



Englobe

Soils Materials Environment

**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 11
Site No. 39W-109
Stations 16+130.5 and 16+135.9 – Township of Idington
GWP 163-98-00**

FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

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Final Foundation Investigation and Design Report

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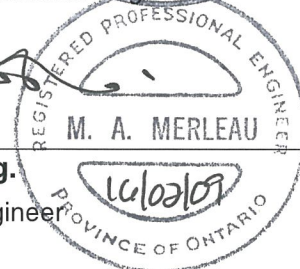


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Test results mentioned herein are only valid for the sample(s) stated in this report.

Englobe's subcontractors who may have accomplished work either on site or in laboratory are duly qualified as stated in our Quality Manual's procurement procedure. Should you require any further information, please contact your Project Manager."

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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 culvert site. The site has been identified as Site No. 39W-109 and is located on Highway 11 at Stations 16+130.5 and 16+135.9 in the Township of Idington, some 0.75 km east of the intersection between Highway 11 and De Coeur Road.

The foundation investigation location was specified by the MTO in the Terms of Reference for work under Agreement No. 5014-E-0001: GWP 163-98-00. The terms of reference for the scope of work of Change Order No. 1 are outlined in Englobes Proposal 15/05/15059 dated June 17, 2017. The purpose of this investigation was to determine the subsurface conditions in the area of the existing culverts. 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

The twin Corrugated Steel Pipe (CSP) culverts are located on Highway 11 at Stations 16+130.5 and 16+135.9 in the Township of Idington. The topography of this site is generally flat. 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 supporting on an embankment consisting of granular fills overlying mixed fills some 4.1 to 4.4 m in height, with centerline elevation of 226.5 m at the culvert location. The existing embankment slopes in the area of the culverts have been built between angles of approximately 2.5H:1V and has been locally steepened to 0.7H:1V. The culverts at this location has been described as twin 2.8 m diameter Corrugated Steel Pipe (CSP) culverts, some 24.5 m long in the RFP and a as twin 3.0 m Structural Plate Pipe (SPP) culvert some 24.4 m long as shown on the plans for the previous Contract package of WP 66-86-00. The current survey has indicated the culverts are 2.9x2.1 m Corrugated Steel Pipe Arch (CSPA) culverts some 24.5 m in length. For the purpose of this report the culverts will be described as twin 3.0 SPP culverts, some 24.4 m in length. The flow through the culvert is from the south to the north (right to left).

Infrastructure at this site consists of the overhead and the underground communication lines running parallel to the highway embankment. An Ontario Northland Rail (ONR) Line runs adjacent to the south of the highway embankment.

2.1 SITE PHYSIOGRAPHY AND SURFICIAL GEOLOGY

This project is located in the Geomorphic Sub-province known as the Cochrane Clay Plain. The topography on this section of Highway 11 is generally flat. Significant layers of earth

overlay the bedrock. Within the project area native overburden primarily consists of fine grained soils (silty clays and silts) overlying a till deposit.

Bedrock in the area, as indicated on OGS Map 2506, is of the Early Precambrian felsic igneous and metamorphic rocks consisting of granitic, metasedimentary, and minor metavolcanic migmatite.

3 INVESTIGATION PROCEDURES

The fieldwork for this investigation was carried out between the period of July 23rd and August 12th, 2015 during which time six (6) sampled boreholes were advanced. Two (2) boreholes were advanced through the embankment at the location of the culverts, and two (2) boreholes were advanced adjacent to each of the inlet (south) and outlet (north) ends of the culverts.

The field investigation was carried out using a bombardier mounted CME drilling rigs equipped with hollow stem augers, standard augers, casing equipment and routine geotechnical sampling equipment. 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. When cohesive deposits were encountered, the in-situ strength was measured using an “N” size field vane, vane collar, and calibrated torque meter. 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 single 19 mm diameter standpipe was installed in selected open boreholes prior to backfilling to allow for post borehole completion monitoring of the shallow groundwater levels. All open boreholes were backfilled upon completion with compacted auger cuttings in the general order 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 borehole 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 under the full time direction of a senior member of the Englobe engineering staff, 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 our North Bay laboratory, plus overall drill supervision. All samples received a visual confirmatory inspection in our 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-7 and Table No. L-8).

The location of the individual boreholes was determined in the field using highway chainage (established by others) and offset relative to highway centerline. The MTO co-ordinates, northing and easting, were then established for the boring locations. Elevations contained in this report are referenced to a geodetic datum. The borehole elevations are based on a survey carried out by others.

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 Nos. 2A and 2B (Appendix 3). Please note that 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 16+130.5 AND 16+135.9, TWP OF IDINGTON

A plan and profile illustrating the borehole locations and stratigraphic sequences is shown on Drawing Nos. 2A and 2B, Appendix 3. During the course of the exploration program, six (6) sampled boreholes were put down at this site, with Borehole Nos. 1 and 2 advanced through the embankment adjacent to the culvert, Borehole Nos. 3 and 5 advanced adjacent to the culvert outlet, and Borehole Nos. 4 and 6 advanced adjacent to the culvert inlet. At the time of the subsurface investigation, the ground surface elevations at Boreholes Nos. 1 to 6, inclusive, were recorded at elevations 226.3, 226.3, 223.9, 224.0, 223.8, and 224.7 m, respectively.

4.1.1 Pavement Structure

Borehole No. 1 and 2 were advanced through the embankment shoulder where a layer of crushed gravel some 100 to 255 mm thick was penetrated.

4.1.2 Granular Fill

Underlying the pavement structure at Borehole Nos. 1 and 2, a layer of granular fill consisting of brown sand trace to with gravel, trace to with silt was penetrated. The natural moisture content measured on samples of this deposit was in the order of 3 to 18%. Gradation analyses were carried out on four (4) samples of this deposit, the results of which indicated 3 to 22% gravel size particles, 69 to 90% sand size particles, and 7 to 23% silt and clay size particles (Figure No. L-1, Appendix 3). Based on SPT 'N' values of 5 to 31 blows per 300 mm penetration, the

compactness of this deposit was described as loose to dense, generally compact. This granular fill layer was encountered to depths of 4.4 and 3.4 m below grade at Borehole Nos. 1 and 2, respectively (elevations 221.9 and 222.9 m, respectively).

4.1.3 **Mixed Fill**

Underlying the granular fill at Borehole No. 2, and underlying the organic soils at Borehole Nos. 4, 5, and 6, a layer of mixed fill consisting of a mixture of sand, silt, and silty sands, as well as silty clays, trace organics/rootlets was penetrated. The natural moisture content measured on samples of this deposit was in the order of 9 to 52%. Gradation (sieve) analyses were carried out on two (2) samples of this deposit, the results of which indicated 5 to 10% gravel size particles, 44 to 74% sand size particles, and 16 to 51% silt and clay size particles (Figure No. L-2, Appendix 3). Gradation (hydrometer) analyses were carried out on two (2) sample of this deposit, the results of which indicated 0 to 15% gravel size particles, 3 to 44% sand size particles, 27 to 81% silt size particles and 14 to 16% clay size particles (Figure No. L-2, Appendix 3). Atterberg Limits testing was carried out on four (4) samples of this deposit. Generally the testing indicated a non-plastic material; however, the results on one (1) sample indicated a Plastic Limit in the order of 33% and a Liquid Limit in the order of 46%, indicating an organic clayey silt (Figure No. L-7, Appendix 3). Based on in-situ shear strengths of greater than 100 kPa, the consistency of the clay portion of this fill was described as very stiff. Based on SPT 'N' values of 3 to 16 blows per 300 mm penetration, the compactness of the sandy portion of this fill was described as very loose to compact, generally loose. This mixed fill layer was encountered to depths of 4.4, 2.1, 2.1, and 1.4 m below grade at Borehole Nos. 2, 4, 5, and 6, respectively (elevations 221.9, 221.9, 221.7, and 223.3 m, respectively).

4.1.4 **Organic Soils**

At ground surface Borehole Nos. 3, 4, 5, and 6, a layer of silty organic soils was penetrated. This organic soil layer was encountered to a depth of 2.1 m below ground surface at Borehole No. 3 (elevation 221.8 m) and 0.1 m below ground surface at Borehole Nos. 4, 5, and 6 (elevations 223.9, 223.7, and 224.6 m, respectively).

4.1.5 **Clayey Silt**

Underlying the organic soils at Borehole No. 3 (adjacent to the north end of the culvert) a deposit of grey clayey silt, trace sand, trace organics, was penetrated. The natural moisture content measured on samples of this deposit was in the order of 21%. A gradation (hydrometer) analysis was carried out on a single sample of this deposit, the results of which indicated 0% gravel size particles, 4% sand size particles, 70% silt size particles, and 26% clay size particles (Figure No. L-3, Appendix 3). Atterberg Limits testing was carried out on one (1) sample of this deposit, the results of which indicated a Plastic Limit in the order of 16% and a Liquid Limit in the order of 22% (Figure No. L-7, Appendix 3). Based on an in situ shear strength of greater than 100 kPa, the consistency of this deposit was described as very stiff. This deposit was encountered to a depth of 3.0 m below grade at Borehole No. 3 (elevation 220.9 m).

4.1.6 Silty Clay

Underlying the granular fill at Borehole No. 1, underlying the mixed fill at Borehole Nos. 2, 4, 5, and 6, and underlying the clayey silt at Borehole No. 3, a deposit of grey silty clay, trace gravel, trace sand, was penetrated. The natural moisture content measured on samples of this deposit was in the order of 16 to 37%. Gradation (hydrometer) analysis were carried out on three (3) samples of this deposit, the results of which indicated 0% gravel size particles, 0 to 4% sand size particles, 34 to 65% silt size particles, and 35 to 62% clay size particles (Figure No. L-4, Appendix 3). Atterberg Limits testing was carried out on three (3) samples of this deposit, the results of which indicated a Plastic Limit in the order of 16 to 20% and a Liquid Limit in the order of 26 to 45% (Figure No. L-7, Appendix 3). Based on in situ shear strengths of greater than 100 kPa, the consistency of this deposit was described as very stiff. This deposit was encountered to depths of 7.1, 5.9, 3.7, 3.7, 4.4, and 4.6 m below grade at Borehole Nos. 1 to 6, respectively (elevations 219.2, 220.4, 220.2, 220.3, 219.4 and 220.1 m, respectively).

4.1.7 Glacial Till

Underlying the silty clay at Borehole No. 6, a deposit of grey silty sand till some gravel trace clay was penetrated. The natural moisture content measured on samples of this deposit was in the order of 12%. A gradation (hydrometer) analysis was carried out on one (1) sample of this deposit, the results of which indicated 11% gravel size particles, 46% sand size particles, 34% silt size particles, and 9% clay size particles (Figure No. L-5, Appendix 3). Based on a SPT 'N' values of 11 blow per 300 mm penetration, the compactness of the deposit was described as compact.

A transition from silty sand till to silty clay till was observed at a depth of some 5.6 m below grade at Borehole No. 6 (elevation 219.1 m). The silty clay till deposit was also encountered underlying the silty clay deposit at Borehole Nos. 1 to 5, respectively. The natural moisture content measured on samples of this deposit was in the order of 11 to 47%. Gradation (hydrometer) analysis were carried out on seven (7) samples of this deposit, the results of which indicated 0 to 5% gravel size particles, 2 to 22% sand size particles, 32 to 53% silt size particles, and 24 to 66% clay size particles (Figure No. L-6, Appendix 3). Atterberg Limits testing was carried out on seven (7) samples of this deposit, the results of which indicated a Plastic Limit in the order of 12 to 27% and a Liquid Limit in the order of 20 to 52% (Figure No. L-7, Appendix 3). Based on in situ shear strengths of greater than 100 kPa, the consistency of this deposit was described as very stiff to hard, generally very stiff. Sampling was terminated the silty clay till at depths of 9.8 m below grade at Borehole Nos. 1, 2, 4, and a depth of 10.1 m below grade at Borehole Nos. 5 and 6 (elevations 216.5, 216.5, 214.2, 213.7, and 214.6 m, respectively). Auger refusal, likely on a boulder, was encountered in this deposit at a depth of 8.6 m below grade at Borehole No. 3 (elevation 215.3 m).

4.2 GROUNDWATER DATA

During the period of investigation (July 23rd to August 12th, 2015), the creek water levels were measured at an elevation of some 223.1 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.

Standpipes were installed in Borehole Nos. 1 and 4 to obtain post borehole completion water levels. These levels are recorded on the individual Record of Borehole Sheets (Appendix 2).

The groundwater levels were measured at elevations 223.2, 223.1, and 222.7 m at Borehole Nos. 1, 2, and 4, respectively. The groundwater levels were encountered at elevations 217.4 and 217.2 m at Borehole Nos. 5 and 6, respectively, however these water levels likely had not stabilized at the time of recording.

Artesian pressures were encountered at Borehole No. 3. The borehole was sealed for the full height with bentonite and some silty clay cuttings using reverse augering techniques. This cut off artesian flow.

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

5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

A foundation investigation was carried for the proposed replacement of twin CSP culverts as identified by the MTO.

The existing culverts, located at Stations 16+130.5 and 16+135.9, in the Township of Idington, are twin 3.0 m diameter SPP culverts some 24.4 m long. The existing culvert invert is established at approximately elevation 222.8 m. The existing highway embankment currently supports two undivided lanes of highway, running in a west-east direction. The flow through the existing culvert is from the south to the north (right to left). Based on data from this foundation investigation, the embankment supporting the existing pavement structure at this site has been constructed using a granular pavement structure overlying granular and mixed fills. The native material, underlying the embankment fill, generally consisted of very stiff silty clays, overlying silty sand and silty clay tills.

As noted, the culverts have been described as a 3.0 m diameter SPP culvert, based on the previous Contract drawings. However, the current survey has indicated the culverts are 2.9x2.1 m CSPA culverts some 24.5 m in length. As such, it appears that the culvert has potentially deformed.

It is understood that a new precast Rigid Frame Box (RFB) culvert will be constructed at an offset of some 0.6 m west of the western edge of the existing twin Corrugated Steel Pipe Arch (CSPA) culverts. The invert of the new RFB culvert will be located at Elevation 222 m and founded on the subgrade of very stiff native silty clay deposit underlain by the very stiff to hard silty clay till deposit encountered at an approximate Elevation 220 m, based on the results of this foundation investigation.

5.2 FOUNDATION CONSIDERATIONS

The founding native very stiff silty clays 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 unduly disturbed during construction and groundwater is controlled throughout construction, as discussed in Section 5.5. Adequate dewatering is required to avoid the potential development of boiling conditions or heave and disturbance of subgrade at the founding level.

Based on the characteristics of the native silty clay subgrades present below the culvert, the response of the existing embankment, and a founding elevation similar to that of the existing culverts, a factored bearing resistance at ULS of 260 kPa can be used for a closed culvert (i.e. precast concrete box culvert or CSP culvert). In consideration of the width of the culvert, depth

of overburden, and response of the existing embankment, a geotechnical reaction at SLS of 150 kPa can be used for design, in consideration of 25 mm settlement.

If open culverts (i.e. concrete frame open culverts, with wall footings, or pipe arch culverts on footings) are considered, then a factored bearing resistance at ULS of 200 kPa, and a geotechnical reaction at SLS of 100 kPa would apply for design, in consideration of 25 mm settlement and taking into consideration the limited depth of overburden and smaller footing width.

