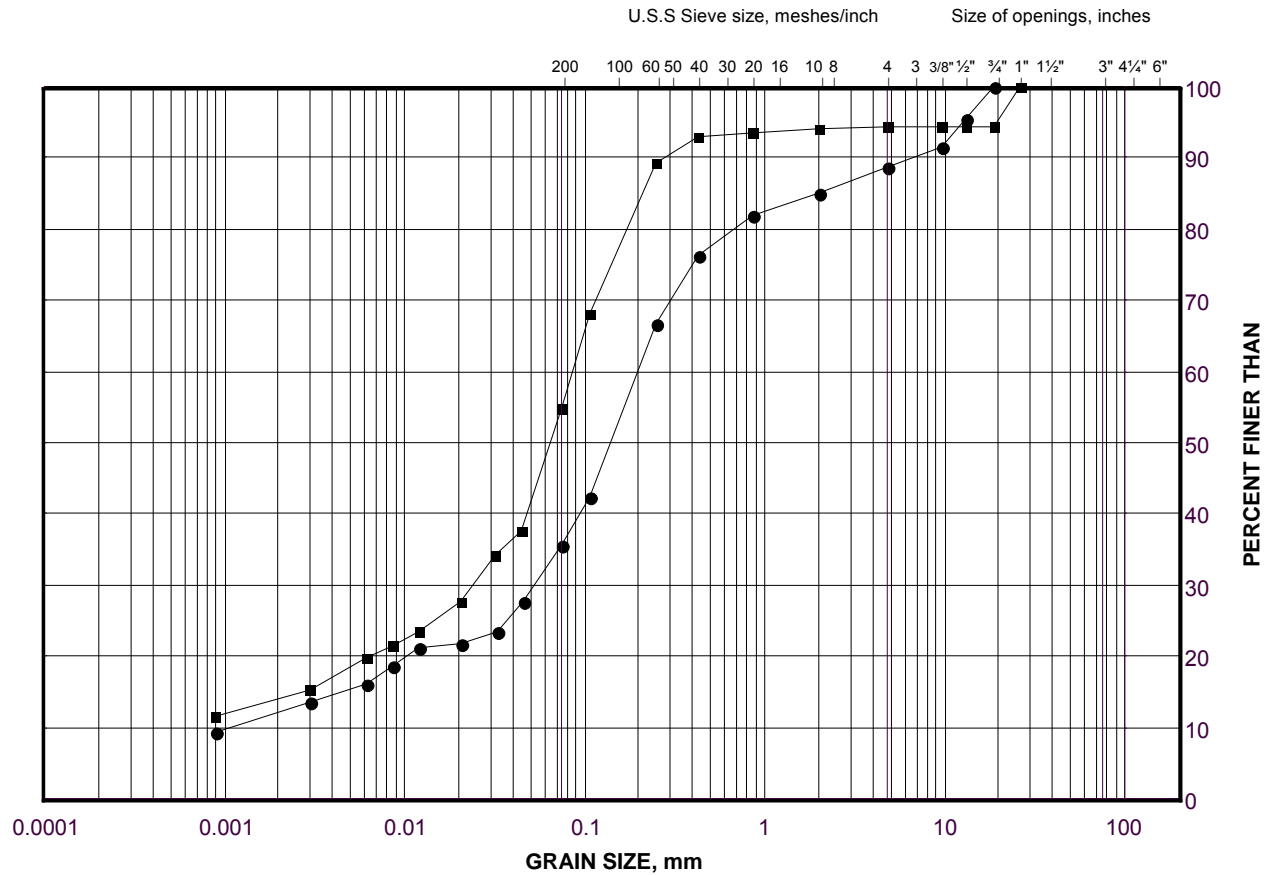
APPENDIX B

Laboratory Test Results

GRAIN SIZE DISTRIBUTION

Silty Sand to Sand and Silt (Fill)

FIGURE B1



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	11-C1-02	2	232.0
■	11-C1-02	3	230.5

