Submitted to AECOM Canada Ltd.
189 Wyld Street Suite 103, North Bay, Ontario P1B 1Z2
On Behalf of the Ontario Ministry of Transportation

Culvert Replacement
Highway 118
Station 18+867 - Twp. of Hindon
GWP 5140-13-00

FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

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TABLE OF CONTENTS

1 INTRODUCTION 1

2 SITE DESCRIPTION 1

2.1 Site Physiography and Surficial Geology 1

3 INVESTIGATION PROCEDURES 2

4 SUBSURFACE CONDITIONS 3

4.1 Culvert Station 18+867, Twp of Hindon 3
4.1.1 Pavement Structure 3
4.1.2 Embankment Fill 3
4.1.3 Organic Soils 4
4.1.4 Sand and Silt to Silty Sand 4
4.1.5 Sand 4
4.1.6 Sandy Silt 4
4.1.7 Bedrock 5
4.2 Groundwater Data 5

5 DISCUSSION AND RECOMMENDATIONS 6

5.1 General 6
5.1.1 Frost Penetration 6
5.2 Foundation Considerations 6
5.2.1 Slope Stability 7
5.3 Culvert Design, Bedding, and Embedment 7
5.3.1 Rigid Concrete Culvert 8
5.3.2 Flexible Culvert 8
5.4 Culvert Installation and Construction Staging Considerations 9
5.4.1 Staged Construction 9
5.4.2 Temporary Protection System 10
5.5 Lateral Earth Pressures 12
5.6 Excavation, Dewatering, and Embankment Reconstruction 12
5.7 Construction Concerns 14

6 STATEMENT OF LIMITATIONS 15

Appendices

Appendix 1 Key Plan
Appendix 2 Subsurface Data
Appendix 3 Borehole Plan and Lab Data
Appendix 4 Photo Essay
Appendix 5 Design Data

Property and Confidentiality

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1 INTRODUCTION

EnGlobe Corp. (Englobe), formerly LVM-Merlex, a Division of Englobe Corp., has been retained by AECOM Canada Ltd. on behalf of the Ministry of Transportation of Ontario (MTO) to carry out a foundation investigation at an existing centreline culvert site. The site is located at Station 18+867 in the Township of Hindon on Highway 118, some 6.2 km west of Brady Lake Road.

The foundation investigation location was specified by the MTO in the Terms of Reference for work under Agreement No. 5014-E-0020: GWP 5140-13-00 for Detailed Design. The terms of reference for the scope of work are outlined in Englobe's Proposal P-14-168-R1, dated January 21, 2015. The purpose of this investigation was to determine the subsurface conditions in the area of the existing culvert for the contract preparation of the Detailed Design package. Englobe investigated the foundation area by the drilling of boreholes, carrying out in-situ tests, and performing laboratory testing on select samples.

2 SITE DESCRIPTION

A 750 mm Corrugated Steel Pipe (CSP) culvert is located on Highway 118 at Station 18+867 in the Township of Hindon, Ontario. The topography in the area of this site is generally rolling. The existing highway embankment currently supports two undivided lanes of highway, running in a west-east direction. The existing highway at the culvert location is constructed on a fill embankment some 3.2 m in height above the culvert invert (at centreline), with centreline at Elevation 335.2 m at the culvert location. At the south slope, the maximum height of the embankment is approximately 3.4 m. At the north slope, the maximum height of embankment fill is some 3.1 m above the culvert invert. The existing embankment slopes in the area of the culvert have been generally established at an angle of approximately 2.0H:1V at the north and south slopes. The culvert at this location is a 750 mm diameter Corrugated Steel Pipe (CSP) culvert, some 22.0 m in length. Flow through the culvert is from the north to the south (left to right).

There is no other known infrastructure at the culvert location.

2.1 SITE PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The topography on this section of Highway 118 is generally rolling. Layers of earth overlie bedrock. Organic materials were also observed. Within the project area, the native overburden consists primarily of sands and silts overlying bedrock.

Bedrock, based on Ontario Geologic Survey (OGS) Map MRD-126, in the area consists of felsic igneous rocks including tonalite, granodiorite, monzonite, granite, syenite and derived gneisses.

3 INVESTIGATION PROCEDURES

The fieldwork for this investigation was carried out between April 24th and August 25th, 2015 during which time four (4) sampled boreholes were advanced. Two (2) boreholes were advanced through the embankment, and one (1) borehole was advanced adjacent to each inlet (north) and outlet (south) end of the culvert, respectively (total of two (2) inlet and outlet boreholes).

The field investigation was carried out using a truck and bombardier mounted CME drilling rig equipped with hollow stem augers, standard augers, casing equipment and routine geotechnical sampling equipment. The drill equipment is owned by Chrisdamat Management Ltd. and was operated by an Englobe drill crew. Soil samples were obtained at the borehole locations at regular intervals of depth using the standard 50 mm O.D. split spoon sampler advanced in accordance with the Standard Penetration Test (SPT) procedures (ASTM D-1586). The SPT method involves advancing a 50 mm O.D. split spoon sampler with the force of a 63.5 kg hammer freely dropping 760 mm. The number of blows per 300 mm penetration was recorded as the "N" value. If refusal to further advance of the augers was encountered within the proposed depth of borehole, the boring was advanced through diamond drilling using NQ size coring equipment. All samples taken during this investigation were stored in labeled airtight containers for transport to our North Bay laboratory for visual examination and select laboratory testing.

Groundwater conditions in the open boreholes were observed during the advancement of and immediately following completion of the individual boreholes. A 19 mm diameter standpipe was installed in Borehole Nos. 1 and 3 prior to backfilling to allow for further monitoring of the shallow groundwater levels. All open boreholes were backfilled upon completion with compacted auger cuttings in the same general order in which they were removed, and where necessary, bentonite pellet backfill was added to the boreholes to bring them up to grade in accordance with requirements of Ontario Regulation 903. At the boreholes through the embankment, the upper portion of the hole, where necessary, was backfilled with an asphalt cold patch to seal the existing asphalt surface.

The fieldwork for this investigation was carried out under the full time direction of a senior member of the Englobe engineering staff (Jame Lavigne), who was responsible for locating the boreholes, clearing the borehole locations of underground services, in-situ sampling and testing operations, logging of the boreholes, labeling and preparation of samples for transport to the Englobe North Bay laboratory, plus overall drill supervision. All samples received a visual confirmatory inspection in the laboratory. Laboratory testing of select samples included routine testing for natural moisture content determination and particle size analysis. The results of the laboratory testing are presented on the individual Record of Borehole Sheets (Appendix 2), with a summary of results presented on the laboratory sheets in Appendix 3 (Figures Nos. L-1 to L-4 and Table No. L-5).

The location of the individual boreholes was determined in the field using highway chainage established by Callon Dietz Inc. (Callon Dietz) and offsets relative to highway centreline. The MTO co-ordinates, northing and easting, were then established for the boring locations using coordinates from MTM Zone 10, NAD 83 CSRS. The borehole elevations are based on coordinating the borehole locations with the highway survey carried out by Callon Dietz. Elevations contained in this report are referenced to geodetic datum.

4 SUBSURFACE CONDITIONS

Details of the subsurface conditions revealed by the investigation program are presented on the enclosed Records of Borehole Logs (Appendix 2) and on Drawing No. 2 (Appendix 3). Please note that the stratigraphic delineation presented on the borehole logs and soil strata plot are the results of non-continuous sampling, response to drilling progress, the results of SPT, plus field observations. Typically such boundaries represent transitions from one zone to another and are not an exact demarcation of specific geological unit. Additional consideration should be given to the fact that subsurface conditions may vary markedly between adjacent boreholes and beyond any specific boring location, and are shown on the drawings for illustration purposes only.

4.1 CULVERT STATION 18+867, TWP OF HINDON

A plan and profile illustrating the borehole locations and stratigraphic sequences is shown on Drawing No. 2, Appendix 3. During the course of the exploration program, four (4) sampled boreholes were put down at this site, with Borehole Nos. 1 and 2 advanced through the embankment, Borehole No. 3 advanced adjacent to the culvert inlet, and Borehole No. 4 advanced adjacent to the culvert outlet. At the time of the subsurface investigation, the ground surface elevations at Boreholes Nos. 1 to 4 were recorded at Elevations 335.2, 335.1, 332.5, and 332.3 m, respectively.

4.1.1 Pavement Structure

Borehole Nos. 1 and 2, were advanced through the embankment and confirmed that the pavement structure consisted of 125 to 150 mm asphalt concrete overlying a layer of crushed gravel base/subbase approximately 255 to 305 mm thick.

4.1.2 Embankment Fill

Underlying the pavement structure at Borehole Nos. 1 and 2, a layer of embankment fill consisting of brown sand, gravelly to some gravel, some to trace silt, was penetrated. Cobble/boulder sized rock pieces were encountered in the embankment fill layer. The natural moisture content measured for recovered samples from this deposit was generally in the order of 4 to 20%. Gradation (sieve) analyses were carried out on two (2) samples of this deposit, the results of which indicated 18% gravel size particles, 73 to 76% sand size particles, and 6 to 9% silt and clay size particles (Figure No. L-1, Appendix 3). Based on SPT ‘N’ values of 0 (static weight of hammer) to 23 blows per 300 mm penetration and 50 blows per 102 mm penetration, the relative density/compactness of this deposit was described as very loose to very dense, but generally compact on average. This embankment fill was encountered to depths of 3.4 and 3.2 m below grade at Borehole Nos. 1, and 2, respectively (Elevations 331.8, and 331.9 m, respectively).

4.1.3 Organic Soils

At ground surface at Borehole Nos. 3 and 4, a layer of black silty organic soil (topsoil) was penetrated. This organic soil layer was encountered to approximate depths of 100 mm below ground surface at Borehole Nos. 3 and 4 (Elevations 332.4 and 332.3 m, respectively).

4.1.4 Sand and Silt to Silty Sand

Underlying the embankment fill at Borehole No. 1, and underlying the organic soils at Borehole No. 3, a deposit of sand and silt to silty sand, trace clay was penetrated. The natural moisture content measured on samples of this deposit was in the order of 27 to 38%. A gradation (hydrometer) analysis was carried out on one (1) sample of this deposit, the results of which indicated 0% gravel size particles, 54% sand size particles, 43% silt size particles, and 3% clay size particles (Figure No. L-2, Appendix 3). According to results of hydrometer testing and the criteria for Frost-susceptibility and Erodibility of soils stated in MTO Pavement Design and Rehabilitation Manual (2013), the silt and sand deposit is classified as moderate frost-susceptibility and moderate erodibility, respectively. Based on SPT 'N' values of 4 to 23 blows per 300 mm penetration, this deposit was described as loose to compact. This deposit was encountered to depths of 4.4 and 0.6 m below ground surface at Borehole Nos. 1 and 3, respectively (Elevations 330.8 and 331.9 m, respectively).

4.1.5 Sand

Underlying the sand and silt to silty sand at Borehole Nos. 1 and 3, underlying the embankment fill at Borehole No. 2, and underlying the organic soils at Borehole No. 4, a deposit of sand, with to trace gravel, some to trace silt, trace clay was penetrated. The natural moisture content measured on samples of this deposit was in the order of 15 to 27%. Gradation (sieve) analyses were carried out on four (4) samples of this deposit, the results of which indicated 0 to 22% gravel size particles, 64 to 89% sand size particles, 4 to 26% silt and clay size particles (Figure No. L-3, Appendix 3). Based on SPT 'N' values of 2 to 53 blows per 300 mm penetration and 46 blows per 254 mm penetration, this deposit was described as very loose to very dense, generally compact. This deposit was encountered to depths of 6.5, 5.6, 2.9 and 2.1 m below ground surface at Borehole Nos. 1 to 4, respectively (Elevations 328.7, 329.5, 329.6 and 330.2 m, respectively).

4.1.6 Sandy Silt

Underlying the sand deposit at Borehole Nos. 2 and 4, a deposit of sandy silt, trace to with gravel, trace clay was penetrated. The natural moisture content measured on samples of this deposit was in the order of 14 to 21%. A gradation (sieve) analysis was carried out on one (1) sample of this deposit, the results of which indicated 23% gravel size particles, 28% sand size particles, 49% silt and clay size particles (Figure No. L-4, Appendix 3). An hydrometer analysis was carried out on one (1) sample of this deposit, the results of which indicated 0% gravel size particles, 37% sand size particles, 59% silt size particles, and 4% clay size particles (Figure No. L-4, Appendix 3). Based on SPT 'N' values of 22 to 40 blows per 300 mm penetration, this deposit was described as compact to dense. This deposit was encountered to depths of 6.7 and 3.4 m below ground surface at Borehole Nos. 2 and 4, respectively (Elevations 328.4 and 328.9 m, respectively).

4.1.7 Bedrock

Underlying the sands at Borehole Nos. 1 and 3 and underlying the sandy silts at Borehole Nos. 2 and 4, bedrock was proven by diamond core drilling. The bedrock was described as black gneiss to pink granite. Based on RQD values of 89 to 100%, the bedrock was described as good to excellent quality. Based on visual review, the bedrock generally showed negligible weathering. Sampling in the bedrock was terminated at depths of 9.6, 9.8, 5.9, and 6.4 m below grade at Borehole Nos. 1 to 4, respectively (Elevations 325.6, 325.3, 326.6, and 325.9 m, respectively). Photos of rock cores recovered at Borehole Nos. 1 to 4 are shown in Enclosure No. 6, Appendix 4. It should be noted that, when encountered, the underlying bedrock surfaces in this area can be very erratic in nature, varying substantially in elevation over short horizontal distances.

