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FOUNDATION INVESTIGATION AND DESIGN REPORT

Culvert Extension, Twinning and Replacement Highway 400 from Essa Road to Dunlop Street West, Barrie, Ontario G.W.P. 2159-11-00

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REPORT





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PART A

**FOUNDATION INVESTIGATION REPORT
CULVERT EXTENSION, TWINNING AND REPLACEMENT
HIGHWAY 400 FROM ESSA ROAD TO DUNLOP STREET WEST
BARRIE, ONTARIO
G.W.P. 2159-11-00**



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 associated with the culvert extension, twinning and replacement of two culverts near the Highway 400/Tiffin Road interchange, in Barrie, Ontario. This report addresses the foundation investigation completed for the proposed culvert extension, twinning and replacement.

The purpose of this investigation is to establish the subsurface conditions at the location of the proposed culvert locations, by means of a limited borehole investigation and geotechnical laboratory testing on selected samples.

Golder has completed the foundation engineering services in general accordance with the scope of work provided in Proposal No. GEOTETOB22161AA, dated March 13, 2015, originally provided to MH by Coffey Geotechnics Inc. (Coffey).

2.0 SITE DESCRIPTION

2.1 Culvert at Station 29+280

The culvert to be extended/twinning is located approximately 250 m south of the Barrie Collingwood Railway Overpass along Highway 400 in the City of Barrie at approximately Station 29+280 as shown on the Key Plan on Drawing 1. The existing culvert is a 1800 mm diameter, 70 m long CSP, with the invert at Elevation 230.0 m. The existing Highway 400 grade at the site is at approximately Elevation 238.5 m.

2.2 Culvert at Station 10+120

The culvert to be replaced is located approximately 100 m north of the Tiffin Street Overpass structure along Highway 400 in the City of Barrie at approximately Station 10+120 as shown on the Key Plan on Drawing 2. The existing culvert is a Rigid Frame Open Footing (RFOF) concrete structure with a span of 1220 mm, a rise of 1200 mm and a length of 61 m. The stream bed at the culvert location and is at Elevation 232.0 m. The existing Highway 400 grade at the site is at approximately Elevation 237.8 m.

3.0 INVESTIGATION PROCEDURES

3.1 Previous Investigation by Others

Coffey completed a preliminary foundation investigation for the culvert extension/replacement comprising six boreholes (Boreholes C1 to C5 and RW12) in October 2014. The locations, ground surface elevations and drilled depths of these boreholes are summarized below and the borehole locations are also shown on Drawings 1 and 2.



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Culvert Location	Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
Culvert Station 29+280	C1	4,914,237.9	288,578.9	232.0	3.1
	C3	4,914,174.7	288,531.9	233.0	8.2
	C5	4,914,205.6	288,547.5	238.7	14.3
Culvert 2 Station 10+120	C2	4,914,672.0	288,212.1	233.3	8.2
	C4	4,914,647.2	288,140.5	233.7	8.2
	RW12	4,914,649.3	288,175.8	237.7	9.8

The results of the culvert foundation investigation are presented in Coffey's Preliminary Foundation Investigation and Design Report (GEOCREC No. 31D-589) dated February 11, 2015.

3.2 Current Investigation

Golder advanced an additional two boreholes adjacent to the two culvert locations: Borehole HF1 was advanced near Culvert Station 29+280; and Borehole TRW-3 was advanced near Culvert Station 10+120. These boreholes were advanced as part of the high fill and retaining wall foundation investigation for the Highway 400 embankment widening adjacent to the culverts. The field work for the subsurface investigation was carried out on June 23 and July 15, 2015, during which time the two boreholes were advanced using a track-mounted drill rig, supplied and operated by Canadian Soil Drilling of Springwater, Ontario.

Boreholes HF1 and TRW-3 were advanced to depths of 10.1 and 12.8 m below existing ground surface using hollow stem auger drilling methods. Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using a 50 mm outer diameter split-spoon sampler driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586).

The groundwater conditions were observed in the open boreholes during and immediately following the drilling operations. All boreholes were backfilled with bentonite upon completion, in accordance with Ontario Regulation 903 (as amended).

The field work was supervised on a full-time basis by a member of Golder's technical staff who observed the drilling, sampling and in situ testing operations, and logged the subsurface conditions encountered in the boreholes. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and laboratory testing. Index and classification tests consisting of water content determinations and grain size distributions were carried out on selected soil samples.

The borehole locations and ground surface elevations were obtained from the digital terrain model provided by MH. The borehole locations, including MTM NAD83 and UTM NAD83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and the drilled depths are summarized below and the borehole locations are shown on Drawings 1 and 2.



FOUNDATION REPORT - CULVERT EXTENSION, TWINNING AND REPLACEMENT, G.W.P. 2159-11-00

Culvert	Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
Culvert Station 29+280	HF1	4,914,216.0	288,583.2	233.2	10.1
Culvert Station 10+120	TRW-3	4,914,663.2	288,187.6	237.8	12.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This section of Highway 400 lies within the Simcoe Lowlands, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam)¹. The soil deposits are typically interlayered non-cohesive, sand and silt deposits, with occasional cohesive clayey silt / silty clay layers.

4.2 Subsurface Conditions

Four boreholes (Boreholes HF1, C1, C3 and C5) were advanced near Culvert Station 29+280 and four boreholes (Boreholes TRW-3, C2, C4 and RW12) were advanced near Culvert Station 10+120. The interpreted stratigraphic conditions at the culvert sites are shown on Drawings 1 and 2, respectively.

The detailed subsurface soil and groundwater conditions encountered in the boreholes advanced as part of the current investigation and the results of in situ and laboratory testing are given on the borehole records contained in Appendix A. The results of geotechnical laboratory testing are also presented on Figures B1 to B4 contained in Appendix B for the current investigation. The borehole records and laboratory test results from the Coffey Geotechnics Inc. investigation (GEOCREC No. 31D-589) are contained in Appendix C.

The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic profiles and cross-sections on Drawings 1 and 2 are inferred from observations of drilling progress and 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 subsoils at the culvert sites consist of embankment fill underlain by a deposit of loose to dense sandy silt to silty sand interlayered with a loose to compact silt deposit. Peat was encountered underneath the fill at one borehole location.

A more detailed description of the subsurface conditions encountered in the boreholes at the culvert sites is provided in the following sections.

¹ 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.



4.2.1.1 Asphalt

An approximately 150 mm thick layer of asphalt was encountered at ground surface in Borehole C5 at Culvert Station 29+280; and an approximately 220 mm and 400 mm thick layer of asphalt was encountered at ground surface in Boreholes TRW-3 and RW12 at Culvert Station 10+120.

4.2.1.2 Topsoil

An approximately 100 mm and 200 mm thick layer of topsoil was encountered at ground surface in Boreholes C1 and C3 at Culvert Station 29+280; and an approximately 100 mm thick layer of topsoil was encountered at ground surface in Boreholes C2 and C4 at Culvert Station 10+120.

4.2.1.3 Fill

Fill materials of variable composition and layer thickness was encountered at all borehole locations. The elevations of the surface and base of the fill and the layer thickness of the fill materials as encountered in the boreholes are summarized below.

Culvert Location	Borehole No.	Depth to Surface of Fill (m)	Fill Surface Elevation (m)	Fill Thickness (m)	Base of Fill Elevation (m)
Culvert Station 29+280	HF1	0.0	233.2	3.7	229.5
	C1	0.1	231.9	1.6	230.3
	C3	0.2	232.8	0.4	232.4
	C5	0.2	238.5	5.1	233.4
Culvert Station 10+120	TRW-3	0.4	237.4	3.3	234.1
	C2	0.1	233.2	1.4	231.8
	C4	0.1	233.6	0.6	233.0
	RW12	0.2	237.5	3.5	234.0

The fill materials vary in composition from silt to silt and sand to silty sand trace gravel; and sand to gravelly sand immediately under the asphalt. Cobbles were encountered in the upper 0.7 m of the fill deposit in Borehole HF1. Rootlets or trace organics were encountered in all boreholes to depths of about 3.0 m below ground surface, except Boreholes TRW-3 and RW12. Silty clay lenses were encountered in the fill deposit in Borehole C5.

The Standard Penetration Test (SPT) "N"-values within the non-cohesive fill materials range from 1 to 42 blows per 0.3 m of penetration, indicating a very loose to dense relative density.

The water content of the fill deposit range from about 4 percent to 31 per cent.

The results of grain size distribution tests completed on two selected samples of the fill from the current investigation are shown on Figures B1 and B2 in Appendix B.



4.2.1.4 Peat

A 1.1 m thick deposit of peat was encountered in Borehole C1 underlying the non-cohesive fill at Elevation 230.3 m. The measured SPT "N"-values within the peat are 1 blow and 5 blows per 0.3 m of penetration, suggesting a very soft to firm consistency.

4.2.1.5 Sandy Silt to Sand

All of the boreholes encountered and terminated in a variable non-cohesive deposit ranging in composition from sandy silt to silt and sand to silty sand to sand, trace clay, trace gravel. Auger grinding was noted between Elevations 231 m and 230 m (2.7 m to 3.7 m depth) in Borehole C4 on inferred cobbles. Discontinuous silty clay to clayey silt layers or lenses were encountered in Boreholes C2, RW12 and C4 within the non-cohesive deposit.

Most boreholes also penetrated through a silt stratum interlayered with the sandy silt to sand deposit as noted below. The elevations of the surface and base of the sandy silt to sand deposit and the thickness of the deposit as encountered in the boreholes are summarized below.

Culvert Location	Borehole No.	Deposit Surface Depth (m)	Deposit Surface Elevation (m)	Deposit Thickness (m)	Deposit Base Elevation (m)
Culvert Station 29+280	HF1	*3.7	229.5	1.9	227.6
		5.6	227.0	>4.5	Below 223.1
	C1	2.8	229.2	> 0.3	Below 228.9
	C3	0.6	232.4	> 7.6	225.5
		*3.1/7.5	229.9/225/5	3.5/0.7	226.4/Below 224.8
	C5	5.3	233.4	3.2	230.2
*8.5		230.2	>5.8	Below 224.4	
Culvert Station 10+120	TRW-3	3.7	234.1	7.6	Below 224.9
		*10.2	227.5	1.5	226.1
	C2	1.5	231.8	3.2	Below 225.1
		*3.7	229.6	3.5	226.1
	C4	0.7	233.0	> 7.5	Below 225.5
	RW12**	3.7	234.0	> 6.1	Below 228.0

* Silt Interlayer

** Including a 1.5 m thick zone of silty clay lenses from Elevation 231.5 m

The results of grain size distribution testing completed on one sample each of the sandy silt to sand deposit and the silt deposit from the current investigation are shown on Figures B3 and B4 in Appendix B.

The SPT "N"-values measured within the sandy silt to sand deposit range from 8 to 44 blows per 0.3 m of penetration, indicating a loose to dense relative density; and the SPT "N"-values measured within the silt interlayer range from 4 blows to 22 blows per 0.3 m of penetration indicating a very loose to compact relative density.



4.3 Groundwater Conditions

The observed water levels in the open boreholes following completion of drilling and the water level measured by Coffey in the standpipe piezometers are summarized as follows:

Culvert Structure	Borehole No.	Ground Surface Elevation (m)	Groundwater Elevation (m)	Date of Measurement	Notes
Culvert Station 29+280	HF1	233.2	230.1	July 15, 2015	Open Borehole
	C1	232.0	230.2	October 31, 2014	Piezometer
			230.1	November 6, 2015	Piezometer
	C3	233.0	231.5	October 31, 2014	Piezometer
			231.5	November 6, 2015	Piezometer
	C5	238.7	-	-	Not Recorded
Culvert Station 10+120	TRW-3	237.8	227.4	June 23, 2015	Open Borehole
	C2	233.3	229.7	October 31, 2014	Piezometer
			229.4	November 6, 2015	Piezometer
	C4	233.7	231.6	October 31, 2014	Piezometer
			231.2	November 6, 2015	Piezometer
	RW12	237.7	231.0	October 14, 2014	Open Borehole

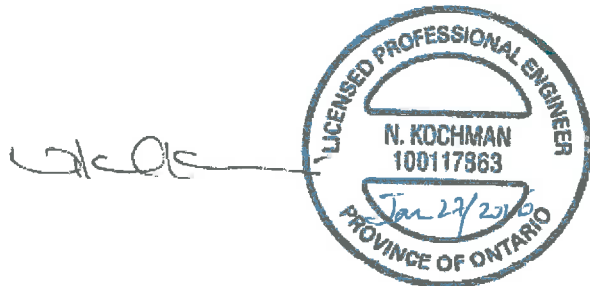
The water levels in the open boreholes are not stabilized. The water levels at the site are expected to fluctuate seasonally in response to changes in precipitation and snow melt, and are expected to be higher during the spring season.



5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Caitlyn Cartwright, E.I.T. and Ms. Nikol Kochmanová, P.Eng., and reviewed by Mr. Jorge Costa, P.Eng., a Designated MTO Foundations Contact and Principal of Golder.

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PART B

**FOUNDATION DESIGN REPORT
CULVERT EXTENSION, TWINNING AND REPLACEMENT
HIGHWAY 400 FROM ESSA ROAD TO DUNLOP STREET WEST
BARRIE, ONTARIO
G.W.P. 2159-11-00**



6.0 DISCUSSION AND ENGINEERING RECOMMENDATION

6.1 General

This section of the report provides foundations engineering recommendations for the detail design of the extension and twinning of Culvert Station 29+280 and the replacement of Culvert Station 10+120.