Project Number: 09-1111-0022

Checked By: _____

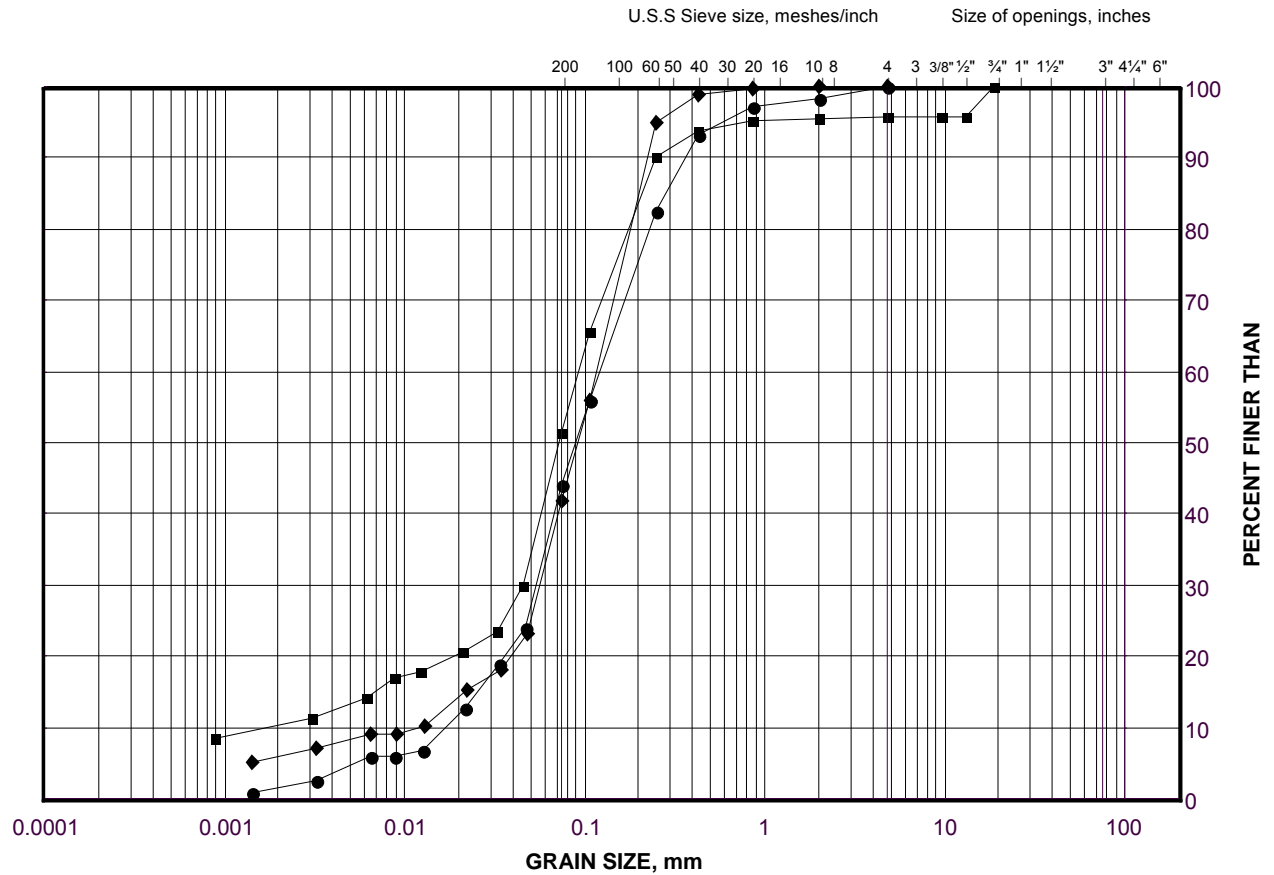
Golder Associates

Date: 05-Jun-12

GRAIN SIZE DISTRIBUTION

Sand and Silt

FIGURE B2



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	11-C1-03	3	229.1
■	11-C1-01	3	229.2
◆	11-C1-02	4	229.7

Project Number: 09-1111-0022

Checked By: _____

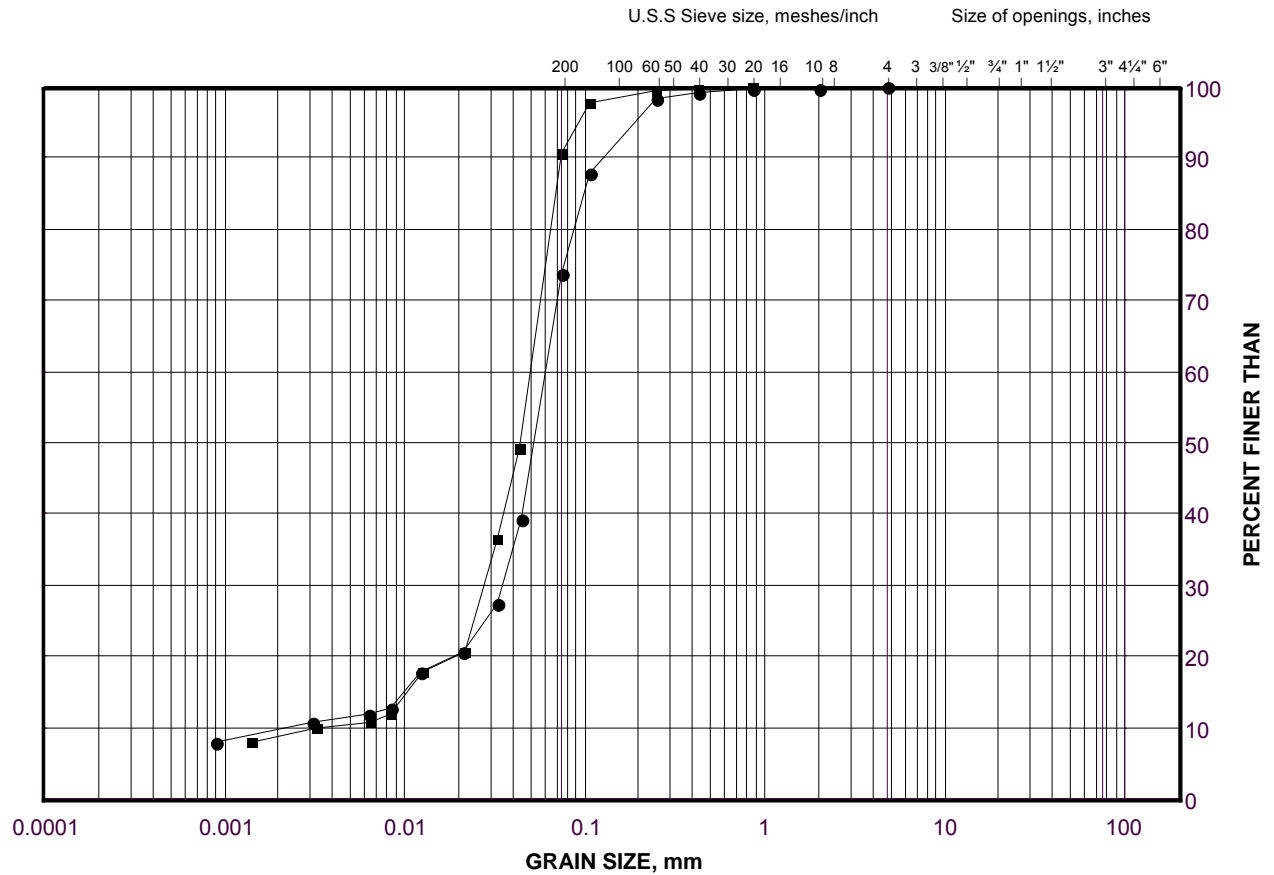
Golder Associates

Date: 05-Jun-12

GRAIN SIZE DISTRIBUTION

Sandy Silt to Silt

FIGURE B3



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	11-C1-01	5	227.7
■	11-C1-02	6	228.2

