

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

**Unnamed Creek Culvert Replacement
Site No. 47-413C
Stations 17+380 - Township of Boston
GWP 5105-12-00
Highway 112
4.7 km north of Blanche River**

FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

Date: March 31, 2015
Ref. N°: 13/05/13073-F11

Geocres No. 42A-101





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

**Unnamed Creek Culvert Replacement
Site No. 47-413C
Stations 17+380 - Township of Boston
GWP 5105-12-00
Highway 112
4.7 km north of Blanche River**

Final Foundation Investigation and Design Report

Prepared by:

Sen Hu, P. Eng.

LVM-Merlex – Senior Geotechnical Engineer

Reviewed by:

M.A. Merleau, P. Eng.

LVM-Merlex – Principal Engineer
MTO Designate

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 17+380, Township of Boston.....	3
4.1.1	<i>Pavement Structure</i>	3
4.1.2	<i>Granular Fill</i>	3
4.1.3	<i>Silty Clay</i>	4
4.2	Dynamic Cone Penetration Testing	4
4.3	Groundwater Data.....	4
5	DISCUSSION AND RECOMMENDATIONS.....	6
5.1	General	6
5.2	Foundation Considerations	6
5.2.1	<i>Slope Stability</i>	7
5.3	Culvert Design, Bedding, and Embedment.....	7
5.3.1	<i>Rigid Concrete Culvert</i>	7
5.4	Culvert Installation and Staged Construction Considerations	8
5.4.1	<i>Staged Construction</i>	9
5.4.2	<i>Protection System</i>	9
5.5	Lateral Earth Pressures	10
5.6	Excavation, Dewatering, and Embankment Reconstruction.....	10
5.7	Construction Concerns	12
6	STATEMENT OF LIMITATIONS	13
Appendices		
Appendix 1	Key Plan	
Appendix 2	Subsurface Data	
Appendix 3	Borehole Plan and Laboratory Data	
Appendix 4	Photo Essay	
Appendix 5	Design Data	

Property and Confidentiality

"This engineering document is the work and property of LVM-Merlex, a Division of EnGlobe Corp. and, as such, is protected under Copyright Law. It can only be used for the purposes mentioned herein. Any reproduction or adaptation, whether partial or total, is strictly prohibited without having obtained LVM Inc.'s and its client's prior written authorization to do so.

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

LVM Inc.'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."

Client:

AECOM Canada Ltd.
189 Wyld Street, Suite 103
North Bay, Ontario
P1B 1Z2
Attention: **Mr. Al Rose**

REVISION AND PUBLICATION REGISTER		
Revision N°	Date	Modification And/Or Publication Details
00	2015-01-23	Draft FIDR Issued
01	2015-03-31	Final FIDR Issued

REPORT DISTRIBUTION	
2 hard copies	AECOM
5 hard copies and 1 electronic copy	MTO Project Manager
1 hard copy and 1 electronic copy	MTO Pavements and Foundations Section, Foundations Group
1 hard copy	File

1 INTRODUCTION

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 the site of an existing centerline culvert. The site is located at Station 17+380 on Highway 112, some 7.5 km north of Highway 11 (4.7 km north of the Blanche River Bridge), in the Township of Boston.

The foundation investigation location was specified by the MTO in the Terms of Reference for additional work under Agreement No. 5012-E-0025. The terms of reference for the scope of work are outlined in LVM-Merlex Ltd.'s Proposal 13/05/13073-F11-R2, dated May 26, 2014 (approved on July 23, 2014). The purpose of this investigation was to determine the subsurface conditions in the area of the culvert. LVM-Merlex 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 topography at the site is a low moderately sloped valley area along an unnamed creek. The existing highway supports two undivided lanes of highway, generally running from the south to the north direction. For the purposes of this project, Highway 112 is considered to be orientated in a south-north direction.

The local topography at the site is a low wetland to the left and right of the embankment. The existing highway embankment currently supports two undivided lanes of highway, locally running in an east to west direction. The existing highway, at the culvert location, is constructed on a granular fill embankment some 5 m in height above the stream bed, with centerline elevation of 271.9 m at the culvert location. The culvert at this location has been described as 3048 x 2438 x 21.76 Structural Plate Corrugated Steel Pipe Arch (SPCSPA) culvert. Flow through the culvert is from the east to the west (right to left). A beaver dam was present at about 10 m upstream of the culvert inlet as described in a publication titled "Hydrology and Hydraulics Report Final" prepared by McCormick Rankin in December 2013. The beaver dam was also observed during the period of foundation investigation (see Photo Essay, Appendix 4).

2.1 Site Physiography and Surficial Geology

This project is located in the Geomorphic Sub-province known as the Temiskaming Clay Plain. The topography on this section of Highway 112 is generally flat to slightly rolling. Organic terrain was also observed. Within the specific project area overburden consists primarily of silts and clays. The crossing is approximately 150 m upstream of the watercourse outlet into Round Lake. Bedrock in the area, as indicated on Ontario Geological Survey (OGS) Map 2506, is of the late to middle Precambrian consisting of carbonatite, nepheline and alkalic syenites, fenite and associated mafic and ultramafic rocks.

3 INVESTIGATION PROCEDURES

The field work for this investigation was carried out during the period of September 22nd to October 7th, 2014 during which time four (4) sampled boreholes, were advanced. Two (2) boreholes were advanced through the existing embankment at the culvert location, and a single borehole was advanced at location close to each of the inlet (east) and outlet (west) ends of the culverts.

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. 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. At select boreholes, a Dynamic Cone Penetration Test (DCPT) was carried out to give a continuous plot of the soil resistance with depth. 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. Two 19 mm diameter standpipes were installed in selected open boreholes 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 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(s) 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 LVM-Merlex 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-4 and Table No. L-5).

The location of the individual boreholes were 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 which was established by others. 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 Record of Borehole Logs (Appendix 2) and on Drawing No. 2 (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 17+380, Township of Boston

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 close to the culvert inlet, and Borehole No. 4 advanced next 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 271.8, 271.8, 268.6, and 268.5 m, respectively.

4.1.1 Pavement Structure

Borehole No. 1 was advanced through the embankment where a pavement structure consisting of 76 mm asphalt and 229 mm crushed gravel underlain by 76 mm asphalt and 152 mm crushed gravel was penetrated. Borehole No. 2 was advanced through the embankment where a pavement structure consisting of 127 mm asphalt and 279 mm crushed gravel 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 with gravel to gravelly trace silt was penetrated. The natural moisture content measured on samples of this deposit was in the order of 4 to 8%. Gradation analyses were carried out on four (4) sample of this deposit, the results of which indicated 27 to 34% gravel size particles, 58 to 65% sand size particles, and 8 to 10% silt and clay size particles (Figure No. L-1 in Appendix 3). Results of gradation analyses for the two boreholes indicate that the granular fill generally meets the requirements of Granular "B" Type I stated in OPS.PROV 1010

except the fine content passing 75 μm for Samples Nos. 1 and 5 of Borehole No. 2. The fine content is 9 % to 10%, which slightly exceed the OPS.PROV 1010 limit of 8%.