4.2 GROUNDWATER DATA

At the time of this investigation (April 24th, 28th, and August 25th, 2015), the surface water level was observed at Elevation 332.0 m at the culvert outlet.

Measurements of the groundwater table and cave-in levels were undertaken, where possible, in the open boreholes during the advance of the individual borings and upon completion. A standpipe was installed in Borehole Nos. 1 and 3 to obtain post borehole completion water levels. These levels are recorded on the individual Record of Borehole Log Sheets (Appendix B).

The groundwater levels were measured at Elevations 331.5, 332.5 and 332.0 m at Borehole Nos. 1, 3 and 4, respectively. The groundwater level was encountered at Elevation 332.1 m at Borehole No. 2 upon completion of sampling at the borehole; however this water level likely had not stabilized at the time of recording.

The groundwater and surface water levels will fluctuate seasonally/yearly.

5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

A foundation investigation was carried out for the proposed replacement of a CSP culvert as identified by the MTO.

The existing culvert, located at Station 18+867, in the Township of Hindon, is a 750 mm diameter CSP culvert some 22.0 m long. The existing culvert invert, at centreline, is estimated at a depth of 3.2 m (Elevation 332.0 m). The culvert inverts at the inlet and outlet are established at Elevations 332.1 and 331.8 m, respectively. The existing highway embankment currently supports two undivided lanes of highway, running in a west-east direction. Flow through the culvert is from the left to the right (north to south). Based on data from this foundation investigation, the embankment supporting the existing pavement structure at this site has been constructed using sand fills containing cobble and boulder sized rock pieces. The native material underlying the embankment fill generally consists of very loose to very dense, generally compact, sands, sands and silts to silty sands, and sandy silt overlying bedrock at relatively shallow depths below ground surface.

The type of culvert (concrete, CSP, or High Density Polyethylene (HDPE)) being proposed to replace the existing culvert is currently unknown. Considering the size of the existing culvert, replacing the culvert with an open culvert (i.e. rigid open frame box culvert) is not practical, unless an increased flow is required based on the results of a hydrological study. It is understood that the new culvert will be constructed along a similar skew and alignment. It is further understood that the final vertical alignment of the highway is to remain essentially the same.

5.1.1 Frost Penetration

Generally, culverts within the depth of frost penetration below the pavement structure are included in the pavement structure frost treatment (see OPSD 803.010 and OPSD 803.030). However, closed culverts are not designed in consideration of frost penetration below the culvert. Culverts with footings, (i.e. open culverts, culvert retaining walls, etc.) require the footings to be designed for frost penetration.

At this site, the frost penetration depth below cleared pavement surfaces is approximately 1.8 m. The culvert at this location is not located within the depth of frost penetration below the pavement surface and as such, will not require frost treatments.

5.2 FOUNDATION CONSIDERATIONS

The founding native sands, sands and silts to silty sands, and sandy silts present below the existing embankment are considered adequate for support of a culvert and for a conventional highway embankment of this height. Geotechnical bearing resistance should not be a major issue provided the natural bearing surface is not disturbed during construction and groundwater is controlled throughout construction, as discussed in Section 5.6.

Based on the characteristics of the native sand to sandy silt subgrade present below the culverts, the response of the existing embankment, and a founding elevation and culvert size similar to that of the existing culvert (i.e. 750 mm diameter), a factored geotechnical resistance at ULS of 160 kPa can be used for a closed culvert (i.e. precast concrete pipe or CSP culvert). In consideration of the width of the culvert, depth of overburden, and response of the existing embankment slopes, a geotechnical reaction at SLS of 100 kPa can be used for design, in consideration of 25 mm total settlement, and 19 mm of differential settlement depending on structure rigidity.

5.2.1 Slope Stability

The maximum height of the embankment above the stream bed at this location is some 3.2 m at centreline, and up to about 3.3 m at the south side of the embankment. A stability analysis was carried out using the GEO-SLOPE computer software, Slope/W (GeoStudio 2007, Version 7.17, Geo-Slope International Ltd.) for this location with the existing 2H:1V embankment slopes assumed in the embankment fills. For the purposes of these analyses, the materials were modeled using the following parameters;

PARAMETER	MATERIAL			
	EMBANKMENT FILL	SAND AND SILT	SAND	SANDY SILT
Unit Weight (kN/m^3)	19.0	18.5	19.0	18.5
Effective Friction Angle (degrees)	32	30	32	32
Cohesion (kPa)	-	-	-	-

The above unit weights and friction angles for the slope calculations are based on general representative values for the various soil types, obtained through laboratory testing and tactile analysis. The groundwater levels used for the analyses are shown on Figure No. S-1, Appendix 5. The results of the analyses indicate factors of safety in the order of 1.5 on the existing south embankment slopes on an inclination angle of 2H:1V against long term deep seated failures (see Figure No. S-1, Appendix 5). Lower factors of safety will occur during excavation and backfilling as discussed in Section 5.5. Short term stability should not be an issue if construction is carried out as described herein.

5.3 CULVERT DESIGN, BEDDING, AND EMBEDMENT

The embankment generally consists of sand fills containing cobble and boulder size rock pieces. The results of this investigation indicate that, below the culvert invert, the native subgrade soils generally consisted of compact to dense sands, sands and silts, and sandy silts. A review of the condition of the pavement surface at the culvert locations revealed that the embankment appears to have performed satisfactorily. The existing embankment has preloaded the soils at the culvert locations and since there will be no appreciable change in the height of the embankment and correspondingly, no increase in embankment load, no appreciable settlement of the embankment is anticipated. As such, installing the culvert on a camber will not be required at this site.

5.3.1 Rigid Concrete Culvert

Concrete pipes can be considered for culvert replacement at this site. A Class B Bedding for the concrete pipes shall consist of Granular A with a thickness of 300 mm. Alternatively, specifically if construction is carried out under wet conditions, a bedding and levelling course consisting of 19 mm clear stone per OPSS.PROV 1004 should be used, which would aid in dewatering operations. During backfilling, the material of bedding (including haunches) and cover shall be placed in uniform layers not exceeding loose thickness of 200 mm, as per OPSS.PROV 401. The elevation difference of backfilling on either side of the rigid pipe shall be limited to a maximum 200 mm per OPSS.PROV 401. Cover material for concrete pipes can consist of Granular A and placed to the dimensions as shown on OPSD 802.031. If circular concrete pipes are used, compaction of the haunch is critical and should be constructed and compacted in accordance with OPSS.PROV 501.

As noted, considering the size of the existing culvert, a precast concrete rigid frame box culvert is likely not practical at this site, unless increased flow is required, based on the results of a hydrological study.

The inlet and outlet stream bed shall be protected with a rip-rap (R-50 size as per OPSS.PROV 1004) apron. The apron shall be 3 m in length, a minimum 400 mm thick and extend across the stream bed to 3 m beyond the outside edges of the culvert. Clay seals are generally used only where significant head differences exist between the inlet and outlet of the culverts to prevent flow through the bedding/embedment granulars. In consideration of the culvert size and anticipated flow, clay seals are not considered necessary at this location, provided embedment/bedding materials are properly compacted in the haunch area and rip rap over a Class II geotextile is placed around the inlet end of the culvert.

5.3.2 Flexible Culvert

Flexible culverts (i.e. CSP/SPCSP/HDPE) can also be considered for culvert replacement at this site. If flexible pipes are used for replacement, embedment material should consist of Granular B Type I per OPSS.PROV 1010 provided the maximum size of stone inclusions is limited to 25 mm or less in size and placed in accordance with OPSD 802.010 for a Type 3 soil. The material in the haunch area must be compacted to 100% Standard Proctor Dry Density prior to placing the remainder of the embedment material. During backfilling, the embedment material shall be placed in uniform layers not exceeding loose thickness of 200 mm. The elevation difference of the embedment fill on either side of the flexible pipe must be limited to a maximum 200 mm per OPSS.PROV 401. The backfill should be placed to a minimum depth of 900 mm above the crown of the pipe before power tractors or rolling equipment can be used for compacting per OPSS.PROV 401.

In consideration of the culvert size and anticipated flow, clay seals are not considered necessary at this location, provided embedment/bedding materials are properly compacted in the haunch area and rip rap over a Class II geotextile is placed around the inlet end of the culvert. The inlet and outlet stream bed shall be protected with a rip-rap (R-50 size as per OPSS.PROV 1004) apron. The apron shall be 3 m in length, a minimum 400 mm thick and extend across the stream bed to 3 m beyond the outside edges of the culvert.

5.4 CULVERT INSTALLATION AND CONSTRUCTION STAGING CONSIDERATIONS

At the centreline, the invert elevation of the existing culvert is at Elevation 332.0 m, with the top of the embankment at Elevation 335.2 m. The culvert inverts at the inlet and the outlet are established at Elevations 332.1 and 331.8 m, respectively. As such, the embankment at this location is some 3.2 m in height above the culvert invert at the centreline. Therefore, a minimum 3.5 m deep excavation (i.e. to Elevation 331.7 m) will be required (at centreline) in consideration of a 300 mm thick layer of bedding/embedment material. At the inlet and outlet of the culvert, the excavations will be required to depths of some 3.4 and 3.7 m, respectively (Elevations 331.8 and 331.5 m, respectively). The present platform width at this location is some 10 m as can be seen on the cross section on Drawing No. 2. The platform width at this location, as is, will not be sufficient to carry out an open excavation using staged construction unless local lowering of the grade and/or sliver widening is undertaken. In general, an open cut excavation can be considered if the platform is temporarily lowered by some 1.4 m. If this lowering cannot be accommodated then consideration can be given to a combination of lowering and widening or to constructing a temporary vertical wall for use as a protection system.

5.4.1 Staged Construction

As noted, the platform at this location, as is, is of insufficient width to carry out an open excavation using staged construction unless temporarily lowering of the vertical alignment is carried out. To carry out an open cut excavation, locally lowering the grade to allow for staged construction using staged sequencing and limiting traffic flow to one lane would be required (see Figure No. SK-3, Appendix 5).

A possible staging plan for a continuous open cut excavation under a 24/7 traffic control operation, as shown on Figure No. SK-3, Appendix 5, is as follows:

- Locally lower the grade at the culvert to an elevation of approximately 333.7 m.
- Limit traffic to a single lane on the left, with a minimum platform width of 6 m, under 24/7 traffic control.

- Open cut excavate, to the right, and install approximately 11 m of new culvert.
- Reconstruct the embankment on the right, with a minimum platform width of 6 m for traffic.
- Divert the single lane of traffic to the right and continue open excavation to install the remainder of the culvert on the left.
- As the width of the platform increases on the right, the vertical alignment can be raised, and the traffic can revert back to two lanes when sufficient width permits.

It should be noted that additional subsurface information may be required if widening beyond the existing embankment toe is required.

5.4.2 Temporary Protection System

As noted above, consideration could be given to constructing a vertical wall, along centreline, for use as a temporary protection system, should lowering of the grade at the culvert location not be feasible.

The installation of a protection system for use in the culvert replacement operation will require penetration through some 3.4 m of fills (at centreline). The embankment fill generally contained cobble/boulder size rock fill. The embankment fills are generally underlain by compact sands to sandy silts to sandy silt overlying bedrock at depths ranging from 2.5 to 2.9 m below the culvert inverts (i.e. Elevation 329.6 m at location adjacent to the inlet and Elevation 328.9 m at location adjacent to the outlet). The bedrock was encountered at relatively shallow depths below the embankment fills and native soils at this culvert location, which may result in difficulties adequately fixing the toe of the steel sheet piles into the bedrock to resist the active pressure of the backfill. As such, if a temporary flexible wall is required for protection, it would be more appropriate to use a shoring wall which requires drilled support members to penetrate a sufficient depth into bedrock.

One method to construct a protection system would be to penetrate the embankment fill with H piles (soldier piles) extending into the underlying compact sands to sandy silts and/or into bedrock and install lagging with the required dewatering system as discussed in Section 5.6. If a boulder is encountered during driving, the pile could be left high until the boulder is removed during excavation and then driving continued. The H piles will have to be socketed into the bedrock to supply adequate toe resistance. Pre-drilling may be considered to advance the H piles through large, over-sized boulder(s) in the embankment fills and into the bedrock underlying the sands to sandy silt deposits. The H piles would be installed at an interval of 2 to 3 m apart and the lagging would be installed as the excavation progresses. Alternatively, a caisson wall or a drilled micropile system with an intermediate support system of reinforced shotcrete to act as lagging could also be considered for roadway protection at this site; however these shoring systems are generally more costly.

If tiebacks are required, the resistance (R) for grouted anchors, located outside the active failure wedge, in cohesionless soils can be estimated from the following equation as supplied in Section 26.12.4.1 of the Canadian Foundation Manual (4th Edition):

$$R = \sigma_z' A_s L_s \alpha_g$$

Where: σ_z' = effective vertical stress at the midpoint of the load carrying length

A_s = effective unit surface area of the anchor

L_s = effective embedment length of the anchor

α_g = anchorage coefficient use 1.0 for granular backfill

For tieback design, a triangular earth pressure distribution over the height of the cut would be appropriate for design.

Unless the pull-out resistance (capacity) of the anchor is proven with a load test program, the allowable anchor load (as suggested by the Canadian Foundation Engineering Manual, 4th Edition), is commonly obtained by dividing the computed capacity of the anchor by a factor of safety of 3. Alternatively, proprietary anchor systems can be used.