5.2.1 Slope Stability

The maximum height of the embankment above the stream bed at this location is some 4.4 m. The inclination angles of existing slopes ranging from approximately 2.5H:1V to 0.7H:1V (locally steepened below elevations of some 225 m). Stability analyses, using the GEO-SLOPE computer program, Slope/W (GeoStudio 2007, version 7.17, Geo-Slope International Ltd.), were carried out at this location for the north and the south slopes with existing inclinations in the granular fill. For the purposes of these analyses, the materials were modeled using the following parameters;

MATERIAL	PARAMETER		
	UNIT WEIGHT (KN/M3)	EFFECTIVE FRICTION ANGLE (DEGREES)	UNDRAINED SHEAR STRENGTH (KPA)
Granular Fill	19.0	32	-
Mixed Fill (undrained)	17.0	-	75
Mixed Fill (drained)	17.0	28	5
Silty Organics	10.0	-	10
Silty Clay (undrained)	17.0	-	100
Silty Clay (drained)	17.0	28	8
Silty Sand Till	19.0	32	-
Silty Clay Till (undrained)	18.0	-	100
Silty Clay Till (drained)	18.0	28	8

The 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 results of the analyses indicate factors of safety in the order of 0.7 to 0.8 on the existing embankment slopes, against minor surficial slippage on the embankment (see Figure Nos. S-1 and S-3, Appendix 5). The factor of safety against long term deep seated failures is in the order of 1.3 to 1.5 with the existing slopes (see Figure Nos. S-2 and S-4, Appendix 6). It is recommended that the finished slopes of embankment be established at 2H:1V or shallower. 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 consists of granular fills overlying mixed fills. The results of this investigation indicate that, below the culvert invert, the native soils encountered at Boreholes No. 1 to 6 consisted of very stiff silty clays overlying silty sand to silty clays tills. A review of the condition of the pavement surface, at the culvert locations, revealed minor asphalt cracking; however, in general, the embankment appears to have performed well. The existing embankment has preloaded the soils at the culvert locations and since there will be no change in the height of the embankment, and therefore no increases in embankment load, no appreciable long term settlement of the embankment is anticipated. As such, installing the culverts 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 and cover shall be placed in uniform layers not exceeding uncompacted thickness of 200 mm. The elevation difference of backfilling on either side of the rigid pipe shall be limited to a maximum 200 mm per OPSS 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 in accordance with OPSS 501.

A precast concrete rigid frame box culvert can also be considered for culvert replacement at this site. Bedding for a rigid frame box culvert shall consist of Granular A with a thickness of 300 mm. The bedding under the middle third of the box unit base should be loosely placed and upcompacted. The upper 75 mm portion of the Granular A bedding should be uncompacted throughout the length/width of the box and incorporated as the top levelling course in conformance with OPSS 422. 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 applications. During backfilling, the material of bedding, cover and backfill shall be placed in uniform layers not exceeding uncompacted thickness of 200 mm. Backfilling shall be placed in a balanced manner in layers not exceeding 200 mm in thickness on each side of the box unit. The elevation difference of backfilling on either side of the box unit shall be limited to a maximum 400 mm as per OPSS 422. Backfilling and construction of pre-cast concrete box culverts shall be in accordance with OPSS 422. Cover material for concrete box culverts can consist of Granular A, placed to the dimensions as shown on MTOD-803.021.

The joints between precast box units should be covered with a strip of Non-Woven Class II Geotextile (per OPSS 1860) 600 mm in width, centered over the joint, covering the top of the culvert and extending down the sides of the culvert to prevent the infiltration of fines.

Apron (cut-off) walls, 1.2 m deep, must be added to the ends of the rigid frame box culvert in accordance with the MTO Concrete Culvert Design Manual.

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 minimum 3 m in length, minimum 400 mm thick and extend across the stream bed to a minimum 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. Considering the head difference between the inlet and outlet, it is recommended that clay seals not be used at this culvert location.

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 OPS.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% of Standard Proctor Maximum Dry Density prior to placing the remainder of the embedment material. During backfilling, the embedment material shall be placed in uniform layers not exceeding uncompacted 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 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 401.

Considering the porous nature of the embankment fill, inlet clay seals along the culvert or outlet cut-off walls are not required; however, 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 minimum 3 m in length, minimum 400 mm thick and extend across the stream bed to a minimum 3 m beyond the outside edges of the culvert.

5.4 CULVERT INSTALLATION AND CONSTRUCTION CONSIDERATIONS

The invert of the proposed precast rigid frame box culvert with a 3 m rise has been established at a depth of some 4.5 m below centreline (i.e. elevation 222 m). Therefore, a minimum 4.8 m deep excavation (i.e. to elevation 221.7 m) will be required in consideration of a 300 mm thick layer of bedding/embedment material. If the mixed fills are encountered below the culvert invert during construction, it is recommended that they should be sub-excavated to the subgrade of very stiff native silty clay.

The present platform width at this location is some 16 m as can be seen on the cross sections on Drawing No. 2B. 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 m below the centerline of highway. 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 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 225.5 m.
- Limit traffic to a single lane on the left (north), with a minimum platform width of 6 m, under 24/7 traffic control.
- Open cut excavate, to the right (south), and install approximately 12 m in length of new culvert.
- Reconstruct the embankment on the right (south), allowing for 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 (north).
- As the width of the platform increases on the left, the vertical alignment can be raised, and the traffic can revert back to two lanes when sufficient width permits.

5.4.2 **Protection System**

As noted above, consideration could be given to constructing a vertical wall, along centerline, for use as a temporary protection system.

Considering the nature of this foundation investigation, only two boreholes were advanced through the embankment. Depending upon the type of protection system proposed by the contractor, additional borehole information, beyond the existing embankment boreholes, may be required, if the variation in elevation of the silty clay till deposit could impact their design of protection system.

The installation of a protection system for use in the culvert replacement operation will require penetration through some 4.4 m of embankment fills. The embankment fill is generally underlain by some very stiff silty clays, overlying compact silty sand till to very stiff silty clay till. Considering the embankment generally consists of granular fills, the recommended method of constructing a temporary vertical wall for a protection system along the centreline of the highway alignment would be to drive steel sheet piles through the embankment fill into the underlying native soils. Conceptual shoring locations and sections are illustrated on Figure Nos. SK-4 and SK-5, Appendix 5.

The granular pavement structure over granular fills are considered cohesionless, as such, a rectangular apparent pressure distribution over the height of the cut would be appropriate for design of the temporary shoring in granular fills. The width of the apparent rectangular pressure distribution, over the height of excavation, can be considered equal to $0.65 \cdot K_a \cdot \gamma \cdot H$, where:

K_a = active earth pressure coefficient, as described in Section 5.6,

γ = unit weight, as described in Section 5.6, and

H = height of wall above the base of excavation.

The existing mixed fill, underlying the granular fill at Borehole No. 2, is largely composed of cohesive materials (silty clay). This will be replaced with granular fill during the backfilling of Stage 1. As such, the rectangular apparent pressure distribution would apply. However, the presence of the cohesive backfill encountered during Stage 1 may require that the protection system be designed using the “layered strata” method, as outlined in the Canadian Foundation Engineering Manual, 4th Edition, Section 26.10.7.

Surcharge loads from the active lane of traffic must also be considered during design of the temporary protection system with sufficient embedment depth into the silty clay till deposit to provide sufficient geotechnical resistance for the lateral pressure during construction. The contractor’s protection system design must be carried out by a geostructural engineer with appropriate experience.

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 is illustrated on Figure No. SK-4 in Appendix 5.

The protection system can be designed using the lateral earth pressure parameters as outlined in Section 5.6. The temporary protection system should be designed and constructed to comply with OPSS.PROV 539. In consideration of the location of the protection system and traffic volume, a Performance Level 2 is considered appropriate. The protection system should be removed upon completion of the work.

5.5 EXCAVATION, DEWATERING, AND EMBANKMENT CONSTRUCTION

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 and/or native materials will have to be cut back to an angle of 2H:1V, possibly shallower, dependent upon the Contractors' chosen method of controlling the groundwater.

The excavation backfill above the culvert bedding/cover should consist of granular fills per OPSS.Prov 1010, up to the underside of the pavement structure. Frost tapers should be constructed at 10H:1V on both sides of the trench from a depth of 2.5 m up to a depth of 0.8 m, and 1H:1V tapers from that point up to surface, see Englobe's Pavement Design Report Reference No. 15/05/15059-P1, provided under a separate cover.

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.

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.

The water levels in the creek were recorded at elevations some 223.1 m at the culvert outlet during the period of this investigation and the groundwater level at Borehole Nos. 1, 2, and 4 had stabilized at elevations of 223.2, 223.1, and 222.7 m, respectively, at the time of this investigation. All excavations extending below the groundwater table, present at the time of construction, will have to be maintained in a dewatered condition. 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, 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 for controlling flow. For base design, shoring 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. Since this site has twin culverts, by-pass pumping/diversion through one of the culverts can be carried out, while the adjacent culvert is being replaced. Temporary erosion control should be carried out in accordance with OPSS 805 requirements.

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.

5.6 LATERAL EARTH PRESSURES

Lateral earth pressures should be computed in accordance with the Canadian Highway Bridge Design Code (CHBDC). The design parameters for the bedding/embedment and backfill materials are as follows:

PARAMETER	GRANULAR A	GRANULAR B TYPE I	GRANULAR FILL	MIXED FILL	SILTY ORGANICS
Unit Weight (kN/m ³)	22	21	19	17.0	10.0
Angle of Internal Friction	34°	33°	32°	-	-
Undrained Shear Strength (kPa)	-	-	-	75	10
Coefficient of Active Earth Pressure (K_a)	0.28	0.29	0.31	-	-
Coefficient of Passive Earth Pressure (K_p)	3.54	3.39	3.23	-	-
Coefficient of Earth Pressure at Rest (K_o)	0.44	0.46	0.47	-	-
PARAMETER	SILTY CLAY	SILTY SAND TILL	SILTY CLAY TILL		
Unit Weight (kN/m ³)	17.0	19.0	18.0		
Angle of Internal Friction	-	32°	-		
Undrained Shear Strength (kPa)	100	-	100		
Coefficient of Active Earth Pressure (K_a)	-	0.31	-		
Coefficient of Passive Earth Pressure (K_p)	-	3.23	-		
Coefficient of Earth Pressure at Rest (K_o)	-	0.47	-		

For rigid structures, such as a precast rigid frame box culvert, the “at-rest” condition (K_o) applies. For flexible structures, such as CSP/HDPE culverts, 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).

5.7 CONSTRUCTION CONCERNS

Considering the nature embankment fill consisting of granular fills overlying mixed fills, no major construction concerns are anticipated if construction is carried out in general conformance with the above discussion. As noted in Section 5.5 the culvert subgrade must be adequately dewatered to maintain the bearing resistance of the foundation subgrade. Sufficiently robust sheet piles will be required due to the dense/very stiff to hard till deposits.

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

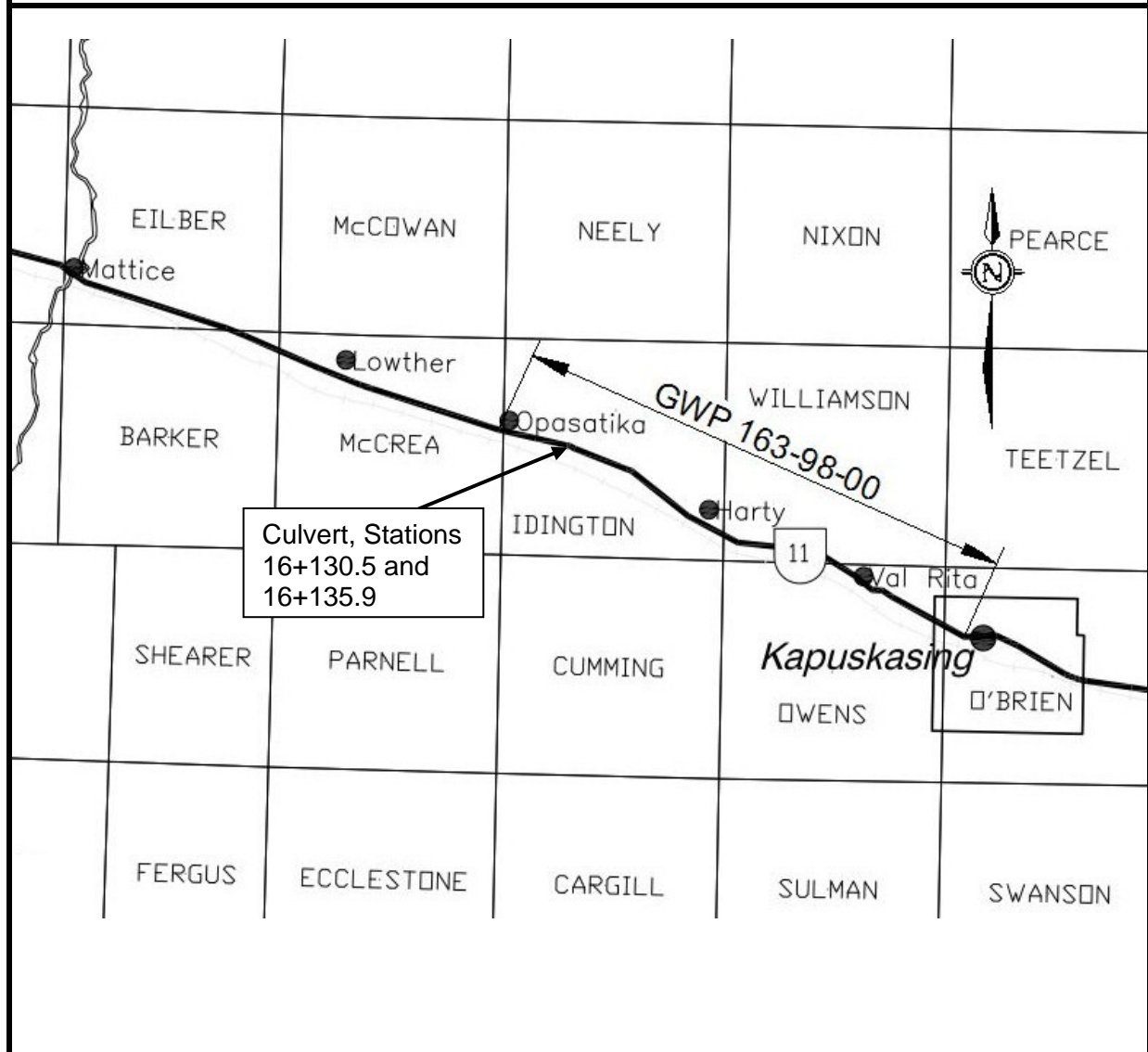
Drawing No. 1

Key Plan

MACRO KEY PLAN

Drawing No.1

NOT TO SCALE



FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

GWP 163-98-00

Highway 11

Station 16+130.5 to 16+135.9 Culvert

Township of Idington, Ontario

Reference No: 15/05/15059-F2

February 2016



Appendix 2 Subsurface Data

Enclosure No. 1	List of Abbreviations and Symbols
Enclosure Nos. 2 to 7	Record of Borehole Sheet

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.