Based on SPT 'N' values of 17 to 45 blows per 300 mm penetration, the compactness of this deposit was described as compact to dense. This deposit was encountered to depths of 2.9 m and 3.7 m below grade at Borehole Nos. 1 and 2 respectively (elevations 268.9 m and 268.1 m, respectively).

4.1.3 Silty Clay

Underlying the granular fill at Boreholes Nos. 1 and 2, and at ground surface at Borehole Nos. 3 and 4, a silty clay deposit described as grey silty clay, occasional gravel, grass rootlets and wood pieces, varved with clay was encountered to the depths at which sampling was terminated (8.4 m to 16 m below ground surface). The nature moisture contents of the silty clay samples ranges from about 30% to 67%. Results of grain size distribution hydrometer testing carried out on seven (7) samples recovered from Boreholes Nos. 1 to 4 are shown on Figure No. L-2, Appendix 3. Results of Atterberg limits testing carried out on seven (7) samples in Boreholes Nos. 1 to 4 gave Liquid Limits of some 35% to 61% and Plastic Limits of some 20% to 26% to give correspondent Plasticity Index ranging from some 15% to 40% (see Figure No. L-3, Appendix 3). The results of the Atterberg Limits testing indicated this material is classified as silty clay of medium plasticity (CI) to clay of high plasticity (CH).

Standard penetration tests carried out within the silty clay deposit returned "N" values ranging from 0 to 8 blows per 300 mm of penetration. Based on the in-situ shear strength testing, which returned values ranging from 66 kPa to 28 kPa, this deposit was described as stiff to soft, generally firm consistency, medium to sensitive with sensitivities ranging from 2 to 7. The shear strengths generally decreased with depth in this deposit, to the depth sampled (see Figure No. L-4, Appendix 3). Regular sampling was terminated within this deposit at a depth of 16 m, 16 m, 8.4 m, 8.4 m below ground surface at Boreholes Nos. 1 to 4 (Elevations 255.8 m, 255.8 m, 260.2m and 260.1 m, respectively).

4.2 Dynamic Cone Penetration Testing

A dynamic cone penetration test (DCPT) was advanced from the sampled bottom of Borehole No. 3. DCPT refusal was encountered at a depth 19.1 m below ground surface (Elevation 249.6 m). Based on the response of the DCPT advance, it is estimated that the native soils are a continuation of the silty clay, to within about 1 m above the refusal depth.

4.3 Groundwater Data

At the time of this investigation (October 7, 2014), the water level in the creek was measured at elevation 268.0 m.

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. Two standpipes were installed in Borehole Nos. 2 and 4 to obtain post borehole completion water levels. The groundwater level in the standpipe at Borehole No.2 appears stable at elevation

269.2 m after 14 days. However, the groundwater level in the standpipe at Borehole No. 4 does not appear to have stabilized. These levels are recorded on the individual Record of Borehole Log Sheets (Appendix 2).

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 a SPCSPA culvert as identified by the MTO.

The existing culvert, located at Station 17+380, in the Township of Boston, is a 3048 x 2438 SPCSPA culvert, some 22 m long. The existing culvert invert at centerline is at a depth of some 4.8 m (elevation 267.1 m). The existing highway embankment currently supports two undivided lanes of highway, running in a south to north direction at the culvert location. Flow through the culvert is from right to left (east to west). 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 fill. The native material, underlying the embankment fill, generally consisted of stiff to firm silty clay.

A concrete culvert is being considered to replace the existing culvert. The dimensions of the new culvert have not been determined at the time of preparing this report; however it is understood that the new culvert will be constructed at the same location and the underside of the new concrete culvert will be located, in the order of, 0.6 m lower than the existing culvert invert. It is further understood that the final vertical alignment of the highway will remain essentially the same. For the following discussions, outlined in Sections 5.3 and 5.4, it has been assumed that the size of a new concrete rigid frame box culvert would be in the order of 3000 X 2400 mm.

5.2 Foundation Considerations

The founding native firm silty clay present below the existing embankment is considered adequate for support of a culvert and for a conventional highway embankment provided the invert level of culvert and height of the embankment remain essentially the same as existing structure.

Based on the characteristics of the native silty clay subgrade 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 60 kPa can be used for a closed culvert (i.e. precast concrete frame box culvert). In consideration of the width of the culvert, depth of overburden, and response of the existing embankment, a geotechnical reaction at SLS of 50 kPa can be used for design, in consideration of 25 mm settlement, provided that the invert level of culvert and height of the embankment remain essentially the same.

If an open culvert (i.e. concrete frame open culvert with wall footings) is considered, then a factored bearing resistance at ULS of 50 kPa, and a geotechnical reaction at SLS of 40 kPa would apply for design, in consideration of 25 mm settlement, provided that the invert level of culvert and height of the embankment remain essentially the same, 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 2.0 m. A stability analysis, using the GEO-SLOPE computer program, Slope/W (GeoStudio 2007, version 7.17, Geo-Slope International Ltd.), was carried out at this location with standard embankment slopes of 2H: 1V in granular fill. For the purposes of these analyses, the materials were modeled using the following geotechnical parameters:

PARAMETER	EMBANKMENT GRANULAR FILL	SILTY CLAY
Unit Weight (kN/m ³)	20	17
Undrained Shear Strength (kPa)	-	25
Effective Cohesion (kPa)	0	5
Effective Friction Angle (degrees)	32	26

The unit weights and friction angles for the slope stability analyses are based on general representative values for the various soil types, obtained through laboratory testing and tactile analysis.

The results of the analyses indicated factors of safety for the new embankment, constructed with 2:1 (H: V) side slopes, are in the order of 1.69 for the short term stability and 1.62 for the long term stability (see Figure Nos. S-1 and S-2, Appendix 5). Lower factors of safety will occur during excavation and backfilling as discussed in Section 5.6. Short term stability should not be an issue if construction is carried out as described herein. The long term stability of the new embankment will not be an issue provided it is properly constructed.