A table outlining the possible temporary excavation protection/flexible retaining systems and their relative advantages, disadvantages, and costs, as well as comments on the viability of the methods is provided in Table A in Appendix 5. A Conceptual shoring location and a schematic cross section are illustrated on Figures Nos. SK-4 and SK-5 in Appendix 5.

The protection system can be designed using the lateral earth pressure parameters as outlined in Section 5.5. Considering the cohesionless nature of the embankment fills (granular pavement structure over sand fills mixed with rock pieces) a rectangular apparent pressure distribution over the height of the cut would be appropriate for design of the temporary shoring. The width of the apparent rectangular pressure distribution, over the height of excavation, can be considered equal to $0.65*K_a*\gamma*H$, where:

K_a = active earth pressure coefficient, as described in Section 5.5,

γ = unit weight, as described in Section 5.5, and

H = height of wall above the base of excavation.

Surcharge loads from the active lane of traffic must also be considered during design of the temporary shoring system.

The contractor’s shoring/protection system design must be carried out by a geostructural engineer with appropriate experience.

The temporary protection system should be designed and constructed to comply with OPSS 539. In consideration of the location of the protection system and traffic volume, a Performance Level 2 is considered appropriate.

5.5 LATERAL EARTH PRESSURES

Lateral earth pressures should be computed in accordance with the Canadian Highway Bridge Design Code (CHBDC). The parameters for bedding, cover, embedment and backfill materials are based on compaction levels of 100% SPMDD. The design parameters for the bedding/embedment and backfill materials are as follows:

PARAMETER	GRANULAR A	GRANULAR B TYPE I	EMBANKMENT FILL	SAND AND SILT
Unit Weight (kN/m^3)	22.8	21.2	19.0	18.5
Angle of Internal Friction	35°	33°	32°	30°
Coefficient of Active Earth Pressure (K_a)	0.27	0.30	0.31	0.33
Coefficient of Passive Earth Pressure (K_p)	3.70	3.33	3.23	3.00
Coefficient of Earth Pressure at Rest (K_o)	0.43	0.46	0.47	0.50
PARAMETER	**SAND**	**SANDY SILT**		
Unit Weight (kN/m^3)	19.0	18.5		
Angle of Internal Friction	32°	32°		
Coefficient of Active Earth Pressure (K_a)	0.31	0.31		
Coefficient of Passive Earth Pressure (K_p)	3.23	3.23		
Coefficient of Earth Pressure at Rest (K_o)	0.47	0.47		

For rigid structures, such as a precast concrete culverts, deflection cannot occur, as such the “at-rest” condition (K_o) applies. For flexible structures, such as CSP/HDPE culverts, deflection can occur, as such the “active” condition (K_a) applies. The “passive” condition (K_p) applies when the wall is in compression (in a direction opposite to the wall loading).

5.6 EXCAVATION, DEWATERING, AND EMBANKMENT RECONSTRUCTION

All temporary excavations greater than 1.2 m in depth must, at a minimum, be sloped or shored in accordance with the Occupational Health and Safety Act Regulations for Construction Projects. The embankment material, above the water table, is considered a Type 3 soil as defined in the Occupational Health and Safety Act and Regulations for Construction Projects. Temporary open excavations above the groundwater table, could be cut back at an angle of 1H:1V, provided they are monitored continuously; however, below the groundwater table, the side slopes in fill an/or native materials may slough to angles as flat as 3H:1V or possibly shallower, dependent upon the Contractors' chosen method of controlling the groundwater.

The excavation backfill above the culvert bedding/cover should consist of granular fill per OPSS.PROV 1010 up to the underside of the pavement structure.

Final (permanent) embankment side slopes in granular fills should be established to match the existing slopes or as per OPSD 200.010. Final slopes should be treated with a seed and mulch to prevent ravelling.

Bedrock was not encountered at the borehole locations within the anticipated depth of excavation, therefore bedrock excavation and/or blasting operations are not anticipated.

Excavations must be maintained in a dewatered condition during excavation and foundation construction, and every reasonable effort must be made to prevent disturbing (piping/boiling) at the founding subgrade. Groundwater control, in accordance with OPSS 517 and 518, will be required to maintain a stable subgrade during culvert installation.

At the time of investigation, no surface water was encountered at the culvert location. Groundwater was encountered at Elevations of 331.5, 332.1, 332.5, and 332.0 m at Borehole Nos. 1 to 4, respectively. Excavations to minimum Elevations 331.8 and 331.5 m at the culvert inlet and outlet, respectively, will likely be required to install the culvert and bedding. As such, dewatering will likely be required during excavation and culvert installation.

During construction, installation of filtered sumps and pumping from the base of the excavation will, at a minimum, be required to maintain the excavation in a dewatered condition during subgrade preparation and culvert installation. The effectiveness of this method of groundwater control would be limited to conditions where the prevailing groundwater table is less than some 1 m above the final excavation depth. If the excavation must penetrate to a greater depth below the prevailing groundwater table a more effective groundwater control method, such as a vacuum well point system, or sheet pile cut-off wall, should be considered by the contractor to maintain a stable excavation base.

A cofferdam, constructed of earth fill, sand bags, or water-filled bag (i.e. aquadam) can be considered at this site. Steel sheet piles may also be considered for controlling stream flow. For base design, sheet piles should extend a minimum depth below base of proposed excavation equal to the height of water above the base of excavation. By-pass pumping can be carried out to divert the stream flow at the time of construction. It is recommended that by-pass pumping, through a temporary culvert installed through the embankment, be carried out to divert the stream flow past the work area isolated with the cofferdam system.

Ultimately, the method of excavation, dewatering and stream flow diversion will be the choice of the contractor; however the importance of maintaining the subgrade in a dewatered stable condition during excavation and construction operations cannot be stressed enough.

5.7 CONSTRUCTION CONCERNS

Considering the nature of the embankment fills containing boulder/cobble sized rock pieces, no major construction concerns are anticipated if construction is carried out in general conformance with the above discussion. However, it is recommended that the potential to encounter oversized boulders requiring removal or pre-drilling be anticipated in the Contract documents. The Contractor must be prepared to excavate and advance protection systems through these materials. Bedrock was also encountered at relatively shallow depths.

As noted in Section 5.6, the culvert subgrade must be adequately dewatered to maintain the bearing resistance of the foundation subgrade. The Contractor must also be prepared to deal with seasonal and yearly fluctuations of ground/surface water. A Notice to Contractor is included in Appendix 5.

6 STATEMENT OF LIMITATIONS

The design recommendations given in this geotechnical report are applicable only to the project described in the text and only if constructed substantially in accordance with details of alignment and elevations stated in the report. Since all details of the design may not be known, in our analysis certain assumptions had to be made. The actual conditions may however, vary from those assumed, in which case changes and modifications may be required to our geotechnical recommendations. We recommend, therefore, that we be retained and provided the opportunity during the design stage to review the design drawings, site survey information, proposed elevations, etc. to verify that they are consistent with our recommendations or the assumptions made in our analysis. It is further recommended that we be retained to review the final design drawings and specifications relative to the geotechnical recommendations.

If, during construction, conditions in the field vary from those assumed at the design stage, an engineer from this office must be notified immediately.

Proper subgrade preparation, groundwater control, compaction, etc. are all critical aspects of the bearing capacity of native soils. It must be noted that different aspects of the geotechnical design are based on the assumption that Englobe will be retained during site preparation and construction of the proposed works to ensure that both the geotechnical site characteristics and the construction operations/techniques are consistent with our recommendations. Should Englobe not be involved during the full construction phase, our liability is strictly limited to the factual information contained herein only.

The comments in this report are intended solely for the guidance of the design engineer and address the geotechnical conditions only. The number of boreholes required to determine the localized conditions between boreholes directly affecting construction costs, equipment, scheduling, etc. would in fact be greater than what has been carried out for design purposes. Therefore, contractors bidding on this project or undertaking this work should make their own interpretations of the factual borehole results and carry out further work as they deem necessary to assess the scope of the project.

Section 5 of this reported is intended for the use of the client and the design team only and is not intended to be included in the tender documents. Inclusion of the factual information (Sections 1 to 5 inclusive) in the tender documents is furnished merely for the general information of bidders and is not in any way warranted or guaranteed by or on behalf of the owner or the owner's consultants and its subconsultants or the consultants' or subconsultants' employees, and neither the owner nor its consultants or its employees shall be liable for any representations negligent or otherwise contained in the documents.

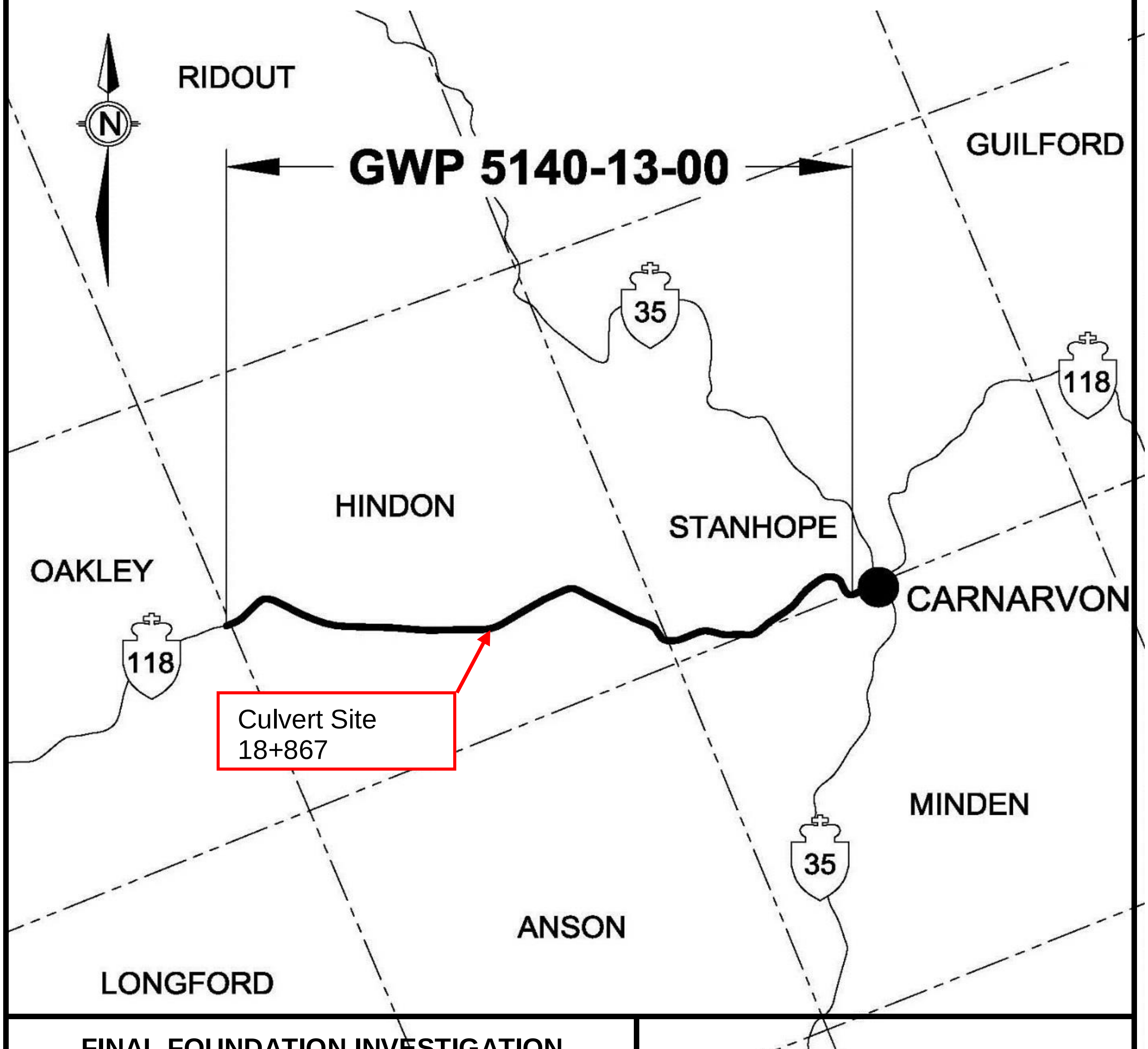
Appendix 1 Key Plan

Drawing No. 1	Key Plan

MACRO KEY PLAN

Drawing No. 1

NOT TO SCALE



FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

GWP 5140-13-00

Highway 118

Culvert Station 18+867 - Township of Hindon

Reference No: 15/03/15019-F2 September 2016

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Appendix 2 Subsurface Data

Enclosure No. 1	List of Abbreviations and Symbols
Enclosure Nos. 2 to 5	Record of Borehole Sheet

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LIST OF ABBREVIATIONS & DESCRIPTION OF TERMS

The abbreviations and terms, used to describe retrieved samples and commonly employed on the borehole logs, on the figures and in the report are as follows:

1. ABBREVIATIONS

AS Auger Sample
CS Chunk Sample
DS Denison type sample
FS Foil Sample
NFP No Further Progress
PH Sampler advanced by hydraulic pressure
PM Sampler advanced by manual pressure
RC Rock core with size & percentage of recovery
SS Split Spoon
ST Slotted Tube
TO Thin-walled, open
TP Thin-walled, piston
WS Wash Sample
WH Sampler advanced by static weight of hammer and/or rods
Rec % recovery from individual run of rock core
RQD Rock quality designation (%)

2. PENETRATION RESISTANCE/"N"

Dynamic Cone Penetration Test (DCPT):

A continuous profile showing the number of blows for each 300 mm of penetration of a 50 mm diameter 60° cone attached to AW rod driven by a 63 kg hammer falling 760 mm.