Project Number: 09-1111-0022

Checked By: _____

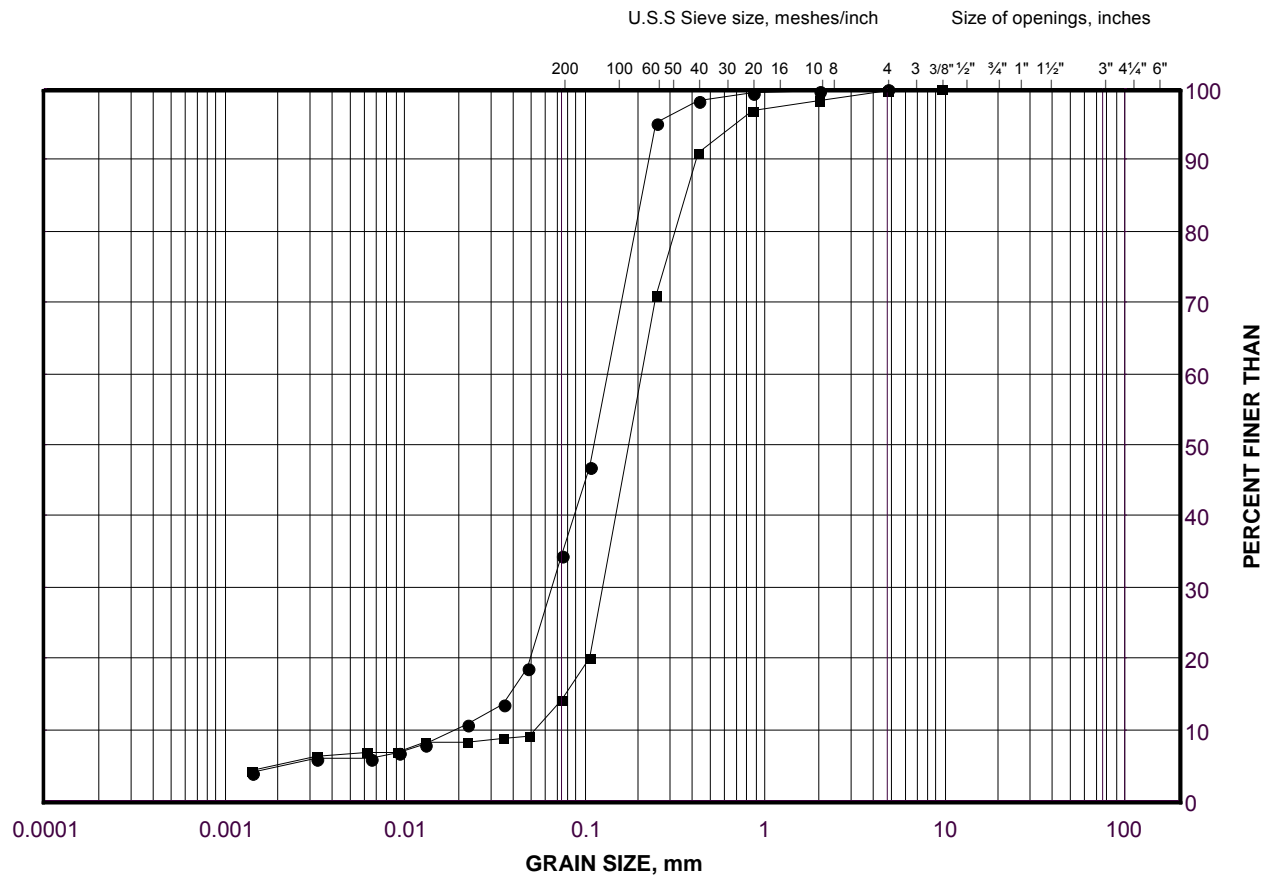
Golder Associates

Date: 05-Jun-12

GRAIN SIZE DISTRIBUTION

Sand to Silty Sand

FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	11-C1-03	7	226.1
■	11-C1-01	8	224.6

Project Number: 09-1111-0022

Checked By: _____

Golder Associates

Date: 05-Jun-12



APPENDIX C

Non-Standard Special Provisions



PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Non Standard Special Provision

February 2009

1. SCOPE

This specification covers the general requirements for the installation of pipes by trenchless methods.

The Contractor shall determine the most appropriate method of installation. Specifications for Jack & Bore, Pipe Ramming, Directional Drilling, and Tunnelling are provided herein, and shall be applied to the installation method considered feasible by the Contractor.

OPSS 415 (Construction Specification for Pipeline and Utility Installation by Tunnelling), OPSS 416 (Construction Specification for Pipeline and Utility Installation by Jacking and Boring) and OPSS 450 (Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling) shall not be used to do the work for the above tender item.

2. REFERENCES

This specification refers to the following report, standards, specifications, and publications:

Golder Associates Ltd., “Foundation Investigation and Design Report, Culvert Replacement at Station 18+515, Highway 400 Northbound Rehabilitation, Highway 11 to Highway 93, Simcoe County, Ontario”, Report Number 09-1111-0022-10, dated June 2012.

Ontario Provincial Standard Specifications, General

OPSS 180 Management and Disposal of Excess Material

Ontario Provincial Standard Specifications, Construction

OPSS 504 Preservation, Protection, and Reconstruction of Existing Facilities

OPSS 507 Site Restoration Following Installation of Pipelines, Utilities and Associated Structures in Open Cut

OPSS 514 Trenching, Backfilling, and Compaction

OPSS 517 Dewatering of Pipeline, Utility, and Associated Structure Excavation

OPSS 538 Support Systems

OPSS 539 Protection Schemes

Ontario Provincial Standard Specifications, Material

OPSS 1004 Aggregates - Miscellaneous

OPSS 1350 Concrete - Materials and Production



OPSS 1440 Steel Reinforcement for Concrete

OPSS 1802 Smooth Walled Steel Pipe

MTO Specifications

OPSS 1820 Material Specification for Circular Concrete Pipe

OPSS 1840 Material Specification for Non-Pressure Polyethylene Plastic Pipe Products

American Society for Testing and Materials (ASTM) International Standards

ASTM A252-93 Welding and Seamless Steel Pipe Piles

ASTM D2657-03 Standard Practice for Heat Fusion Joining of Polyelofin Pipe and Fittings

ASTM D3350 Standard Specification for Polyethylene Plastics Pipe and Fittings Materials

ASTM F894 Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

Canadian Standards Association Standards:

CSA B182.6 Profile Polyethylene Sewer Pipe and Fittings.

CAN/CSA A5-93 Portland Cement

CSA W59 Welded Steel Construction (Metal Arc Welding)

3. DEFINITIONS

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

Backreamer: a cutting head suitably designed for the subsurface conditions, that is attached to the end of a drill string to enlarge the pilot bore during a pullback operation.

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

Design Engineer: means the Engineer retained by the Contractor who produces the original design and working drawings. The design engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer: means the Engineer retained by the Contractor who checks the original design and working drawings. The design checking engineer shall be licensed to practice in the Province of Ontario.

Digger Shield/Hand Mining: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead while tunnelling advances using hand-mining (man-entry operation or



FOUNDATION REPORT - TRENCHLESS CULVERT INSTALLATION, HIGHWAY 400 NBL REHABILITATION

“Jack and Mine) or a “digger” type shield with a hydraulic excavator arm to remove materials from inside the liner pipe.

Drilling Fluids: 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.

Drilling Fluid Fracture or Frac Out: a condition where the drilling fluid’s pressure in the bore is sufficient to overcome the in situ confining stress, thereby fracturing the soil and/or rock materials and allowing the drilling fluids to migrate to the surface at an unplanned location.