5.3 Culvert Design, Bedding, and Embedment

The embankment consists of granular fills. The results of this investigation indicate that, below the culvert invert, the native soils at Borehole Nos. 1 and 2 generally consists of stiff to firm silty clays. A review of the condition of the pavement surface, at the culvert locations, revealed minor longitudinal and transverse 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 consolidation 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

A precast concrete rigid frame box culvert is 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 one third of the box unit base should be loosely placed and

uncompacted. 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. This requirement ensures that when the loads on the box are transmitted to the outer sides of the box base, the middle one third of the box can settle slightly without applying a bending stress to the base span. 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 embankment fill should be placed in a balanced manner on the outer sides of the box unit. The elevation difference of the backfill on either side of the box unit must be limited to a maximum of 300 mm. 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, 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 5 m in length, 400 mm thick and extend across the stream bed to 5 m beyond the outside edges of the culvert. Clay seals are generally used where significant head differences exist between the inlet and outlet of the culverts to prevent flow through the bedding/embedment granulars. Considering the anticipated water levels and flow at this culvert location, clay seals are not considered necessary.

5.4 Culvert Installation and Staged Construction Considerations

The invert elevation of the existing culvert is at the order of 267 m, with the top of the embankment at elevation 271.9 m at centerline. As such, the embankment at this location is some 4.9 m in height above the existing culvert invert at the centerline. Therefore, a minimum 5.8 m deep excavation (i.e. to Elevation 266.1 m) will be required in consideration of a 300 mm thick layer of bedding/embedment material below the underside of the concrete culvert. The new concrete culvert bottom will be some 300 mm thick and the culvert invert will be recessed some 300 mm below existing stream bed. The present platform width at this location is some 13 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. Considering the embankment geometry, a minimum 6 m platform width would be required to allow for open cut excavations. If this widening cannot be accommodated then consideration can be given 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 along with embankment widening. 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 with temporary portable traffic lights, as shown on Figure No. SK-3, Appendix 5, is as follows:
- Locally lower the grade 1.8 m. at the culvert to an elevation of approximately 270.1 m.
- Limit traffic to a single lane on the left, with a minimum platform width of 6 m, under portable temporary traffic light control.
- Open cut excavate, to the right, and install approximately 15 m of new culvert.
- Reconstruct the embankment on the right by some 0.5 m widening (sliver) as required, 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.

5.4.2 Protection System

As noted above, consideration can be given to constructing a vertical wall, along centerline, for use as a temporary protection system. The installation of a protection system for use in the culvert replacement operation will require penetration through some 5 m of embankment fill. The embankment fill is generally underlain by stiff to firm silty clay. As such, a temporary vertical wall for a protection system can likely consist of driven steel sheet piles. The embankment generally consists of granular fill, as such, 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 silty clay deposit of sufficient embedment depth. Conceptual shoring locations and sections are illustrated on Figure Nos. SK-4 and SK-5, Appendix 5.

Considering the cohesionless nature of the embankment fills (granular pavement structure over granular fills) 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 $0.65 \cdot K_a \cdot \gamma \cdot H$, 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 protection system can be designed using the lateral earth pressure parameters as outlined in Section 5.5.

The contractor's shoring/protection system design must be carried out by a geotechnical 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 on Table A in Appendix 5. Conceptual shoring location is illustrated on Figure No. SK-4, Appendix 5. 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.

A preliminary cost estimate has been carried out and due to the fact that the grade would have to be lowered some 1.8 m the cost for staged construction with grade lowering was some 30% to 40% greater than a temporary shoring system.

5.5 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	EMBANKMENT FILL	SILTY CLAY
Unit Weight (kN/m ³)	22.8	21.2	20	17
Angle of Internal Friction	34°	31°	32°	26°
Coefficient of Active Earth Pressure (K_a)	0.28	0.32	0.31	0.39
Coefficient of Passive Earth Pressure (K_p)	3.54	3.12	3.25	2.56
Coefficient of Earth Pressure at Rest (K_0)	0.44	0.48	0.47	0.56

For rigid structures, such as a precast concrete culvert, deflection cannot occur, as such the "at-rest" condition (K_0) applies. For flexible structures, such as CSP/ SPCSPA/HDPE culverts, deflection can occur, as such the "active" condition (K_a) applies.

5.6 Excavation, Dewatering, and Embankment Reconstruction

All 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 will have to be cut back to an angle of 2H:1V, possibly shallower, dependent upon the Contractors' chosen method of controlling the groundwater. Temporary open cuts with a slope of 1H: 1V cannot be left unattended (i.e. overnight, during breakdowns, etc.). If work must stop for extended periods of time, the temporary slopes must be flattened to a minimum angle of 2H: 1V.

The excavation backfill should consist of Select Subgrade Material (SSM) per OPSS.Prov 1010, at a minimum, up to the underside of the pavement structure. An SSM material must be used within the depth of frost penetration. 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 (base heave/instability) 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 level in the creek was recorded at Elevation 268 m at the time of this investigation and excavations to a minimum Elevation 266.1 m will be required to install the culvert and bedding. As such dewatering will 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. This method of groundwater control is generally only effective when the groundwater in the excavation is less than a depth of some 1 m above the final base of the excavation to maintain subgrade stability and to allow for the placement of bedding, engineered fill, and/or construction of structures in the dry.

To effectively lower the groundwater to a greater depth, a more sophisticated groundwater control system in fine grained soils (i.e. silty clay), such as vacuum well points, would have to be considered. To provide a stable working surface the groundwater level must be controlled to below the base of excavation. When wet, silty clay subgrade can become easily disturbed, and can lose a significant portion of its natural bearing capacity.

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 at the culvert outlet. Sheet piles should extend a minimum embedment depth equal to the height

of excavation below the base of proposed excavation. By-pass pumping can be carried out to divert the stream flow at the time of construction.

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

No major construction concerns are anticipated if construction is carried out in general conformance with the above discussion.

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 LVM-Merlex Ltd. 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 LVM-Merlex Ltd. 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 4 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