The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation, supplemented with boreholes advanced during the preliminary geotechnical investigation by Coffey. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to carry out the detail design of the culverts. Where comments are made on construction, they are provided to highlight those aspects which could affect the design of the project, and for which special provisions may be required in the Contract Documents. Those requiring information on the 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.

It is understood that the existing 1800 mm corrugated steel pipe (CSP) culvert at Station 29-280 is to be lined and extended eastward and twinned with an adjacent 1800 mm CSP installed by trenchless methods. The new (twin) culvert is approximately 70 m long and will cross perpendicular to Highway 400 immediately adjacent to the existing culvert. Based on the cross-sections provided by MH, it is understood that the highway grade is at about Elevation 238.5 m.

The existing 1220 x 1200 concrete open footing Culvert Station 10+120 is to be plugged and abandoned and a new 1650 mm CSP culvert is to be installed by trenchless methods. The new culvert is approximately 61 m long and will cross Highway 400 at a skew of approximately 15 degrees at approximately Station 10+120. Based on the cross-sections provided by MH, it is understood that the proposed highway grade will be at about Elevation 240.8 m, representing a grade raise of 3.0 m.

The subsurface conditions as encountered in the boreholes advanced for both culverts consist of embankment fill underlain by deposits of loose to dense sandy silt to silty sand to sand. The groundwater level is inferred to be about Elevation 231.5 m at Culvert Station 29+280 and Elevation 231.6 m at Culvert Station 10+120.

It is understood that the construction of the new NBL embankment may be sequenced such that the eastern portion of the culverts may be constructed in cut-and-cover before the embankment is constructed. Construction of the culverts is to be carried out in accordance with the Non-Standard Special Provision (NSSP) titled "Pipe Installation by Trenchless Method" included in Appendix D.

The following sections provide recommendations and comments regarding the pipe material, alignment and trenchless installation options for Culverts Station 29+280 and Station 10+120.

6.2 Pipe Material Options

Installation of the culverts by either the jack and bore or pipe ramming method will require that a steel casing be installed during boring or ramming to accommodate the permanent corrugated steel pipe (CSP) within it. The steel casing would remain in place, and the annular space between the CSP culvert and the steel casing would be filled by injecting grout. To accommodate pipe installation and potential misalignment during casing advance



it is understood that the steel casing could be about 1.5 times the diameter of the culvert pipe. Therefore, for an 1,800 mm diameter culvert at Station 29+280, a steel casing of up to 2,700 mm diameter would be installed, and for a 1,650 mm diameter culvert at Station 10+120, a steel casing of up to 2,475 mm would be installed. Depending on the invert elevation requirements discussed below, consideration could be given to using a smaller diameter casing, but such use may carry more installation risk of misalignment.

If micro-tunnelling methods are selected for this project, it is likely that the pipe will be jacked into place behind the micro-tunnelling cutter head. Different pipe materials could be used from interlocking steel pipe to glass-fibre reinforced concrete (mortar) pipe specially manufactured for micro-tunnelling applications. In such cases, the jacking pipe may be used as the permanent culvert pipe, depending on materials and installed diameter selected. It will be essential to specify appropriate hydraulic, joint integrity and long-term abrasion resistance performance requirements in the contract if alternative pipe materials are proposed by the trenchless contractor.

The liner/pipe must be selected to support overburden and highway loads, hydrostatic pressures (if present) and to withstand the grouting pressure and installation forces. Overburden pressure may be calculated using a unit weight of 21 kN/m³ for soil and 9.8 kN/m³ for water.

6.3 Culvert Tunnel Alignment

Table 1 provides a summary of the conditions for the culvert installation related to the invert of the steel casing, proposed culvert dimensions, the approximate cover below the final grade of the highway and the corresponding overburden cover expressed as a function of the tunnel diameter (the number of tunnel diameters between the crown of the tunnel and the ground surface). Table 1 also provides a summary of the subsurface conditions encountered in the boreholes at the depth zone within which the culverts are to be advanced. Plan and stratigraphic sections at the proposed culvert crossing locations are shown on Drawings 1 and 2 for Culverts Station 29+280 and Station 10+120, respectively.

For tunnels under 400-series highways, MTO requires that the minimum overburden cover shall not be less than two tunnel diameters or 1.5 m, whichever is greater, at any point along the entire length of the crossing. While the required minimum cover thickness is available at Culvert Station 29+280, at Culvert Station 10+120 the minimum cover thickness will only be present after the proposed 3 m grade raise. Hence, at this site, the culvert will have to be constructed after the grade raise and embankment widening is completed.

Tunnels are typically mined in the direction of increasing elevation to allow for gravity drainage of groundwater seepage; this would require that the tunnels be mined from east to west. Therefore the entry shafts would be on the west side of the existing highway and the exit shafts would be on the east side of the existing highway. It will likely be necessary that the shafts be dewatered to maintain stability of the excavation base as discussed in Section 6.10.

6.4 Pipe Installation Methods

The Contractor will be responsible for choosing the method and equipment for culvert installation consistent with the NSSP for "Pipe Installation by Trenchless Method" included in Appendix D, unless specific methods are otherwise prohibited. Ground behaviour will be, in part, dependent on the installation method adopted and this



report provides guidance on the influence of ground behaviour on possible culvert 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 Foundation Investigation Report.

Based on the culvert profiles provided by MH, it is understood that it is preferable that the culverts be installed using trenchless methods under Highway 400. Potential trenchless methods include: jacking and boring; pipe ramming; micro-tunnel boring machine (MTBM); horizontal directional drilling (HDD) and open face shield tunnelling.

HDD uses drilling fluid under pressure to create the pilot hole and is typically used for smaller diameter crossings below embankments or rivers, where the installed pipe is not dependant on gravity drainage as is the case for sewers and culverts. Furthermore, HDD would typically require a greater amount of cover than is present at the culvert locations to minimize the risk of hydraulic fracturing of the ground and loss of drilling fluid to the surface ("frac-out"). Therefore the HDD method is not considered suitable for either of these crossings and is not considered further.

The following sections of the report present and address the geotechnical design recommendations and construction issues for the four main types of construction: jack and bore; pipe ramming; MTBM and open-face shield tunnelling. A comparison of these trenchless pipe installation methods based on advantages a, disadvantages, cost and risk/consequences is presented in Table 2.

6.4.1 Jack and Bore

Conventional "jack and bore" is a method of forming a near horizontal bore from a jacking/drive (i.e., entry) pit. Boring is undertaken with a rotating cutter head and a continuous welded casing is jacked through reaction against a thrust block located within the jacking pit. Spoil from the tunnel excavation is transported to the jacking pit along helical auger flights and the new pipe is then installed within the casing. The casing may be lubricated to reduce the frictional forces between casing and the surrounding soil. The jack and bore method is generally suitable for penetrating cohesive soils (clayey silt to clay) and wet but unsaturated cohesionless soils that are well-graded (i.e., broadly graded). Jack and bore methods can lead to excessive ground losses, settlement and development of sinkholes extending to the surface when passing through saturated (flowing) or dry (running) sand, silt and/or gravel. The presence of boulders and cobbles can obstruct augering operations, damage the equipment and require manual interventions that slow progress. The removal of obstructions may also result in loss of ground at the face and ground settlement at the ground surface, depending on the soil conditions. Difficulties may also be encountered in maintaining alignment control of the tunnel as it advances due to the presence of stiffer or more compact/dense soils ahead of the face, cobbles or boulders at the face or due to mixed face conditions. Because the steel casing is jacked from the rear, there is little opportunity to adjust the alignment if deviations begin to occur as a result of obstructions or variability in the ground conditions at the tunnel face.

The size of the jacking pit is controlled by the equipment size and the length of the casing sections which are being installed. Typically, a work area of about 10 m long by about 3 m to 5 m wide is required to accommodate the jacking/drive pit for jack and bore operations. The receiving pit is typically about 3 m square.



6.4.2 Pipe Ramming

Pipe ramming involves the use of a percussive hammer to advance a steel casing with a cutting shoe attached at the front end of the casing, much like horizontal pile driving. The casing is generally advanced open-ended and the soil within the casing is typically removed after the casing has been driven the entire length of the installation, thereby reducing the potential for ground loss into the casing during driving. As each casing length is installed the rammer is removed, the next casing is welded in place and the rammer replaced and restarted. On completion of the bore, compressed air or water, pressure jetting or augering is used to remove the spoils from within the casing. In some cases, depending on the ground conditions and length of the pipe, soil can be removed periodically from within the pipe to reduce the total mass being driven and the resistance to driving.

Pipe ramming is best suited for soft to firm clays and very loose to compact sands above the water table. Pipe ramming methods are also better suited for penetrating through/displacing potential obstructions such as cobbles and boulders in comparison to the jack and bore installation method, though this method can still be obstructed by cobbles and boulders depending on their size and number. Difficulties in maintaining alignment control of the tunnel as it advances can still occur if cobbles and boulders are encountered. Vibrations from the pipe ramming operations may result in settlement of loose materials in the immediate vicinity of the installation. Furthermore, a “plug” of soil may form at the head of the casing inducing surficial heave as the pipe is advanced. This can be controlled by stopping the operation and removing spoil from within the pipe before advancing further. Compared to the jack and bore method, the single most important advantage of pipe ramming is that the soil is typically removed from the pipe only after the pipe has fully passed beneath overlying infrastructure. Another advantage of pipe ramming is that there is no need for a thrust block in the entrance pit, therefore a smaller pit size is suitable for pipe ramming.

6.4.3 Micro – Tunnel Boring Machine (MTBM)

Micro-tunnel boring machines (MTBM) typically use pressurized bentonite slurry to counterbalance the earth and water pressures acting at the tunnel face and to transport the cuttings to the surface. A remotely-controlled rotating cutterhead is used to excavate soil in a controlled manner at the face and together with the pressurized slurry these act to minimize loss of ground during tunnel advance. The slurry is circulated back through the tunnel to transport cuttings to a settling tank fitted with cyclone and screen separators. The MTBM can also be specified and equipped to cut and/or crush cobbles and boulders that are anticipated along the proposed tunnel alignment. While many MTBMs are stated as capable of cutting or crushing cobbles and boulders, these machines can still be “choked” if there are a sufficient number of cobbles and progress can still be obstructed if boulders cannot be efficiently cut by the face tools or they move around at the face in loose soils rather than being cut. Given the machine’s ability to control soil and water pressures at the face, dewatering of cohesionless soils along the tunnel alignment is seldom necessary with this tunnelling method.

Micro-tunnelling, as described above, is typically considered to be the method that minimizes the risk of loss of ground and ground surface settlement. However, it is relatively expensive to mobilize this type of equipment and the availability of machines with the suitable diameter bore and the mobilization costs for such equipment may constrain their use on this project.

In the greater Toronto area, some trenchless contractors use a “small boring unit (SBU)” and present this system as “micro-tunnelling”. In general, the small boring unit often consist of a rotating cutter head system that is



temporarily welded to the lead end of a steel casing. The ground is cut using a variety of face tools (similar to MTBMs described above), but the spoil is transported to the surface using an auger system, much like a conventional jack and bore system. Face openings on the small boring unit are typically much smaller than the auger opening on conventional jack and bore systems and the risk of uncontrolled ingress of ground into the lead end of the casing is lower for this system as compared to the jack and bore method. This system does not, however, provide consistent and positive support to the ground at all face openings with any slurry or cuttings, unlike the slurry-based MTBM described above. Therefore, while the small boring unit is more suitable and advantageous for cutting through stiff to hard cohesive glacial till and weathered rock materials, it should only be used with caution if non-cohesive soils may be encountered along the alignment.

6.4.4 Open Face Shield Tunnelling

Open face shield tunnelling involves excavating the soils using a hydraulic excavator arm, working within a full-circumference tunnelling shield. Alternatively, hand mining (i.e., manual and mechanically-assisted excavation) within the tunnelling shield could be carried out whereby the soil would be excavated using manual equipment with workers at the face. Typically, the liner would consist of a solid steel casing, jacked in sections from the launching shaft. Unlike auger jack and bore, this method allows personnel to enter the tunnel to allow more control over the operations such as for removal of obstructions or control of groundwater seepage or localized instabilities. Similar to jack and bore, however, groundwater lowering is necessary to control cohesionless soils below the groundwater level. Machine-assisted excavation generally requires a tunnel diameter of about 1.2 m or more.

6.5 Anticipated Soil Behaviour and Feasibility of Tunnelling Methods

The anticipated soil and groundwater conditions within the proposed tunnel horizons are presented on Table 1. The feasibility for installing the culvert using the jack and bore, pipe ramming, MTBM or open shield tunnelling method is summarized in Table 3.

Based on the fines content and the coefficient of uniformity² of the site soils as well as the SPT 'N' values of the soil deposits along the tunnel horizon, the soil has been classified according to the Tunnelman's Ground Classification System by Terzaghi as reported in Heuer (1974). This system is commonly used to describe the expected behaviour of an unsupported tunnel face during excavation and uses qualitative "stand-up time" criteria to classify the ground at and above the tunnel face into the following principal categories: firm, slowly ravelling, fast ravelling, cohesive-running, running and flowing.