METRIC

RECORD OF BOREHOLE NO. 1



REFERENCE 15/05/15059-F2 DATUM Geodetic LOCATION N 5487219 E 391978.8 - Idington Twp., Station 16+128.5 ORIGINATED BY JL
 PROJECT GWP 163-98-00, Highway 11 BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers COMPILED BY SH
 CLIENT AECOM DATE (Started) 23 July 2015 TIME
 DATE (Completed) 23 July 2015 (Completed) 4:35:00 PM CHECKED BY MAM

SOIL PROFILE		STRATA PLOT	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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)		NUMBER	TYPE			"N" VALUES	20					
226.3	Ground Surface												
0.0	100 mm Crushed Gravel Granular FILL- sand, trace to with gravel, trace to some silt brown, moist (dense/loose)		1	SS	23								22 69 (9)
			2	SS	31								
			3	SS	11								
	wet		4	SS	12								
			5	SS	7								
	greyish brown		6	SS	6								17 70 (13)
221.9			7	SS	3								
4.4	silty CLAY, trace gravel, trace sand grey, moist (very stiff)		8	SS	9								0 4 34 62
			9	SS	11								
219.2													
7.1	silty CLAY TILL, trace gravel, some to with sand grey (very stiff/hard)		10	SS	22								5 21 49 25
216.5			11	SS	34								
9.8	End of Sampling End of Borehole												
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) 23/7/15 4:40:00 PM 6.6 - 驗 2) 23/7/15 7:00:00 PM 4.1 - - 3) 12/8/15 9:10:00 AM 3.1 - -					

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

EnGlobe Corp.

120 Progress Court, North Bay, On P1A 0C2 Phone: (705)476-2550 Fax: (705)476-8882 Email: northbay@vm.ca

MEL-GEO 15059 - F2 BOREHOLE LOGS.GPJ MEL-GEO.GDT 4/2/16

METRIC

RECORD OF BOREHOLE NO. 2



REFERENCE 15/05/15059-F2 DATUM Geodetic LOCATION N 5487207.1 E 391985 - Idington Twp., Station 16+138.5 ORIGINATED BY JL
 PROJECT GWP 163-98-00, Highway 11 BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers COMPILED BY SH
 CLIENT AECOM DATE (Started) 23 July 2015 TIME
 DATE (Completed) 23 July 2015 (Completed) 7:10:00 PM CHECKED BY MAM

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	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV. DEPTH	DESCRIPTION (see Enclosure No. 1)	STRATA PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa							WATER CONTENT (%)			
							20	40	60	80	100							
226.3	Ground Surface																	
0.0	255 mm Crushed Gravel Granular FILL- sand, trace gravel, trace to with silt and clay brown, moist (compact/loose)		1	SS	17													
			2	SS	5													
			3	SS	15													
			4	SS	8													
222.9			5	SS	11													
3.4	Mixed FILL - mixture of sand, silt and silty clay, trace gravel sand and silt, trace gravel		6	SS	18													
221.9			7	SS	11													
4.4	silty CLAY, trace gravel, trace sand very stiff grey		8	SS	20													
220.4			9	SS	9													
5.9	silty CLAY TILL, trace gravel, some sand very stiff/hard grey		10	SS	37													
			11	SS	22													
216.5																		
9.8	End of Sampling End of Borehole																	
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) 23/7/15 7:10:00 PM			3.2		3.4						
							2)			-		-						
							3)			-		-						

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

MEL-GEO 15059 - F2 BOREHOLE LOGS.GPJ MEL-GEO.GDT 4/2/16

METRIC

RECORD OF BOREHOLE NO. 3



REFERENCE	15/05/15059-F2	DATUM	Geodetic	LOCATION	N 5487228.5 E 391978.6- Idington Twp., Station 16+125	ORIGINATED BY	JL
PROJECT	GWP 163-98-00, Highway 11			BOREHOLE TYPE	Track Mounted CME 45 - Hollow Stem Augers	COMPILED BY	SH
CLIENT	AECOM	DATE (Started)	28 July 2015	TIME (Completed)	10:30:00 AM	CHECKED BY	MAM
		DATE (Completed)	28 July 2015				

[illegible]

MEL-GEO 15059 - F2 BOREHOL LOGS.GPJ MEL-GEO.GDT 4/2/16

METRIC

RECORD OF BOREHOLE NO. 4



REFERENCE	15/05/15059-F2	DATUM	Geodetic	LOCATION	N 5487197.2 E 391984 - Idington Twp., Station 16+141		ORIGINATED BY	JL
PROJECT	GWP 163-98-00, Highway 11			BOREHOLE TYPE	Track Mounted CME 45 - Hollow Stem Augers		COMPILED BY	SH
CLIENT	AECOM			DATE (Started)	11 August 2015	TIME (Completed)	10:10:00 AM	CHECKED BY
				DATE (Completed)	11 August 2015			MAM

[illegible]

MEL-GEO 15059 - F2 BOREHOL LOGS.GPJ MEL-GEO.GDT 4/2/16

METRIC

RECORD OF BOREHOLE NO. 5



REFERENCE 15/05/15059-F2 DATUM Geodetic LOCATION N 5487226.1 E 391993.8 - Idington Twp., Station 16+140 ORIGINATED BY JL
 PROJECT GWP 163-98-00, Highway 11 BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers COMPILED BY SH
 CLIENT AECOM DATE (Started) 12 August 2015 TIME
 DATE (Completed) 12 August 2015 (Completed) 9:30:00 AM CHECKED BY MAM

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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	STRATA PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
							20	40	60	80	100	20	40	60	
223.8	Ground Surface														
223.0	Brown silty organics		1	SS	3										
	Mixed FILL- mixture of brown silty sand and grey organic clayey silt, trace gravel														
	organic clayey silt, trace grass rootlets, dark grey		2	SS	11										
	(stiff)														
221.7			3	SS	3										
2.1	silty CLAY - trace sand trace thin seams of silt														
	grey		4	SS	4										
	(very stiff)														
			5	SS	11										
			6	SS	1										
219.4															
4.4	silty CLAY TILL - trace gravel, some to with sand		7	SS	20										
	grey														
	(very stiff)														
			8	SS	22										
			9	SS	11										
			10	SS	5										
213.7															
10.1	End of Sampling End of Borehole														

COMMENTS		WATER LEVEL RECORDS		
		Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
		1) 12/8/15 9:30:00 AM	6.4	6.9
		2)	-	-
		3)	-	-

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

MEL-GEO 15059 - F2 BOREHOLE LOGS.GPJ MEL-GEO.GDT 4/2/16

METRIC

RECORD OF BOREHOLE NO. 6



REFERENCE 15/05/15059-F2 DATUM Geodetic LOCATION N 5487204.5 E 391968.6 - Idington Twp., Station 16+124 ORIGINATED BY JL
 PROJECT GWP 163-98-00, Highway 11 BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers COMPILED BY SH
 CLIENT AECOM DATE (Started) 12 August 2015 TIME (Completed) 11:55:00 AM CHECKED BY MAM
 DATE (Completed) 12 August 2015

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100 WATER CONTENT (%) 20 40 60	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	STRATA PLOT	NUMBER	TYPE	"N" VALUES								
224.7	Ground Surface												
224.0	Brown silty soils, some organics Mixed FILL- mixture of brown silty sand and grey silty clay, some gravel, trace grass rootlets		1	SS	7								
	moist		2	SS	8								
223.3	(loose)												
1.4	silty CLAY - trace gravel, trace sand		3	SS	8								
	grey												
	(very stiff)		4	SS	5								
			5	SS	10								
			6	SS	11								
220.1													
4.6	silty SAND TILL - some gravel, trace clay		7	SS	11								
	grey												
219.1	(compact)												
5.6	silty CLAY TILL - trace gravel, some sand		8	SS	21								
	grey												
	(very stiff)												
			9	SS	16								
	clayey SILT at depth from 7.6 m to 8.1 m												
			10	SS	8								
214.6													
10.1	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) 12/8/15 11:55:00 AM	7.5	8.2
2)	-	-
3)	-	-

MEL-GEO 15059 - F2 BOREHOLE LOGS.GPJ MEL-GEO.GDT 4/2/16

Appendix 3 Borehole Plan and Laboratory Data

Drawing No. 2A and 2B: Borehole Location and Soil Strata

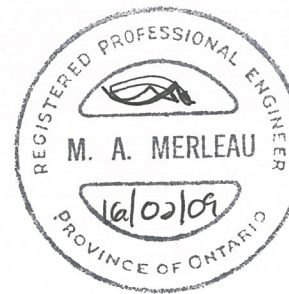
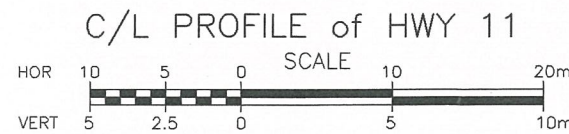
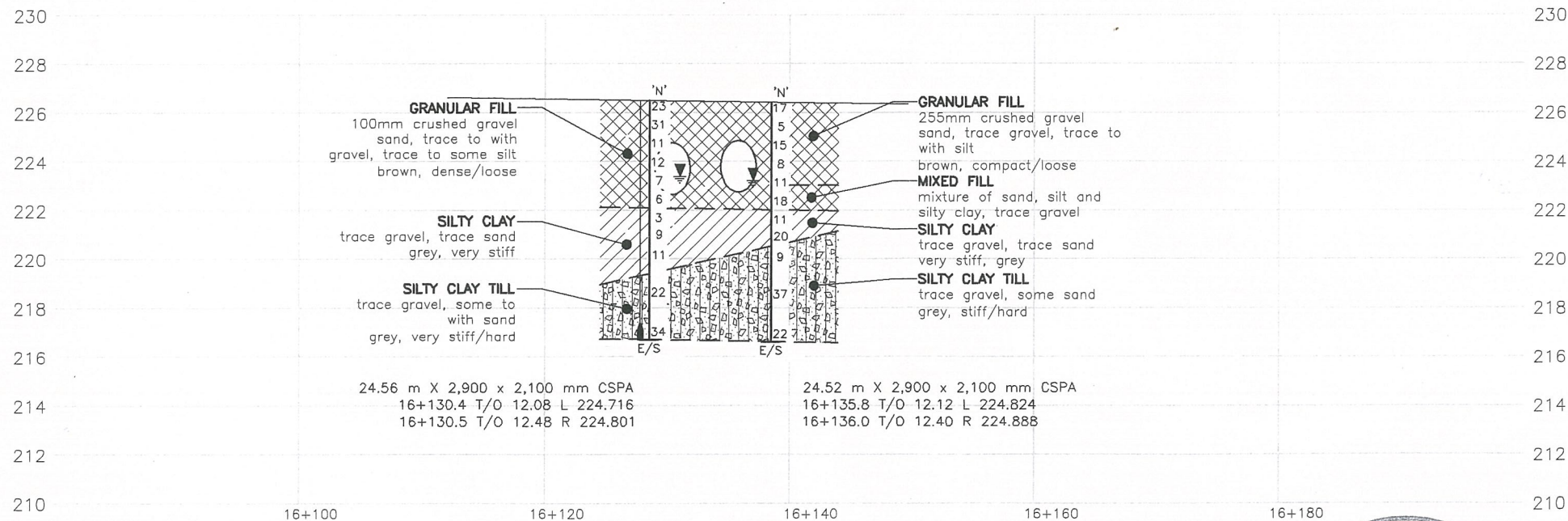
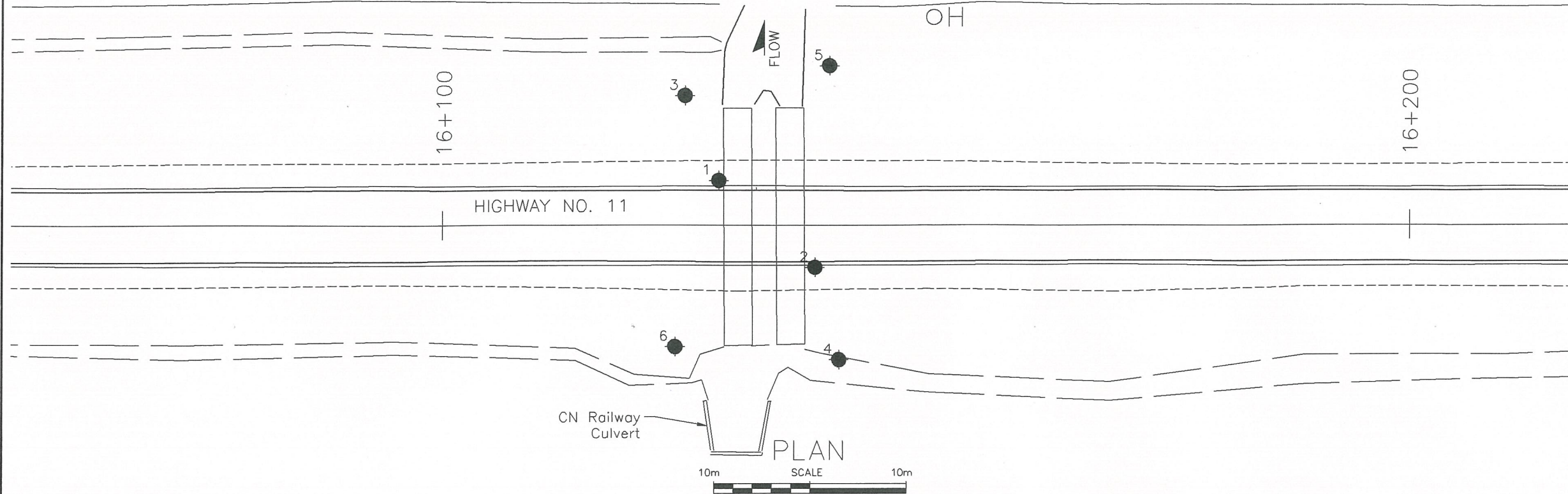
Figure Nos. L-1 to L-6: Grain Size Distribution Curves

Figure No. L-7: Atterberg Limits

Table No. L-8: Laboratory Test Summary Sheet

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DATE PLOTTED: 2/3/2016 11:06:10 AM BY: DUNCAN MITCHELL

PR-9-707 BB-05
MINISTRY OF TRANSPORTATION, ONTARIO

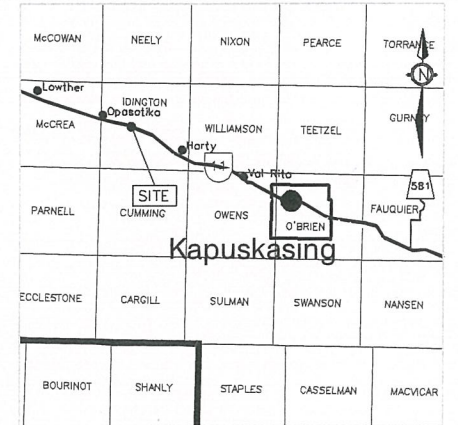


DISTRICT
CONT. No.
GWP No. 163-98-00

HWY 11 CULVERTS
STA. 16+130.5 TO STA. 16+135.9
SITE NO. 39W-109

BOREHOLE LOCATIONS
AND SOIL STRATIGRAPHY

DRAWING
2A



KEY PLAN
N.T.S.