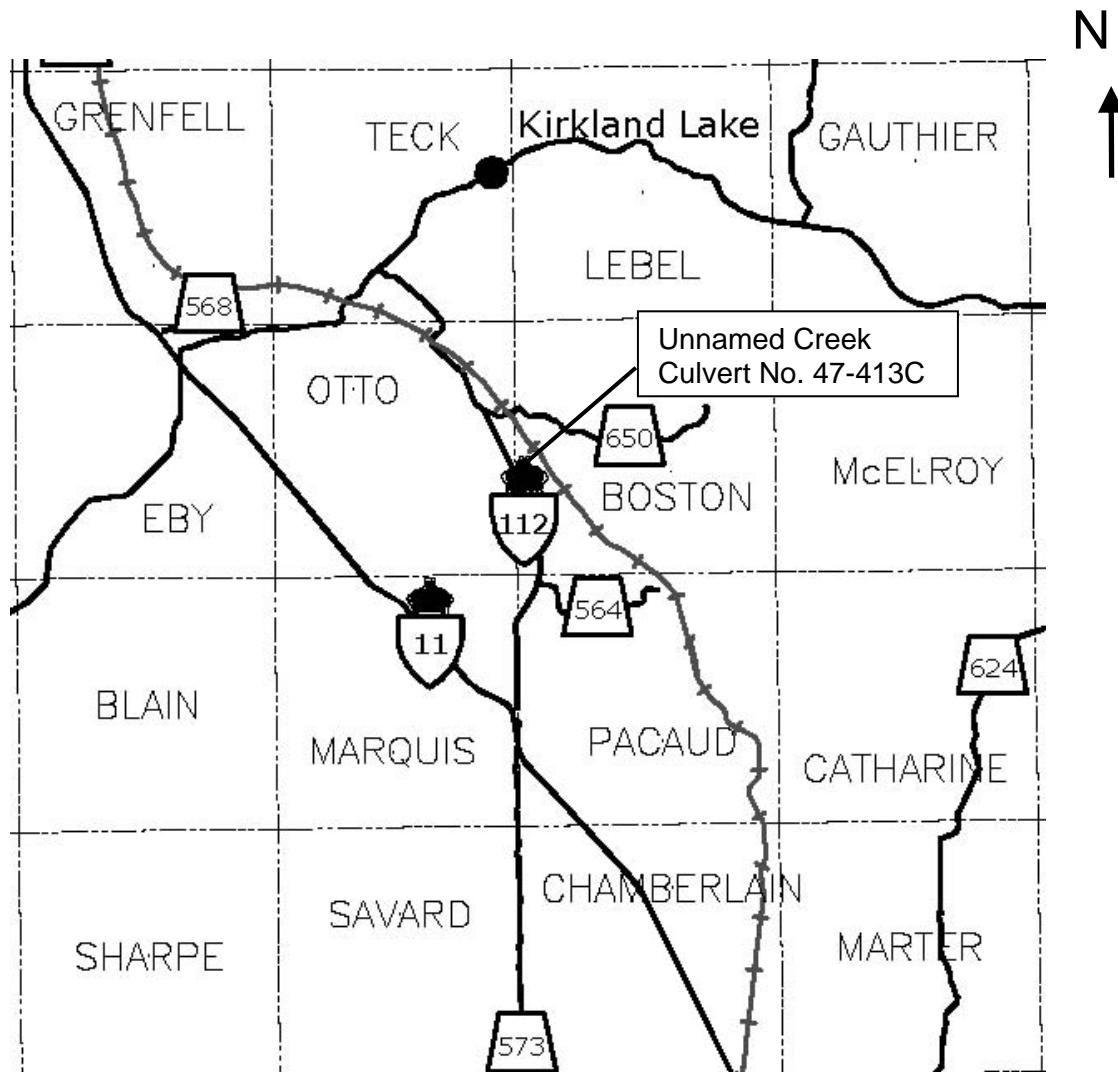
Drawing No. 1

Key Plan

MACRO KEY PLAN

Drawing No.1

NOT TO SCALE



FINAL
FOUNDATION INVESTIGATION
AND DESIGN REPORT
GWP 5105-12-00
Highway 112
Unnamed Creek Culvert



Reference No: 13/05/13073-F11

March 2015

Appendix 2 Subsurface Data

Enclosure No. 1	List of Abbreviations and Symbols
Enclosure Nos. 2 to 5	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) *Cohesive Soils:*

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 13/05/13073-F11 DATUM Geodetic LOCATION N 5322094.9 E 378548.5 - Boston Township, Station 17+405 ORIGINATED BY JL
 PROJECT GWP 5105-12-00, Highway 112 - Unnamed Creek BOREHOLE TYPE Truck Mounted CME 45 - Hollow Stem Augers COMPILED BY SH
 CLIENT AECOM Inc. DATE (Started) 22 September 2014 TIME 4:45:00 PM
 DATE (Completed) 22 September 2014 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	STRATA PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
	Continued from Previous Page												
			12	SS	PM								
			13	SS	PM								
			14	SS	PM								
			15	SS	PM								
255.8													
16.0	End of Sampling End of Borehole												

MEL-GEO 13073-F11 - BOREHOLE LOGS - DRAFT.GPJ MEL-GEO.GDT 10/3/15

METRIC

RECORD OF BOREHOLE NO. 2



REFERENCE	13/05/13073-F11	DATUM	Geodetic	LOCATION	N 5322096.1 E 378537.7 - Boston Township, Station 17+413	ORIGINATED BY	JL
PROJECT	GWP 5105-12-00, Highway 112 - Unnamed Creek			BOREHOLE TYPE	Truck Mounted CME 45 - Hollow Stem Augers	COMPILED BY	SH
CLIENT	AECOM Inc.	DATE (Started)	23 September 2014	TIME		CHECKED BY	MAM
		DATE (Completed)	23 September 2014	(Completed)	2:00:00 PM		

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)								
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			<div><div>20406080100</div><div>SHEAR STRENGTH kPa</div><div>○ UNCONFINED + FIELD VANE</div><div>● QUICK TRIAXIAL × LAB VANE</div><div>20406080100</div></div>							<div><div>PLASTIC LIMIT</div><div>NATURAL MOISTURE CONTENT</div><div>LIQUID LIMIT</div><div>w_p w w_L</div><div>WATER CONTENT (%)</div><div>204060</div></div>							
								271.8	Ground Surface													
								0.0	127 mm Asphalt 279 mm Crushed Gravel		1	SS			23							28 64 (9)
									FILL - sand with gravel trace silt brown (compact/dense)		2	SS			37							
											3	SS			40							
			4	SS	43																	
			5	SS	22							27 63 (10)										
268.1																						
3.7	SILTY CLAY trace sand occasional gravel, grass rootlets and wood pieces		6	SS	4																	
	grey (stiff)		7	TO	WH																	
	(firm)		8	TO	PM								0 0 25 75									
	varved clay at depths between 9.1 m and 16 m		9	SS	PM																	
			10	TO	PM																	
			11	SS	PM																	
Continued Next Page																						
COMMENTS						<div>+ 3 , × 3 : Numbers on right refer to Sensitivity Numbers on left refer to values greater than 120 kPa</div> <div>○ 3% STRAIN AT FAILURE</div>							WATER LEVEL RECORDS									
													Date (dd/mm/yy)/Time		Water Depth (m)	Cave In (m)						
													1) 23/9/14 2:00:00 PM		Dry	▽	-					
													2) 7/10/14 3:30:00 PM		2.6	▽	-					
													3)		-	▽	-					