The interpreted soil conditions within the tunnel horizon are classified on Table 3 and generally range from "slow ravelling" to "fast raveling" to "flowing." Soils that are classified as "flowing" are not considered suitable for the jack and bore method or the open face shield method of tunnelling because of the risk for uncontrolled inflows into the casing that would lead to increased settlement (and potentially sink holes) at the ground surface. These methods can be utilized if the sandy silt to silty sand deposits are dewatered/depressurized such that the

² The coefficient of uniformity is an indicator of the degree to which the soil is well graded, and is expressed as the ratio of the particle size at which 60 per cent of the particles are finer divided by the particle size at which 10 per cent are finer.



groundwater level is lowered to below the tunnel invert along the full alignment. In a moist, depressurized condition, the sandy silt to silty sand deposits would behave as ravelling ground, providing the ability to advance the tunnel with minimal ground losses if the tunnelling excavation is undertaken on a continuous controlled basis. Pipe ramming is likely suitable through the majority of the soil conditions.

In general, the soil conditions at Culvert Station 10+120 are considered suitable for culvert installation using all four of the described trenchless methodologies. At Culvert Station 29+280, MTBM methods are considered suitable, while the jack and bore method and the open face shield method would require dewatering/depressurization of the sandy silt to silt and sand layers to minimize the risk of ground losses at the face during tunnelling. For both of the culverts at Station 29+280 and 10+120, the large casing diameter, the length of the bore, and the very dense relative density of the soils anticipated at some locations within the tunnel horizon may pose challenges in advancing the casing continuously over the full length of the required crossing using pipe ramming methods.

6.5.1 Culvert at Station 29+280

The groundwater level measured at Culvert Station 29+280 is above the currently proposed invert and dewatering is recommended to lower the groundwater level below the tunnel invert. The groundwater level is subject to seasonal fluctuations and it is recommended that the groundwater conditions be verified immediately prior to the start of construction.

For the proposed invert at approximately Elevation 230.0 m, the casing pipe bore would generally encounter loose sand and silt to silty sand fill, potentially peat at the east end of the drive/shaft, and loose to dense sandy silt to silty sand.

Using the Tunnelman's Ground Classification System by Terzaghi as reported in Heuer (1974) the loose sand and silt to silty sand fill and the loose to dense silty sand above the water table would be classified as "slow to fast ravelling" and would initially have reasonable "stand-up" time. If these soils are encountered below the water level, as anticipated, they would be classified as fast ravelling to flowing and would have very little "stand-up" time.

6.5.2 Culvert at Station 10+120

The groundwater level measured in the piezometer at Culvert Station 10+120 is below the proposed invert. The groundwater level is subject to seasonal fluctuations and it is recommended that the groundwater conditions be verified immediately prior to the start of construction.

For the proposed invert of approximately Elevation 232.0 m, the casing pipe bore would generally encounter loose silty sand fill and compact to dense sandy silt to silty sand.

Using the Tunnelman's Ground Classification System by Terzaghi as reported in Heuer (1974) the loose silty sand fill and the compact to dense sandy silt to silty sand above the water table would be classified as "slow to fast ravelling" and would initially have reasonable "stand-up" time. If these soils are encountered below the water level, they would be classified as fast ravelling to flowing and would have very little "stand-up" time.



6.5.3 Jack and Bore Considerations

Jack and bore operations can be carried out below the groundwater table in soils that have a high fines content and exhibit suitable “stand-up” time; however, under such wet conditions the specifications should require that a plug of spoil material remain in the lead end of the casing at all times. This can be achieved by maintaining the auger cutting head at the appropriate distance behind the leading edge of the casing or retracting it into the casing during the jacking operations through such soils. The objective is to balance the potential inflow of material into the casing, with a plug of soil at the front of the casing to minimize ground loss and consequent settlement. Once started, the jack and bore operation should continue without interruption until complete.

If obstructions, such as a boulder or a nest of cobbles, are encountered, it would be necessary to remove the augers and soil plug. Depending on the soil conditions at the location of the obstructions, this may result in loss of ground at the face and ground settlement at the ground surface. The contractor should have a contingency plan for such an event that includes highway closure to protect the travelling public.

Difficulties may also be encountered in maintaining alignment control of the tunnel as it advances due to the presence of cobbles/boulders, stiffer or more compact/dense soils ahead of the face or mixed face conditions.

Ground movements should be monitored during casing installation to measure ground surface movements (i.e. settlement/heave) as compared to specified tolerances. Construction specifications for the installation of the sewer/culvert by jacking and boring and pipe ramming are given in the NSSP “Pipe Installation by Trenchless Method” included in Appendix D.

6.5.4 Pipe Ramming Considerations

The feasibility of pipe ramming is questionable at the crossing locations where non-cohesive loose to compact silty sand fill and a sandy silt to silty sand deposit as well as a high groundwater level were encountered within the tunnel horizon.

As with the jack and bore method, tunnel alignment may be difficult to control due to the potential presence of mixed face conditions. Also, there is an increased risk of difficulty with alignment control for the option where the tunnelled portion is extended beyond the east shoulder of the southbound lanes into the median, owing to the increased installation length. If cobbles and boulders are encountered requiring, the casing to be cleaned out to allow for access of equipment to break up the obstructions, cleaning out the spoils from inside the casing may result in the loss of ground at the face of the casing.

Ground movements should be monitored during pipeline installation to measure ground surface movements (i.e., settlement/heave) as compared to specified tolerances. Construction specifications for the installation of the sewer/culvert by jacking and boring and pipe ramming are given in the NSSP “Pipe Installation by Trenchless Method” included in Appendix D.

6.5.5 MTBM Considerations

The MTBM method uses bentonite slurry to counterbalance the earth and water pressures acting at the tunnel face. If the slurry pressure at the face is allowed to become excessive for the soil conditions, hydraulic fracture



(typically referred to as “frac-out”) of the ground can occur, allowing bentonite slurry to exit at ground surface. “Frac-out” can then result in a sudden drop in face pressure, creating face instability if tunnelling through non-cohesive soils below the groundwater table. To minimize the risk of “frac-out” the MTBM method should not be used for culvert crossing locations on this project with cover of less than 2.5 m. Further, to properly support ground at the cutting face and along the pipe if an over-cut is used, slurries should have a Marsh funnel viscosity of not less than about 70 seconds.

An advantage of the MTBM is that lowering of the groundwater level in non-cohesive soils is not required. Another advantage is that the MTBM can also be specified to have the capability to cut and crush boulders may be encountered along the proposed tunnel alignments. For tunnelling in the anticipated ground conditions on this project, MTBMs should be specified to include rock disc cutters and/or roller bit cutters as well as soft-ground excavation tools on the MTBM face.

Microtunnelling should not be undertaken on this project using a “small boring unit (SBU)” where there is a risk that saturated or dry granular soils (native or highway and pavement fill materials) might be encountered. While the small boring unit is often highly effective in penetrating the till deposit types in the area (depending on face tool configuration), the openings in the cutting head are not well protected against uncontrolled ingress of running or flowing ground.

Ground movements should be monitored during casing installation to measure ground surface movements (i.e., settlement/heave) as compared to specified tolerances.

6.5.6 Open Face Shield Tunnelling Considerations

If the open face shield tunnelling method is selected as the liner/culvert installation method at either of these two sites, the contractor should have a means to readily secure the face if inward ground deformation is encountered or if unanticipated work stoppages are necessary (pre-fabricated breasting boards, etc.). Further, the tunnelling work should be continuous from start to finish (24 hours per day, 7 days per week). If it is necessary to stop the tunnelling operations, the contractor should be prepared to immediately support the face. Filling of the annular space between the liner and native ground should be carried out as soon as the liner is installed (bentonitic grout/lubricant in the case of jacked pipes, with cementitious grout provided at the completion of construction).

Ground movements should be monitored during liner installation to measure ground surface movements (i.e. settlement/heave) as related to specified tolerances. Construction specifications for the installation of the culvert by tunnelling are given in the NSSP “Pipe Installation by Trenchless Method” included in Appendix D.

6.6 Settlement

Based on the cross-sections provided by MH, it is understood that at Culvert Station 10+120, the proposed highway grade will be at about Elevation 240.8 m, requiring a grade raise of about 3 m atop the existing Highway 400 SBL lanes. Additionally, widening of the highway to the east and to the west will result in up to about 7 m and 4.5 m, respectively, of additional fill being placed on the embankment side slopes. For Culvert Station 29+280, no grade raise is proposed, but the widening of the highway to the east to create the new NBL



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embankment will result in up to 6.5 m of additional fill being placed. This embankment widening will induce some settlement in the foundation soils beneath the culvert in the widening area.

Settlement analyses were performed using the commercially available software program "Settle3D" produced by Rocscience Inc. to estimate the settlement of the foundation soils.

The values of the parameters used in the analyses of settlement for the culverts as given below are based on field and geotechnical laboratory test data and correlations suggested by Bowles (1984) from the soil conditions encountered in the boreholes at this site. An average groundwater level of approximately Elevation 231.0 m was used in the model.

Culvert Location	Soil Layer	Approximate Thickness (m)	Bulk Unit Weight (kN/m ³)	Young's Modulus, E (MPa)
Culvert Station 29+280	Existing fill	2.5	20	15
	Compact Silt	1.6	19	15
Embankment Widening	Loose to dense Silty Sand	4.4	19	20
Culvert Station 10+120 Grade Raise	Existing fill	3.8	20	20
	Compact to dense Sand to Silty Sand	6.5	19	25
	Compact Silt	1.5	19	15
	Dense Silty Sand	1.1	19	25
Culvert Station 10+120 Embankment Widening	Existing fill	1.5	20	15
	Compact Silty Sand	2.2	19	20
	Compact Silt to Sandy Silt	4.5	19	20

The analyses were carried out for both culverts and assume that all organic and loose surficial soils have been removed prior to embankment fill placement. The estimated magnitude of settlement for the culvert areas is provided in the table below.

Location	Estimated Elastic Settlement (mm)
Culvert Station 29+280 Embankment Widening to the East	65 - 70
Culvert Station 10+120 Grade Raise on Existing SBL	35 - 45
Culvert Station 10+120 Embankment Widening to the East	50 - 75



The majority of the settlement is expected to occur during or shortly after construction in response to filling, based on the non-cohesive nature of the silt to sand deposits, and the generally very stiff to hard nature of the cohesive layers.

Given the above estimated magnitude of settlement, the liner will have to be designed to accommodate such settlement or the widening and any grade raise should be completed prior to pipe installation by tunnelling.

6.6.1 Instrumentation and Monitoring During Trenchless Installation

An instrumentation and monitoring program is recommended at the crossing locations for Culvert Station 29+280 and Culvert Station 10+120 to:

- document the effects of the trenchless culvert installation on the overlying roadways, adjacent structures or services lines/pipes;
- identify adverse movement trends;
- measure the Contractor's compliance with the settlement limits specified in the Contract; and
- provide information to support adaptation of the culvert installation methods to observed behaviour and ground conditions toward compliance with the settlement limits.

Monitoring of settlement instruments on this project is constrained by the continuous and high traffic volume on Highway 400 and the limited periods during which access to the highway can be obtained. By necessity, settlement points located on the road at spacings not greater than 5 m intervals along the tunnel alignment must be read remotely and the use of electromagnetic distance measuring equipment reading reflectors installed on the highway is recommended. A specialist surveying firm should be retained to confirm the set-up and to carry out the settlement monitoring during construction; their equipment and procedures must be capable of surveying the settlement point elevation to within ± 2 mm of the actual elevation.

In addition, in-ground settlement points, consisting of a sleeved iron bar, set/anchored below the depth of frost penetration but not deeper than 0.3 m above the tunnel obvert elevation should be installed at each crossing at accessible locations on the highway shoulders. The elevation of the top of the bar would be read using conventional precision levelling equipment. The in-ground monitoring points provide the best measure of the ground settlement effects of tunnelling, as they are unaffected by frost heave, thaw settlement or the bridging action of the pavement structure.

All monitoring points should be read at least three times (on separate days) before the start of culvert installation to establish a pre-construction baseline. All points behind the face of the excavation and those within 10 m of the front of the face should be read every 4 hours over the duration of the tunnel drives. The effectiveness of this monitoring method could be impacted by weather conditions if the work is undertaken during the winter months.

Where concrete pavements exist, these may temporarily bridge over and mask underlying ground losses or settlements. High traffic volumes and the need to preserve the integrity of pavements further inhibit installation of monitoring points through concrete pavements. Therefore, to the extent practicable and possible, it will be important to measure the volume of ground removed from beneath paved areas as compared to the theoretical



cut hole volume on a frequency of at least once per 6 m section of pipe installed. Measuring excavated ground volumes will be difficult because of bulking that occurs when excavating soils and the spoil discharge systems on some systems are not readily conducive to such measurements (e.g., jack and bore, MTBM). However, on-site observation of construction operations and measurement of grout and/or lubricant volumes should assist in identifying atypical conditions that could be indicative of unacceptable ground losses.

A Non-Standard Special Provision for trenchless installation is provided in Appendix D for incorporation into the Contract Documents, and this NSSP includes requirements for settlement monitoring during trenchless operations. A settlement monitoring plan, including setting of Review and Alert Levels, consistent with the requirements in the “Appendix: Settlement Monitoring Guideline – Tunnelling” of MTO’s “Guideline for Foundation Engineering – Tunnelling Speciality for Corridor Encroachment Permit Application”, should be established as part of the Contract Administration for construction.

6.7 Grouting

After the permanent culvert pipe is installed within the jacked or rammed casing, post installation grouting to fill the annular space between the culvert and the casing should be carried out, consistent with the requirements in the NSSP for culvert installation via trenchless technology presented in Appendix D.

For any installations at which the settlement monitoring indicates that pavement settlement has occurred, or where signs of ground loss have been noted, provision should be made for a program of compensation grouting above the pipe and/or repair of the pavements.