Plotted as ——•——•——•——•

Standard Penetration Test (SPT) or "N" Values

The number of blows of a 63 kg hammer falling 760 mm required to advance a 50 mm O.D. drive open sampler 300 mm.

3. SOIL DESCRIPTION

a) *Cohesionless Soils:*

"N" (blows/0.3 m)	*Relative Density*
0 to 4	very loose
4 to 10	loose
10 to 30	compact
30 to 50	dense
over 50	very dense

b) *Cohesive Soils:*

Undrained Shear Strength (kPa)	*Consistency*
Less than 12	very soft
12 to 25	soft
25 to 50	firm
50 to 100	stiff
100 to 200	very stiff
over 200	hard

3. SOIL DESCRIPTION (Cont'd)

c) *Bedrock:*

RQD (%)	*Classification*
Less than 25	Very poor quality
25 to 50	Poor quality
50 to 75	Fair quality
75 to 90	Good quality
90 to 100	Excellent quality

d) *Method of Determination of Undrained Shear Strength of Cohesive Soils:*

+ 3.2 - Field Vane test in borehole. The number denotes the sensitivity to remoulding.

D - Laboratory Vane Test

¨ - Compression test in laboratory

For a saturated cohesive soil the undrained shear strength is taken as one-half of the undrained compressive strength.

e) *Soil Moisture:*

Moisture	*Described as*
Dry	Below optimum moisture content
Moist	Near optimum moisture content
Wet	Above optimum moisture content

4. TERMINOLOGY

Terminology used for describing soil strata is based on the proportion of individual particle sizes present in the samples (please note that, with the exception of those samples subject to a grain-size analysis, all samples were classified visually and the accuracy of visual examination is not sufficient to determine exact grain sizing):

Trace, or occasional	Less than 10%
Some	10 to 20%
With	20 to 30%
Adjective (i.e. silty or sandy)	30 to 40%
And (i.e. sand and gravel)	40 to 60%

Terminology for cobbles and boulders is based on auger response and field observations:

Occasional	Obstructions encountered in borehole, however advance is not impeded
Numerous	Obstructions are essentially continuous over drilled length

SAMPLE DESCRIPTION NOTES:

1. **FILL:** The term fill is used to designate all man-made deposits of natural soil and/or waste materials. The reader is cautioned that fill materials can be very heterogeneous in nature and variable in depth, density and degree of compaction. Fill materials can be expected to contain organics, waste materials, construction materials, shot rock, rip-rap, and/or larger obstructions such as boulders, concrete foundations, slabs, abandoned tanks, etc.; none of which may have been encountered in the borehole. The description of the material penetrated in the borehole therefore may not be applicable as a general description of the fill material on the site as boreholes cannot accurately define the nature of fill material. During the boring and sampling process, retrieved samples may have certain characteristics that identify them as 'fill'. Fill materials (or possible fill materials) will be designated on the Borehole Logs. If fill material is identified on the site, it is highly recommended that testpits be put down to delineate the nature of the fill material. However, even through the use of testpits defining the true nature and composition of the fill material cannot be guaranteed. Fill deposits often contain pockets or seams of organics, organically contaminated soils or other deleterious material that can cause settlement or result in the production of methane gas. It should be noted that the origins and history of fill material is frequently very vague or non-existent. Often fill material may be contaminated beyond environmental guidelines and the material will have to be disposed of at a designated site (i.e. registered landfill). Unless requested or stated otherwise in this report, fill material on this site has not been tested for contaminants however, environmental testing of the fill material can be carried out at your request. Detection of underground storage tanks cannot be determined with conventional geotechnical procedures.

2. **TILL:** The term till indicates a material that is an unstratified, glacial deposit, heterogeneous in nature and, as such, may consist of mixtures and pockets of clay, silt, sand, gravel, cobbles and/or boulders. These heterogeneous deposits originate from a geological process associated with glaciation. It must be noted that due to the highly heterogeneous nature of till deposits, the description of the deposit on the borehole log may only be applicable to a very limited area and therefore, caution must be exercised when dealing with a till deposit. When excavating in till, contractors may encounter cobbles/boulders or possibly bedrock even if they are not indicated on the borehole logs. It must be appreciated that conventional geotechnical sampling equipment does not identify the nature or size of any obstruction.

3. **BEDROCK:** Auger refusal may be due to the presence of bedrock, but possibly could also be due to the presence of very dense underlying deposits, boulders or other large obstructions. Auger refusal is defined as the point at which an auger can no longer be practically advanced. It must be appreciated that conventional geotechnical sampling equipment does not differentiate between nature and size of obstructions that prevent further penetration of the boring below grade. Bedrock indicated on the borehole logs will be labeled 'possibly' or 'probable' etc. based on the response of the boring and sampling equipment, surrounding topography, etc. Bedrock can be proven at individual borehole locations, at your request, by diamond core drilling operations or, possibly, by testpits. It must also be appreciated that bedrock surfaces can be, and most times are, very erratic in nature (i.e. sheer drops, isolated rock knobs, etc.) and caution must be used when interpreting subsurface conditions between boreholes. A bedrock profile can be more accurately estimated, at the clients' request, through a series of closely positioned unsampled auger probes combined with core drilling.

4. **GROUNDWATER:** Although the groundwater table may have been encountered during this investigation and the elevation noted in the report and/or on the record of boreholes, it must be appreciated that the elevation of the groundwater table will fluctuate based upon seasonal conditions, localized changes, erratic changes in the underlying soil profile between boreholes, underlying soil layers with highly variable permeabilities, etc. These conditions may affect the design and type and nature of dewatering procedures. Cave-in levels recorded in borings give a general indication of the groundwater level in cohesionless soils however, it must be noted that cave-in levels may also be due to the relative density of the deposit, drilling operations etc.

ENCLOSURE NO.:2 (Pg. 1 of 1)

METRIC

RECORD OF BOREHOLE NO. 1

Englobe

REFERENCE 15/04/15019	DATUM Geodetic	LOCATION N 4988514.6 E 355398.3 - Hindon Twp., Station 18+866	ORIGINATED BY JL
PROJECT GWP 5140-13-00, Highway 118 - F2		BOREHOLE TYPE Truck Mounted CME 45 - Hollow Stem Augers	COMPILED BY SH
CLIENT AECOM		DATE (Started) 24 April 2015 DATE (Completed) 24 April 2015 TIME (Completed) 10:20:00 AM	CHECKED BY MHM

Column headings: SOIL PROFILE (ELEV / DEPTH; DESCRIPTION (see Enclosure No. 1); STRATA PLOT) — SAMPLES (NUMBER; TYPE; "N" VALUES) — GROUND WATER CONDITIONS — ELEVATION SCALE — DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) — SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100) — PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60 — UNIT WEIGHT γ kN/m³ — REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR SA (SI CL)
335.2	Ground Surface				
0.0	150 mm Asphalt 305 mm Crushed Gravel EMBANKMENT FILL- sand, some gravel, trace silt rockfill encountered at depths of 0.9 to 2.1 m brown, moist (compact/very loose)	1	SS	23	
		2	SS	22	18 73 (9)
		3	SS	13	
		4	SS	2	
		5A	SS	WH	
331.8 / 3.4	SAND and SILT - trace clay trace wood pieces and rootlets Brown to grey, wet Compact	5B	SS		
		6	SS	23	0 54 43 3
330.8 / 4.4	SAND - some to trace silt, trace clay wet grey (compact/very dense)	7	SS	23	
		8	SS	46/254 mm	
328.7 / 6.5	Auger Refual Start Rock Coring Bedrock - black gneiss/pink granite Excellent quality	9	RC	Rec= 97% RQD= 95%	
		10	RC	Rec= 100% RQD= 98%	
325.6 / 9.6	End of Sampling End of Borehole				

Elevation scale: 335, 334, 333, 332, 331, 330, 329, 328, 327, 326

COMMENTS

The stratification lines represent approximate boundaries. The transition may be gradual.

+3, ×3: Numbers on right refer to Sensitivity. Numbers on left refer to values greater than 120 kPa

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1) 24/4/15 10:30:00 AM	2.6	-
2) 28/4/15 12:10:00 PM	2.7	-
3) 25/8/15 11:30:00 AM	3.7	-

MEL-GEO 15019 - BOREHOL LOGS - F2.GPJ MEL-GEO.GDT 24/6/16

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ENCLOSURE NO.:3 (Pg. 1 of 1)

METRIC

RECORD OF BOREHOLE NO. 2

Englobe

REFERENCE 15/04/15019	DATUM Geodetic	LOCATION N 4988506.7 E 355409.0 - Hindon Twp., Station 18+877	ORIGINATED BY JL
PROJECT GWP 5140-13-00, Highway 118 - F2		BOREHOLE TYPE Truck Mounted CME 45 - Hollow Stem Augers	COMPILED BY SH
CLIENT AECOM		DATE (Started) 28 April 2015 / DATE (Completed) 28 April 2015 / TIME (Completed) 5:18:00 PM	CHECKED BY MHM

ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	NATURAL MOISTURE CONTENT w (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
335.1	Ground Surface						
0.0	125 mm Asphalt 255 mm Crushed Gravel EMBANKMENT FILL- sand mixed with rockfill, gravelly to some gravel, trace silt boulder size rock encountered at depths of 0.8 to 1.5 m brown, moist dark brown, wet (compact/very dense) rock pieces encountered at depths from 2.3 m to 3.2 m	1	SS	17		○	18 76 (6)
		2	SS	25/0 mm			
		3	SS	50/102 mm		○	
		4	SS	13		○	
331.9 3.2	SAND - with to trace gravel, some to trace silt, trace clay trace wood pieces and rootlets brown wet (loose/compact) grey	5	SS	9	▽ (approx. 3.1 m)	○	22 64 (14)
		6	SS	26		○	10 86 (4)
		7	SS	11		○	
329.5 5.6	Sandy SILT - with gravel grey compact	8	SS	22		○	23 28 (49)
328.4 6.7	Auger Refual Start Rock Coring Bedrock - black gneiss/pink granite Excellent quality	9	RC	Rec= 100% RQD= 96%			
		10	RC	Rec= 100% RQD= 100%			
325.3 9.8	End of Sampling End of Borehole						

Plot headings: STRATA PLOT; ELEVATION SCALE (335 to 326); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³

COMMENTS

+3, ×3 : Numbers on right refer to Sensitivity. Numbers on left refer to values greater than 120 kPa

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

	Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1)	28/4/15 5:18:00 PM	3	3.1
2)		-	-
3)		-	-

The stratification lines represent approximate boundaries. The transition may be gradual.

MEL-GEO 15019 - BOREHOL LOGS - F2.GPJ MEL-GEO.GDT 24/6/16

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ENCLOSURE NO.:4 (Pg. 1 of 1)

METRIC

RECORD OF BOREHOLE NO. 3

Englobe

REFERENCE 15/04/15019 DATUM Geodetic LOCATION N 4988523.4 E 355398.5 - Hindon Twp., Station 18+866.5 ORIGINATED BY JL

PROJECT GWP 5140-13-00, Highway 118 - F2 BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers COMPILED BY SH

CLIENT AECOM DATE (Started) 25 August 2015 DATE (Completed) 25 August 2015 TIME (Completed) 11:30:00 AM CHECKED BY MHM

ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	NUMBER	TYPE	"N" VALUES	Water content (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
332.5	Ground Surface					
332.4 0.1	ORGANIC SOIL - silty organics, brown	1	SS	4		
331.9 0.6	silty SAND - trace rootlets brown wet (loose)					
	SAND - trace gravel, some silt, trace rootlets and wood pieces. Wet. Brown to grey. (compact/very dense)	2	SS	23		
		3	SS	24		0 74 (26)
		4	SS	53		
329.6 2.9	Auger Refual. Start Rock Coring. Bedrock - black gneiss/pink granite. Good to excellent quality	5	RC	Rec= 93% RQD= 89%		
		6	RC	Rec= 100% RQD= 98%		
326.6 5.9	End of Sampling. End of Borehole					

COMMENTS

The stratification lines represent approximate boundaries. The transition may be gradual.

+3, ×3 : Numbers on right refer to Sensitivity. Numbers on left refer to values greater than 120 kPa

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1) 25/8/15 11:35:00 AM	0	-
2) 28/8/15 7:00:00 AM	0	-
3)	-	-

MEL-GEO 15019 - BOREHOL LOGS - F2.GPJ MEL-GEO.GDT 24/6/16

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ENCLOSURE NO.:5 (Pg. 1 of 1)

METRIC

RECORD OF BOREHOLE NO. 4

Englobe

REFERENCE 15/04/15019 DATUM Geodetic LOCATION N 4988494.7 E 355400.7 - Hindon Twp., Station 18+869 ORIGINATED BY JL

PROJECT GWP 5140-13-00, Highway 118 - F2 BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers COMPILED BY SH

CLIENT AECOM DATE (Started) 25 August 2015 DATE (Completed) 25 August 2015 TIME (Completed) 4:05:00 PM CHECKED BY MHM

ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	NATURAL MOISTURE CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
332.3	Ground Surface							
332.2 / 0.1	ORGANIC SOIL - silty organics, black							
	SAND - fine sand, trace silt grey, wet (compact/dense)	1	SS	2	▽	332	~45	
		2	SS	26			~22	0 89 (11)
		3	SS	33		331	~21	
330.2 / 2.1	SANDY SILT - trace clay (dense)	4	SS	40		330	~20	0 37 59 4
		5	SS	50/102 mm			~18	
328.9 / 3.4	Auger Refusal Start Rock Coring Bedrock - black gneiss Excellent quality	6	RC	Rec= 100% RQD= 100%		329, 328		
		7	RC	Rec= 97% RQD= 94%		327		
325.9 / 6.4	End of Sampling End of Borehole					326		

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

COMMENTS

The stratification lines represent approximate boundaries. The transition may be gradual.