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

MEL-GEO 13073-F11 - BOREHOL LOGS - DRAFT.GPJ MEL-GEO.GDT 10/3/15

METRIC**RECORD OF BOREHOLE NO. 2**

REFERENCE 13/05/13073-F11 DATUM Geodetic LOCATION N 5322096.1 E 378537.7 - Boston Township, Station 17+413 ORIGINATED BY JL
 PROJECT GWP 5105-12-00, Highway 112 - Unnamed Creek BOREHOLE TYPE Truck Mounted CME 45 - Hollow Stem Augers COMPILED BY SH
 CLIENT AECOM Inc. DATE (Started) 23 September 2014 TIME 23 September 2014
 DATE (Completed) 23 September 2014 (Completed) 2:00:00 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	STRATA PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					
	Continued from Previous Page												
			12	SS	PM								
			13	SS	PM								
			14	SS	PM								
			15	SS	PM								
255.8 16.0	End of Sampling End of Borehole												

MEL-GEO 13073-F11 - BOREHOLE LOGS - DRAFT.GPJ MEL-GEO.GDT 10/3/15

METRIC

RECORD OF BOREHOLE NO. 3



REFERENCE	<u>13/05/13073-F11</u>	DATUM	<u>Geodetic</u>	LOCATION	<u>N 5322110.1 E 378552.6 - Boston Township, Station 17+413</u>	ORIGINATED BY	<u>JL</u>
PROJECT	<u>GWP 5105-12-00, Highway 112 - Unnamed Creek</u>			BOREHOLE TYPE	<u>Track Mounted CME 45 - Hollow Stem Augers</u>	COMPILED BY	<u>SH</u>
CLIENT	<u>AECOM Inc.</u>	DATE (Started)	<u>7 October 2014</u>	TIME (Completed)	<u>12:00:00 PM</u>	CHECKED BY	<u>MAM</u>
		DATE (Completed)	<u>7 October 2014</u>				

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)				
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES		ELEVATION SCALE	SHEAR STRENGTH kPa							WATER CONTENT (%)			
								○ UNCONFINED	+ FIELD VANE						×	QUICK TRIAXIAL	LAB VANE	
268.6	Ground Surface																	
0.0	SILTY CLAY trace sand occasional grass rootlets Brown (stiff) dark grey grey (firm) varved clay at depths between 2.3 m and 8.4 m		1	SS	4													
			2	SS	WH													
			3	SS	PM													
			4	SS	PM													
			5	SS	PM													
			6	SS	PM													
			7	SS	PM													
			8	SS	PM													
			9	SS	PM													
260.2	End of Sampling Continuation of DCPT																	
8.4																		
Continued Next Page																		
COMMENTS							+ ³ , × ³ : Numbers on right refer to Sensitivity Numbers on left refer to values greater than 120 kPa			WATER LEVEL RECORDS								
After pulling AW rods, after driving DCPT, water observed rising in hollow stem augers. Upon reversing augers to plug hole and pulling 3 m of augers, artesian flow stopped. Borehole fully plugged with clay and 3 bags of bentonite. The stratification lines represent approximate boundaries. The transition may be gradual							○ 3% STRAIN AT FAILURE			Date (dd/mm/yy)/Time			Water Depth (m)		Cave In (m)			
										1) 7/10/14 12:00:00 PM			0		0.91			
										2)			-		-			
										3)								

MEL-GEO 13073-F11 - BOREHOLE LOGS - DRAFT.GPJ MEL-GEO.GDT 10/3/15

METRIC**RECORD OF BOREHOLE NO. 3**

REFERENCE 13/05/13073-F11 DATUM Geodetic LOCATION N 5322110.1 E 378552.6 - Boston Township, Station 17+413 ORIGINATED BY JL
 PROJECT GWP 5105-12-00, Highway 112 - Unnamed Creek BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers COMPILED BY SH
 CLIENT AECOM Inc. DATE (Started) 7 October 2014 TIME
 DATE (Completed) 7 October 2014 (Completed) 12:00:00 PM CHECKED BY MAM

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	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE						
	Continued from Previous Page									
258										
257										
256										
255										
254										
253										
252										
251										
250										
249.6										
19.1	DCPT Refusal End of Borehole									

MEL-GEO 13073-F11 - BOREHOLE LOGS - DRAFT.GPJ MEL-GEO.GDT 10/3/15

METRIC**RECORD OF BOREHOLE NO. 4**

REFERENCE 13/05/13073-F11 DATUM Geodetic LOCATION N 5322081.8 E 378532.3 - Boston Township, Station 17+407 ORIGINATED BY JL
 PROJECT GWP 5105-12-00, Highway 112 - Unnamed Creek BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers COMPILED BY SH
 CLIENT AECOM Inc. DATE (Started) 7 October 2014 TIME
 DATE (Completed) 7 October 2014 (Completed) 3:30:00 PM CHECKED BY MAM

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	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	STRATA PLOT	NUMBER	TYPE	"N" VALUES								
268.5	Ground Surface												
0.0	SILTY CLAY trace sand dark Brown, occasional grass rootlets wood encountered at depth of 1.2 m (stiff)		1	SS	5		268						
			2	SS	3								
	grey						267						
	(firm)		3	SS	PM								
							266						
	varved clay at depths between 3.8 m and 8.4 m		4	SS	PM								
			5	SS	PM		265						
			6	SS	PM		264						
			7	SS	PM		263						
			8	SS	PM		262						
			9	SS	PM		261						
260.1	End of Sampling End of Borehole												
8.4													