LEGEND

- Borehole w/ DCPT
- Borehole
- Blows/0.3 m (Std Pen Test, 475 J/blow)
- Blows/0.3 m (60' Cone, 475 J/blow)
- Water Level at Time of Investigation
- Auger Refusal at Elevation
- End of Sampling
- Piezometer

BOREHOLE No.	ELEVATION	O/S	NORTHING	EASTING
1	226.3	4.6m Lt	5487219.0	391978.8
2	226.3	4.4m Rt	5487207.1	391985.0
3	223.9	13.4m Lt	5487228.5	391978.6
4	224.0	14m Rt	5487197.2	391984.0
5	223.8	16.5m Lt	5487226.1	391993.8
6	224.7	12.6m Rt	5487204.5	391968.6

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 August 4, 2015

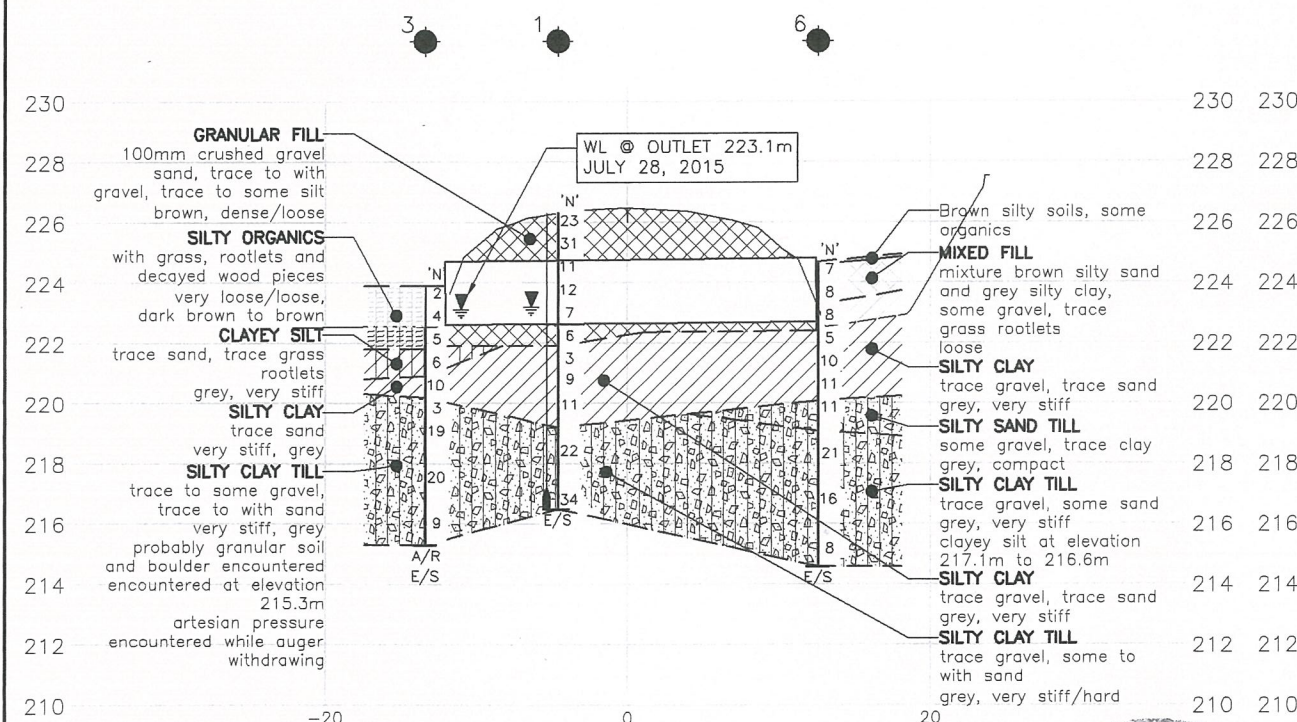
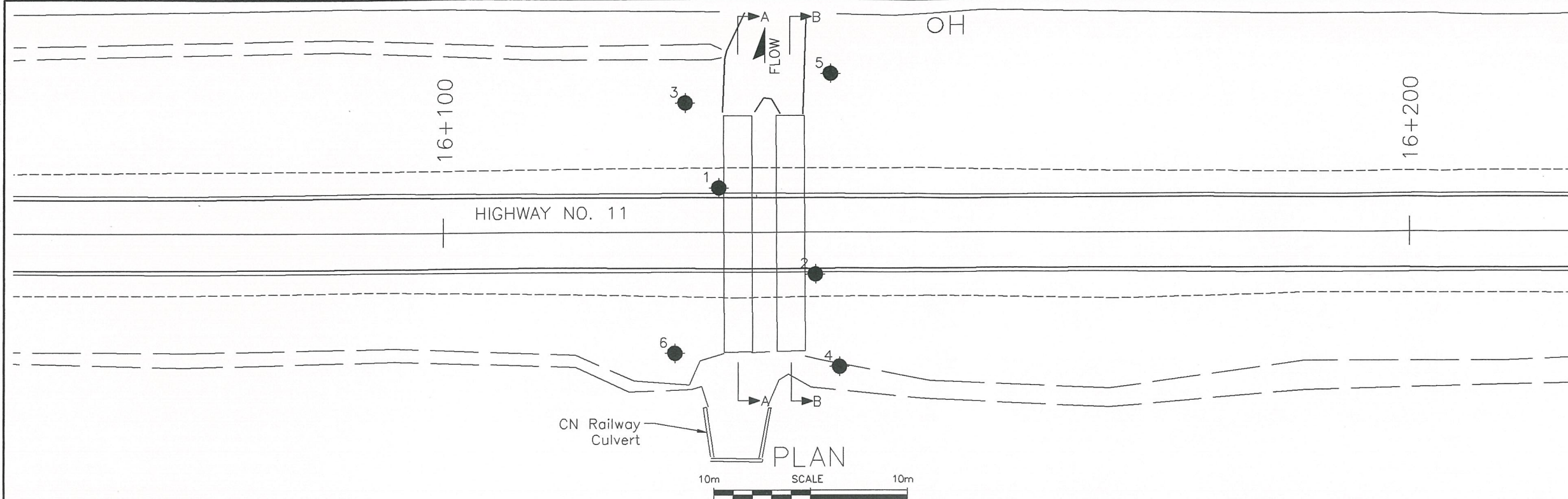
Coordinates based on MTM Zone 13 NAD83 CSRS

GEOCREs No. 42G-58

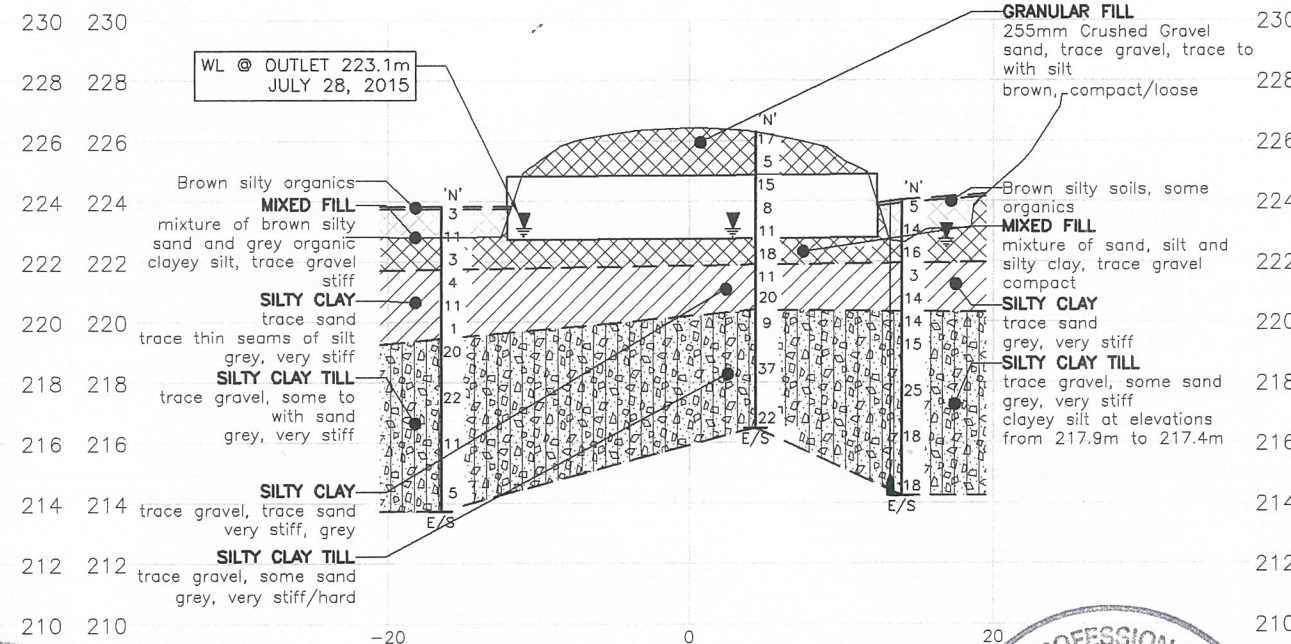
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	FEB/16		DM	FINAL				
DESCRIPTION								
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DRAWN	DM	CHK	SH	SITE 39W-109		STRUCT	SCHEME	DWG 2A

CAD FILE LOCATION AND NAME: C:\2015\15059 - HWY 11 - 163-98-00 & 5145-05-00 (ACCOM)\FOUNDATIONS\Drawings\F2\15059 - F2 - Twin Creek Culvert - Drawing.dwg
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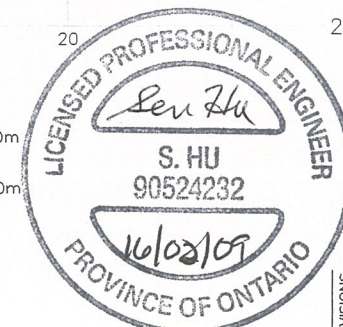
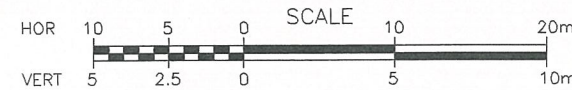
MINISTRY OF TRANSPORTATION, ONTARIO
PR-1-707 08-05



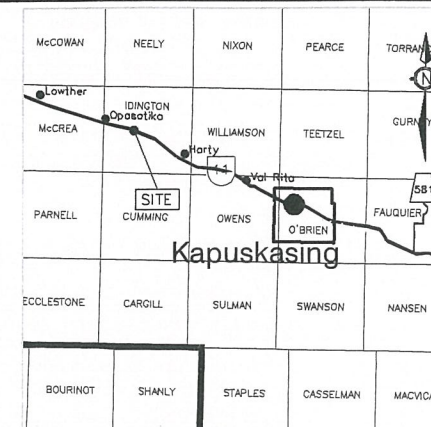
Section A-A of HWY 11



Section B-B of HWY 11



DISTRICT CONT. No. GWP No. 163-98-00	DRAWING 2B
HWY 11 CULVERTS STA. 16+130.5 TO STA. 16+135.9 SITE NO. 39W-109	
BOREHOLE LOCATIONS AND SOIL STRATIGRAPHY	



KEY PLAN
N.T.S.

LEGEND

	Borehole w/ DCPT
	Borehole
	Blows/0.3 m (Std Pen Test, 475 J/blow)
	Blows/0.3 m (60° Cone, 475 J/blow)
	Water Level at Time of Investigation
	Auger Refusal at Elevation
	End of Sampling
	Piezometer

BOREHOLE No.	ELEVATION	O/S	NORTHING	EASTING
1	226.3	4.6m Lt	5487219.0	391978.8
2	226.3	4.4m Rt	5487207.1	391985.0
3	223.9	13.4m Lt	5487228.5	391978.6
4	224.0	14m Rt	5487197.2	391984.0
5	223.8	16.5m Lt	5487226.1	391993.8
6	224.7	12.6m Rt	5487204.5	391968.6

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.

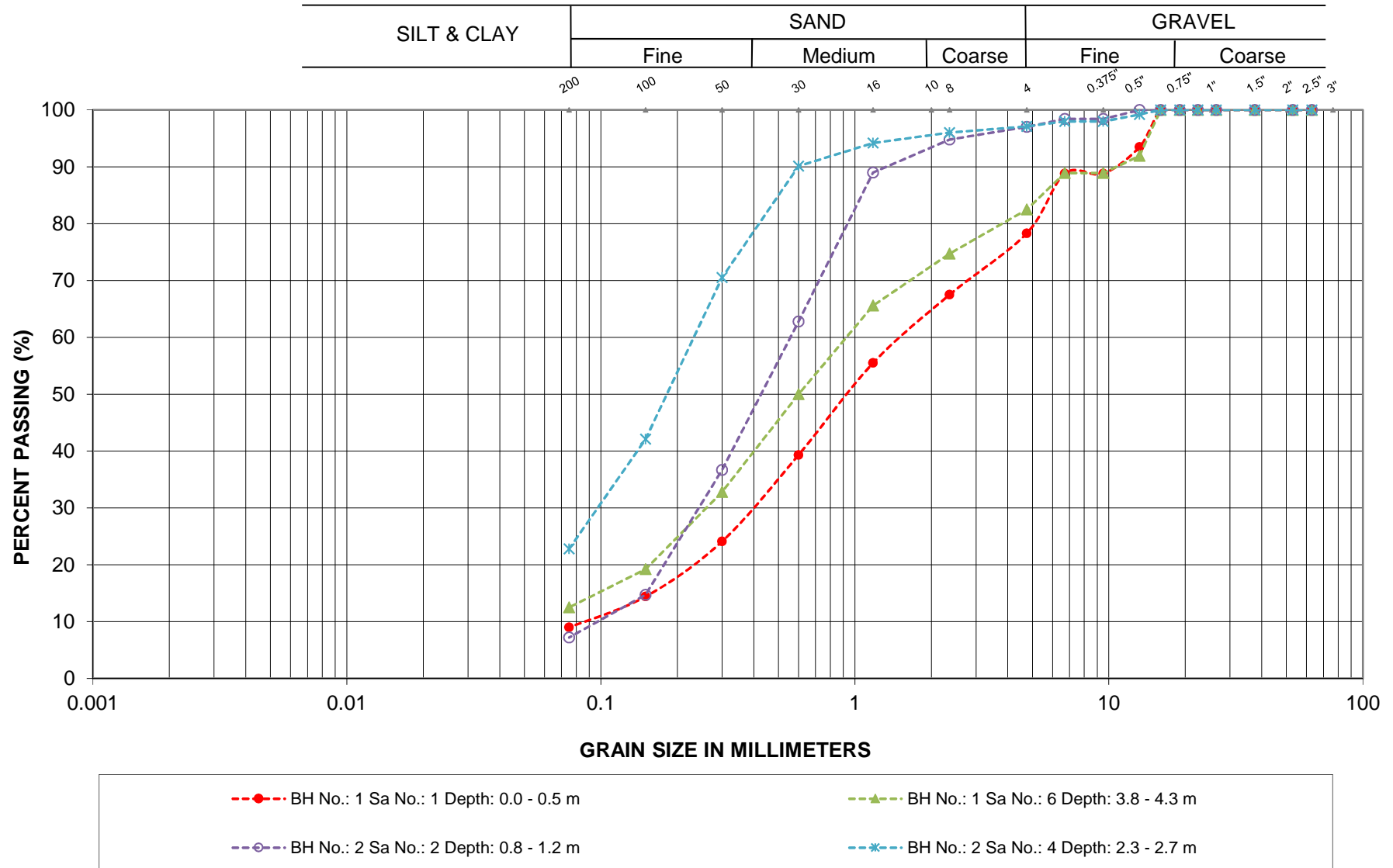
Base plan and alignment provided in digital format by Callon Dietz on August 4, 2015