+3, ×3: Numbers on right refer to Sensitivity. Numbers on left refer to values greater than 120 kPa

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

	Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1)	25/8/15 4:05:00 PM	0.3	-
2)		-	-
3)		-	-

MEL-GEO 15019 - BOREHOL LOGS - F2.GPJ MEL-GEO.GDT 24/6/16

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Appendix 3 Borehole Plan and Lab Data

Drawing No. 2:	Borehole Location and Soil Strata
Figure Nos. L-1 to L-4:	Grain Size Distribution Curves
Table No. L-5:	Lab Test Summary Sheet

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DISTRICT
CONT. No.
GWP No. 5140-13-00

HWY 118 CULVERT
STA. 18+867

DRAWING 2

BOREHOLE LOCATIONS AND SOIL STRATIGRAPHY

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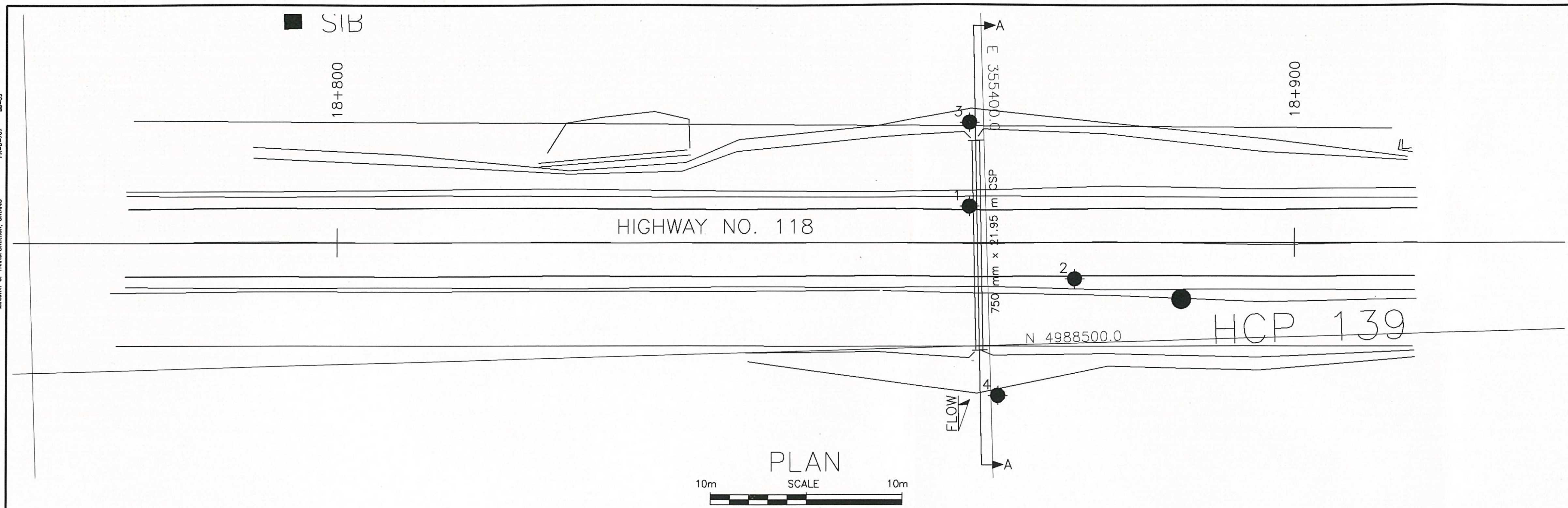
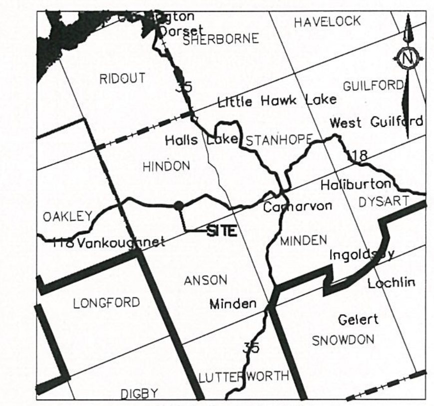


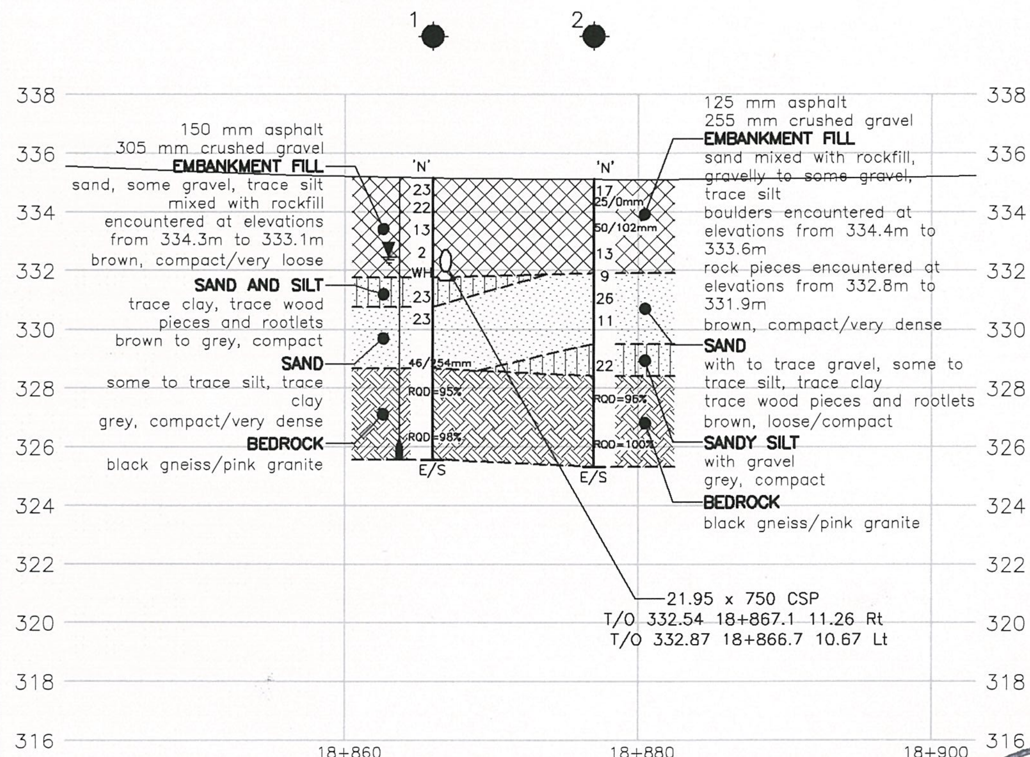


KEY PLAN
N.T.S.

LEGEND

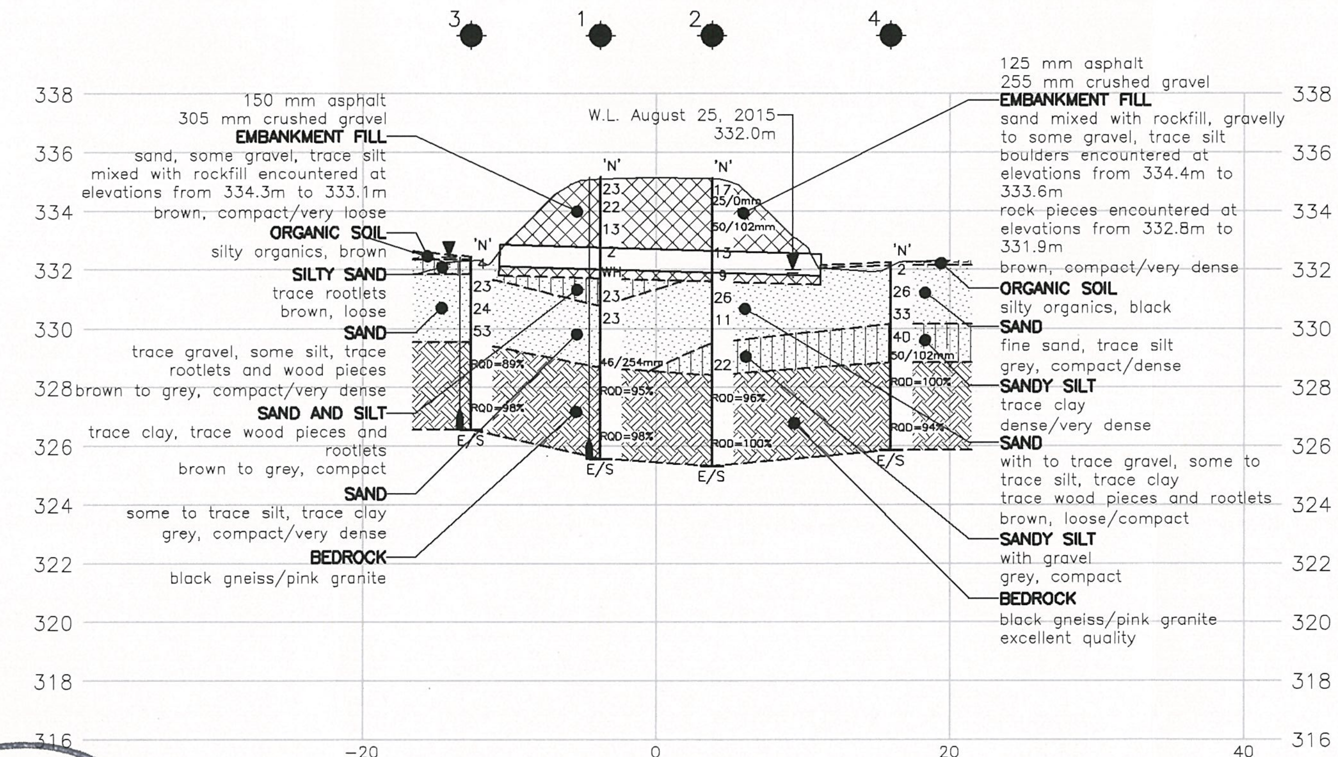
●	Borehole
N	Blows/0.3 m (Std Pen Test, 475 J/blow)
▼	Water Level at Time of Investigation
A/R	Auger Refusal at Elevation
E/S	End of Sampling
	Piezometer

BOREHOLE No.	ELEVATION	O/S	NORTHING	EASTING
1	335.2	3.8m Lt	4988514.6	355398.3
2	335.1	3.8m Rt	4988506.7	355409.0
3	332.5	12.6m Lt	4988523.4	355398.5
4	332.3	16m Rt	4988494.7	355400.7



C/L PROFILE HWY 11

SCALE: HOR 10 5 0 10 20m; VERT 5 2.5 0 5 10m



CROSS SECTION A–A

SCALE: HOR 10 5 0 10 20m; VERT 5 2.5 0 5 10m

NOTES:

The boundaries between soil strata have been established at the borehole locations only. The boundaries illustrated and stratigraphy between boreholes on this drawing are assumed based on borehole data and may vary. They are intended for design only.

Base plan and alignment provided in digital format by Callon Dietz on February 26, 2016

Coordinates based on MTM Zone 10 NAD83 CSRS

GEOCRES No. 31E-365

This drawing is for subsurface information only. Surface details and features are for conceptual illustration. The proposed structure location is shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

LICENSED PROFESSIONAL ENGINEER — S. HU 90524232 — Oct 24/16 — PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER — M. H. MacKAY — Oct 24/16 — PROVINCE OF ONTARIO