COMMENTS

Water level probably not stabilized

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

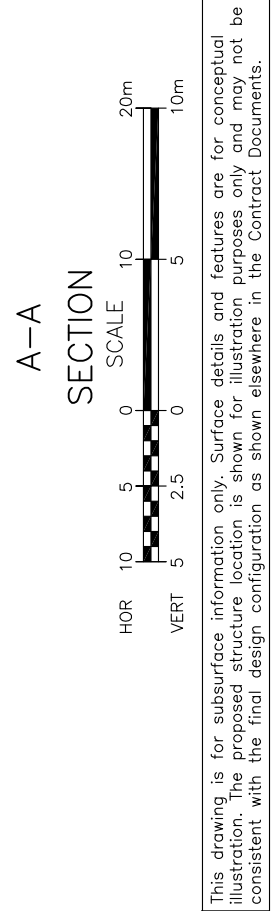
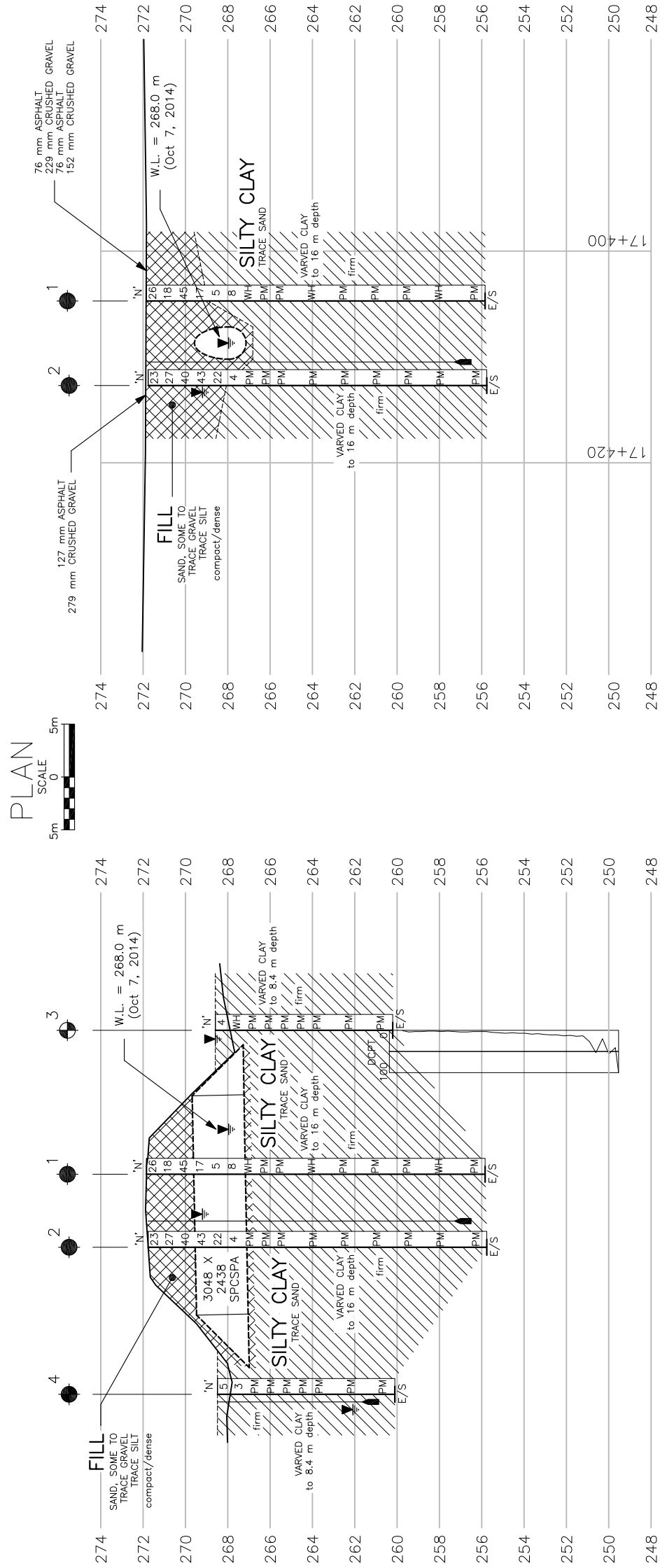
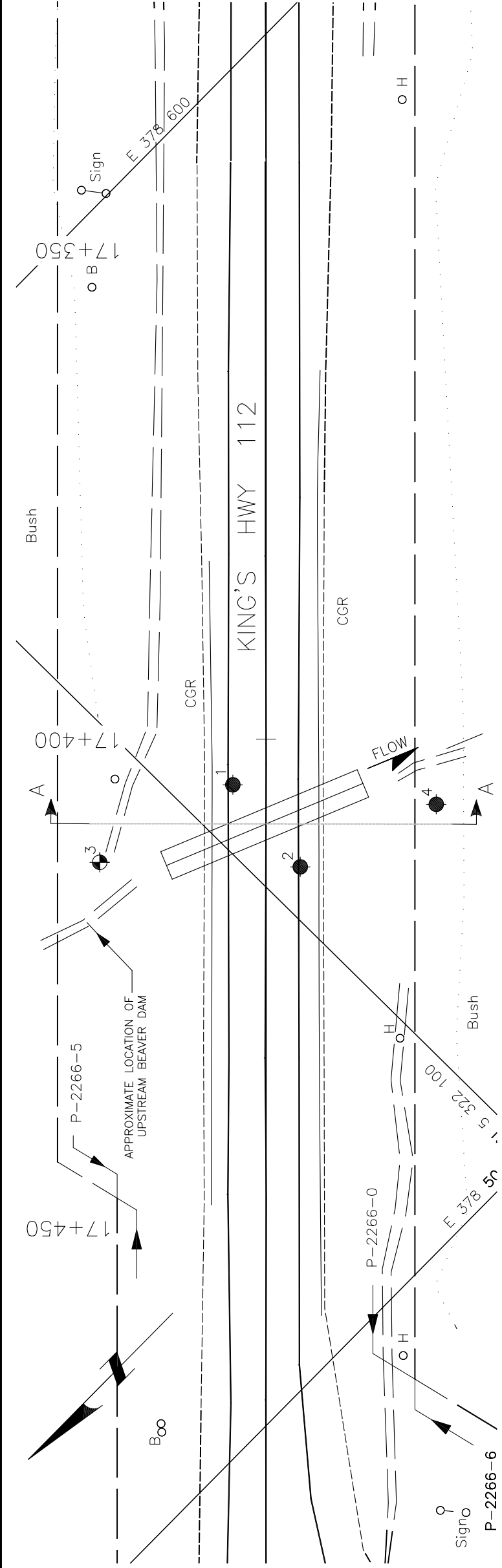
WATER LEVEL RECORDS



Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1) 7/10/14 3:50:00 PM	6.4	▽
2)	-	▽
3)	-	▽

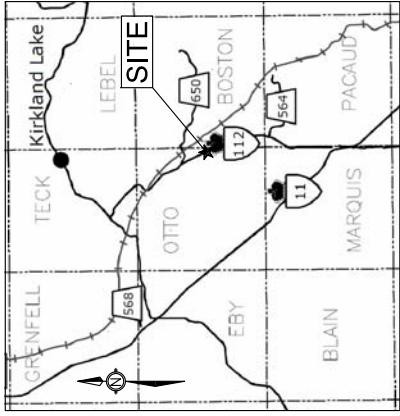
MEL-GEO 13073-F11 - BOREHOLE LOGS - DRAFT.GPJ MEL-GEO.GDT 10/3/15





Appendix 3 Borehole Plan and Laboratory Data

Drawing No. 2: Borehole Location and Soil Strata
Figure Nos. L-1 and L-2: Grain Size Distribution Curves
Figure No. L-3: Atterberg Limits Chart
Figure No. L-4: In-situ Shear Strengths Chart
Table No. L-5: Laboratory Tests - Summary Sheet