Coordinates based on MTM Zone 13 NAD83 CSRS

GEOCRES No. 42G-58

REVISIONS	NOV/15	DM	DRAFT					
	FEB/16	DM	FINAL					
				DESCRIPTION				
DESIGN		CHK		CODE	LOAD		DATE FEB/16	
DRAWN	DM	CHK	SH	SITE 39W-109	STRUCT	SCHEME	DWG 2B	

GRAIN SIZE ANALYSIS



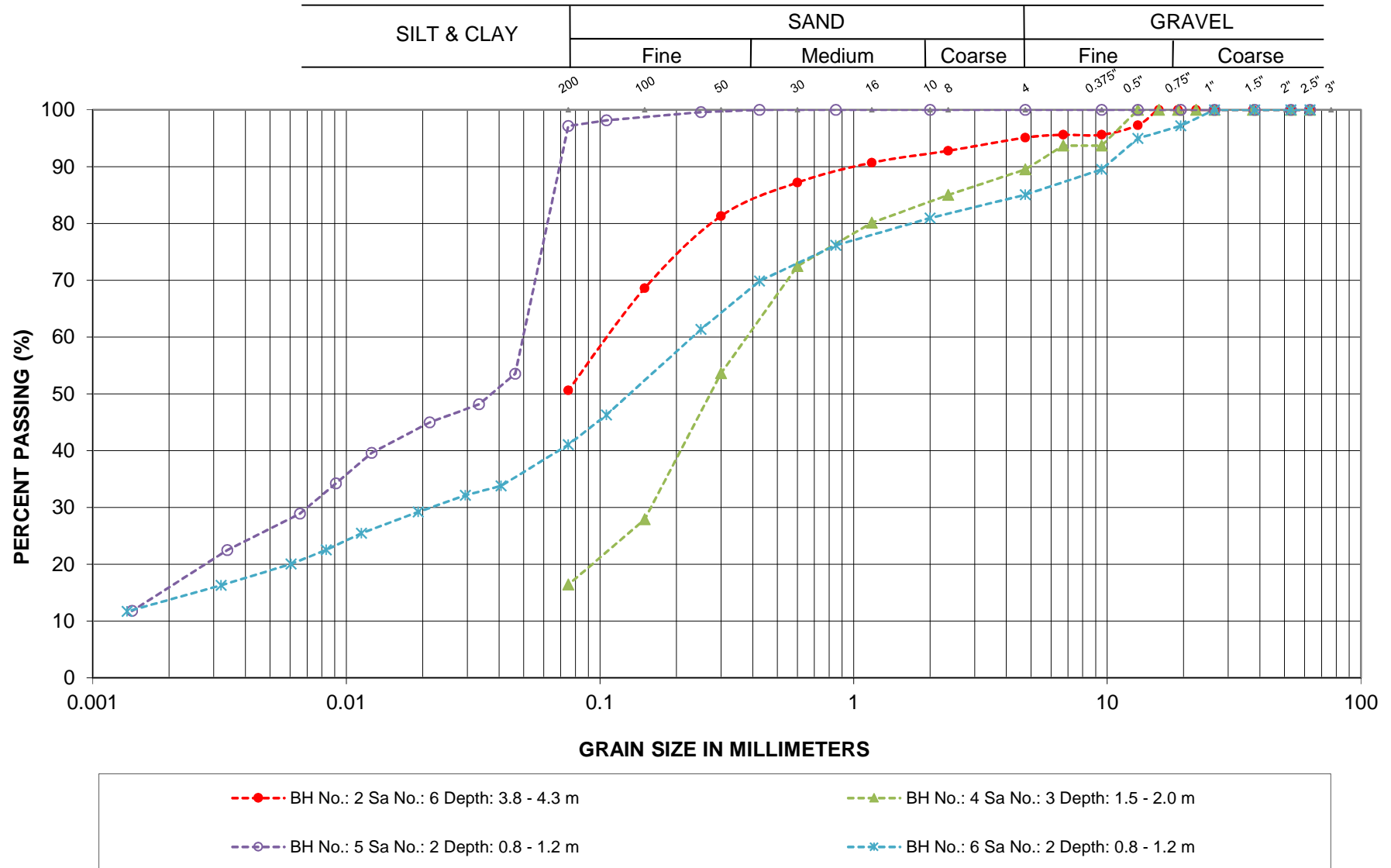
GRANULAR FILL

LOCATION: Hwy 11, Stations 16+130.5 to 16+135.9
TWP of Idington

Englobe Corp.

FIGURE L-1

GRAIN SIZE ANALYSIS

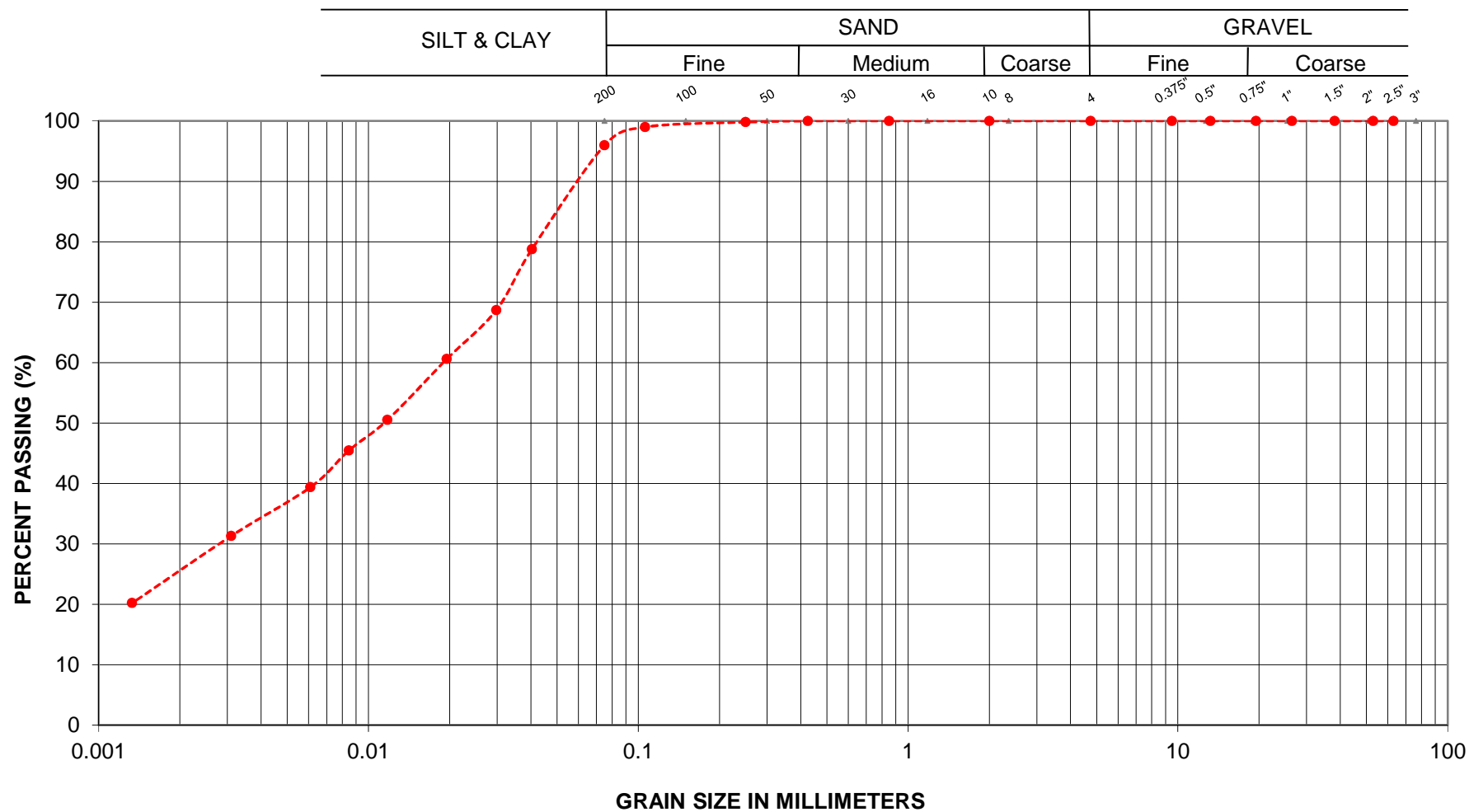


MIXED FILL

LOCATION: Hwy 11, Stations 16+130.5 to 16+135.9
TWP of Idington

Englobe Corp.

FIGURE L-2

GRAIN SIZE ANALYSIS

---●--- BH No.: 3 Sa No.: 4 Depth: 2.3 - 2.7 m

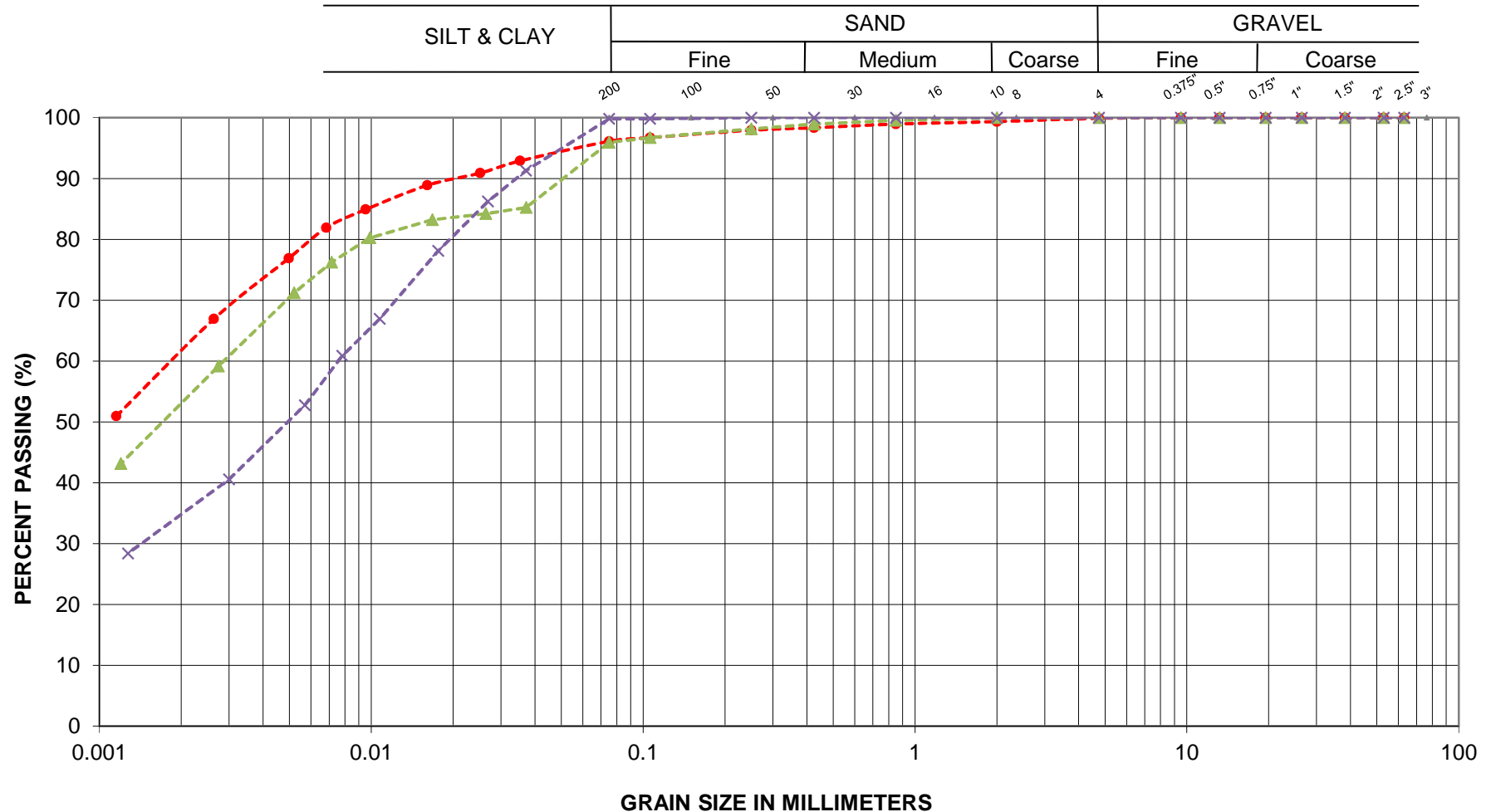
CLAYEY SILT

LOCATION: Hwy 11, Stations 16+130.5 to 16+135.9
TWP of Idington

Englobe Corp.

FIGURE L-3

GRAIN SIZE ANALYSIS



—●— BH No.: 1 Sa No.: 8 Depth: 5.3 - 5.8 m

—▲— BH No.: 4 Sa No.: 5 Depth: 3.0 - 3.5 m

—×— BH No.: 5 Sa No.: 4 Depth: 2.3 - 2.7 m

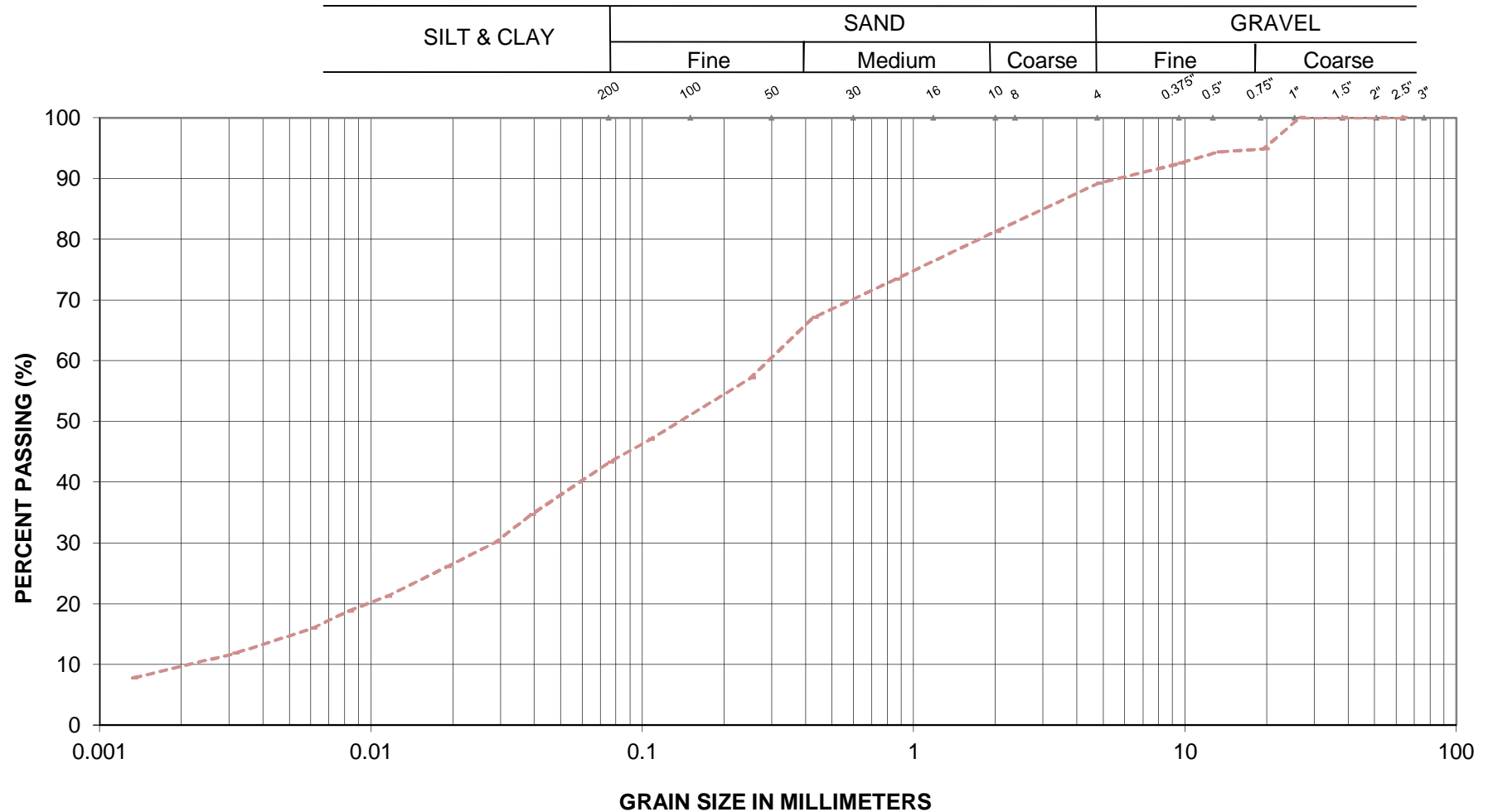
SILTY CLAY to CLAY

LOCATION: Hwy 11, Stations 16+130.5 to 16+135.9
TWP of Idington

Englobe Corp.