Engineer: a Professional Engineer licensed by the Professional Engineers of Ontario to practice in the Province of Ontario.

Excavation: includes all materials encountered regardless of type and extent. Excavation shall include removal of natural soil, large boulders, cobbles, wood and fill regardless of means necessary to break consolidated materials for removal.

Environmentally Sensitive Area (ESA): areas adjacent to construction that are off limits to the Contractor as specified elsewhere in the Contract.

Fill: man-made mixture of previously placed/handled materials such as sand, clay, silt, gravel, broken rock, sometimes containing organic and/or deleterious materials, placed in an excavation or other area to raise the surface elevation.

Grouting: injection of grout into voids.

Guidance System: an electronic system capable of locating the position, depth and orientation of the drill head during the directional drilling process.

Directional Drilling (DD): directional boring or guided boring.

HDPE: high density polyethylene.

Inadvertent Returns: the unexpected flow of fluids, saturated materials (or running soil) towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

Jack & Bore: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead and rotating a cutter head, followed by removal of material from inside the bore.

Loss of Circulation: the discontinuation of the flow of drilling fluid in the bore back to the entry or exit point or other planned recovery points.

Pilot Bore: the initial bore to set directional controlled horizontal and vertical alignment between the connecting points.

Pipe Jacking: a method for installing steel casing or concrete pipe in the subsurface utilizing hydraulically operated jacks of adequate number and capacity to ensure smooth and uniform advancement without overstressing the liner/pipe.



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Pipe Ramming: a method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached at the front end of the casing.

Primary Liner (Support): system installed prior to or concurrent with excavation, to maintain stability of an excavation and to support earth or rock and any structure utilities or other facilities in or on the supported earth or rock mass, until the excavation is completed.

Product: pipe culverts, pipe sewers, watermain pipe and sanitary pipe.

Pullback: that part of the DD method in which the drill string is pulled back through the bore path to the entry point.

Quality Verification Engineer (QVE): an Engineer who has a minimum of five (5) years experience in the field of pipe installation using trenchless methods or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the contract. The Quality Verification Engineer shall be retained by the Contractor to certify that the work is in general conformance with the contract documents and to issue Certificate(s) of Conformance.

Reaming: a process for pulling 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 typically includes multiple passes.

Rock: natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a size equivalent to 0.3 m in diameter or greater.

Secondary Liner: concrete pipe, HDPE pipe or un-reinforced cast-in-place concrete, installed subsequent to tunnel excavation.

Shaft: vertically sided excavation used as entry and/or exit points from which the trenchless method is initiated or directed for the installation of product.

Strike Alert: a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm may be audio or visual or both.

Slurry: a mixture of soil and/or rock cuttings, and drilling fluid.

Soil: all materials except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials; includes rock fragments having an equivalent size less than 0.3 m in diameter.

Tunnelling: an underground method of constructing a passage open at both ends that involves installing a pipe.



4. DESIGN AND SUBMISSION REQUIREMENTS

4.01 General

The Contractor's documentation, submission requirements and installation methods shall specifically consider and address the subsurface conditions at each pipe crossing as identified in the Foundation Investigation Report.

4.02 Working Drawings

Three copies of stamped working drawings for portal or shaft construction, primary liner, excavation, secondary lining, dewatering and groundwater control and grouting shall be submitted to the Contract Administrator (CA) at least one (1) week prior to the commencement of the work for information purposes. All submissions shall bear the seal and signature of the Design Engineer and Design Checking Engineer. The Contractor shall have a copy of the stamped working drawings at the site during construction.

As a minimum, working drawings/details pertaining to the tunnel design and construction shall include the following (as appropriate):

a) Plans, Elevations and Details:

- A work plan outlining the materials, procedures, methods and schedule to be used to execute the work;
- A list of personnel, including backup personnel, and their qualifications and experience;
- A safety plan including the company safety manual and emergency procedures;
- The work area layout;
- An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail;
- A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails;
- Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations; and
- Excavated materials disposal plan.

b) Design Criteria:

- Primary liner design details, if applicable; and
- Design assumption and material data when materials other than those specified are proposed for use.
- Drill path design, details of alignment and alignment control, maximum curvature and reaming stages;

c) Materials:

- Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application; and
- Material mixture for filling voids and installation procedures.



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d) Upstream/Downstream Portal Installation Procedure:

- The access shaft or entry/exit pit details designed and stamped/signed by the Design Engineer, as applicable; and
- Face support and other temporary support details, if applicable.

e) Primary Liner/Secondary Liner Installation and Grouting Procedure:

- Excavation and pipe jacking procedures, including methodology to handle obstructions and preventing soil cave-in; and
- Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

- Ground control/dewatering details, as applicable, describing the proposed method for control, handling, treatment, and disposal of water.

g) Monitoring Method

- The methods to be employed to monitor and maintain the alignment of the installation;

4.03 Site Survey

Prior to commencing the work, the Contractor shall, at each pipe location, layout the alignment and install settlement monitoring points.

4.04 Certificate of Conformance

The Contractor shall submit details of the sequence and method of construction to the Quality Verification Engineer for review, prepared and stamped by the Design Engineer. The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer a minimum of one week prior to commencement of work under this item. The Certificate shall state that the construction procedures are in conformance with the requirements and specifications of the contract documents.

The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer upon completion of each of the following operations and prior to commencement of each subsequent operation for each pipe installation:

Site Surveying (as noted in Section 4.02)

Excavation for pits including dewatering of excavation

Jacking/Ramming/Directional Drilling of Casing/Liner

Excavation and Dewatering

Installation of the Product

Grouting Operations



Each Certificate of Conformance shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a **final** Certificate of Conformance sealed and signed by the Quality Verification Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, stamped working drawings and contract documents.

The Design Engineer will not be permitted to carry out the work of the Quality Verification Engineer.

5. MATERIALS

5.01 Product

The product shall be concrete pipe or high density polyethylene pipe as specified.

5.02 Concrete

Concrete shall be according to OPSS 1350. The concrete strength shall be as specified in the Contractor's design submission.

5.03 Concrete Reinforcement

Steel reinforcing for concrete work shall be according to OPSS 1440.

5.04 Timber

Timber shall be sound, straight, and free from cracks, shakes and large or loose knots.

5.05 Grout

The Contractor shall submit the proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces. Purging grout shall consist of a mixture of one part Portland cement conforming to the requirements of CAN/CSA A5-93 and two parts mortar sand conforming to OPSS 1004 wetted with only sufficient water to make the mixture plastic.