DISTRICT CONT. No. GWP No. 5105-12-00		DRAWING	2	METRIC
		HWY 112 UNNAMED CREEK CULVERT BOSTON TOWNSHIP BOREHOLE LOCATIONS AND SOIL STRATA		
				



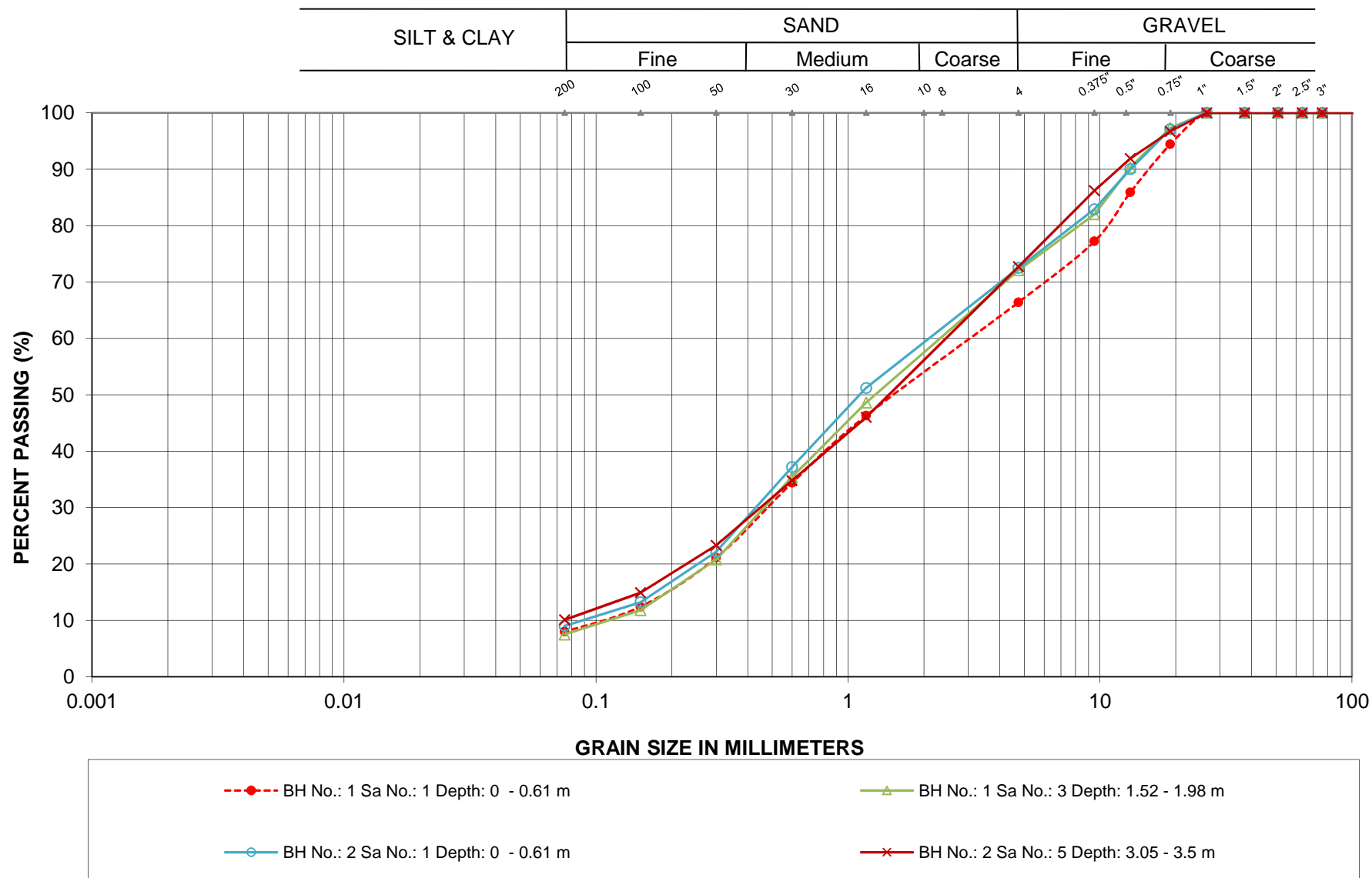
LEGEND				
	Borehole			
	Borehole w/ Dynamic Cone Penetration Test			
N	Blows/0.3 m (Std Pen Test, 475 J/blow)			
DPT	Blows/0.3 m (60° Cone, 475 J/blow)			
	Water Level at Time of Investigation			
A/R	Auger Refusal at Elevation			
E/S	End of Sampling			
	Piezometer			
BOREHOLE No.	ELEVATION	O/S	NORTHING	EASTING
1	271.8	3.4m Rt	5322094.9	378548.5
2	271.8	3.5m Lt	5322096.1	378537.7
3	268.6	17.0m Rt	5322110.1	378552.6
3	268.5	17.4m Lt	5322081.8	378532.3

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 exp. on October 22, 2014.

GEOCRES No. 42A-101[illegible]