FIGURE L-4

GRAIN SIZE ANALYSIS



--- BH No.: 6 Sa No.: 7 Depth: 4.6 - 5.1 m

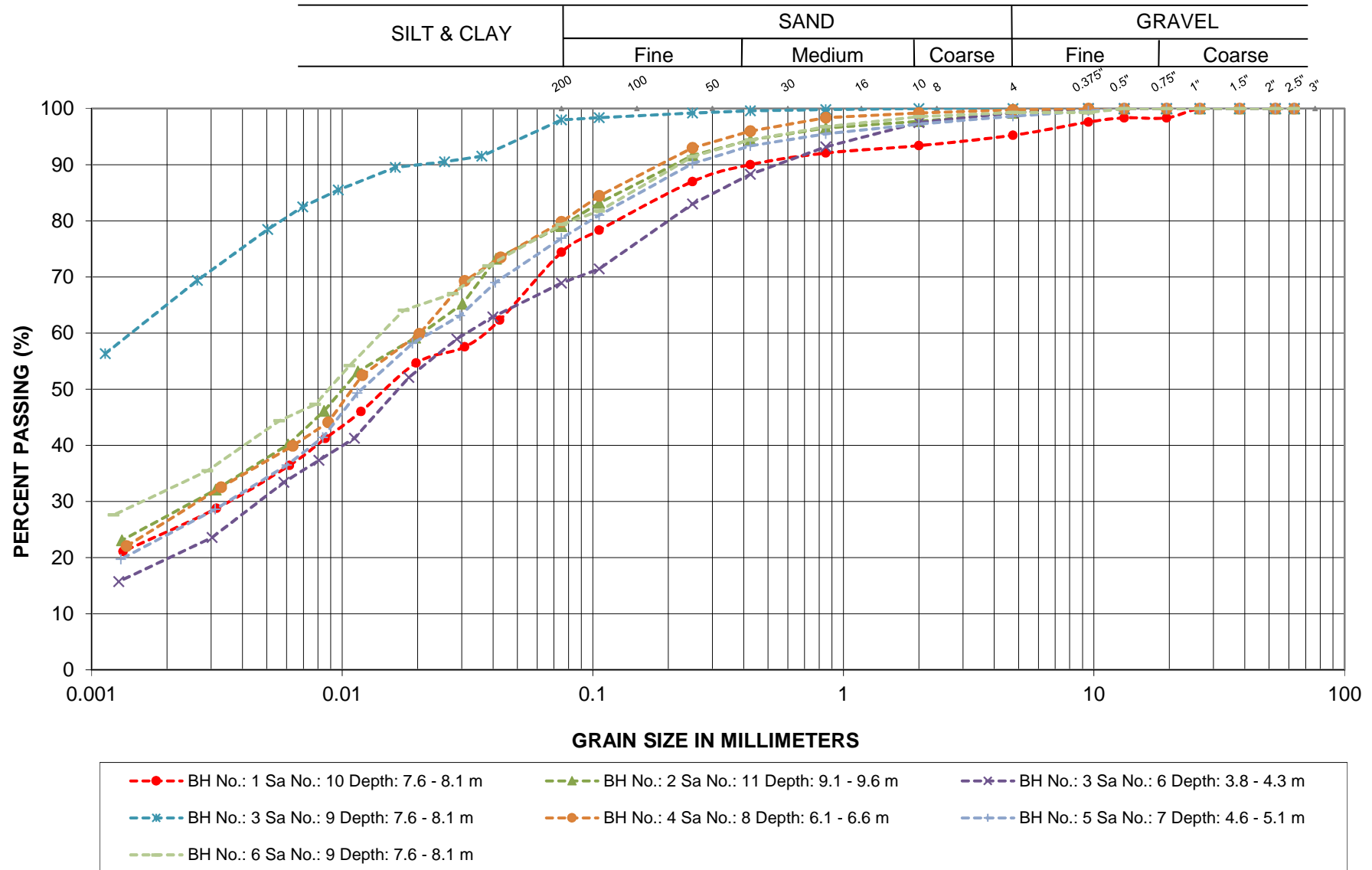
SILTY SAND TILL

LOCATION: Hwy 11, Stations 16+130.5 to 16+135.9
TWP of Idington

Englobe Corp.

FIGURE L-5

GRAIN SIZE ANALYSIS



SILTY CLAY to CLAYEY SILT TILL

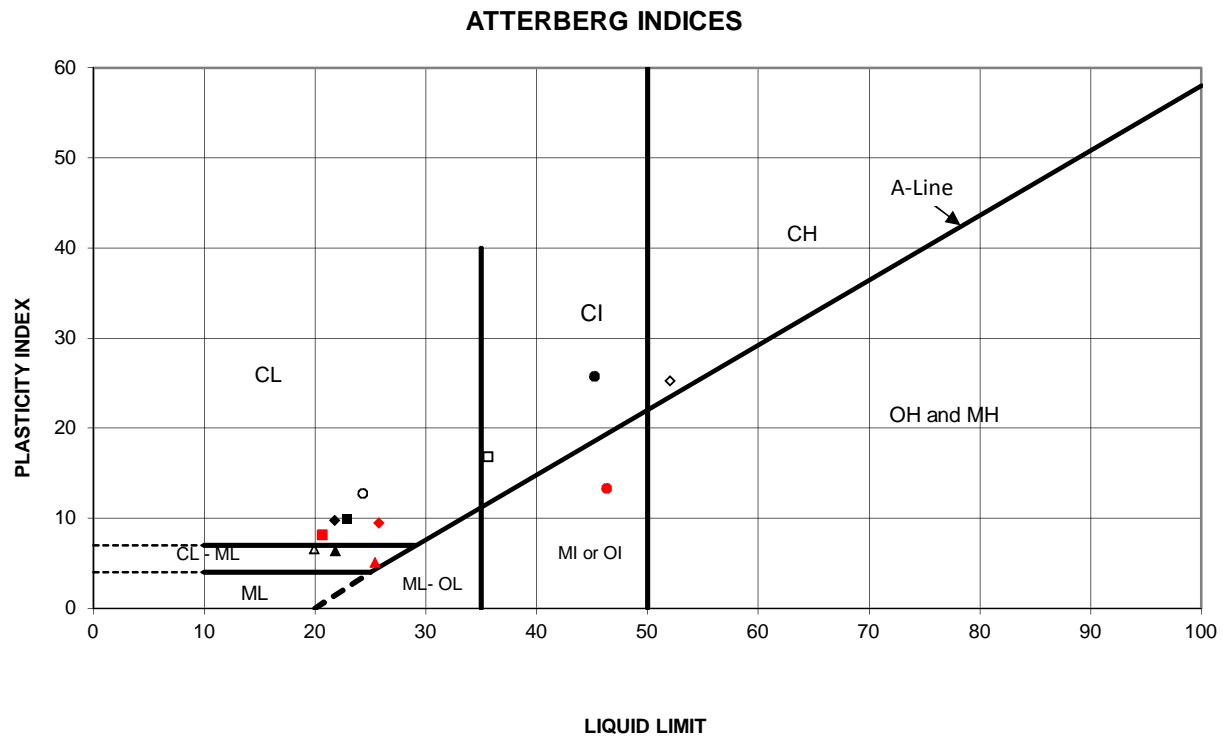
LOCATION: Hwy 11, Stations 16+130.5 to 16+135.9
TWP of Idington

Englobe Corp.

FIGURE L-6

ATTERBERG LIMITS TEST RESULTS

FIGURE L-7



SYMBOL	BH	Sa. No.	Depth(m)	Elev.(m)	Liquid Limit	Plastic Limit	Plasticity Index	NMC %
●	1	8	5.6	220.7	45.3	19.6	25.7	26.9
◆	1	10	7.9	218.4	21.8	12.0	9.7	10.7
■	2	11	9.5	216.8	22.9	13.1	9.8	12.9
▲	3	4	2.5	221.4	21.8	15.5	6.3	21.3
○	3	6	4.0	219.9	24.4	11.7	12.7	13.3
◇	3	9	7.9	216.0	52.0	26.7	25.3	34.9
□	4	5	3.3	220.7	35.7	18.9	16.8	26.5
△	4	8	6.3	217.7	19.9	13.3	6.6	11.3
●	5	2	1.0	222.8	46.4	33.1	13.3	39.1
◆	5	4	2.5	221.3	25.8	16.3	9.5	24.5
■	5	7	4.8	219.0	20.7	12.6	8.1	11.1
▲	6	9	7.9	216.8	25.4	20.3	5.1	15.0

Date: Sep-15
 Project: Hwy 11, Twin Culverts
 Location: Sta. 16+130.5 and 16+135.9, TWP. of Idington
 Englobe Corp.

Prep'd: AT
 Chkd: MAM
 Ref. No.: 15/05/15059-F2

Laboratory Tests - Summary Sheet



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	0.0	22	69	9		4.3				23			
	2	0.8					2.9				31			
	3	1.5					4.0				11			
	4	2.3					9.2				12			
	5	3.1									7			
	6	3.8	17	70	13		18.2				6			
	7	4.6					21.2				3			
	8	5.3	0	4	34	62	26.9	45.3	19.6	25.7	9			
	9	6.1					34.2				11			
	10	7.6	5	21	49	25	10.7	21.8	12.0	9.7	22			
	11	9.2					14.9				34			
2	1	0.0					4.3				17			
	2	0.8	3	90	7		6.1				5			
	3	1.5					4.7				15			
	4	2.3	3	74	23		15.1				8			
	5	3.1					18.9				11			
	6	3.8	5	44	51		17.7				18			
	7	4.6					26.3				11			
	8	5.3					16.0				20			
	9	6.1					12.8				9			
	10	7.6					13.6				37			
	11	9.2	1	20	52	27	12.9	22.9	13.1	9.8	22			

Laboratory Tests - Summary Sheet



Borehole No.	Sample No.	Depth	Grain Size Analysis				NMC	Atterberg Limits			SPT 'N'	USCS	Unit Weight (kN/m ³)	Remarks
			Gravel Size (%)	Sand Size (%)	Silt Size (%)	Clay Size (%)		LL (%)	PL (%)	IP (%)				
3	1	0.0					57.6				2			
	2	0.8					54.0				4			
	3	1.5					42.6				5			
	4	2.3	0	4	70	26	21.3	21.8	15.5	6.3	6			
	5	3.1					26.6				10			
	6	3.8	1	30	49	20	13.3	24.4	11.7	12.7	3			
	7	4.6					10.7				19			
	8	6.1					11.1				20			
	9	7.6	0	2	32	66	34.9	52.0	26.7	25.3	9			
4	1	0.5					52.2				5			
	2	0.5					26.3				14			
	3	0.5	10	74	16		20.8				16			
	4	0.5					27.6				3			
	5	0.5	0	4	43	53	26.5	35.7	18.9	16.8	14			
	6	0.5					13.4				14			
	7	0.5					12.3				15			
	8	0.5	0	20	53	27	11.3	19.9	13.3	6.6	25			
	9	0.5					13.4				18			
	10	0.6					14.0				18			

Laboratory Tests - Summary Sheet



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 (%)				
5	1	0.0					49.7				3			
	2	0.8	0	3	81	16	39.1	46.4	33.1	13.3	11			
	3	1.5					37.3				3			
	4	2.3	0	0	65	35	24.5	25.8	16.3	9.5	4			
	5	3.1					28.6				11			
	6	3.8					17.2				1			
	7	4.6	1	22	53	24	11.1	20.7	12.6	8.1	20			
	8	6.1					13.1				22			
	9	7.6					15.6				11			
	10	9.1					47.0				5			
6	1	0.0					9.2				7			
	2	0.8	15	44	27	14	15.8				8			Non-Plastic (NP)
	3	1.5					35.1				8			
	4	2.3					24.3				5			
	5	3.1					23.0				10			
	6	3.8					29.9				11			
	7	4.6	11	46	34	9	11.6				11			Non-Plastic (NP)
	8	6.1					12.0				21			
	9	7.6	1	20	46	33	15.0	25.4	20.3	5.1	16			
	10	9.1					16.9				8			

Appendix 4 Photo Essay

Enclosure No. 8:

Photo Essay

Embankment at Culvert Location – Looking South, Note: ONR embankment and culvert

Photo: 1



Culvert Inlet – Looking South, Note: ONR embankment and culvert

Photo: 2



Project: Hwy 11 – Culvert, Stations 16+130.5 to 16+135.9, Township of Idington

Photos Provided by:Englobe

Date: August 2015

Culvert Outlet – Looking North

Photo: 3



View of Culvert Inlet – Looking North-West

Photo: 4



Project: Hwy 11 – Culvert, Stations 16+130.5 to 16+135.9, Township of Idington

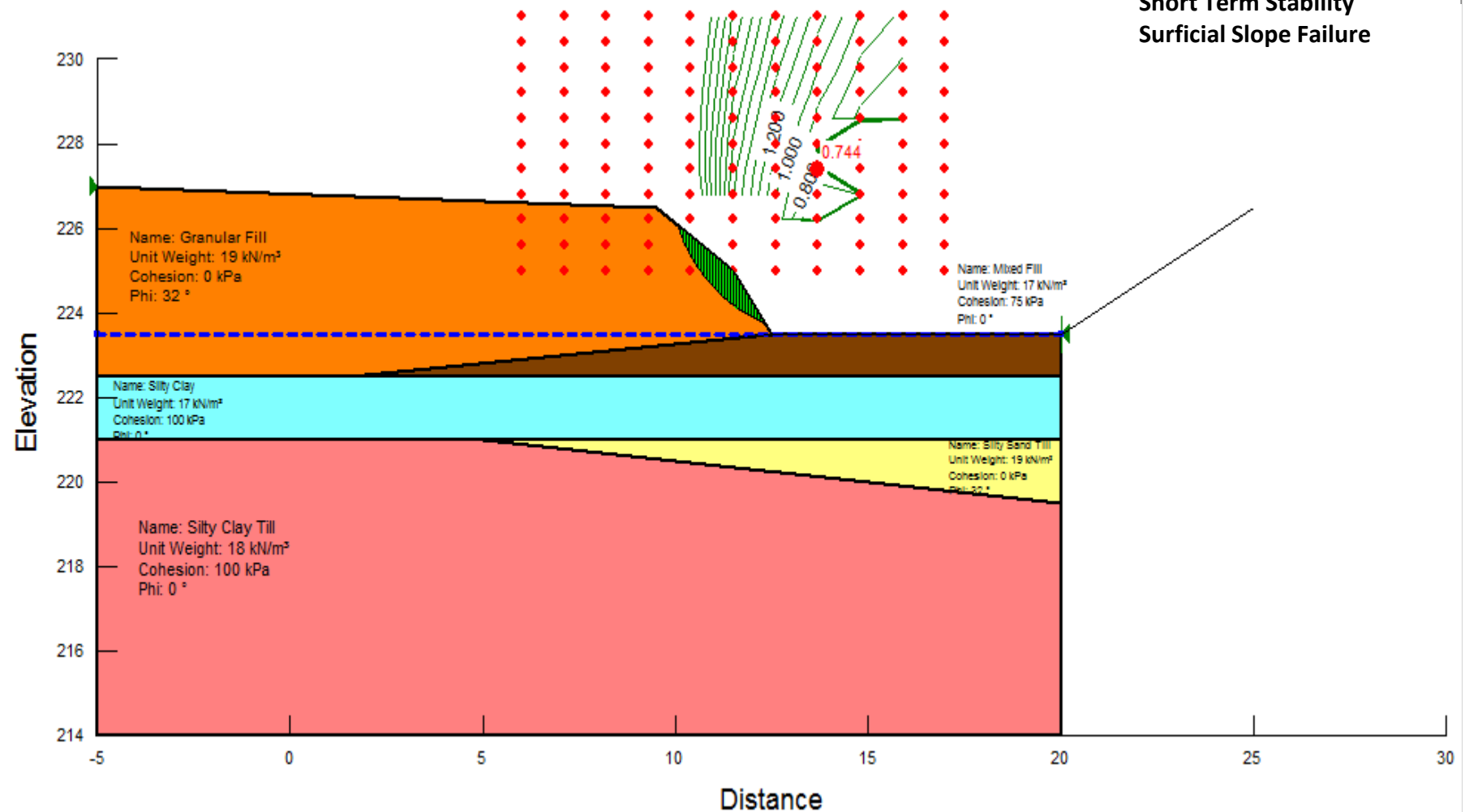
Photos Provided by:Englobe

Date: August 2015

Appendix 5 Design Data

Figure Nos. S-1 to S-4:	Slope Stability Analyses
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

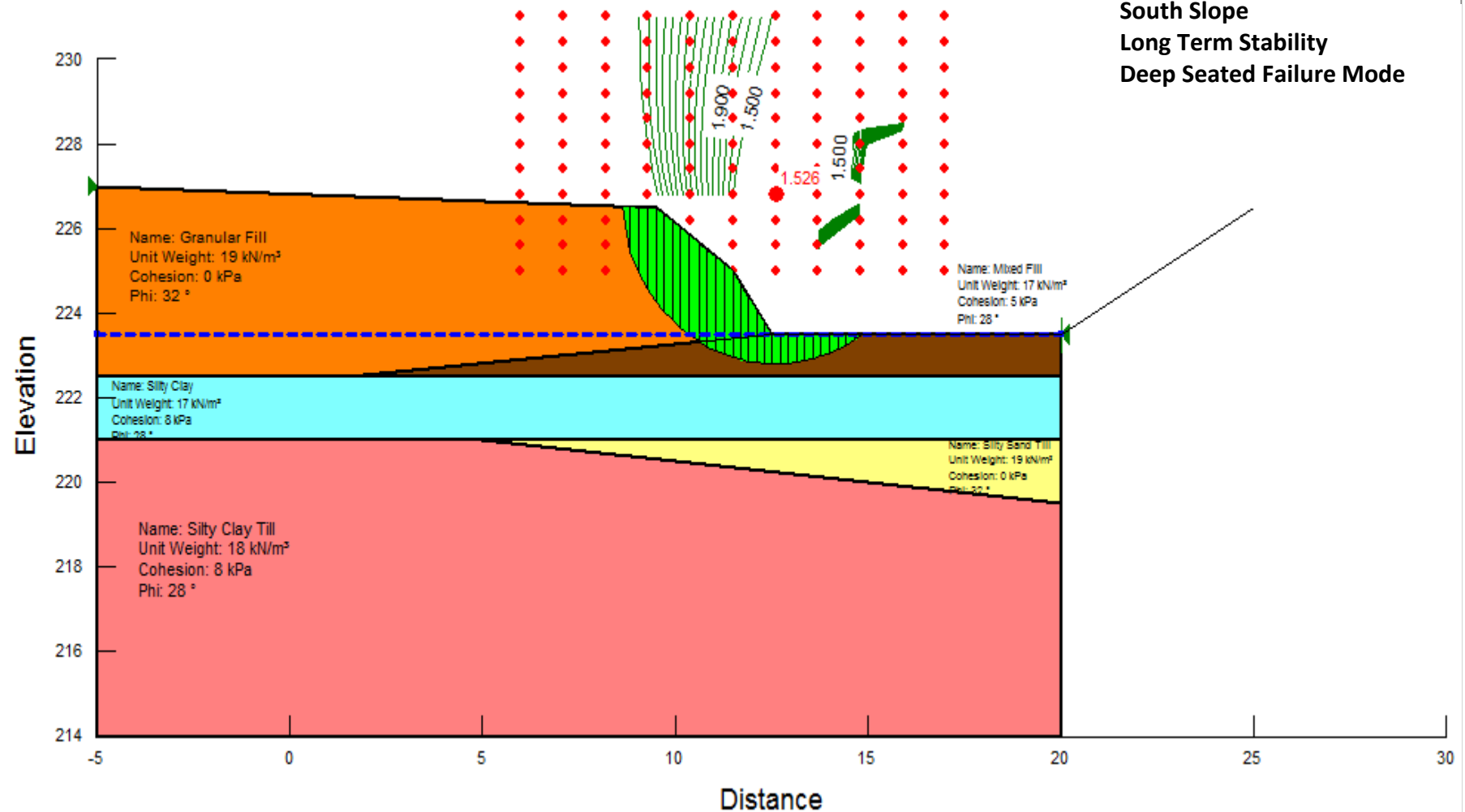
**Stability Analysis
Existing Embankment
South Slope
Short Term Stability
Surficial Slope Failure**