5.06 Jack & Bore Materials

5.06.01 Pipe Materials

Steel pipe shall conform with ASTM A252-95 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS 1820.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.



5.07 Pipe Ramming Materials

5.07.01 Pipe Materials

Steel pipe shall conform with ASTM A 252-93 welded joints.

New steel casing when specified shall be smooth wall carbon steel pipe according to ASTM A252-93 Grade 2.

Used steel casing can be used provided that the steel casing can resist the applicable static and dynamic loadings.

Pipe wall thickness shall be determined by the Contractor based on static and dynamic loads from traffic loading and anticipated ramming forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. A minimum wall thickness of 50 mm and minimum yield strength of 240 MPa is required.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

Steel casing pipe shall have roundness such that the difference between the major and minor outside diameters shall not exceed 1% of the specified nominal outside diameter or 6 mm, whichever is less.

Steel casing pipe shall have a minimum allowable straightness of 1.5 mm maximum per metre of length.

5.07.02 Mill Certificates

For permanent casing, the Contractor shall submit to the Contract Administrator at the time of delivery one copy of the mill certificate, indicating that the steel meets the requirements for the appropriate standards for casings.

Where mill test certificates originate from a mill outside Canada or the United States of America the Contractor shall have the information on the mill certificate verified by testing by a Canadian laboratory. The laboratory shall be accredited by a Canadian National Accreditation Body to comply with the requirements of ISO/IEC Guide 25 for the specific tests or type of tests required by the material standard specified on the mill test certificate. The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date and the signature of an authorized officer of the Canadian testing laboratory.

5.08 Directional Drilling Materials

5.08.01 Drilling Fluids

The drilling fluids shall be mixed according to the manufacturer's recommendations and be appropriate for the anticipated subsurface conditions.

5.08.02 Pipe Materials

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.



The requirements for fittings shall be suitable for and compatible with the class and type of pipe with which they will be used and in according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) of the HDPE pipe to support all subsurface conditions and hydrostatic pressures, and to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

The Contractor's submission shall demonstrate, in conjunction with the manufacturer's specifications, that the heat resistance of the pipe material is sufficient to tolerate without damage the heat of hydration generated by grout curing.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Joining of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the joining process.

Joining of HDPE piping to other piping materials or appurtenances shall be completed using flanged connections.

5.09 Tunnelling Materials

5.09.01 Primary Liner

Tunnelling methods will require installation of a primary liner to provide support and stability to the excavation.

5.09.02 Secondary Liner

Concrete or High Density Polyethylene Pipe shall be used according to the following requirements.

5.09.02.01 Concrete Pipe

Concrete pipe as per OPSS 1820 shall be used. The Contractor shall select the pipe class to withstand grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.09.02.02 High Density Polyethylene (HDPE)

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Joining of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the joining process.



Jointing of HDPE piping to other piping materials shall be completed using flanged connections.

6. EQUIPMENT

6.01 Jack & Bore Equipment

Jack & bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.02 Pipe Ramming Equipment

Pipe ramming equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The pipe ramming hammer(s) shall be capable of driving the pipe casing from the drive pit through the existing subsurface conditions at the site.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.03 Directional Drilling Equipment

6.03.01 General

The directional drilling equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system of sufficient capacity to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The directional drilling rig shall:

- consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head;
- contain a guidance system to accurately guide boring operations;
- be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation; and
- be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

The drill head shall be steerable by changing its rotation, be equipped with the necessary cutting surfaces and drilling fluid jets, and be of the type for the anticipated subsurface conditions,



6.03.04 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any magnetic or electromagnetic anomalies and shall consider such influences in the operation of the guidance system when a magnetic or electromagnetic system is used.

6.03.05 Drilling Fluid Mixing System

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

6.03.06 Drilling Fluid Delivery System

The delivery system shall have a means of measuring and controlling fluid pressures and be of sufficient flow capacity to ensure that all slurry volumes are adequate for the length and diameter of the final bore and the anticipated subsurface conditions. Connections between the delivery pump and drill pipe shall be leak-free.

6.04 Tunnelling Equipment

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the tunnel face shall be submitted to the Contract Administrator information purposes. Use of explosives or rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use.

7. CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of pipe installation shall be subject to the limitations presented in the following subsections.

7.01.01 Layout, Alignment and Depth Control

The location of the installation shall be established from the lines, elevations and tolerances specified in the Contract Documents. The pipe installation shall be to the horizontal and vertical alignments specified in the Contract Drawings. Deviations from location, alignment, grades and/or invert levels shall be corrected by the Contractor at no cost to the Ministry.

All reference points necessary to construct the pipe installation and appurtenances shall be laid out.

The Contractor shall calibrate tracking and locating equipment at the beginning of each work day, and shall monitor and record the alignment and depth readings provided by the tracking system at every 5 m in normal conditions and every 2 m where precise alignment control is necessary;

The Contract Administrator shall be provided with the assistance and access necessary to check the layout of the pipe installation and associated appurtenances.



All excavations shall be carried out in accordance with the Occupational Health and Safety Act (OHSA) of Ontario.

For directional drilling, the contractor shall ensure that during pilot hole drilling the maximum degree of deviation or “dog-leg” shall be 2.5 degrees per 9m drill pipe length. Any deviation exceeding 2.5 degrees will necessitate a pull-back and straightening of the alignment at the Contractor’s sole expense. The pilot hole exit location shall be within 0.5m of the target location.

7.01.02 Shafts

Shafts shall be specified in the Contractor's submission. The boundaries and protection of these shall be as required to contain all disturbances to areas outside of the ESA limits.

Shafts shall be maintained in a drained condition.

A minimum 2.4 m high secure fence shall be installed around the perimeter of the construction shaft area with gates and truck entrances. The fence shall be removed on completion of the work.

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS 539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA’s may be impaired due to the method of operation, protection shall be provided. Protection systems include primary liner and portal excavation support systems. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works

7.01.04 Settlement or Heave

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contract, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.

The construction methods, plant, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 504.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer’s handling and storage recommendations shall be followed.



7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 514.

7.01.09 Dewatering

The work of this Section includes control, handling, treatment, and disposal of groundwater. The Contractor shall review the foundation investigation report for reference to soil and groundwater conditions on the project site and plan a dewatering scheme accordingly.

The Contractor shall control groundwater inflows to excavations to maintain stability of surrounding ground, to prevent erosion of soil, to prevent softening of ground exposed in the excavation, and to avoid interfering with execution of the work.

The Contractor shall maintain excavations free of standing water at all times during excavation, including while concrete is curing.