2016-10-27

REVISIONS			
JUN/16	DM	DRAFT	
SEP/16	DM	FINAL	
		DESCRIPTION	

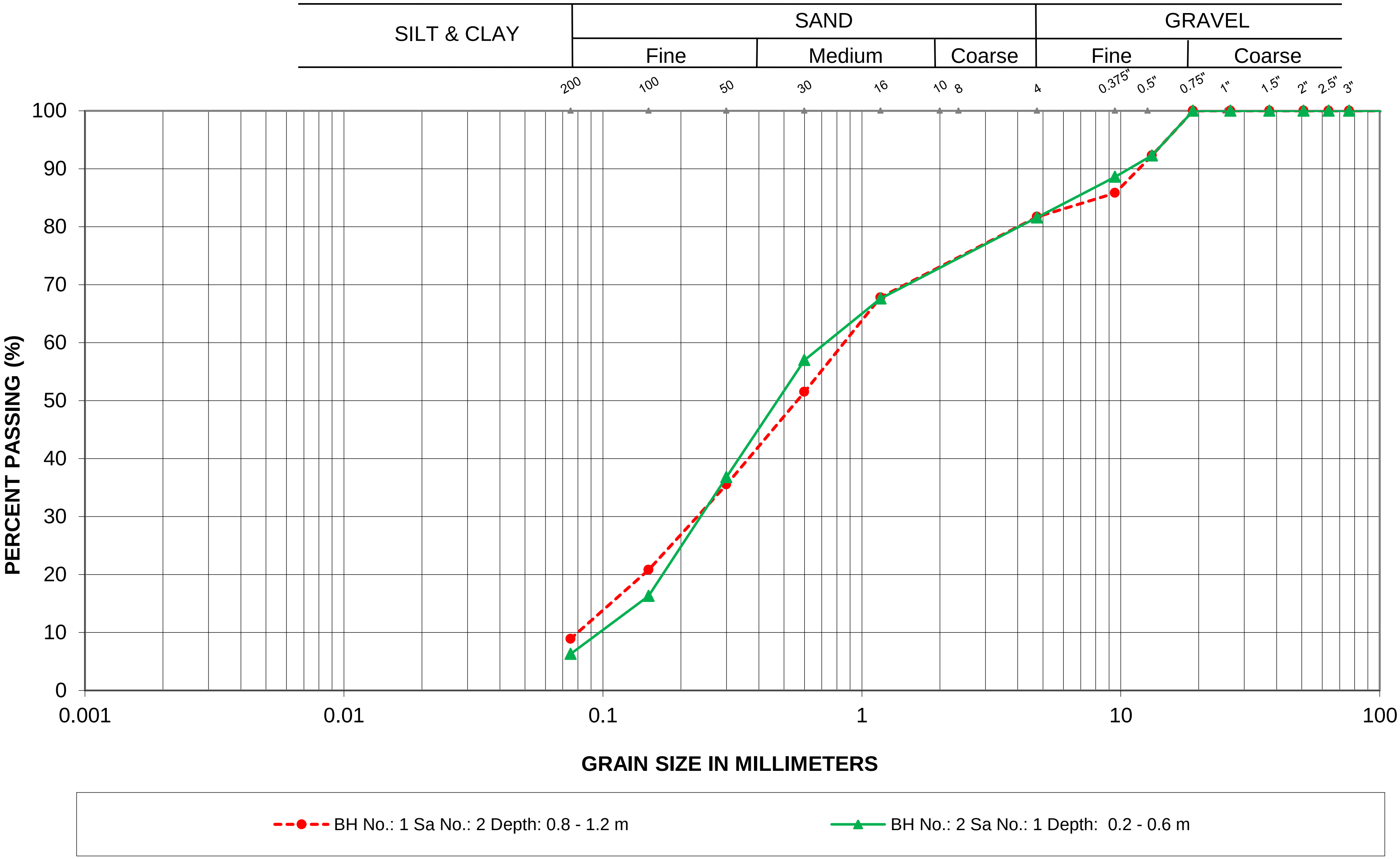
DESIGN	CHK	CODE	LOAD	DATE SEP/16
DRAWN DM	CHK SH	SITE	STRUCT	SCHEME	DWG 2

CAD FILE LOCATION AND NAME: G:\2015\15019 – PAV & FDN, Hwy 35 & 118 5014–E–0020 (AECOM)\FOUNDATION\Drawings\F2\15019 F2 – Culvert at Sta. 18+880.dwg
MODIFIED: 9/21/2016 2:20:36 PM BY: MITCOU
DATE PLOTTED: 9/21/2016 2:24:07 PM BY: DUNCAN MITCHELL

MINISTRY OF TRANSPORTATION, ONTARIO PH-D-757 88-05

Reference No.: 15/03/15019-F2
Date: June 2016

GRAIN SIZE ANALYSIS



LOCATION: Hwy 118 Sta.18+867
TWP. Hindon, Ontario

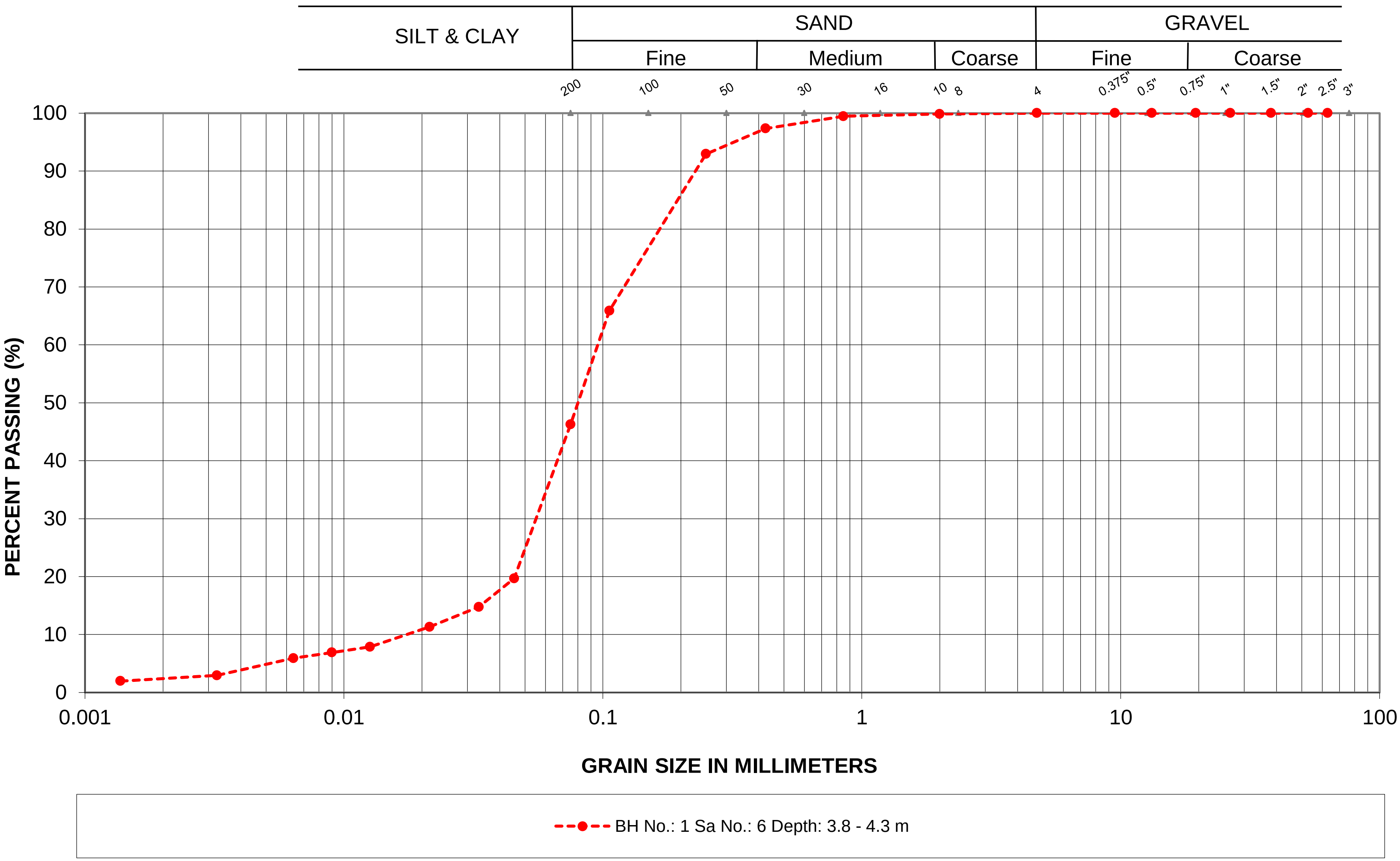
EMBANKMENT FILL

EnGlobe Corp.

FIGURE L-1

Reference No.: 15/03/15019-F2
Date: June 2016

GRAIN SIZE ANALYSIS



LOCATION: Hwy 118 Sta.18+867
TWP. Hindon, Ontario

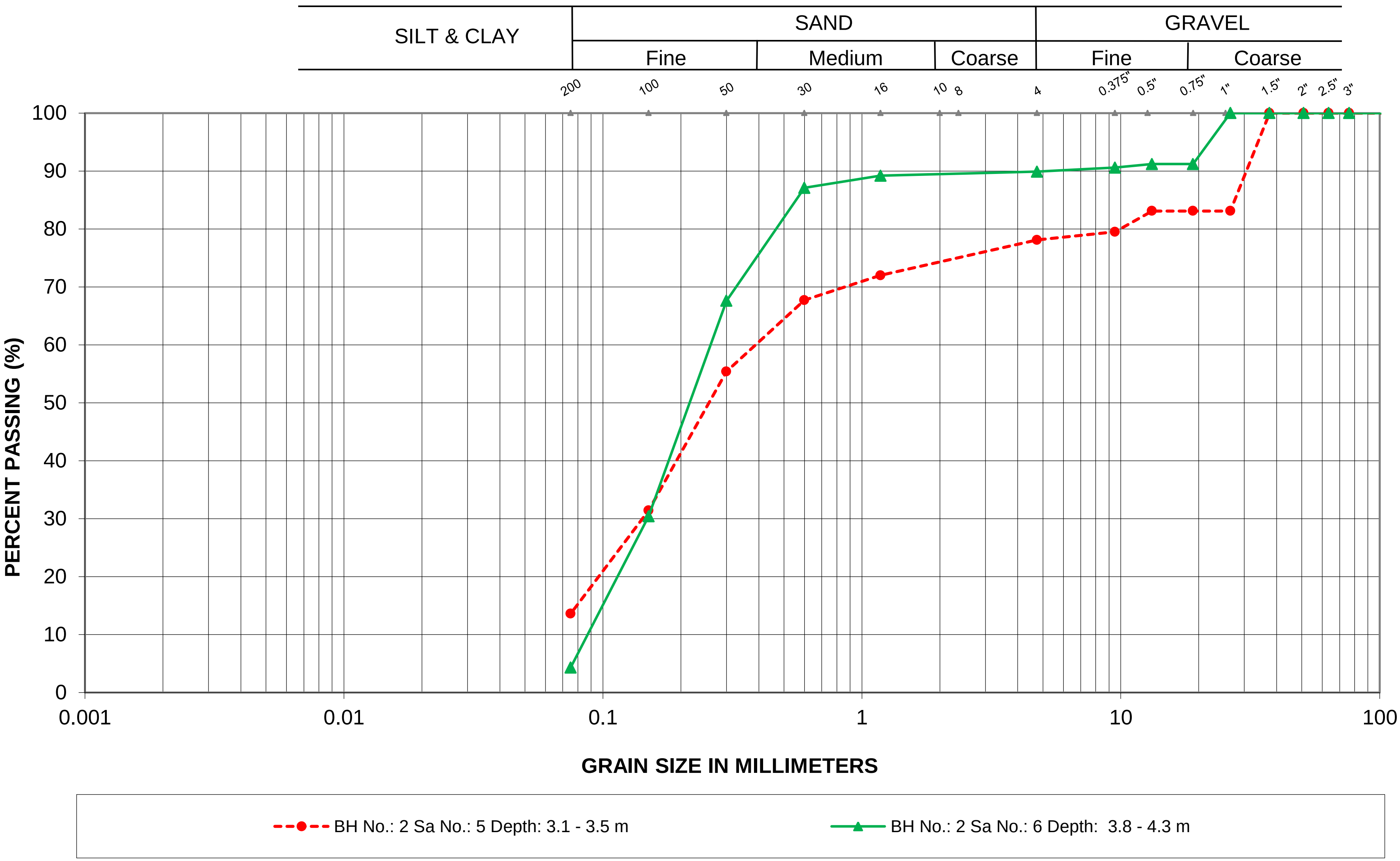
SAND AND SILT

Englobe Corp.

FIGURE L-2

Reference No.: 15/03/15019-F2
Date: June 2016

GRAIN SIZE ANALYSIS



LOCATION: Hwy 118 Sta.18+867
TWP. Hindon, Ontario

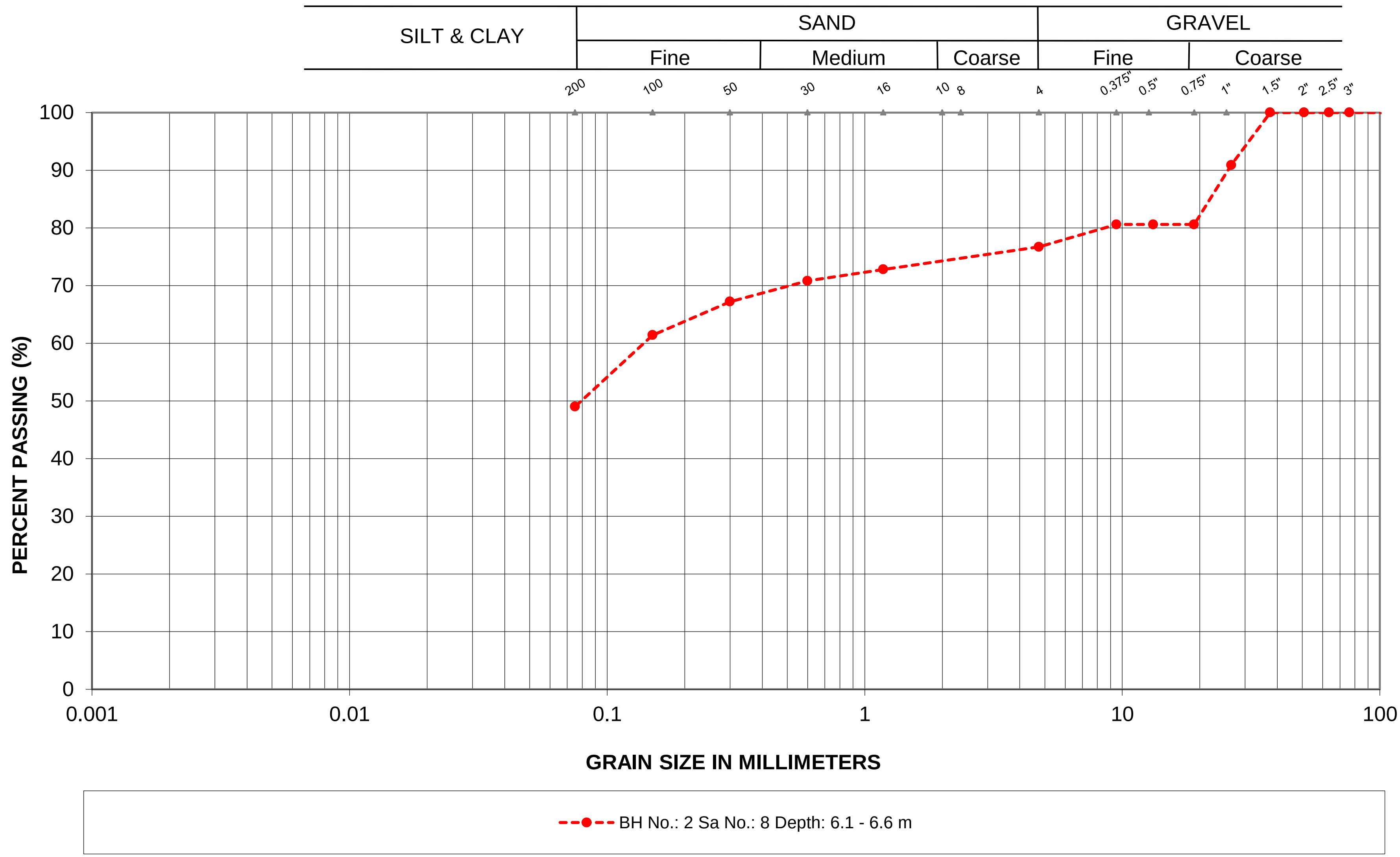
SAND

Englobe Corp.