South Slope

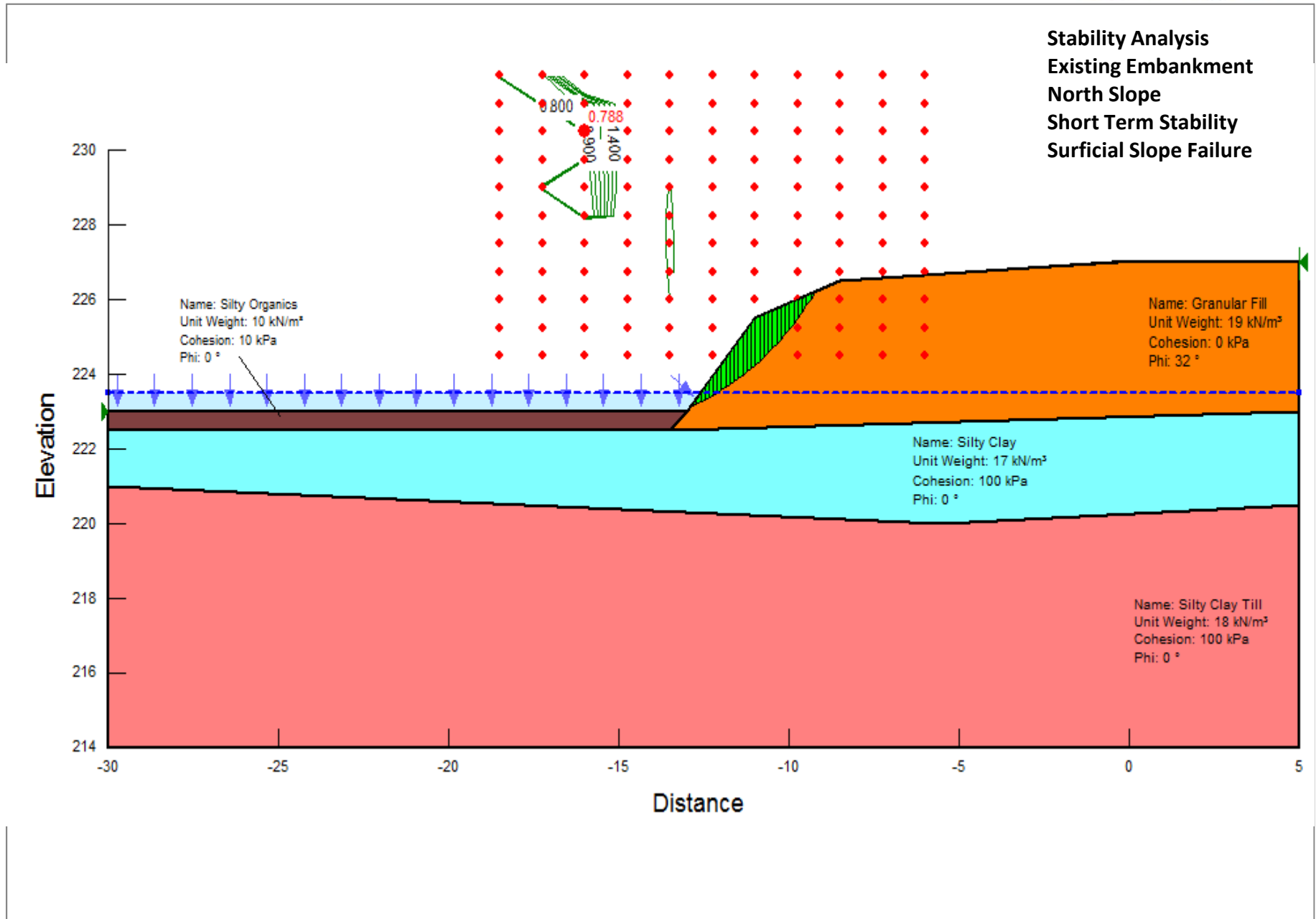
Culvert Station 16+130.5 and 16+135.9

**Stability Analysis
Existing Embankment
South Slope
Long Term Stability
Deep Seated Failure Mode**



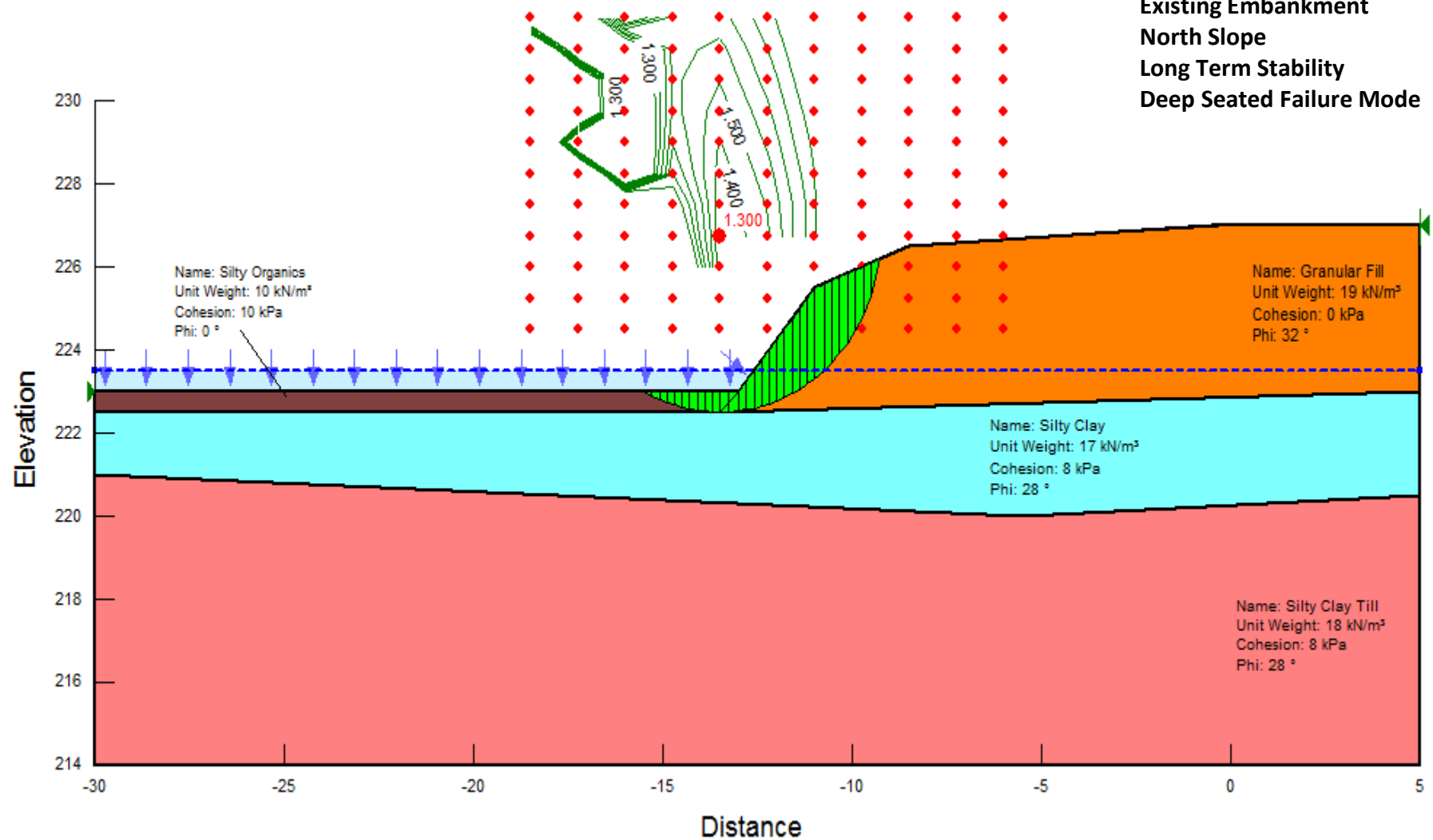
South Slope

Culvert Station 16+130.5 and 16+135.9



North Slope
Culvert Station 16+130.5 and 16+135.9

**Stability Analysis
Existing Embankment
North Slope
Long Term Stability
Deep Seated Failure Mode**

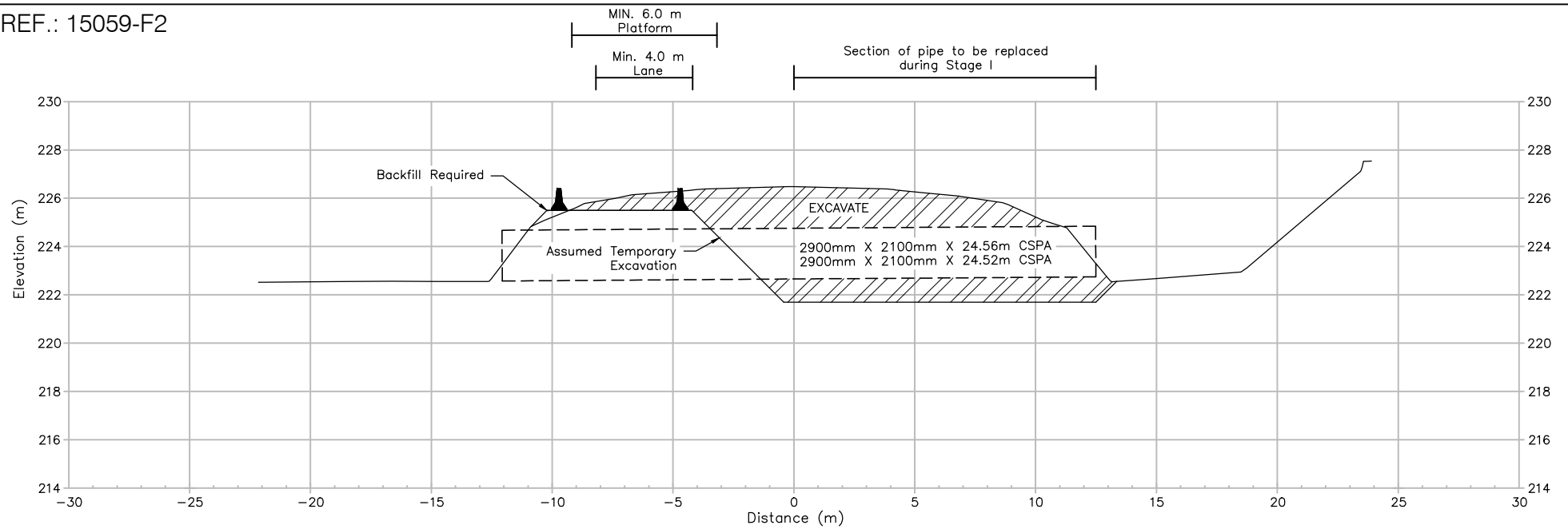


North Slope

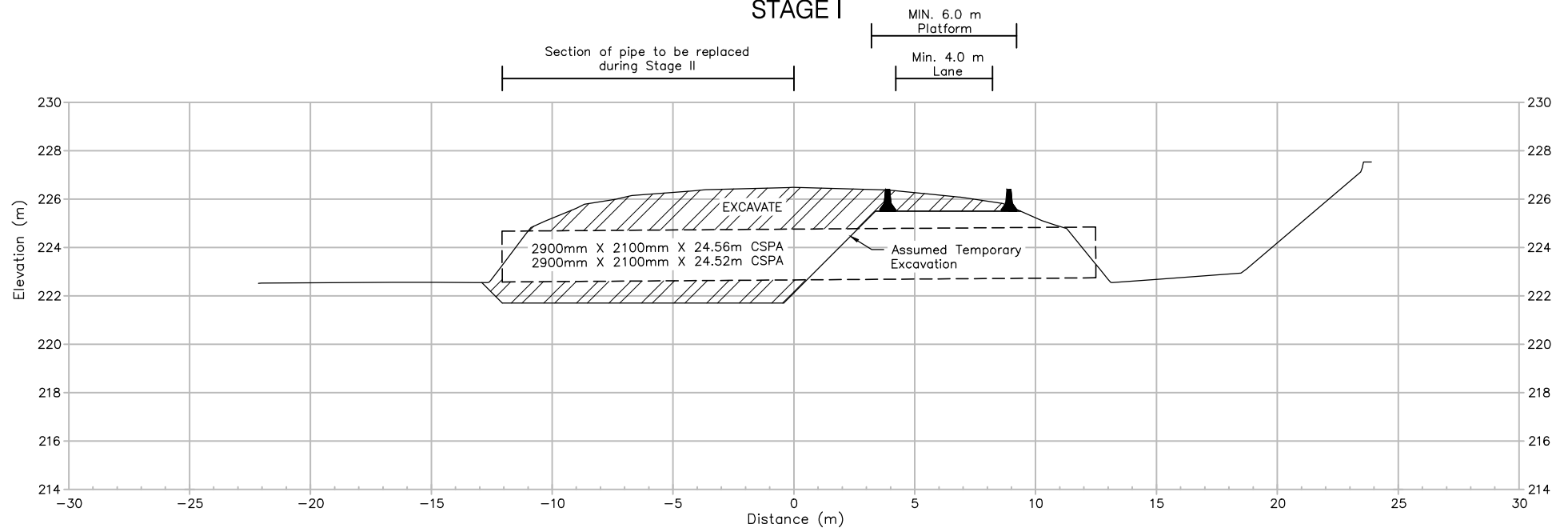
Culvert Station 16+130.5 to 16+135.9

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	Considered as alternative protection system.	\$ 650/m ²
Steel Sheet Piles	5 – 21	-High strength, continuous, -Readily available	-Limited by soil conditions (i.e. obstructions)	Recommended for protection system, provided with sufficiently robust strength and embedment depth into the silty clay till deposit	\$ 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	Not considered due to higher cost	\$ 725/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	Not Considered due to higher costs	
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	Not Considered due to higher costs	\$ 900/m ²



STAGE I



STAGE II

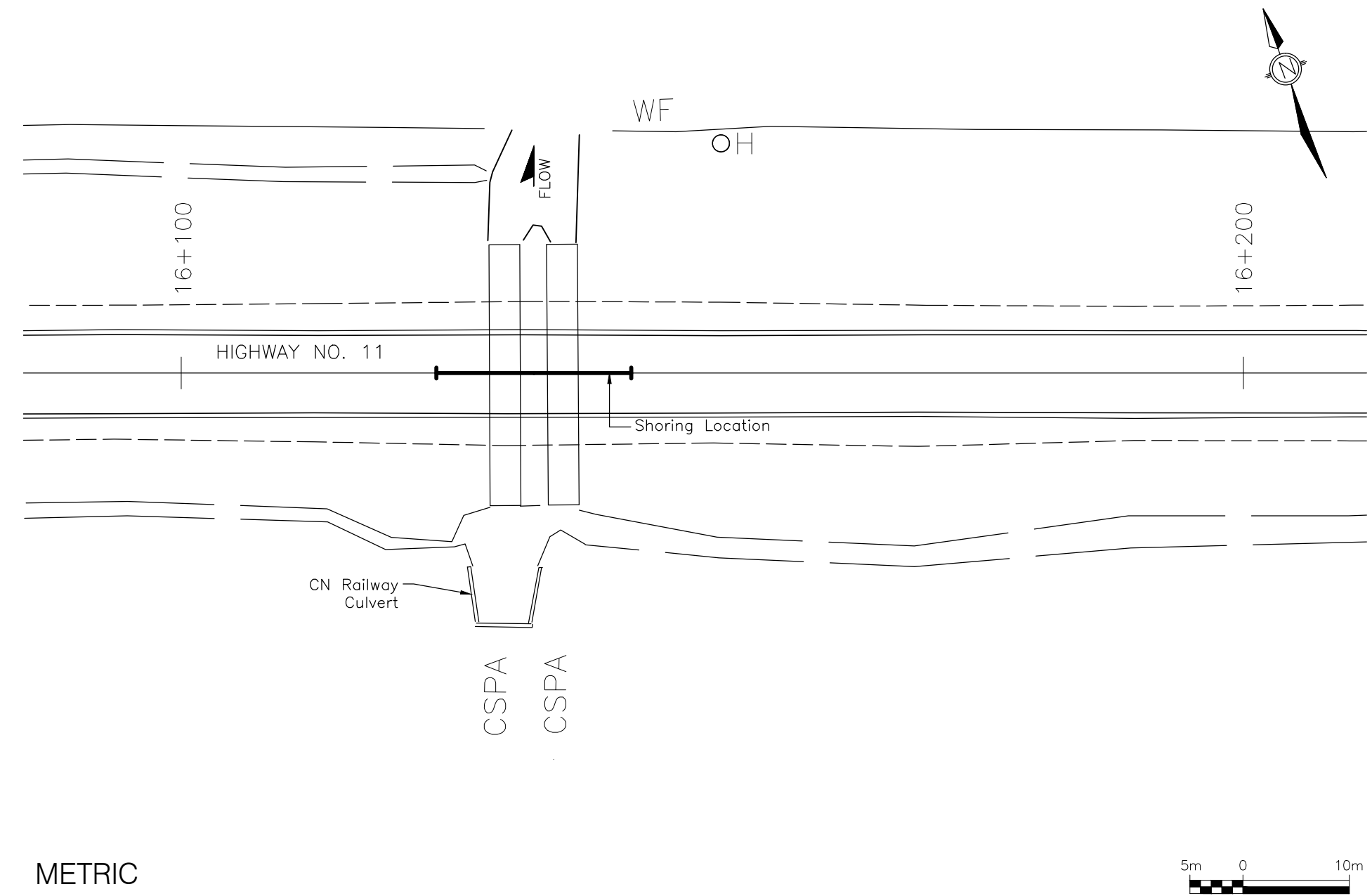
METRIC

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

Highway 11, Township of Idington - Culvert at Stations 16+130.5 to 16+135.9
Conceptual Staging Cross-Section



FIGURE SK-3

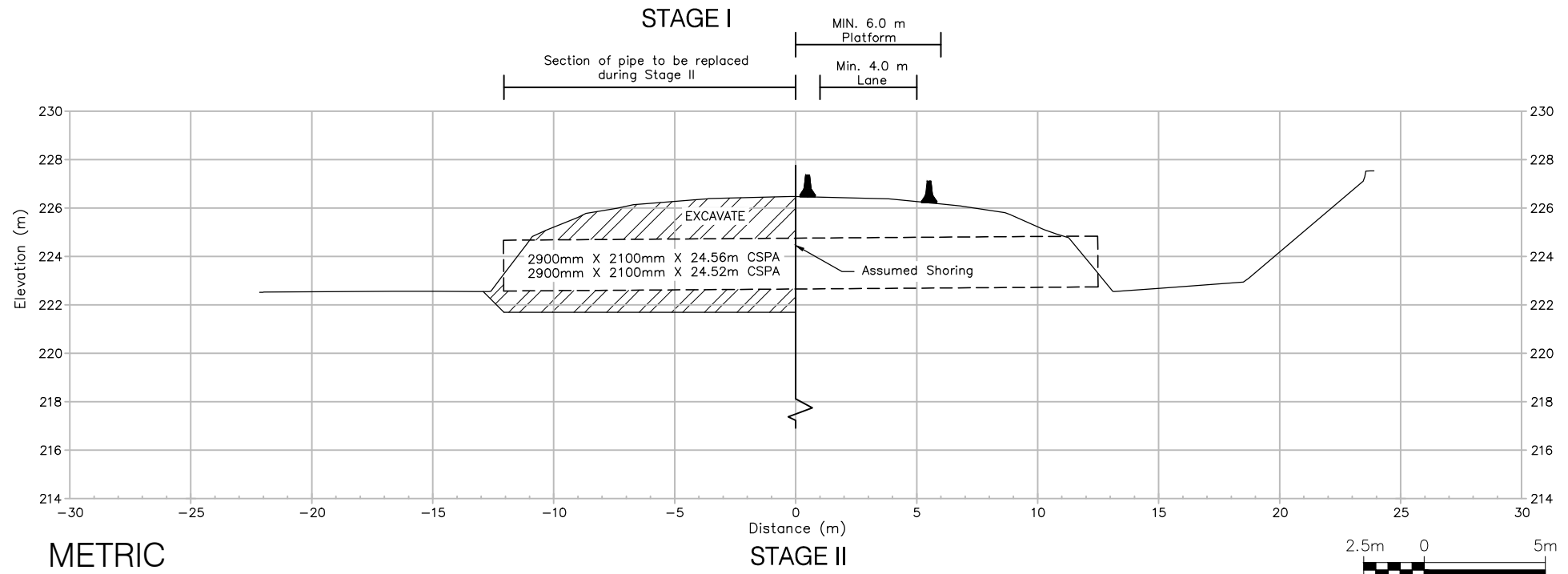
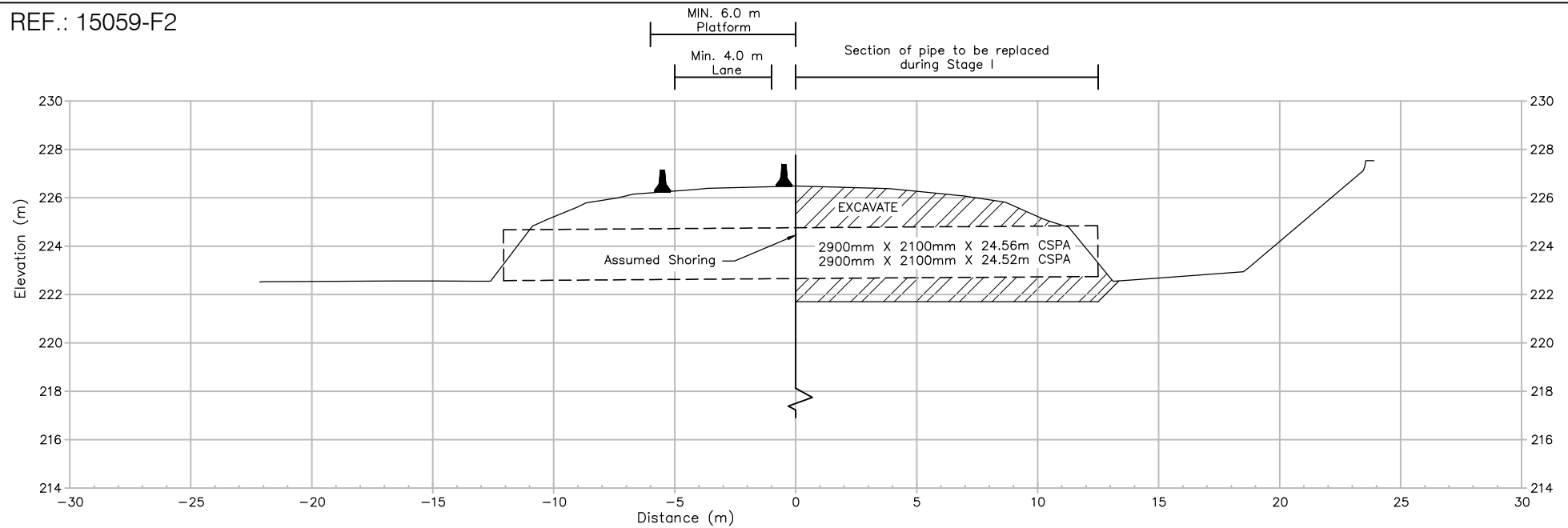


METRIC

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

Highway 11, Township of Idington - Culvert at Stations 16+130.5 to 16+135.9
Conceptual Shoring Location Plan

FIGURE SK-4



METRIC

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

Highway 11, Township of Idington - Culvert at Stations 16+130.5 to 16+135.9
Conceptual Shoring Cross-Section

FIGURE SK-5