Should water enter the excavation in amounts that could adversely affect the performance of the work or could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

The Contractor is alerted that seepage zones of perched water within the fill materials should be expected, particularly where granular materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.10 Removal of Boulders

The Contractor is alerted that cobbles and boulders should be anticipated in the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.11 Record Keeping

Verification record requirements of the alignment and depth of the installation 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 installation.

7.01.12 Testing

Testing of the product installation shall consist of verifying the specified grade between the two ends of the pipe and passing of water from the median end of the pipe to the outlet end to confirm gravity flow conditions.

7.01.13 Management and Disposal of Excess Material

Management and disposal of excess material shall be according to OPSS 180. Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.



7.01.14 Site Restoration

Site restoration shall be according to OPSS 507.

7.01.15 Supervision

A qualified individual, who is experienced in the pipe installation by trenchless methods, shall supervise the work at all times.

7.02 Jack & Bore Installation

7.02.01 Method of Installation Procedure

The installation procedure to be used shall be subject to the following limitations:

- Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

Concrete pipe joints shall be water tight and according to OPSS 1820 and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner the space between the liner and the wall of the excavation shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavation shall be filled with grout.

The annular space between the liner and the product shall be fully grouted with a water tight, expandable and stable grout.

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

Only smooth walled steel pipe shall be used. But welding of pipe joints shall conform to CAS W59.

Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement without overstressing of the pipe. Delays shall be avoided between ramming operations.

A ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.

Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.

Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator. Any voids remaining between the pipe and the excavation wall shall be grouted as soon



as the pipe is rammed. The annular space between the liner pipe and the product shall be fully grouted with a water tight, expandable and stable grout.

7.04 Directional Drilling Installation

7.04.01 General

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

7.04.02 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 DD operations are to be made. All activities shall be confined to designated work areas.

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as indicated on the Contractor's submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor's methods shall take into consideration the conditions at each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

In the event the pilot bore deviates from the submitted path, 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 before 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 action shall be taken in accordance with the Contractor's submitted contingency plan.

At the entry and exit points, there is potential for ravelling of the existing soil, fill and or weathered rock areas along the alignment. This is conventionally addressed by the use of drilling fluid. However, casing may be required. The Contractor's methods shall take into consideration the potential need to install sections of casing to manage ravelling at or near ground surface.

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

The Contractor shall maintain drilling fluid pressure and circulation throughout the DD process, including during the initial pilot bore and during the reaming process.

The Contractor shall at all times and for the entire length of the installation alignment be able to demonstrate the horizontal and vertical position of the alignment, the fluid volume used, return rates and pressures.

7.04.04 Drilling Fluid Fracture (Frac-Out)

In order to reduce the potential for hydraulic fracturing of the hole during directional drilling, a minimum depth of cover of 5m is normally maintained between the pipe and the ground surface. Sections of the pipe close to the exit pit with less than 5m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are



properly set and controlled to prevent frac-out, for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Since fluid loss normally occurs in fault zones, fracture zones, or seams of coarse material, fluid migration does not always gravitate to the surface, thus making detection difficult. Once a fluid loss is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to mitigate fluid loss. If no surface migration is evident, resume operation while paying particular attention to fluid monitoring.

In the event of a fluid migration to the surface occurring, the Contractor shall halt all operations immediately, isolate the migration site, and recover fluids. Once the fracture is controlled, continue drilling operations with the operator paying particular attention to the fracture points

7.04.05 Reaming

The bore shall be reamed using the appropriate tools to a diameter at least 50% greater than the outside diameter of the product.

7.04.06 Product Installation

7.04.06.01 General

The product shall be jointed according to manufacturer's recommendations. The length of the product to be pulled shall be jointed as one length before commencement of the continuous pulling operation.

The product shall be protected from damage during the pullback operation.

The minimum allowable bending radius for the product shall not be exceeded.

Product shall be allowed to recover before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

After successfully reaming the bore to the required diameter, the product shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product is completely pulled into bore unless otherwise approved by the Contract Administrator.

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from being transferred to the product. 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 where visible at excavation pits and where it exits the bore. Any damage noted shall be rectified to the satisfaction of the Contract Administrator,

The pull back and reaming operations shall not exceed the fluid circulation rate capabilities. Reaming and back pulling operations shall be planned to insure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the excavation walls shall be filled with grout.



7.05 Tunnelling Installation

7.05.01 General

The method of tunnelling shall be selected by the Contractor and shall be submitted to the Contract Administrator prior to commencement of the work for information purposes.

Excavation of native soil and fill shall be done in a manner to control groundwater inflow to the excavation and to prevent loss of ground into the excavation.

Methods of excavating the tunnel shall be capable of fully supporting the face and shall accommodate the removal of boulders and other oversize objects from the face. Continuous ground support shall be maintained during excavation.

As the excavation progresses, the Contractor shall continuously monitor (every 2m) indications of support distress, such as cracking, deflection or failure of support system and subsidence of ground near the excavation.

The Contractor shall advance the ventilation system as a regular part of the normal excavation cycle.

The Contractor shall provide lighting in accordance with OHSA requirements for the entire length of the tunnel.

The tunnel is to be kept sufficiently dry at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times in tunnels.

In the event that excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the work.

The Contractor shall maintain tunnel excavation line and grade to provide for construction of final lining within specified tolerances.

7.05.01 Tunnelling Method

The tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. The selection of the tunnelling method should consider the soil conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

7.05.02 Primary Liner (Support System)

Primary support systems shall prevent deterioration, loosening, or unravelling of ground surfaces exposed by excavation.

The primary liner support system shall be designed and installed to achieve the intended performance requirements.

Primary liner support system shall maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the excavation.



The primary liner shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting, and shall ensure that no ground loading or other loading will be placed on the new work until after design strength has been reached.

The primary liner shall be installed so that the exterior is as tight as possible to the excavated surface of the tunnel and allows the placement of the full design thickness of the secondary lining.

Primary support systems shall be compatible with the encountered ground conditions, with the method of excavation, with methods for control of water, and with placement of the permanent lining.

All voids between the primary lining and the surface of the excavation shall be filled with cement grout. If an unexpanded liner is used, the space outside the liner plates shall be grouted at least daily.

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

The void outside the finished secondary liner shall be filled with cement grout according to the Contractor's submission.

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property.

7.06 Instrumentation Monitoring

The work specified in this Section includes furnishing and installing instruments for monitoring of settlement and ground stability.

Surface settlement markers for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at not greater than 5 m intervals along the tunnel alignment and as an array of in ground measurement points on the shoulder of the highway perpendicular to the alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within ± 1 mm of the actual elevation.