6.8 Pipe Culvert in Open Cut

The existing embankment is to be widened along the east side and the new section of three culverts extending beyond the toe of the existing embankment to the toe of the widened embankment will likely be constructed in an open cut excavation. In this case, this section of the pipe culverts should be constructed in accordance with OPSS 421 (Pipe Culvert Installation in Open Cut), and the bedding, levelling course and backfill for a concrete pipe culvert should be in accordance with OPSD802.034 (Rigid Pipe Bedding and Cover in Embankment). It is important that the backfill at the haunches of the culvert sections be well compacted. The pipe culvert sections should be constructed on a minimum 300 mm thick layer of OPSS.PROV1010 (Aggregates) Granular ‘A’ or Granular B Type II material for bedding purposes.

If the top of the pipe culvert section is located above the frost penetration depth (1.6 m for this site location), depending on the thickness of embankment over the culvert for the chosen culvert size and invert elevation, a frost taper should be constructed with a geometry similar to that provided on OPSD803.031 (Frost Treatment).

6.9 Lateral Earth Pressures for Design

The lateral earth pressures acting on any associated head and wing walls and the walls will depend on the type and method of placement of the backfill materials, the nature of the soils behind the backfill, the magnitude of the



surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls.

The following recommendations are made concerning the design of the head/wing walls. These design recommendations and parameters assume level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free-draining granular fill meeting the specifications of OPSS.PROV 1010 Granular A or Granular B Type II (but with less than 5 per cent passing the 200 sieve) should be used as backfill behind the walls.
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the head/wing walls, in accordance with CHBDC Section 6.9.3 and Figure 6.6. Compaction equipment should be used in accordance with OPSS 501 (Compacting). Other surcharge loadings should be accounted for in the design as required.
- The granular fill should be placed within the wedge shaped zone defined by a line drawn at 1.5H:1V extending up and back from the base of the rear face of the walls as per Case B in Figure C6.20(b) of the Commentary to the CHBDC. The depth of frost penetration for this site may be taken as 1.6 m as per OPSS 3090.101 (Frost Penetration Depths for Southern Ontario).
- For Case B, where the pressures are based on OPSS.PROV 1010 Granular A or Granular B Type II fill behind the wall, the following parameters (unfactored) may be assumed:

	Granular A	Granular B Type II
Soil unit weight:	22 kN/m ³	21 kN/m ³
Coefficients of static lateral earth pressure:		
Active, K_a	0.27	0.27
At rest, K_o	0.43	0.43

Where the culvert head/wing wall does not allow for lateral yielding, at-rest earth pressures should be assumed for the geotechnical design. Where the wall and the support allows lateral yielding of the stem, active earth pressures should be used in the geotechnical design of the wall structure. The movement required to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.9.1 and Table C6.6 of the Commentary to the CHBDC.

6.9.1 Seismic Considerations

Based on Section 4.1.6 of MTO's Gravity Pipe Design Guidelines for Circular Culverts and Storm Sewers (2006), seismic loads are generally not considered in design for pipes less than 3 m in diameter/span. However, seismic design for corrugated steel pipe culverts can be assessed, if necessary, according to the seismic requirements in Chapter 7 of CHBDC.



6.10 Construction Considerations

6.10.1 Surface Water and Groundwater Control

Control of the surface water and groundwater will be necessary for the construction of the new/replacement culverts and the section of eastern extension, to allow excavation and construction to be carried out in dry conditions where required.

Depending on the creek flow at the time of construction, the surface water flow could be passed through the existing culvert area by means of a temporary pipe, or diverted by pumping from behind a temporary cofferdam. Surface water should be directed away from the excavation areas, to prevent ponding of water that could result in disturbance and weakening of the subgrade soils.

Groundwater control will be required at the Culvert Station 29+280, and possibly at Culvert Station 10+120 depending on the seasonal time of construction, as the foundation excavation for the access shafts and the open cut eastern extension is expected to extend below the groundwater level. Where the excavation will be advanced through existing fill and will be advanced through or into water-bearing cohesionless soils, appropriate dewatering of the water-bearing granular soil deposits will be required to maintain the water level below the founding level for the culvert during excavation and construction. It is recommended that an NSSP be included in the Contract Documents to warn the Contractor of the soil conditions and the requirement for design and installation of groundwater control for the culvert replacements. An NSSP is given in Appendix D for incorporation into the Contract Documents. An NSSP is also provided in Appendix D to address cofferdams.

It is noted that a trichloroethylene (TCE) plume exists within the limits of this contract. As a result, it is understood that Morrison Hershfield has incorporated an NSSP into the Contract Documents to address environmental monitoring of groundwater during any dewatering that is required. It is further understood that the draft Permit to Take Water that has been completed for this contract includes environmental groundwater monitoring requirements related to the TCE plume.

6.10.2 Excavations and Temporary Roadway Protection

Temporary excavations for the eastern extension of the culvert s and for the access shafts/pits for the trenchless installations will be made through the existing embankment fill and native soils, which typically vary from loose to dense non-cohesive 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. The existing fill and the sandy silt to silty sand soils would be classified as Type 3 soil, according to the Occupation Health and Safety Act, assuming that proper groundwater control is in place to dewater cohesionless soil deposits prior to excavation, where necessary. Where space permits, and provided that proper groundwater control is in place, temporary open-cut excavations through these materials should be made with side slopes formed no steeper than 1H:1V.

Temporary protection systems will likely be required for the entry and exit pits, to facilitate construction staging to maintain traffic on Highway 400 during the culvert works.

The temporary excavation support systems for the culvert work should be designed and constructed in accordance with OPSS.PROV539 (Temporary Protection Systems). The lateral movement of the temporary



shoring system should meet Performance Level 2 as specified in OPSS.PROV 539, provided that any adjacent utilities can tolerate this magnitude of deformation.

The maximum excavation depth of the protection systems is different at each culvert site but may be up to about 8 m deep. Although the selection and design of the protection system will be the responsibility of the Contractor, it is considered that either a driven, interlocking sheet pile system or a soldier pile and timber lagging system would be suitable for the roadway protection at these culvert sites, based on the subsurface soil and groundwater conditions. An interlocking sheet pile system would contribute to both ground and groundwater control. For the soldier pile and lagging system, it would be necessary to lower the groundwater level to control seepage from the non-cohesive fill or native soils, or include measures to mitigate loss of soil particles through the lagging boards.

The sheet piles or soldier piles would have to be driven/socketted to sufficient depth to provide the necessary passive resistance for the retained soil height. Lateral support to the sheet piles or soldier piles could be provided in the form of rakers or temporary anchors.

6.10.3 Settlement Monitoring

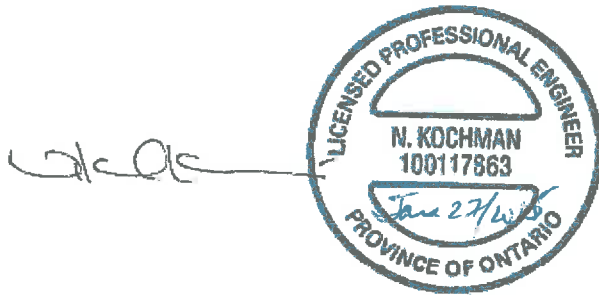
As discussed in Section 6.6.1, the NSSP for trenchless installation includes requirements for settlement monitoring of the existing Highway 400 embankment (shoulders and lanes) during trenchless operations. In addition, it is recommended that a limited settlement monitoring program be conducted during and immediately following construction of the new northbound lane embankment, with the timing for construction of the final culvert (within the primary liner) controlled by an Operational Constraint (OC). The OC that has been developed for the embankment and culvert construction is provided in Appendix D. The NSSPs for supply and installation of the settlement monitoring instrumentation are provided in Golder's Foundation Investigation and Design Report for the embankment widening and retaining walls.



7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Nikol Kochmanová, P. Eng., with technical input from Ms. Lisa Coyne, P.Eng., senior geotechnical engineer. The report was reviewed by Mr. Jorge Costa, P.Eng., a Designated MTO Foundations Contact and Principal of Golder.

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- OPSS.PROV 501 Construction Specification for Compacting
- OPSS.PROV 539 Construction Specification for Temporary Protection Systems
- OPSS.PROV 1010 Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
- Ontario Provincial Standard Drawings
- OPSD 802.034 Rigid Pipe Bedding and Cover in Embankment, Original Ground: Earth or Rock
- OPSD 421 Construction Specification for Pipe Culvert Installation in Open Cut
- OPSD 3090.101 Foundation, Frost Penetration Depths for Southern Ontario
- OPSD 803.031 Frost Treatment – Pipe Culvert, Frost Penetration Line between Top of Pipe and Bedding Grade
- Ontario Water Resources Act
- Ontario Regulation 903/90 Wells: O. Reg. 468/10 Amendment to Ontario Regulation 903
- Ontario Occupational Health and Safety Act
- Ontario Regulation 213 (Construction Projects)



Table 1: Summary of Culvert Construction and Interpreted Subsurface Conditions

Culvert Station (Hwy 400) (m)	Embankment/ Roadway Grade Elevation (m)	Approximate Culvert Invert Elevation (m)	Proposed Culvert Diameter (mm)	Assumed Casing Diameter (mm)	Approximate Depth of Cover to Obvert of Culvert (m)	Equivalent Tunnel Diameters of Overburden Cover to Obvert of Culvert	Anticipated Subsurface Conditions at Culvert Level	Distance Between Groundwater and Invert of Culvert at Outlet (m)
Culvert Station 29+280	239.0	230.0	1800	2700	5.8	2.1	<div><div></div> Compact to dense silty sand to sand and silt fill</div> <div><div></div> Loose to dense silt and sand to sandy silt to silty sand</div>	About 1.5 m above invert
Culvert Station 10+120	240.8 (after 3.0 m grade raise)	232.0	1650	2475	6.3	2.5	<div><div></div> Compact to dense silty sand to sand and silt fill</div> <div><div></div> Loose to dense sandy silt to silty sand</div>	About 0.5 m below invert

Prepared By: NK

Reviewed By: JMAC



Table 2: Evaluation of Trenchless Culvert Installation Methods

Installation Method	Feasibility of Trenchless Method	Advantages	Disadvantages	Estimated Costs/m of Culvert Installation	Risk/Consequences
Jack and Bore Installation	Yes, although dewatering would be required to control the ground for the culvert at Station 29+280, and may be required for the culvert at Station 10+120	<ul style="list-style-type: none">■ Culverts can be installed without lane closures resulting in minimal traffic disruption.■ Appropriate for the pipe length required at these sites	<ul style="list-style-type: none">■ Large work area required for jacking pit.■ Obstructions (e.g. cobbles and boulders) may deflect and/or halt bore. Greatest risk of ground subsidence of highway particularly if obstructions that slow down installation procedures or if unanticipated granular soils are encountered.■ Likely require groundwater lowering for these two sites.	\$900 ² /m to \$1,800 ³ /m	<ul style="list-style-type: none">■ Risk of encountering refusal on obstructions within native deposits, particularly till, where man entry to remove obstructions is not possible.■ Obstructions can result in deflection of the casing resulting in misalignment of culvert.■ Potential for loss of ground into casing particularly if cohesionless materials are encountered and groundwater level is inadequately lowered.■ Risk of ground surface subsidence increases with decreasing cover.
Pipe Ramming Installation	Yes, although this method may be challenging due to length of bore, casing diameter, and hard ground conditions at some locations within tunnel horizon	<ul style="list-style-type: none">■ Minimal traffic disruption.■ Less risk of subsidence above culvert alignment than jack and bore installation methods.■ Better suited for penetrating through potential obstructions such as cobbles and boulders than jack and bore methods.	<ul style="list-style-type: none">■ Large work area required for ramming pit.■ Large obstructions can deflect casing. Potential for heaving at ground surface. May require groundwater lowering.■ Potential noise objections in urban areas.■ Potentially not appropriate for the pipe lengths required at these sites.	\$1,800 ² /m to \$3,600 ³ /m	<ul style="list-style-type: none">■ Obstructions can cause deflection of casing resulting in misalignment of culvert.■ Nests of cobbles and/or boulders can stop penetration of casing requiring hand mining.■ Vibration from pipe ramming may be experienced by the users of the highway.
MTBM	Yes	<ul style="list-style-type: none">■ Minimal traffic disruption.■ Typically does not require groundwater lowering except for use of a “small boring unit (SBU)” without slurry face pressure and cuttings transport systems.■ Slurry machines able to counterbalance earth and water pressures in a controlled manner, thereby reducing the risk of ground losses during tunnelling.■ Machine can also be specified to have the capability to cut and crush boulders.	<ul style="list-style-type: none">■ Relatively expensive. High mobilization cost for short crossings.■ Slurry processing systems required together with additional working area at shaft/pit locations for some systems.■ “SBU” systems are not capable of fully controlling saturated granular soils.■ Susceptible to hydraulic fracture depending on slurry viscosity and pressure.	\$8,000/m	<ul style="list-style-type: none">■ Hydraulic fracture is possible at culvert locations with cover less than 2.5 m and any slurry exiting onto the pavements could be a significant hazard to the travelling public■ Use of SBUs or low viscosity slurries could contribute to excessive ground losses when cutting through granular soils that result in pavement damage and a significant hazard to the travelling public



FOUNDATION REPORT - CULVERT EXTENSION, TWINNING AND REPLACEMENT, G.W.P. 2159-11-00

Installation Method	Feasibility of Trenchless Method	Advantages	Disadvantages	Estimated Costs/m of Culvert Installation	Risk/Consequences
Open Face Shield Tunnelling	Yes	<ul style="list-style-type: none">Minimal traffic disruption.Better suited for penetrating through potential obstructions such as cobbles and boulders than jack and bore methods.	<ul style="list-style-type: none">Risk of ground subsidence of highway but more control than jack and bore methods.Requires groundwater lowering as saturated granular soils might be encountered at one of the culvert sites.Requires diameter sufficient for person entry (>1 m)Additional health and safety concerns	\$1,800 ² /m to \$3,600 ³ /m	<ul style="list-style-type: none">Potential for loss of ground into shield particularly if cohesionless materials are encountered.Risk of ground surface subsidence increases with decreasing cover.