FIGURE L-3

Reference No.: 15/03/15019-F2
Date: June 2016

GRAIN SIZE ANALYSIS



LOCATION: Hwy 118 Sta.18+867
TWP. Hindon, Ontario

SANDY SILT

Englobe Corp.

FIGURE L-4

Laboratory Tests - Summary Sheet

Englobe

Borehole No.	Sample No.	Depth	Grain Size Analysis				NMC	Atterberg Limits			SPT 'N'	USCS	Unit Weight (kN/m3)	Remarks
			Gravel Size (%)	Sand Size (%)	Silt Size (%)	Clay Size (%)		LL (%)	PL (%)	IP (%)				
1	1	0.2					4.3				23			
	2	0.8	18	73	9		5.6				22			
	3	1.5					4.3				13			
	4	2.3					15.6				2			
	5A	3.1					18.6				WH			
	5B	3.4					52.9							
	6	3.8					26.7				23			
	7	4.6					26.1				23			
	8	6.1	0	54	43	3	17.0				46/254 mm			
	9	6.5												Rec= 97% RQD= 95%
	10	8.1												Rec= 100% RQD= 98%
2	1	0.2	18	76	6		4.8				17			
	2	0.8									25/0 mm			
	3	1.5					6.4				50/102 mm			
	4	2.3	22	64	14		4.8				13			
	5	3.1	10	86	4		20.2				9			
	6	3.8					19.6				26			
	7	4.6	23	28	49		20.6				11			
	8	6.1					14.4				22			
	9	6.7												Rec= 100% RQD= 96%
	10	8.3												Rec= 100% RQD= 100%
3	1	0.0					38.0				4			
	2	0.8					26.5				23			
	3	1.5	0	74	26		26.0				24			
	4	2.3					15.2				53			
	5	2.9												Rec= 93% RQD= 89%
	6	4.4												Rec= 100% RQD= 98%

Laboratory Tests - Summary Sheet

Englobe

Borehole No.	Sample No.	Depth	Grain Size Analysis				NMC	Atterberg Limits			SPT 'N'	USCS	Unit Weight (kN/m3)	Remarks
			Gravel Size (%)	Sand Size (%)	Silt Size (%)	Clay Size (%)		LL (%)	PL (%)	IP (%)				
4	1	0.0									2			
	2	0.8	0	89	11						26			
	3	1.5									33			
	4	2.3	0	37	59	4					40			
	5	3.1												Rec= 100% RQD= 100%
	6	3.3												Rec= 97% RQD= 94%
	7	4.9												

Appendix 4 Photo Essay

Enclosure No. 6: Photo Essay

Embankment at Culvert Location – Looking East	Photo: 1

Embankment at Culvert Inlet – Looking East	Photo: 2

Project: Hwy 118 – Culvert, Station 18+867, Township of Hindon	Photos Provided By: Englobe Date: April 2015

Embankment at Culvert Outlet – Looking West	Photo: 3
	
Culvert Outlet – Looking South	Photo: 4
	
Project: Hwy 118 – Culvert, Station 18+867, Township of Hindon	Photos Provided By: Englobe Date: April 2015

Rock Cores – Borehole Nos. 1 (left) and 2 (right)	Photos: 5 and 6
	
Project: Hwy 118 – Culvert, Station 18+867, Township of Hindon	Photos Provided By: Englobe Date: April 2016

Rock Cores – Borehole Nos. 3 (left) and 4 (right)	Photos: 7 and 8

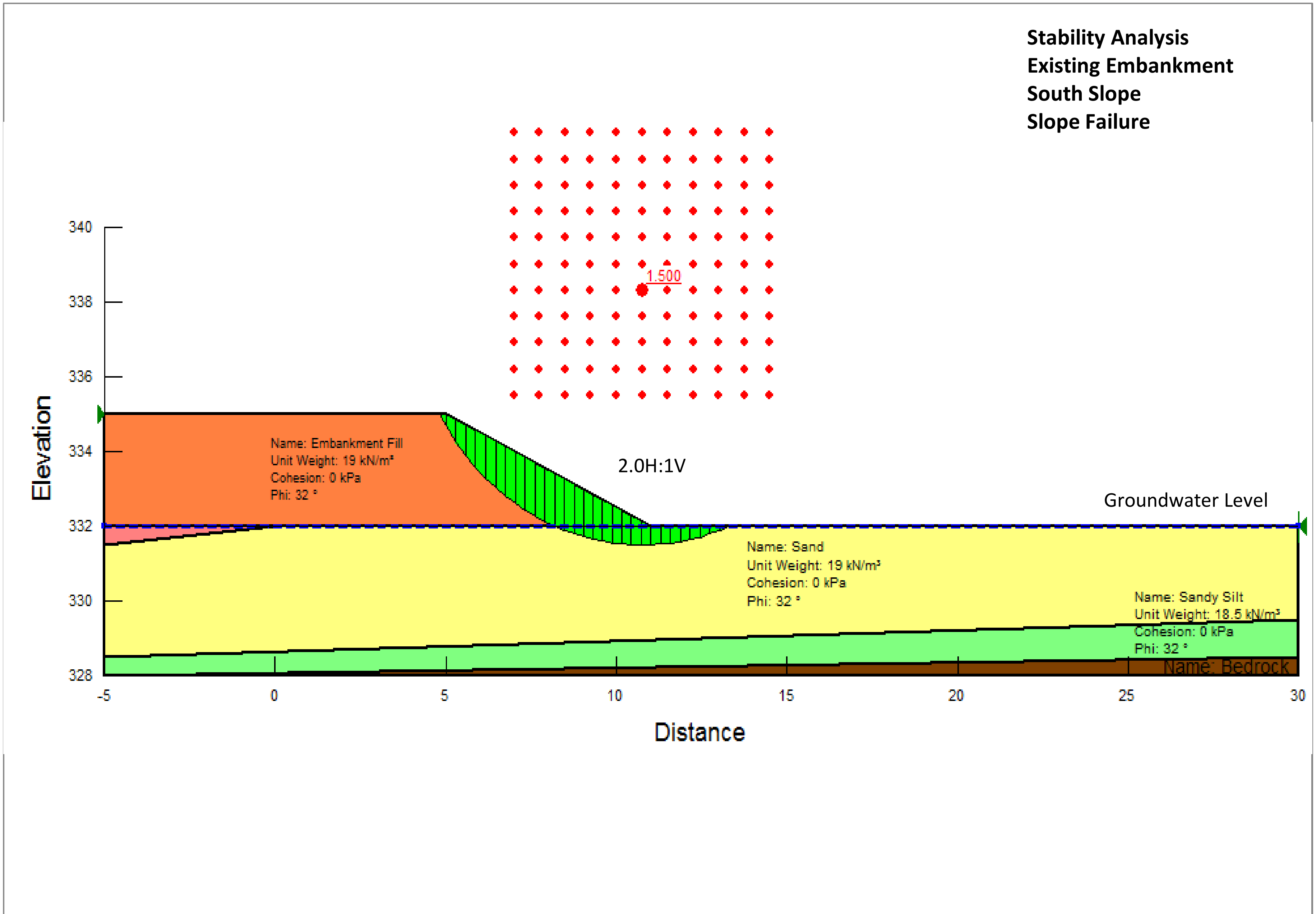
Project: Hwy 118 – Culvert, Station 18+867, Township of Hindon	Photos Provided By: Englobe Date: June 2016

Appendix 5 Design Data

Figure Nos. S-1 :	Slope Stability
Table A:	Comparison of Shoring Alternatives
Figure No. SK-3:	Conceptual Staging Plan
Figure No. SK-4:	Conceptual Shoring Locations
Figure No. SK-5	Conceptual Shoring Sections
	Notice to Contractor

Englobe

Reference No.: 15/04/15019-F2
Date: June 2016



South Slope
Culvert at Station 18+867

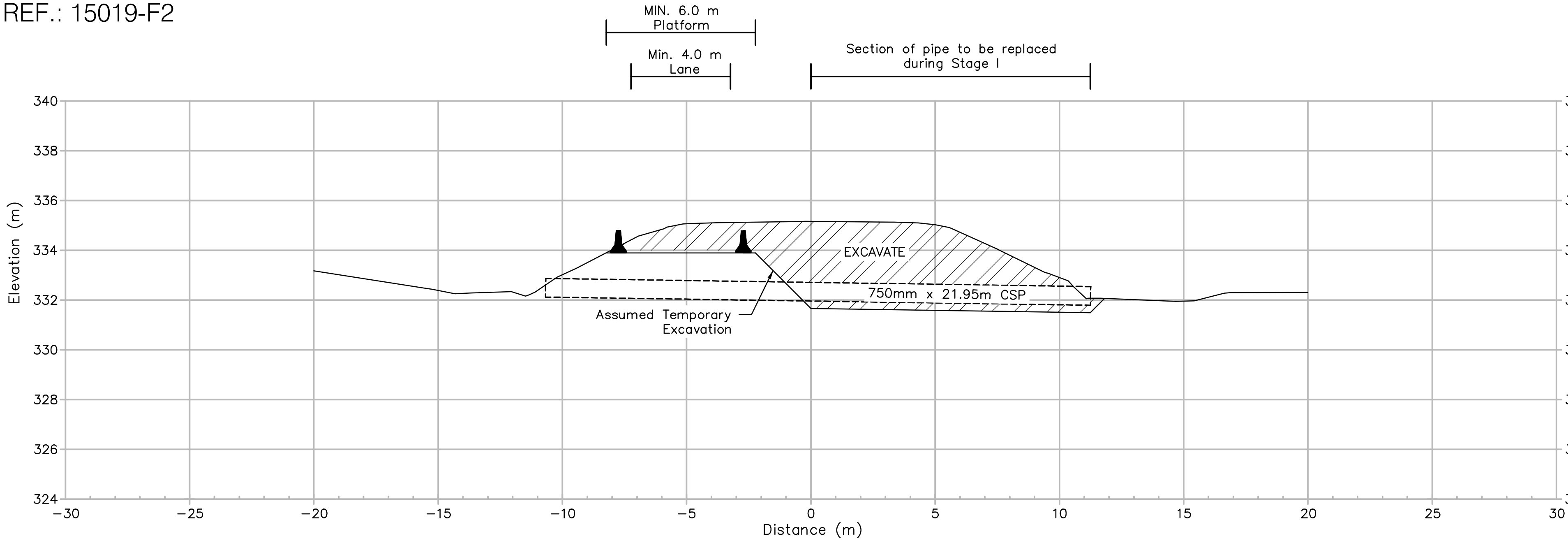
Project: G.W.P 5140-13-00
Location:Hwy 118, Township of Hindon

Figure No. S-1

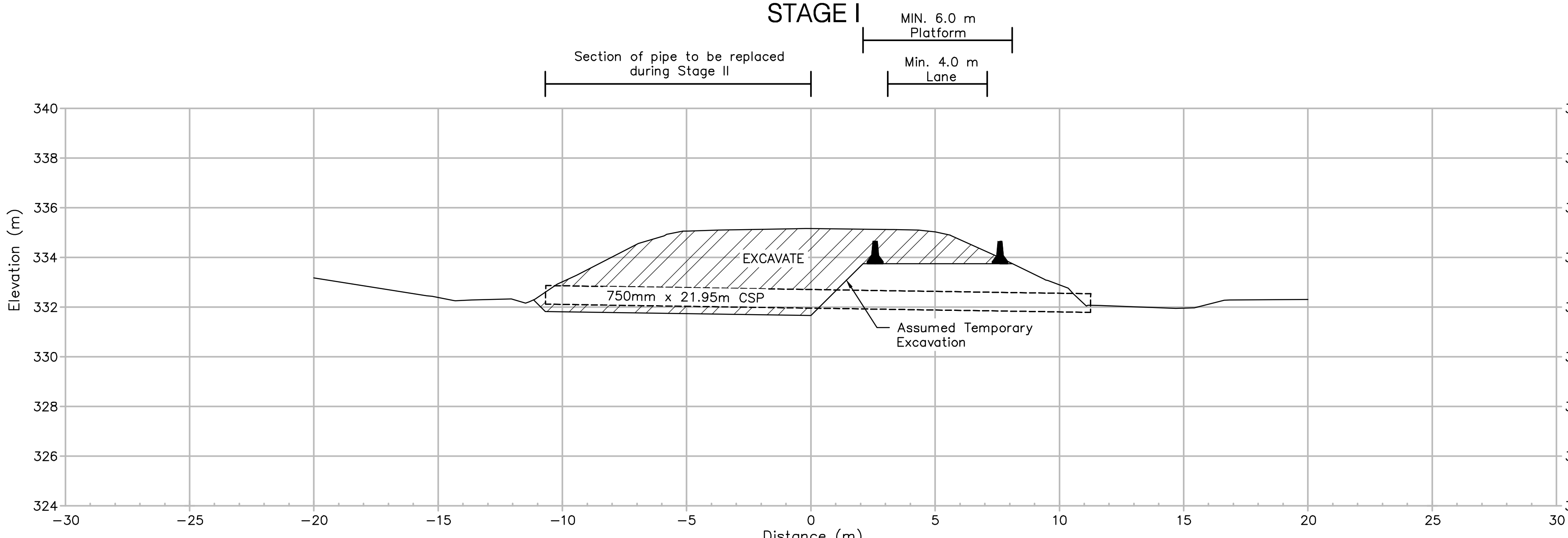
Table A – Comparison of Shoring Alternatives