Surface settlement markers installed on the pavement shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the contractor using short term lane closures in accordance with the Ontario Traffic Manual (OTM).

In general, settlement monitoring points installed in unpaved areas shall be 12-19 mm rebar encased in a 25-50 mm, SCH40 PVC pipe, set to the depths specified in the settlement instrumentation plan. The assembly shall be placed in a drill hole and backfilled with uniform sand as shown on the Contract Drawings.

The Contractor shall install all surface settlement instruments a minimum of one week prior to the start of works.

The surface settlement instruments shall be clearly labelled for easy identification.



FOUNDATION REPORT - TRENCHLESS CULVERT INSTALLATION, HIGHWAY 400 NBL REHABILITATION

The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation recorded at the following time intervals:

- Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- Once per shift during tunnelling operations period; and
- Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrative for information purposes on a weekly basis. Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07 Criteria for Assessment of Roadway Subsidence/Heave

Based on the monitoring of ground movement as specified in Subsection 4.02, the following represents trigger levels that define magnitude of movement and corresponding action:

- **Review Level:** If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate of sequence of construction or ground stabilization measures to mitigate further ground displacement.

If the Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.

- **Alert Level:** If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

No construction shall take place until all the following conditions are satisfied:

- The cause of the settlement has been identified.
- The Contractor submits a corrective/preventive plan.
- Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
- The CA deems it is safe to proceed.

The Contractor shall avoid damaging instrumentation during construction. Instrumentation that is damaged as a result of the Contractor's operation shall be repaired or replaced by the Contractor within one business day. The costs for replacement/repair shall be borne by the Contractor.

At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work.



8. MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centre line of the pipes from centre to centre of maintenance holes or chambers (catch basins) or from/to the end of the pipe where no maintenance hole or chamber is installed, of the actual length of pipe installed by trenchless methods.

9. BASIS OF PAYMENT

Payment at the contract price shall be full compensation for providing all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, supply and installation of pipe liners, settlement monitoring and instrumentations site restoration and for all other work necessary to complete the installation as specified.

Payment for the rigid or flexible pipe conduits installed inside the pipe liners shall be paid separately under the appropriate tender items.

Where a protection system is made necessary because of the Contractor's operations (e.g. choice of trenchless installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

Payment for connecting intercepted drains and service connections shall be made on the following basis:

- (a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.
- (b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

Payment for removal of boulders/obstructions greater than an equivalent 0.3 m in diameter shall be on a time and materials basis. The Contractor shall inform the Contract Administrator when boulders/obstructions are encountered and prior to removal to allow for proper and accurate tracking of time and material charges.

Notes to Designer:

- *Under Section 7.01.06, minimum horizontal and vertical clearances to existing facilities shall be identified in the Contract Documents. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed. The number of exposures required to monitor work progress shall be specified in the Contract Documents.*



APPENDIX D

Settlement Monitoring Plan

METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 2179-10-00

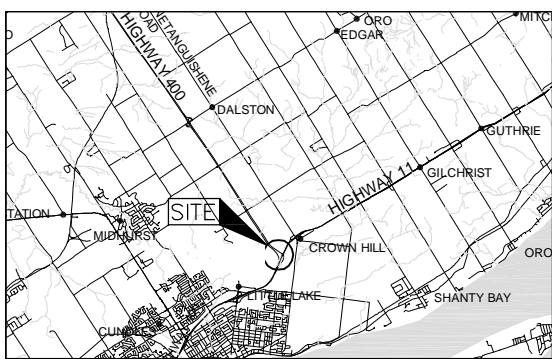


CROWN HILL CULVERT REPLACEMENT
HIGHWAY 400 (NBL) - STATION 18+515
MONITORING PROGRAM - TUNNELLING

SHEET



Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



SCALE
3 0 3 6 km

LEGEND

- Borehole - Current Investigation (Golder, 2011)
- Borehole and DCPT - Current Investigation (Golder,2011)
- In-ground Monitoring Point
- Surface Monitoring Point

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
11-C1-01	231.0	4920690.3	292743.7
11-C1-02	233.8	4920671.2	292762.0
11-C1-03	230.9	4920650.2	292772.6

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

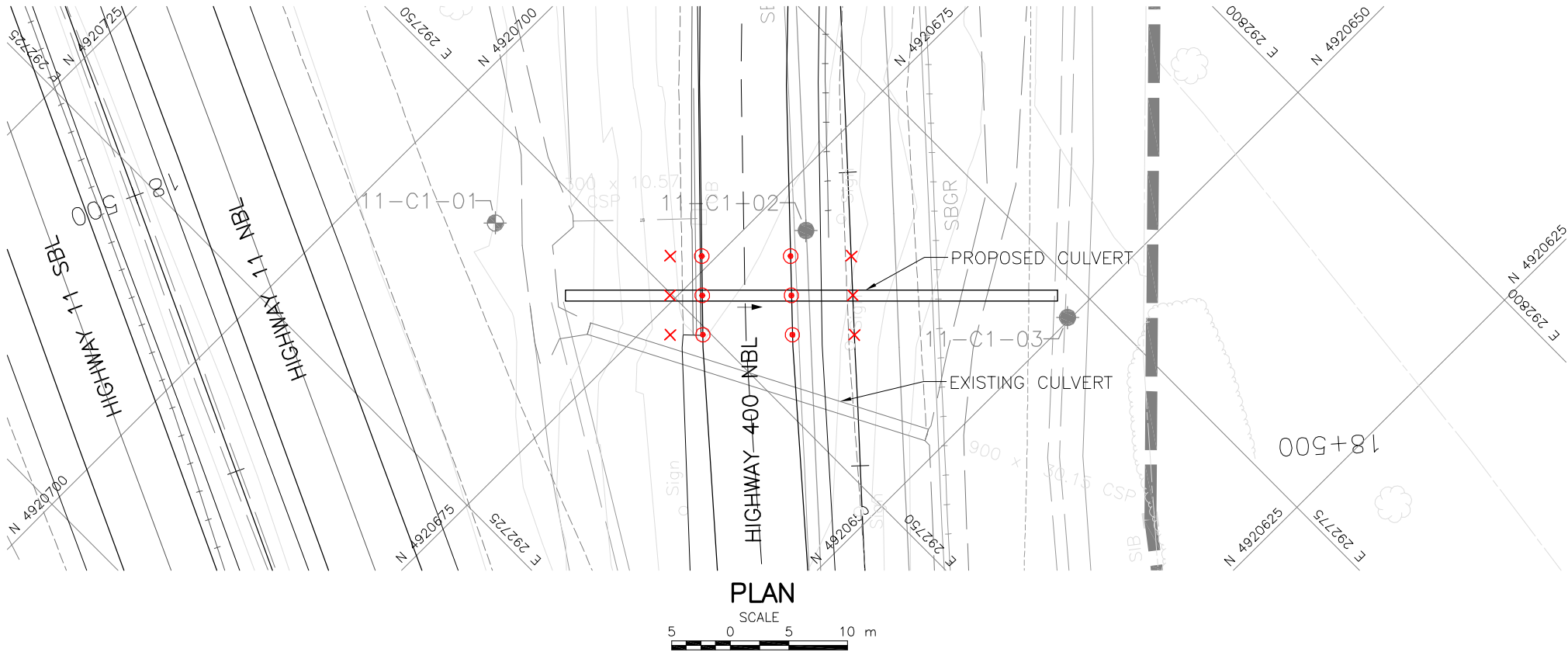
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by MH, drawing files x84117Align.dwg, x84117Base.dwg and x84117design.dwg received May 24, 2012 and X094197Contours.dwg, received July 18, 2011. Culvert section obtained from drawing file no. 60% Sections May 2 2012.dwg, received June 4, 2012.