Prepared By: NK Reviewed By: JMAC



FOUNDATION REPORT - CULVERT EXTENSION, TWINNING AND REPLACEMENT, G.W.P. 2159-11-00

Table 3: Feasibility of Jack and Bore, Pipe Ramming and MTBM Pipe Installation Methods

Culvert Station (Hwy 400) (m)	Proposed Culvert Diameter (Length) (mm)	Approximate Depth of Cover to Casing Obvert (m)	Borehole Designation	Soil Conditions ¹ (ground surface to invert)	Fines Content ² (%)	SPT 'N' Values (ground surface to invert) (per 0.3 m)	Coefficient of Uniformity	Behaviour	Feasibility of Jack and Bore	Feasibility of Pipe Ramming	Feasibility of MTBM	Feasibility Of Open Face Shield
Culvert 1 Station 29+280	1800 (70 m)	5.8	C1	Silty sand fill	-	1, 3	-	Fast Ravelling, Flowing	Yes but requires dewatering	Questionable	Yes	Yes but requires dewatering
			C3	Sand and silt fill	-	8	-	Fast Ravelling, Flowing				
			C5	Silty sand fill, silt ^{*a} , Silty Sand ^{*b}	77 ^{*a} , 23 ^{*b}	38, 18, 32, 16, 12, 15, 28, 44, 30, 20	>28 ^{*a} , >2.7 ^{*b}	Fast Ravelling, Flowing				
			HF-1	Silty sand fill, sand and silt fill ^{*a}	38 ^{*a}	9, 6, 4, 4	7.5 ^{*a}	Fast Ravelling, Flowing				
Culvert 2 Station 10+120	1650 (61 m)	3.3	C2	Silty sand fill	-	6, 9	-	Slow to Fast Ravelling	Yes	Questionable	Yes	Yes
			C4	Silty sand fill, Silty Sand to Sandy Silt ^{*a}	9 ^{*a}	12, 8, 30	18.9 ^{*a}	Slow to Fast Ravelling				
			TRW-3	Sand fill ^{*a} , silty sand fill, Sand	10 ^{*a}	42, 35, 37, 13, 29	0.5 ^{*a}	Slow Ravelling				
			RW12	Gravelly sand fill, silty sand fill ^{*a} , Silty Sand	27 ^{*a}	18, 10, 19, 32, 32, 44, 19, 13	>3.3 ^{*a}	Fast Ravelling				

Notes:

1. Soil conditions from ground surface to invert, bold soil condition indicates soil conditions at tunnel horizon.
2. Fines content is the percentage by weight passing the number 200 sieve.
- ^{*a} and ^{*b} Fines content marked with ^{*a} coincide with soil material marked with an ^{*a} and Fines content marked with ^{*b} coincide with soil material marked with an ^{*b}

Prepared By: NK

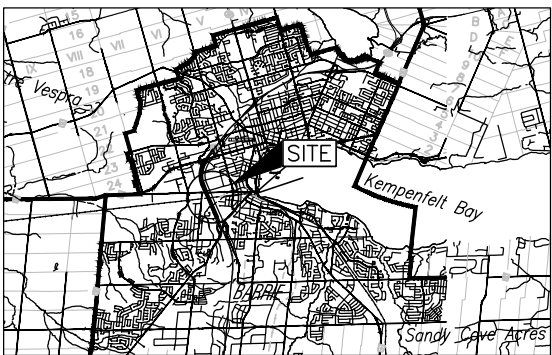
Reviewed By: JMAC

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

CONT No.
GWP No. 2159-11-00

HIGHWAY 400
CULVERT AT STA 29+280
BOREHOLE LOCATIONS AND SOIL
STRATA

SHEET



KEY PLAN

LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation By Others (2014)
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- R Refusal
- WL in piezometer, measured on OCT 31, 2014
- WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
HF1	233.2	4914216.0	288583.2
BH C1	232.0	4914237.9	288578.9
BH C3	233.0	4914174.7	288531.9
BH C5	238.7	4914205.6	288547.5

NOTES

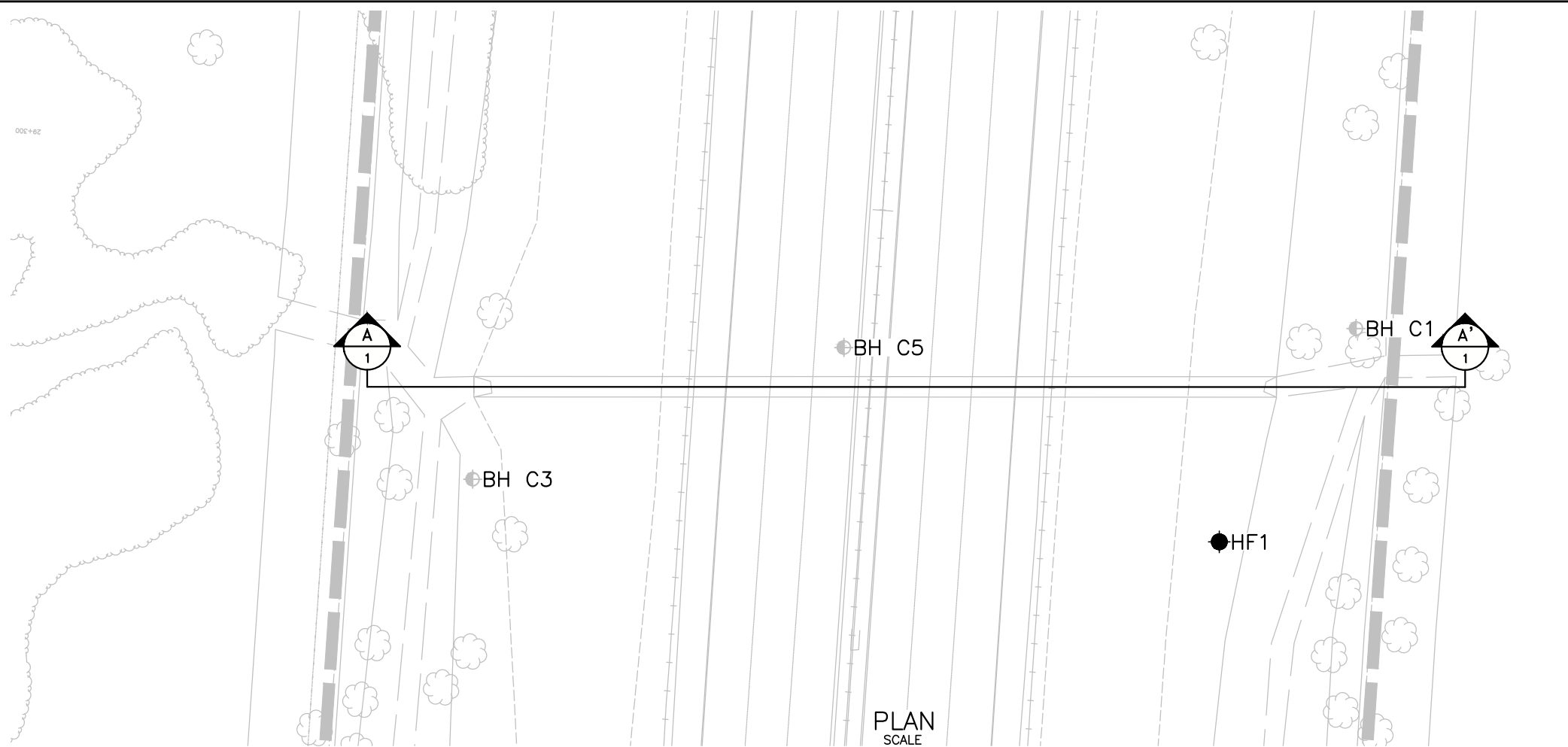
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

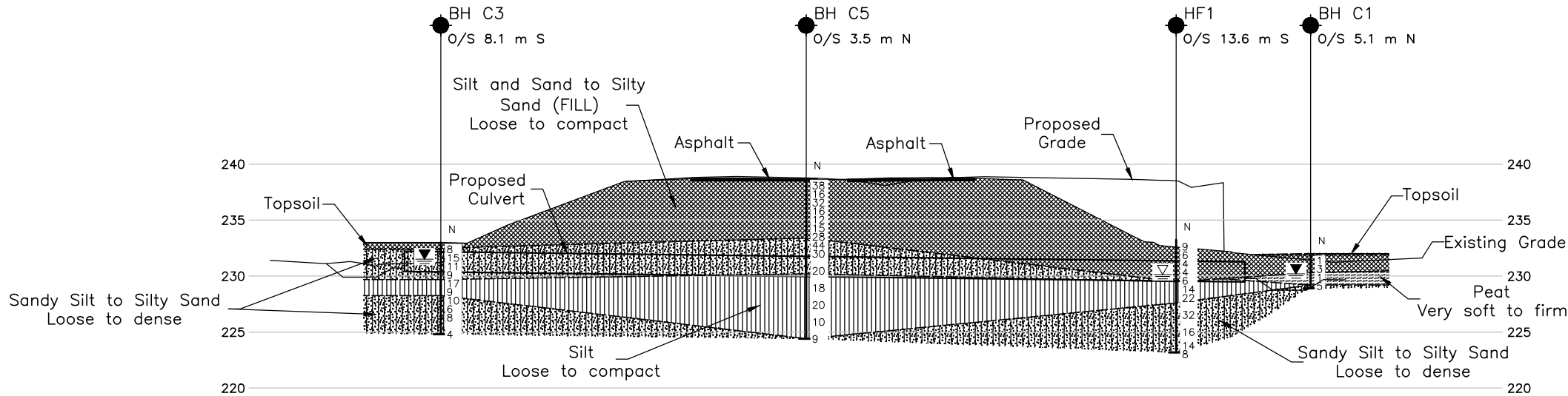
The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS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

REFERENCE

Base plans provided in digital format by Morrison Hershfield, drawing file nos. x1124220_Base.dwg, received Aug. 08, 2015. Proposed culvert profile provided by Morrison Hershfield, drawing file no. NEW-CULVERT-PROFILES_RAH_08Jan16.dwg, received Jan. 20, 2016.



PLAN SCALE



PROFILE

HORIZONTAL SCALE



VERTICAL SCALE

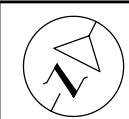


NO.	DATE	BY	REVISION
Geocres No. 31D-634			
HWY. 400	PROJECT NO. 1532543		DIST. CENTRAL
SUBM'D. NLP	CHKD. NLP	DATE: 1/21/2016	SITE: .
DRAWN: TB	CHKD. NK	APPD. JMAC	DWG. 1

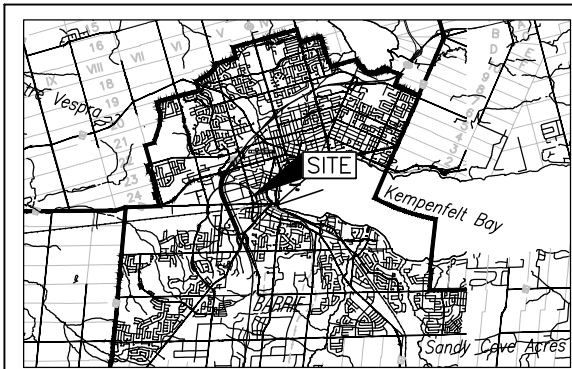
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 2159-11-00

HIGHWAY 400
CULVERT AT STA 10+120
BOREHOLE LOCATIONS AND SOIL
STRATA



SHEET



KEY PLAN

LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation By Others (2014)
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- R Refusal
- WL in piezometer, measured on OCT 31, 2014
- WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
TRW-3	237.8	4914663.2	288187.6
BH C2	233.3	4914672.0	288212.1
BH C4	233.7	4914647.2	288140.5
RW12	237.7	4914649.3	288175.8