Method	Depth Range (m)	Advantages	Disadvantages	Remarks	Estimated Costs
Wood Sheeting	1.5 – 5	-Low cost, -Easily installed in good ground conditions	-Limited by soil conditions, -Limited depth of installation, -Low strength, -discontinuous	Not recommended due to rockfill encountered in embankment	$ 650/m^2
Steel Sheet Piles	5 – 21	-High strength, continuous, -Readily available	-Limited by soil conditions (i.e. obstructions)	Not recommended due to rockfill encountered in embankment and embedment into shallow bedrock	$ 650/m^2
Pre-cast concrete panels	3 – 10	-Durable -Assists in minimizing seepage	-Limited depths -Can be damaged during installation -Limited by soil conditions (i.e. obstructions)	Not considered due to higher cost	
Soldier piles	5 – 25	-Easy installation -Readily available -Adaptable to various ground conditions	-Pre-drilling may be required -Possible ground loss	Recommended provided sufficiently predrilled through rockfill mixed in embankment fills and dewatering during excavation	$ 725/m^2 Predrilling 1500/m^2
Tangent/ Secant/ Staggered Drilled Piles	10 – 18	-Readily available -Adaptable to various ground conditions	-Possible ground loss and/or seepage -Poor alignment tolerance	Feasible using special equipment drilled through rockfill mixed in embankment fills	
Concrete Diaphragm	10 – 30	-High Strength -Durable -Can be permanent	-High cost -Requires specialized equipment/control	Not considered due to higher costs	
Micropiles with reinforced shotcrete face		-Can be installed in various ground conditions -High strength -Good tolerance	-High Cost -Requires specialized equipment	Considered as alternative for protection system, however, higher cost	$ 1200 to 1500/m^2

REF.: 15019-F2



STAGE I



STAGE II

METRIC

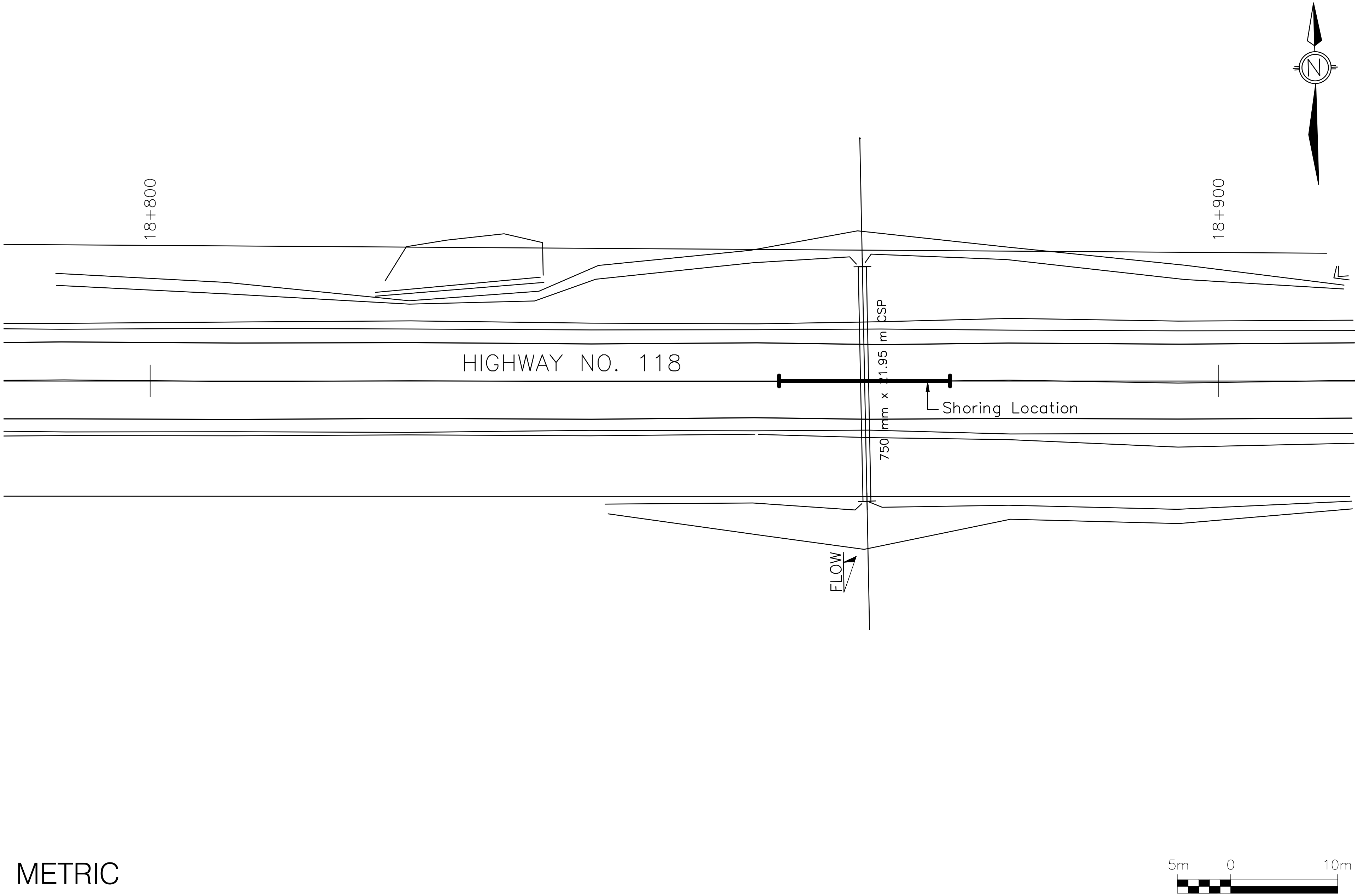
Dimensions are in meters and/or millimeters unless otherwise shown. Stations are in kilometers + meters.

2.5m 0 5m

Highway 118, Township of Hindon - Culvert at Station 18+867
Conceptual Shoring Location Plan

FIGURE SK-3

REF.: 15019-F2



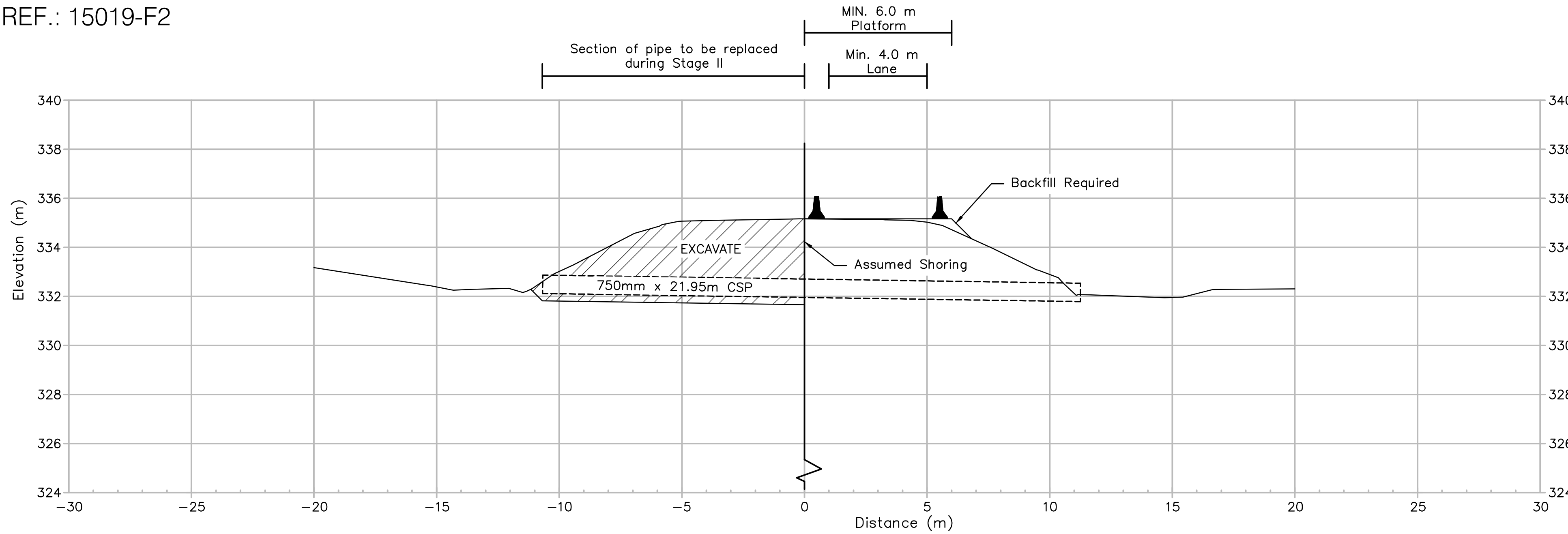
METRIC

Dimensions are in meters and/or millimeters unless otherwise shown. Stations are in kilometers + meters.

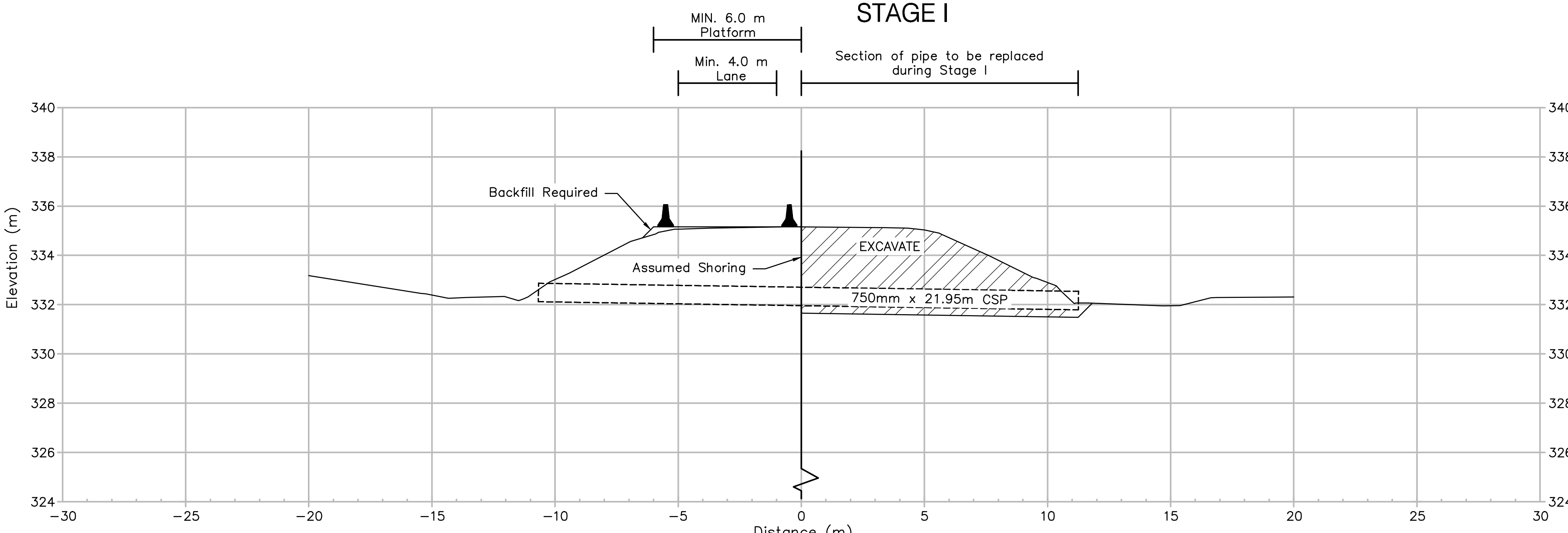
Highway 118, Township of Hindon - Culvert at Station 18+867
Conceptual Shoring Location Plan

FIGURE SK-4

REF.: 15019-F2



STAGE I



STAGE II

METRIC

Dimensions are in meters and/or millimeters unless otherwise shown. Stations are in kilometers + meters.

2.5m 0 5m

Highway 118, Township of Hindon - Culvert at Station 18+867
Conceptual Shoring Location Plan

FIGURE SK-5

<u>NOTICE TO CONTRACTOR</u> – Obstructions in Fills

Special Provision

The Contractor is notified that, during foundation field investigations for the culvert at Station 18+867, Township of Hindon on Highway 118, cobble/boulder sized rock fragments were encountered in the embankment fills. The Contractor shall take into account the obstructions for designing and constructing the temporary protection system and coffer dams. The Contractor must also be prepared to deal with seasonal and yearly fluctuations of ground/surface water.