REVISION			
NO.	DATE	BY	REVISION
Geocres No. 31D-548			
HWY. 400		PROJECT NO. 09-1111-0022	DIST.
SUBM'D. TVA	CHKD. RAA	DATE: 9/25/2012	SITE:
DRAWN: CD/JFC	CHKD.	APPD. FJH	DWG. D1

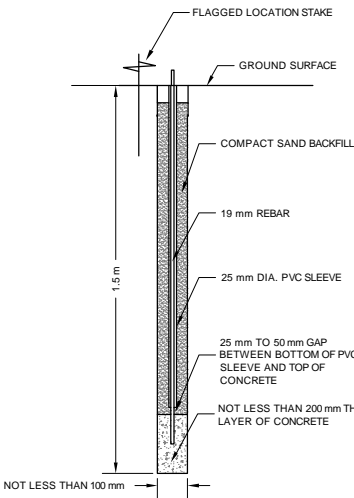
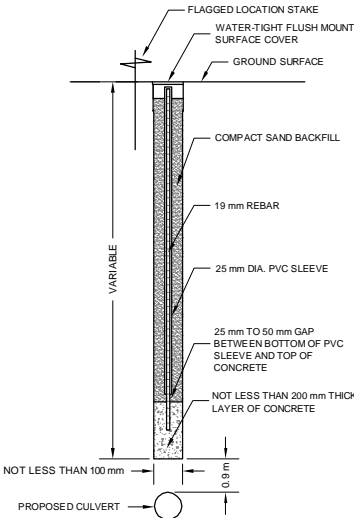


NOTES:

- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH GOLDER ASSOCIATES LTD. REPORT NO. 09-1111-0022, DATED JUNE 2012.
- ALL MONITORING LOCATIONS SHOULD BE CONSIDERED APPROXIMATE AND MUST BE CONFIRMED BY THE CONTRACTOR IN CONSULTATION WITH THE GEOTECHNICAL ENGINEER PRIOR TO INSTALLATION; AND MAY HAVE TO BE ADJUSTED IN THE FIELD TO SUIT LOCAL CONDITIONS/CONSTRAINTS.
- THE CONTRACTOR SHALL RETAIN A SURVEYOR REGISTERED IN ONTARIO FOR ESTABLISHING AND SURVEYING THE MONITORING POINTS FOR THE DURATION OF CONSTRUCTION.
- ALL MONITORING EQUIPMENT SHALL BE INSTALLED AT LEAST 7 DAYS PRIOR TO ANY EXCAVATION OR TUNNELLING TAKING PLACE.
- SURFACE MONITORING POINTS INSTALLED ON THE UNPAVED ROW SHALL BE FOUNDED BELOW FROST PENETRATION DEPTH.
- THE CONTRACTOR SHALL ESTABLISH 1 TEMPORARY BENCHMARK OUTSIDE THE AREA OF CONSTRUCTION. THE CONTRACTOR SHALL SUBMIT THE PROPOSED BENCHMARK LOCATION TO THE ENGINEER FOR APPROVAL. PRIOR TO CONSTRUCTION ALL MONITORING POINTS SHALL BE SURVEYED FOR ELEVATION AND LOCATION TO A TOLERANCE OF NOT MORE THAN 2mm IN THE VERTICAL AND HORIZONTAL DIRECTION.
- DURING TUNNELLING, ALL POINTS SHALL BE SURVEYED A MINIMUM OF 3 TIMES PER DAY.
- DURING MONITORING, IF SETTLEMENTS REACH THE "REVIEW LEVEL" OF 10mm, THE CONTRACTOR SHALL PROVIDE A FORMAL PLAN TO ENSURE FURTHER SETTLEMENTS DO NOT OCCUR. IF SETTLEMENTS REACH THE "ALERT LEVEL" OF 15mm, THE CONTRACTOR SHALL SUSPEND TUNNELLING AND THE OWNER WILL HAVE THE AUTHORITY TO ORDER THE CONTRACTOR TO MAKE THE FACE SECURE AND SUSPEND ALL TUNNELLING UNTIL AN APPROVED MITIGATIVE SOLUTION IS DEVELOPED.
- AFTER TUNNELLING HAS BEEN COMPLETED, THE CONTRACTOR SHALL SURVEY THE MONITORING POINTS ONCE PER DAY FOR 10 DAYS OR UNTIL DATA INDICATES THAT ALL MOVEMENTS HAVE ESSENTIALLY CEASED.
- WITHIN 2 HOURS OF COMPLETION OF ANY MEASUREMENT A COPY OF PRELIMINARY RESULTS SHALL BE MADE AVAILABLE TO THE ENGINEER AND FINALIZED RESULTS SHALL BE PROVIDED WITHIN 24 HOURS OF COMPLETION OF THE SURVEY.
- THE CONTRACTOR SHALL MAKE ALL ARRANGEMENTS FOR TRAFFIC SAFETY.
- REMOVE ALL MONITORING POINTS ON COMPLETION OF SURVEY, SUBJECT TO APPROVAL FROM THE ENGINEER.

IN-GROUND MONITORING
POINT INSTALLATION DETAIL
N.T.S.

SURFACE MONITORING POINT
(UNPAVED ROW) INSTALLATION
DETAIL
N.T.S.



At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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