NOTES

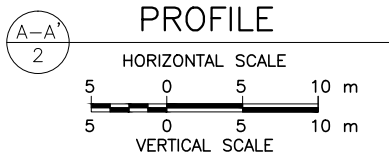
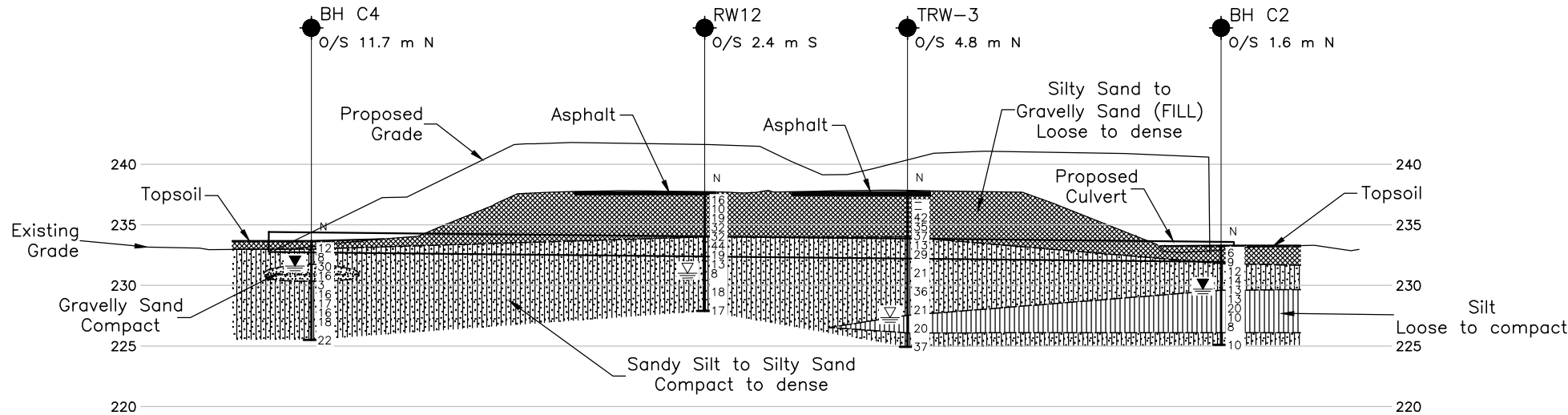
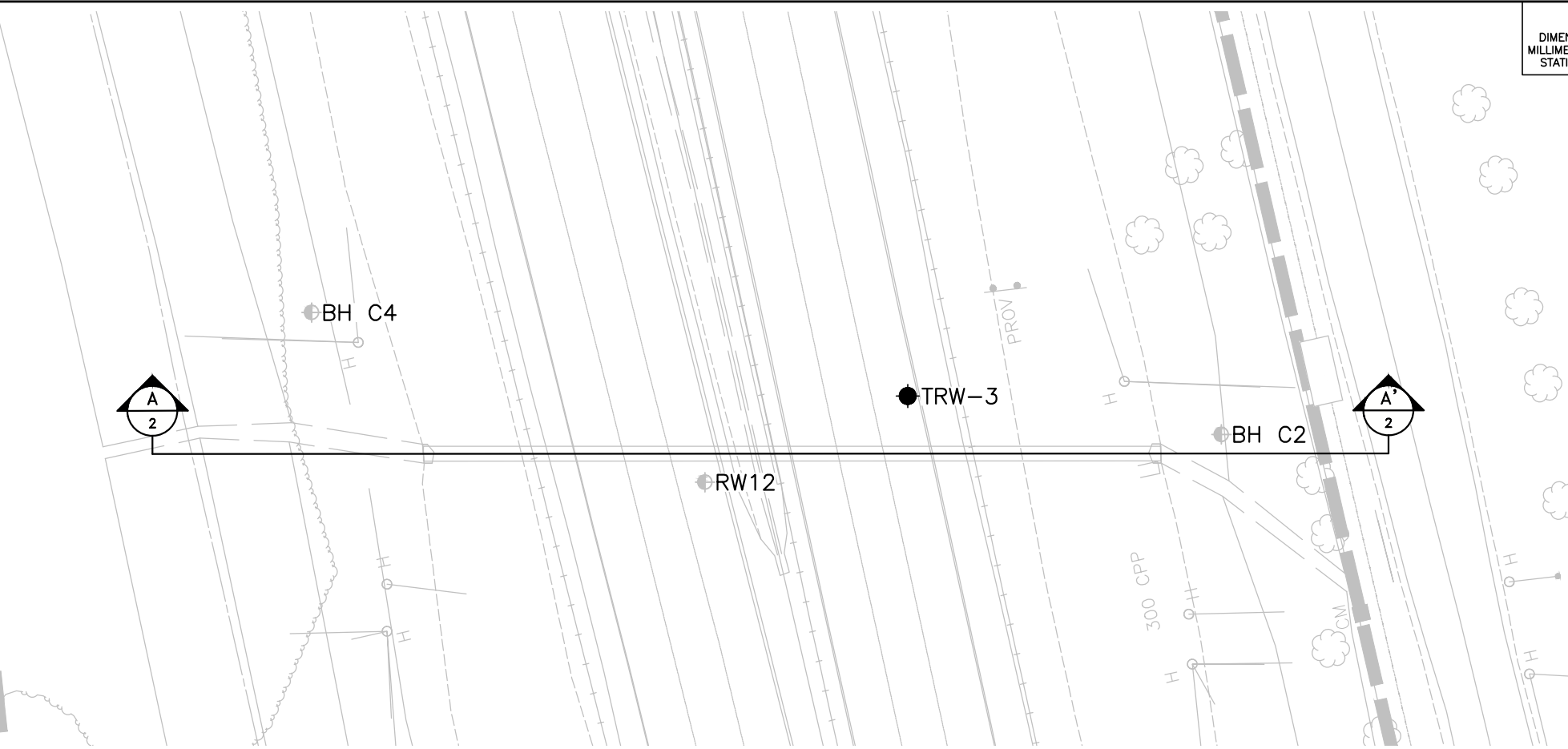
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NO.	DATE	BY	REVISION
Geocres No. 31D-634			
HWY. 400	PROJECT NO. 1532543	DIST. CENTRAL	
SUBM'D. NLP	CHKD. NLP	DATE: 1/21/2016	SITE: .
DRAWN: TB	CHKD. NK	APPD. JMAC	DWG. 2



APPENDIX A

Record of Boreholes from Current Investigation



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
FoS	factor of safety

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

$$\tau = c' + \sigma' \tan \phi'$$
$$\text{shear strength} = (\text{compressive strength})/2$$



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
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
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) Non-Cohesive (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

Per cent 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 (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

[illegible]

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

SUD-MTO 001 1532543.GPJ GAL-MISS.GDT 30/11/15 DATA INPUT:

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



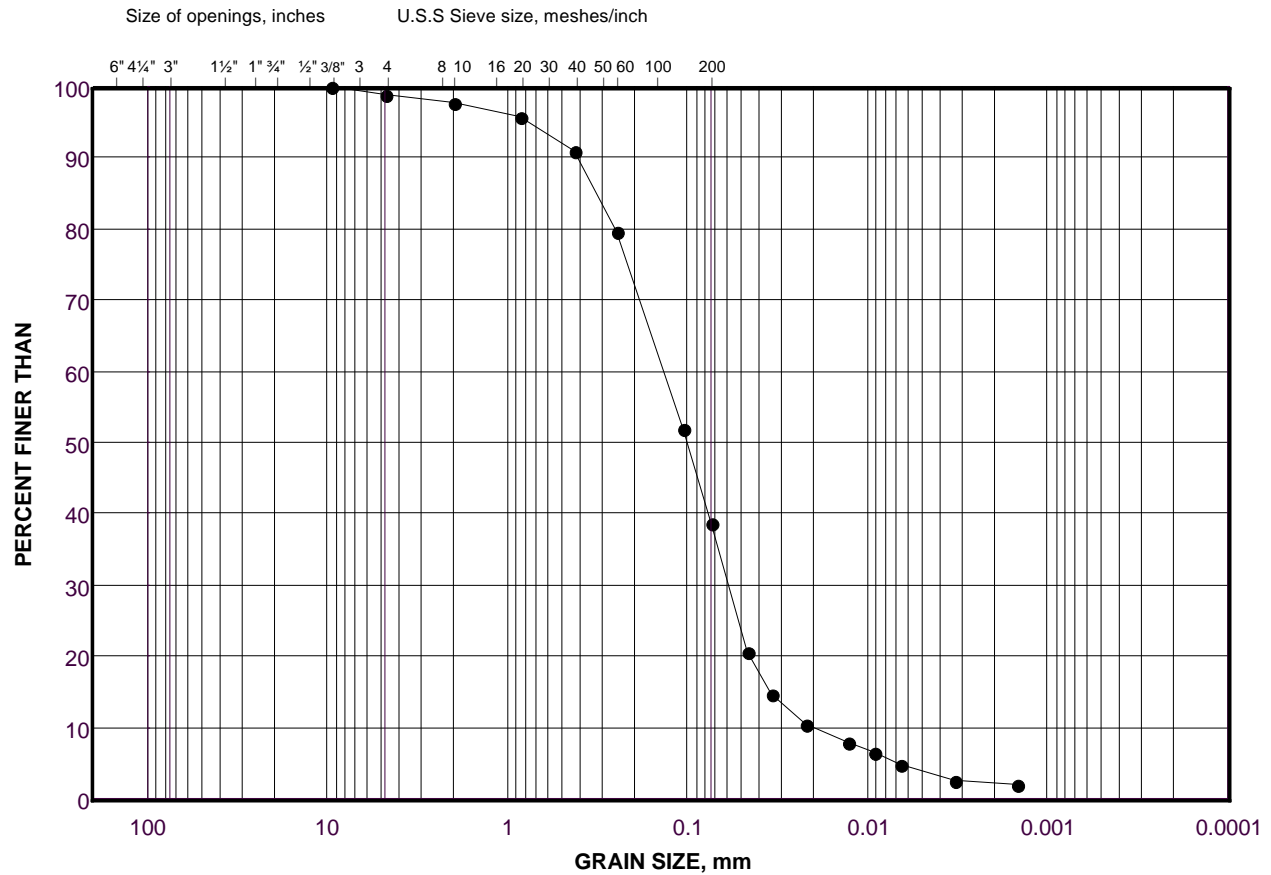
APPENDIX B

Geotechnical Laboratory Test Results

GRAIN SIZE DISTRIBUTION

Silt and Sand (Fill)

FIGURE B1



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	HF1	3	231.4

Project Number: 1532543

Checked By: NK

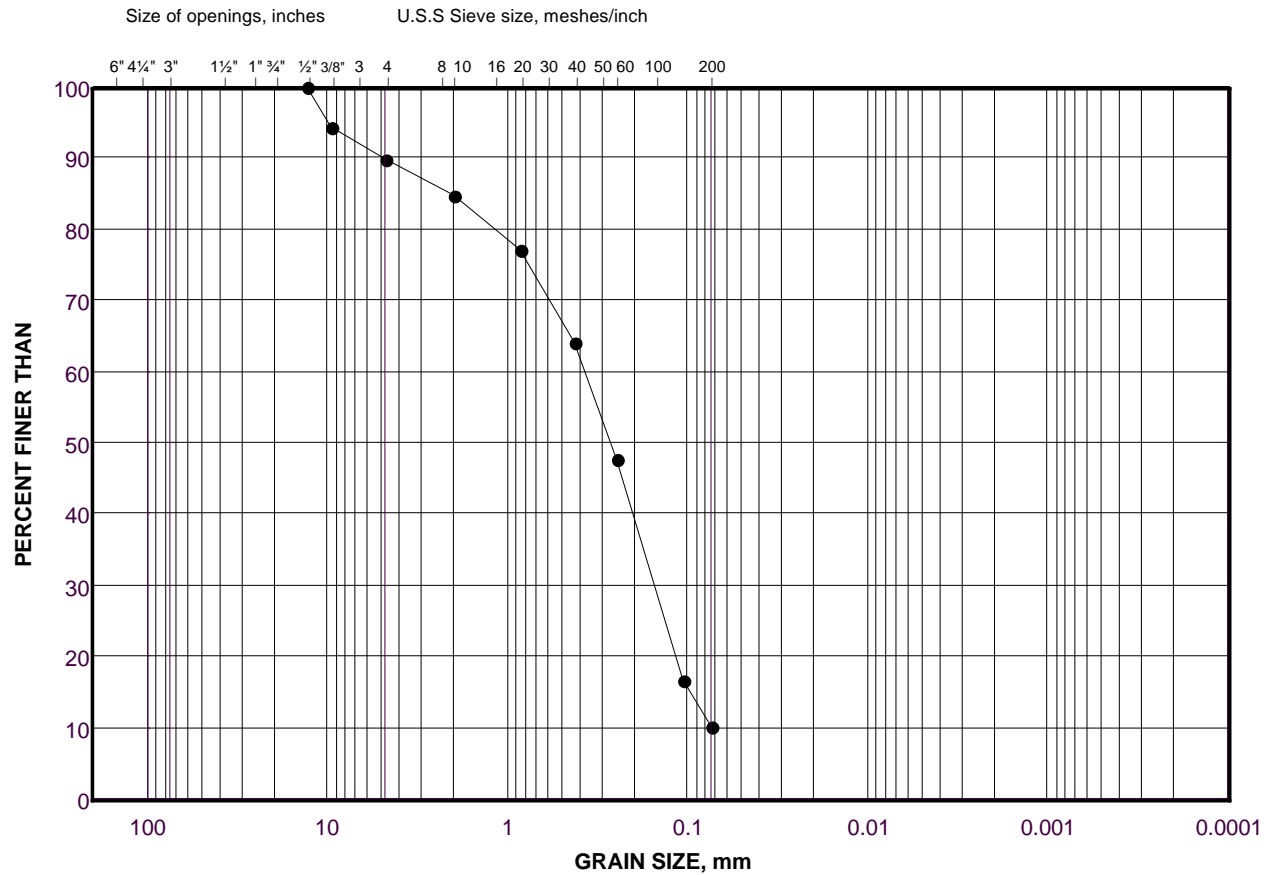
Golder Associates

Date: 25-Nov-15

GRAIN SIZE DISTRIBUTION

Sand (Fill)

FIGURE B2



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	TRW-3	2	236.7

Project Number: 1532543

Checked By: NK

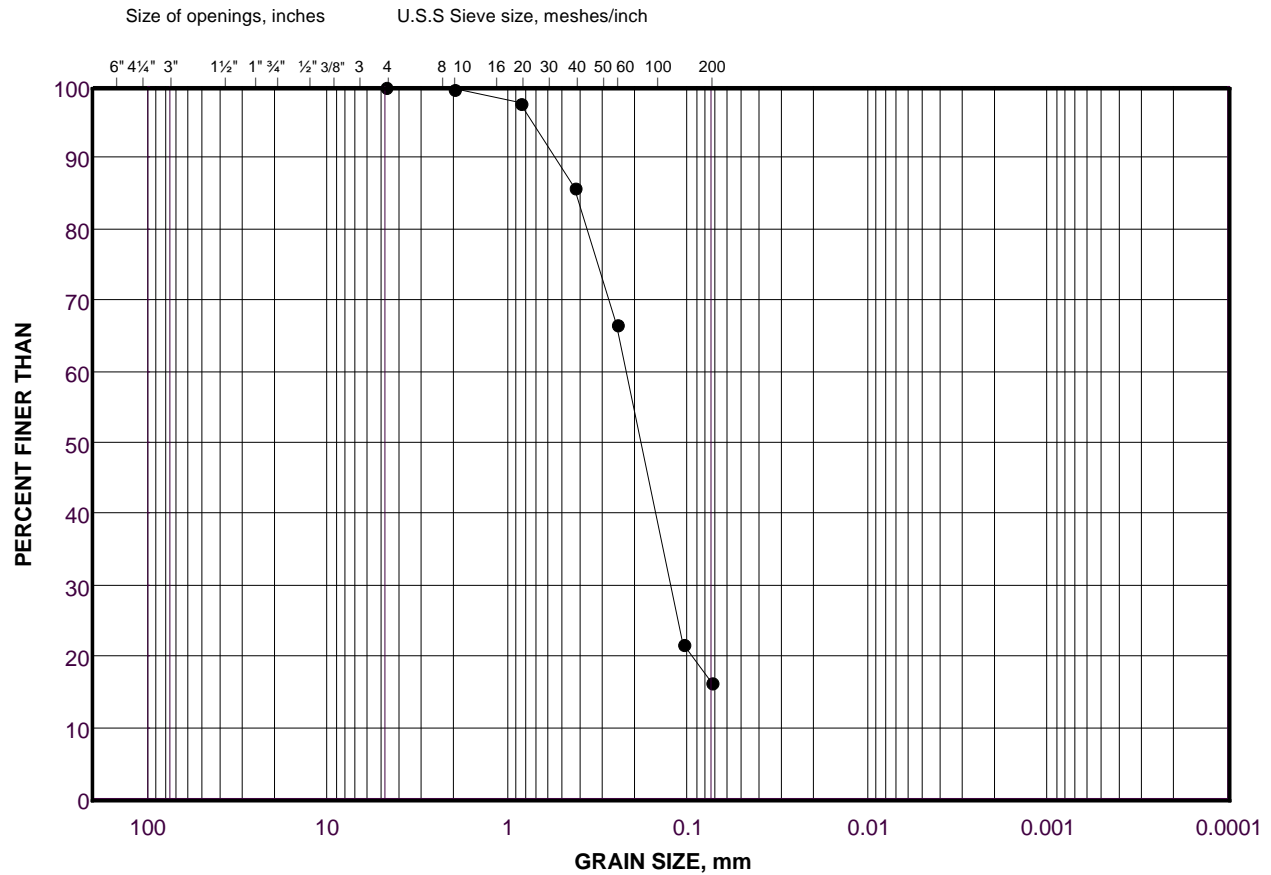
Golder Associates

Date: 25-Nov-15

GRAIN SIZE DISTRIBUTION

Sand

FIGURE B3



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	TRW-3	8	231.3

Project Number: 1532543

Checked By: NK

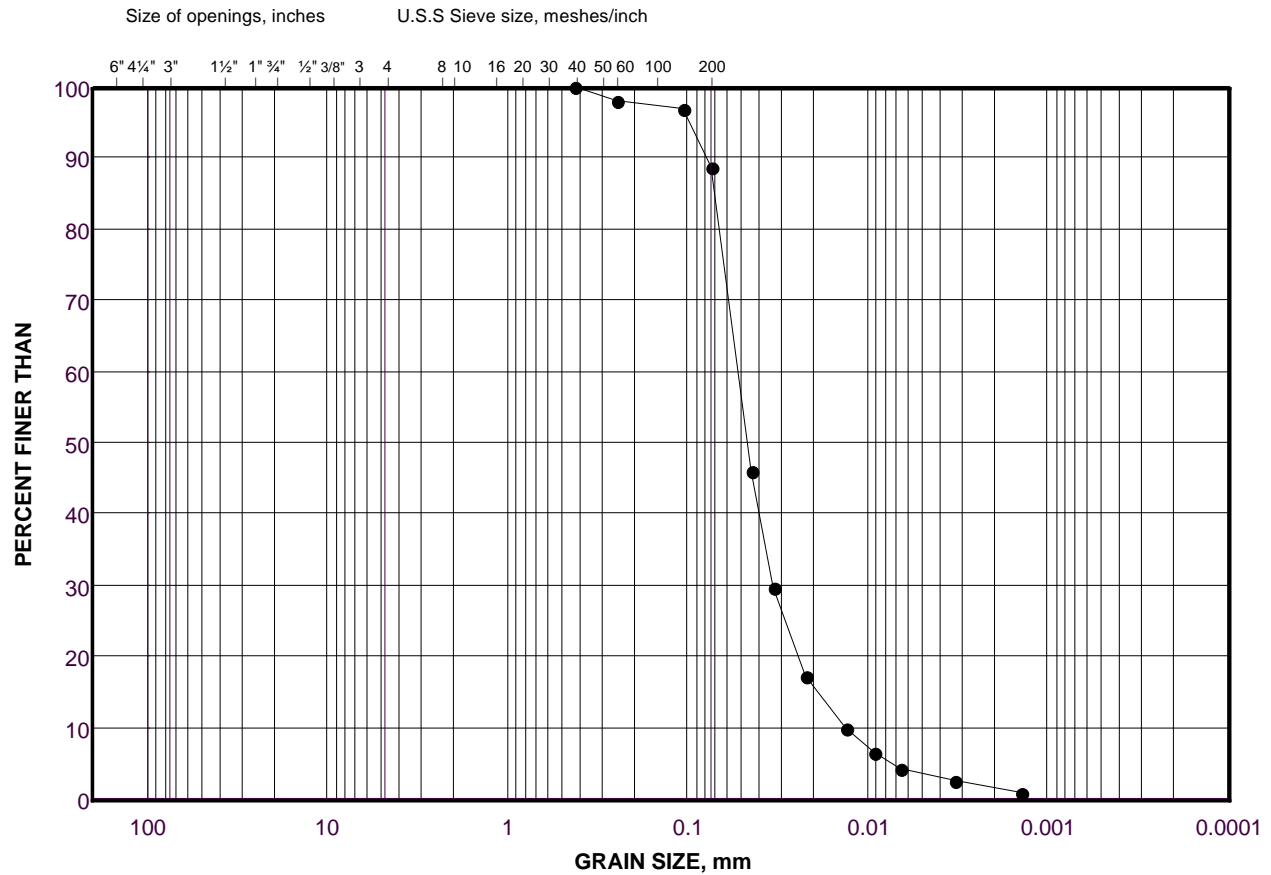
Golder Associates

Date: 25-Nov-15

GRAIN SIZE DISTRIBUTION

Silt

FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	HF1	7	228.3

Project Number: 1532543

Checked By: NK

Golder Associates

Date: 25-Nov-15



APPENDIX C

Record of Boreholes from Previous Investigation (GEOCRES No. 31D-589)







GEOTETO22161AA: Hwy 400/ Tiffin Street

RECORD OF BOREHOLE No BH C1

1 OF 1

METRIC

GWP 2074-11-00 LOCATION 29+288, 42.4 m R/L C/L (N 4914237.9, E 288578.9) ORIGINATED BY JD
DIST HWY 400 BOREHOLE TYPE Hollow Stem Auger COMPILED BY MP
DATUM Geodetic DATE 08/10/2014 CHECKED BY SH

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)						
232.0	GROUND SURFACE						232	20 40 60 80 100	10 20 30					
0.0	0.1 m TOPSOIL FILL: Silty Sand trace gravel, trace rootlets brown, very loose, moist to wet		1	SS	1		231				○			
			2	SS	3							○		
230.3							230					○		
1.7	PEAT dark grey to dark brown, very soft to soft, moist		3	SS	1								71	0 56 38 6 wet spoon
			4	SS	5								82	
229.2							229					○		
2.8	SAND AND SILT dilatant, trace clay grey, firm, wet													
229.0														
3.1														
	End of Borehole Piezometer installed to 3.1 m. Piezometer water level records : Oct. 31, 2014 1.8 m (El. 230.2 m)													

+³, ×³: Numbers refer to
Sensitivity

20
15 10 5
(%) STRAIN AT FAILURE

GEOTETO22181AA: Hwy 400/ Tiffin Street

RECORD OF BOREHOLE No BH C2

1 OF 1

METRIC

GWP 2074-11-00 LOCATION 10+123, 37.8 RI C/L (N 4914872.0, E 288212.1) ORIGINATED BY JD
 DIST HWY 400 BOREHOLE TYPE Hollow Stem Auger COMPILED BY MP
 DATUM Geodetic DATE 08/10/2014 CHECKED BY SH

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 (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE							
233.3 0.0	GROUND SURFACE							20 40 60 80 100							
	0.1 m TOPSOIL FILL: Silty Sand trace gravel, trace rootlets brown, loose, moist		1	SS	6		233								
			2	SS	9		232								
231.8 1.5	SILTY SAND grey, compact, moist to wet		3	SS	12		231								0 69 (31) wet spoon
			4	SS	14		230								
			5	SS	13		229								
228.6 3.7	SILT with occasional silty clay layers, trace sand moist, loose to compact		6	SS	13		228								
			7	SS	20		227								
			8	SS	10		226								0 1 63 36
			9	SS	8		225								
226.1 7.2	SILTY SAND TO SANDY SILT grey, compact, wet						224								
225.1 8.2	End of Borehole Piezometer installed to 8.2 m. Piezometer water level records : Oct. 31, 2014 3.6 m (El. 229.7 m)		10	SS	10		223								

GEOTETO22181AA: Hwy 400/ Tiffin Street

RECORD OF BOREHOLE No BH C3

1 OF 1

METRIC

GWP 2074-11-00 LOCATION 29+274, 34.3 m Lt C/L (N 4914174.7, E 288531.9) ORIGINATED BY LG
DIST HWY 400 BOREHOLE TYPE Hollow Stem Auger COMPILED BY MP
DATUM Geodetic DATE 16/10/2014 CHECKED BY SH

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)								WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE	● POCKET PENETR. × LAB VANE						
233.0	GROUND SURFACE						20	40	60	80	100					
0.0	0.2 m TOPSOIL		1	SS	8											
232.4	FILL: Sand and Silt															
0.6	trace gravel, trace rootlets															
	brown to grey, loose, moist															
	SANDY SILT TO SILTY SAND		2	SS	15											
	brown to grey, loose to compact, wet															
			3	SS	11										wet spoon	
			4	SS	9										0 57 38 5	
			5	SS	17											
	trace to some sand, trace clay		6	SS	9											
	brown, compact to loose, wet		7	SS	10											
			8	SS	6											
			9	SS	8											
			10	SS	4											
224.8	some sand, trace clay															
8.2	grey, very loose, wet															
	End of Borehole															
	cave-in @ 1.8 m															
	Piezometer installed to 7.6 m.															
	Piezometer water level records :															
	Oct. 31, 2014 1.5 m (EL 231.5 m)															

+³, X³: Numbers refer to
Sensitivity

20
15-5
10 (%) STRAIN AT FAILURE

GEOTETOB22181AA: Hwy 400/ Tiffin Street

RECORD OF BOREHOLE No BH C4

1 OF 1

METRIC

GWP 2074-11-00 LOCATION 10+150, 33.1 m LL C/L (N 4914647.2, E288140.5) ORIGINATED BY LG
 DIST HWY 400 BOREHOLE TYPE Hollow Stem Auger COMPILED BY MP
 DATUM Geodetic DATE 27/10/2014 CHECKED BY SH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					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 ○ POCKET PENETR.		FIELD VANE + LAB VANE ×					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L
20	40	60	80	100	20	40	60	80	100	10	20	30					
233.7 0.0	GROUND SURFACE																
233.0 0.7	0.1m TOPSOIL FILL: Silty Sand trace organic brown to dark brown, compact, moist		1	SS	12												
	SILTY SAND TO SANDY SILT trace organic brown, loose to compact, moist to wet		2	SS	8												
	gravelly sand trace silt		3	SS	30												
			4	SS	16												
			5	SS	3												
	clayey silt lenses from 3 m to 8.2 m		6	SS	16												
			7	SS	17												
			8	SS	16												
			9	SS	18												
</																	

+³, ×³: Numbers refer to
Sensitivity

20
15 10 5
(%) STRAIN AT FAILURE

GEOTETO22181AA: Hwy 400/ Tiffin Street

RECORD OF BOREHOLE No BH C5

1 OF 1

METRIC

GWP 2074-11-00 LOCATION 29+288, 2.6 m LI C/L (N 4814205.6, E 288547.5) ORIGINATED BY JD
DIST HWY 400 BOREHOLE TYPE Hollow Stem Auger COMPILED BY MP
DATUM Geodetic DATE 18/10/2014 CHECKED BY SH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH (kPa)				
							20 40 60 80 100	20 40 60 80 100	PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	
							○ UNCONFINED + FIELD VANE	● POCKET PENETR. × LAB VANE	WATER CONTENT (%)			GR SA SI CL
238.7	GROUND SURFACE											
238.6	150 mm ASPHALT											
0.2	0.5 m gravelly sand		1	SS	38				○			
	FILL: Silty Sand trace organic, trace silty clay lenses brown, dense to compact, moist		2	SS	16				○			
			3	SS	32							
236.1	2.6 silty clay, very stiff		4	SS	16				○			1 22 60 27
	FILL: Silt with occasional silty clay layers, trace sand grey to brown, compact, moist		5	SS	12					○		wet spoon
			6	SS	15				○			
			7	SS	28							
233.4	6.3 SILTY SAND trace gravel brown to grey, compact to dense, moist		8	SS	44				○			
			9	SS	30				○			1 76 (23)
	wet		10	SS	20					○		
230.2	8.6 SILT sandy to some sand, trace clay grey, loose to compact, moist											
			11	SS	18					○		1 33 59 7
			12	SS	20					○		
	wet		13	SS	10					○		
	loose											
			14	SS	9					○		
224.4	14.3 End of Borehole											

+³, X³: Numbers refer to
Sensitivity

20
15-5
10 (%) STRAIN AT FAILURE

GEOTETOB22181AA: Hwy 400/ Tiffin Street

RECORD OF BOREHOLE No BH RW12

1 OF 1

METRIC

GWP 2074-11-00 LOCATION 10+129, 4.5 m Lt C/L (N 4914649.3, E 288175.8) ORIGINATED BY LG
DIST HWY 400 BOREHOLE TYPE Hollow Stem Auger COMPILED BY MP
DATUM Geodetic DATE 14/10/2014 CHECKED BY SH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
237.7	GROUND SURFACE													
239.6	220 mm ASPHALT													
0.2	PAVEMENT GRANULAR FILL: 0.3 m Gravelly Sand 0.3 m Sandy, some gravel		1	SS	18		237							
	EMBANKMENT FILL: Silty Sand trace gravel brown, compact to dense, moist		2	SS	10									
			3	SS	19		236							
			4	SS	32		235							
			5	SS	32									
234.0			6	SS	44		234							
3.7	SILTY SAND trace gravel brown to grey, dense to compact moist to wet		7	SS	19		233							
			8	SS	13		232							
			9	SS	8		231							
			11	SS	18		230							
			12	SS	17		229							
228.0							228							
9.8	End of Borehole Water level @ 6.7 m (not stabilized)* upon completion.													

+³, X³: Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE



APPENDIX D

Non-Standard Special Provisions

DEWATERING FOR CULVERTS – Item No.

Special Provision

SCOPE

The work under this item includes the design, installation, operation, maintenance and removal of temporary dewatering systems to facilitate the culvert extensions and replacements where such work is carried out by excavation (i.e., non-trenchless methods) under the future Highway 400 NBL embankment prior to its construction.

The culvert extensions/replacements will require excavation below the groundwater level. Non-cohesive soils below the groundwater table will be subjected to conditions of unbalanced hydrostatic head and can slough, boil and cave in during temporary excavation work.

SUBMISSION REQUIREMENTS

At least two weeks prior to commencing dewatering operations, the Contractor shall submit to the Contract Administrator, for information purposes only, written details and drawings for the proposed dewatering system(s).

CONSTRUCTION

The dewatering system shall be adequate to lower the groundwater level to at least 0.3 m below the founding level for the culvert extension or replacement, to allow excavation, subgrade preparation and construction in dry conditions. The Contractor shall reference borehole records as shown elsewhere in the Contract Documents as a guide in determining dewatering requirements.

A continuous dewatering operation shall be provided to facilitate the culvert construction operations at all times. All components of the dewatering system shall be maintained in an effective, functioning and stable condition during the construction.

The work for dewatering shall be completed in accordance with the environmental and operational constraints specified elsewhere in the Contract Documents.

COFFERDAMS – Item No.

Special Provision

CONSTRUCTION SPECIFICATION FOR COFFERDAMS

1.0 SCOPE

As part of the work under this item, the Contractor shall:

- Design, supply, install, maintain and remove cofferdams as required in order to construct culvert extensions or portions of new culverts in open-cut excavation.
- Dewater the cofferdams and maintain unwatered as required during construction.

The culvert construction will require excavation to near or below the creek water level and groundwater level at the site, through non-cohesive (sand/silt) soils. Groundwater flow should be expected through the non-cohesive soils.

2.0 REFERENCES

This Special Provision refers to the following standards, specifications or publications:

Ontario Provincial Standard Specifications, Construction

OPSS 518 Control of Water from Dewatering Operations

3.0 DEFINITIONS

Stamped means drawings or details that have been reviewed and stamped “Conforms with Contract Documents”. The stamp shall include the date and signature of the Quality Verification Engineer (QVE).

Quality Verification Engineer (QVE) means an Engineer licensed to practice in the Province of Ontario who has a minimum of five (5) years of experience in related construction works. The Quality Verification Engineer shall be retained by the Contractor to ensure conformance with the contract documents and issue Certificate(s) of Conformance.

Cofferdam Design Engineer means an Engineer licensed to practice in the Province of Ontario who has a minimum of five (5) years of experience in the field of design and/or construction of structures and related dewatering/unwatering works. In addition, the Cofferdam Design Engineer shall have had responsible experience in the design of at least three (3) other cofferdams. The Contractor shall retain the Cofferdam Design Engineer to ensure conformance with the Contract Documents and issue Certificate(s) of Conformance for the design.

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Submission Requirements

The Contractor shall, at least three (3) weeks prior to the commencement of the cofferdam installation, submit to the QVE for review and stamping, four (4) sets of drawings and calculations indicating the following:

- the cofferdam design; and
- the location, type and dimensions of each cofferdam to be used based on the staging of the culvert construction.

The QVE shall review all calculations, construction details, shop drawings and procedures.

At least two weeks prior to the commencement of cofferdam construction, the Contractor shall submit to the Contract Administrator, for information purposes only, four (4) sets of stamped drawings/calculations of the cofferdam system. All submissions shall bear the seal and signature of the Cofferdam Design Engineer and QVE.

4.01.01 Dewatering

At least two weeks prior to the commencement of cofferdam construction, the Contractor shall submit a detailed dewatering scheme to the Contract Administrator, for information purposes only, showing the dewatering methods and measures to complete the work in dry conditions. The submission shall also provide details of the proposed methods of preventing dewatering or displaced water from directly entering the creek channel(s).

4.01.02 Certificates of Conformance

The Cofferdam Design Engineer shall inspect the installation of each cofferdam. After the installation of the cofferdam has been completed, the Contractor shall submit a Certificate of Conformance to the Contract Administrator, sealed and signed by the Cofferdam Design Engineer. The Certificates of Conformance shall state that the cofferdam is in place, and has been installed in conformance with the stamped shop drawings and the Contract Drawings.

The Contractor will note that several Certificates of Conformance may be required, to coincide with each cofferdam installation.

5.0 MATERIALS – Not Used

6.0 EQUIPMENT - Not Used

7.0 CONSTRUCTION

The Contractor shall ensure stability of the cofferdams during all stages of construction.

The Contractor shall remove the cofferdam elements or cut them off at a minimum depth of 0.5 m below final grade at the completion of the construction of applicable portions of the culverts.

7.01 Dewatering

Dewatering shall be carried out according to OPSS 902 and the amendments as provided elsewhere in the Contract Documents.

8.0 QUALITY ASSURANCE - Not Used

9.0 MEASUREMENT FOR PAYMENT - Not Used

10.0 BASIS OF PAYMENT

10.01 Cofferdam - Item

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

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision

1. SCOPE

This specification covers the general requirements for the installation of pipes by trenchless methods, including Jack & Bore, Pipe Ramming, Directional Drilling, and Tunnelling. The Contractor shall determine the most appropriate method of installation for each of the crossing locations.

This specification shall supersede OPSS 415 (Construction Specification for Pipeline Installation by Tunneling), 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).

The Contractor is alerted to the following for this contract:

- Pipe installation by trenchless methods shall apply for construction of the culverts at Station 29+280 and 10+120, under the existing Highway 400 embankment. Additional length of casing or primary liner shall be constructed to the east of that portion installed by trenchless methods, under the future Highway 400 NBL embankment, extending to the east limit of the RSS wall. This casing shall be placed prior to construction of the NBL embankment, to permit settlement under the new embankment prior to final construction of the culverts as detailed elsewhere in the Contract Documents. The contractor shall select a casing/primary liner size to accommodate settlement of up to approximately 100 mm under the new NBL embankment, and to accommodate settlement of up to 50 mm under the SBL embankment for the culvert at Station 10+120.
- Water-bearing non-cohesive (sand/silt) soils will be encountered at and above the tunnel alignment for the culvert at Station 29+280, and may be encountered at/above the tunnel alignment for the culvert at station 10+120 depending on the time of year (i.e., seasonal variation in groundwater level). The Contractor shall select tunnelling methods and equipment that are capable of applying full closed face or pressure balance to control the face at culvert installation locations where the groundwater level is at/above the tunnel alignment, or implementing a dewatering system to permit other trenchless methods to be used.

2. REFERENCES

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

Ontario Provincial Standard Specifications, General

OPSS 180	Management and Disposal of Excess Materials
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Ontario Provincial Standard Specifications, Construction

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

Ontario Provincial Standard Specifications, Material

OPSS.PROV 1004	Aggregates - Miscellaneous
OPSS.PROV 1350	Concrete - Materials and Production
OPSS.PROV 1440	Steel Reinforcement for Concrete
OPSS 1802	Smooth Walled Steel Pipe
OPSS.PROV 1820	Circular and Elliptical Concrete Pipe
OPSS 1840	Non-Pressure Polyethylene (PE) 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:

Auger 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 by using an auger.

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

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.

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.

Trenchless Installation: an underground method of constructing a passage open at both ends that involves installing a pipe. For the purpose of this specification, the pipe may be installed by any of the various methods defined herein such as Auger Jack & Boring, Pipe Jacking, Pipe Ramming, Directional Drilling, or using a tunnelling machine or hand mining methods.

Tunnelling: An underground method of constructing a passage using a tunnel boring machine (TBM), a microtunnel boring machine (MTBM) or hand mining using a shield to support the opening.

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 or elsewhere in the Contract Documents.

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 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;
- Design assumption and material data when materials other than those specified are proposed for use; and
- 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.

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 installation procedures, including methods to handle obstructions and prevent 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, lay-out 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 excavations
Jacking/Ramming/Directional Drilling of Casing/Liner
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.PROV 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.PROV 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.PROV 1004 wetted with only sufficient water to make the mixture plastic.

5.06 Auger Jack & Bore Materials

5.06.01 Pipe Materials

Steel pipe shall conform with ASTM A252-93 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS.PROV 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. The pipe minimum wall thickness shall be as per Table 1 of OPSS 1802.

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.

Jointing 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 jointing process.

Jointing 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. The primary liner shall be designed by the Contractor and the design/drawings shall be stamped/signed by the Design Engineer. The design shall be submitted to the Contract Administrator as specified herein.

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.PROV 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.

Jointing 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 jointing process.

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

6. EQUIPMENT

6.01 Auger Jack & Bore Equipment

Pipe auger 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 rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use. Use of explosives is prohibited.

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 to be used by the Contractor shall be submitted to the Contract

Administrator for information purposes prior to commencing the work and 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 Construction Shafts

Construction 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.PROV 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 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 491.

Minimum horizontal and vertical clearances to existing facilities as specified in the Contract Documents shall be maintained. 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.

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. The number of exposures required to monitor work progress shall be as specified in the Contract Documents.

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 401.

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in OPSS.PROV 539.

7.01.10 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 fill materials should be expected, particularly where granular materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Boulders

The Contractor is alerted that cobbles and boulders should be anticipated within soil deposits. 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.

7.01.12 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.

7.01.13 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 inlet end of the pipe to the outlet end to confirm gravity flow conditions.

7.01.14 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.

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.01.16 Supervision

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

7.02 Auger 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.PROV 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

7.04.06.0 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 2 m) 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 OSHA 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 three in-ground (1.5 m depth) 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 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 shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface. The assembly shall be placed in a drill hole and backfilled with uniform sand.

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.

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 Subsections 4.02 and 7.06, 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 or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this 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 of 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.

9. 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.

10. BASIS OF PAYMENT

Payment at the contract price shall be full compensation for all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, supply and installation of pipe liners, settlement instrumentation and monitoring, site restoration, and 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.

OPERATIONAL CONSTRAINT – Preload Period – Embankment Widening Construction

Special Provision

The Contractor shall schedule his operations to include the following preloading times for the new Highway 400 northbound lane (NBL) embankment, to allow time for settlement:

- The new Highway 400 NBL embankment shall be constructed up to the top of the granular sub-base material, and the fills shall remain in place for a minimum period of six (6) weeks before paving.
- The pipe culverts at Station 29+280 and 10+120 shall be constructed within the casing/primary liner a minimum of six (6) weeks following completion of the new Highway 400 NBL embankment fill to the top of the granular sub-base material.

Prior to placement of the Granular A base material and paving, the Contractor shall conduct a survey to determine the elevations of the top of the Granular B sub-base material, and shall place additional Granular B material as and where required to achieve the pavement design sub-base elevation.

The Contractor shall not proceed with final granular placement and paving until approval has been given by the Contract Administrator.

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