GRAIN SIZE ANALYSIS



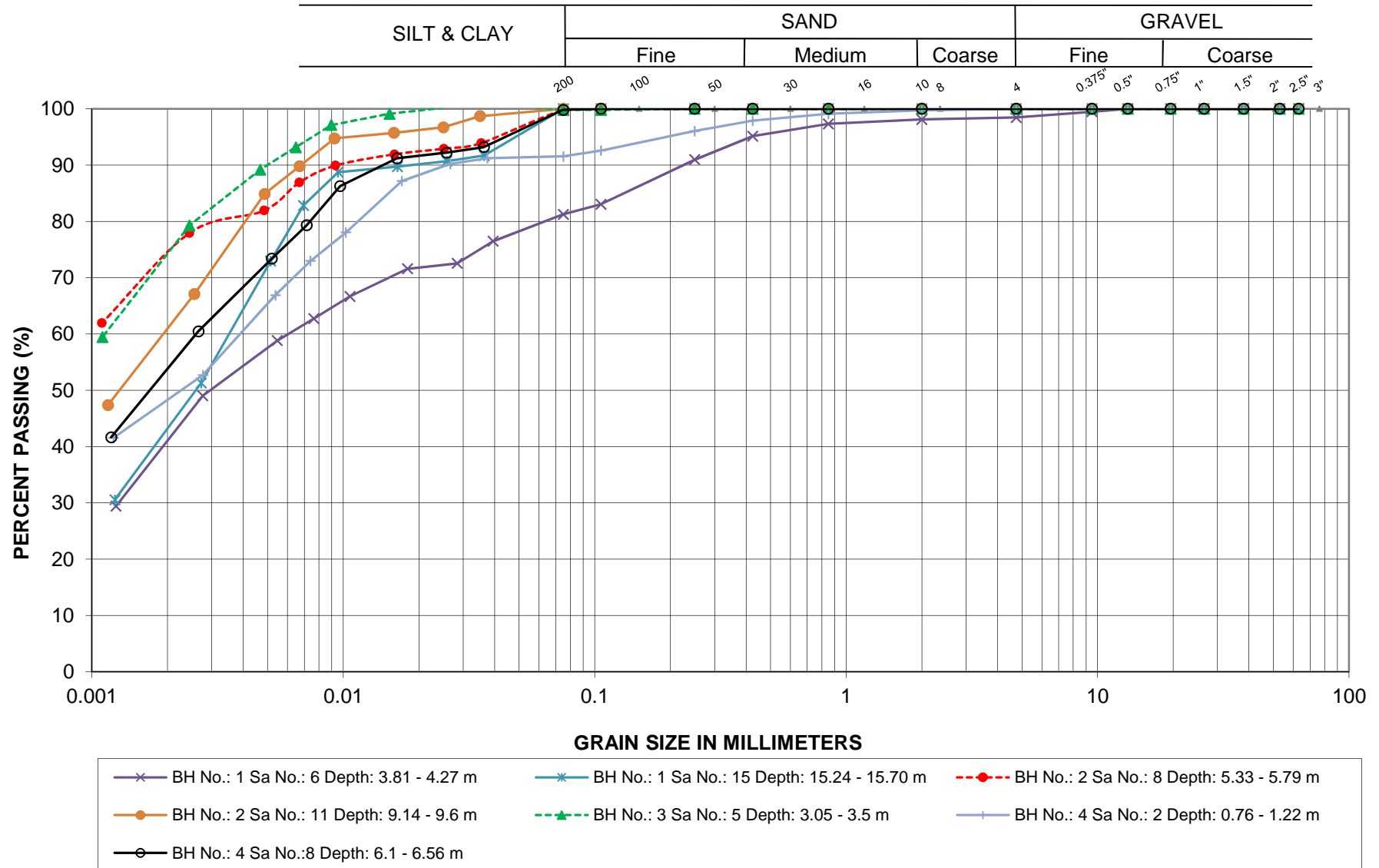
LOCATION: Hwy 112 Unnamed Creek Culvert
TWP Boston, Ontario

SAND FILL

LVM-Merlex, a Division EnGlobe Corp.

FIGURE L-1

GRAIN SIZE ANALYSIS

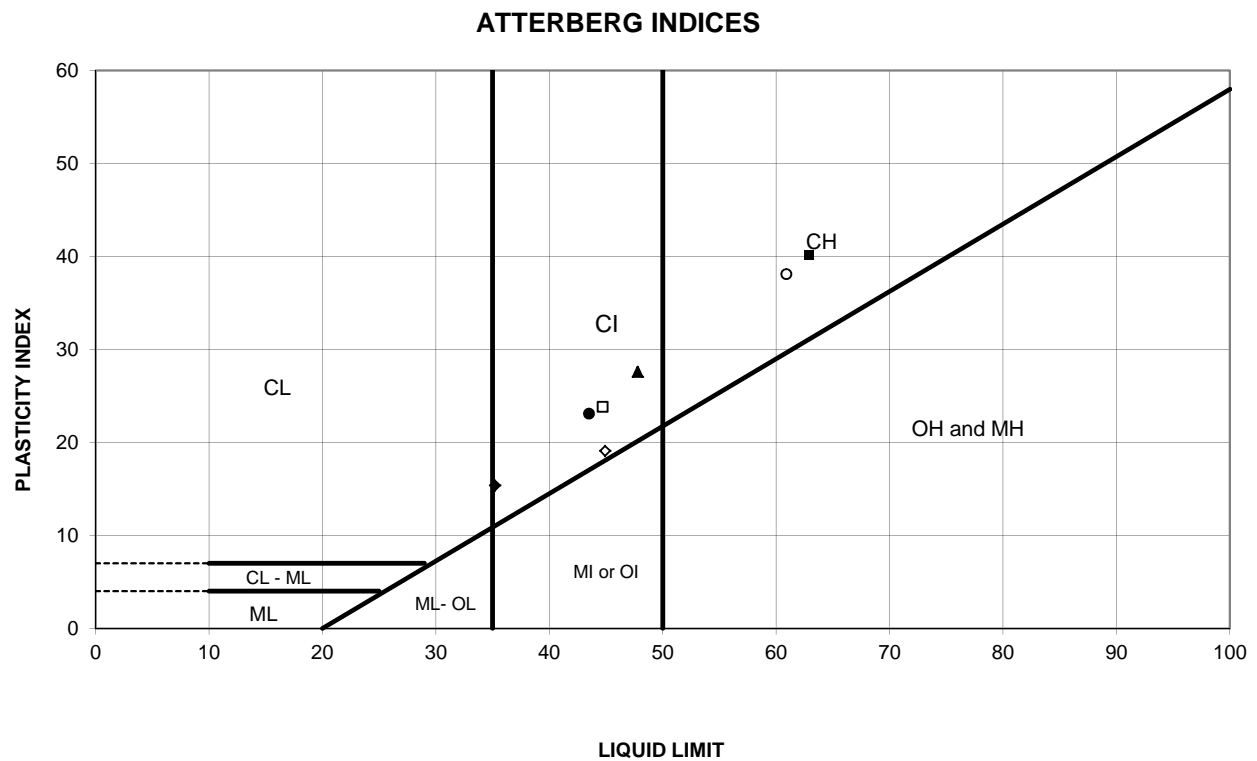


LOCATION: Hwy 112 Unnamed Creek Culvert
TWP Boston, Ontario

SILTY CLAY to CLAY

ATTERBERG LIMITS CHART

FIGURE L-3



SYMBOL	BH	Sa. No.	Depth(m)	Elev.(m)	Liquid Limit	Plastic Limit	Plasticity Index	NMC %
●	1	6	4.0	267.8	43.5	20.4	23.1	30.2
◆	1	15	15.5	256.3	35.2	19.8	15.4	42.9
■	2	8	5.6	266.2	62.9	22.8	40.1	57.0
▲	2	11	9.4	262.4	47.8	20.2	27.6	54.5
○	3	5	3.3	265.3	60.9	22.8	38.1	65.0
◇	4	2	1.0	267.5	44.9	25.8	19.1	46.5
□	4	8	6.3	262.2	44.7	20.9	23.8	53.1

Date: Mar-15

Project: Hwy 112, Unnamed Creek Culvert

Location: Sta. 17+400

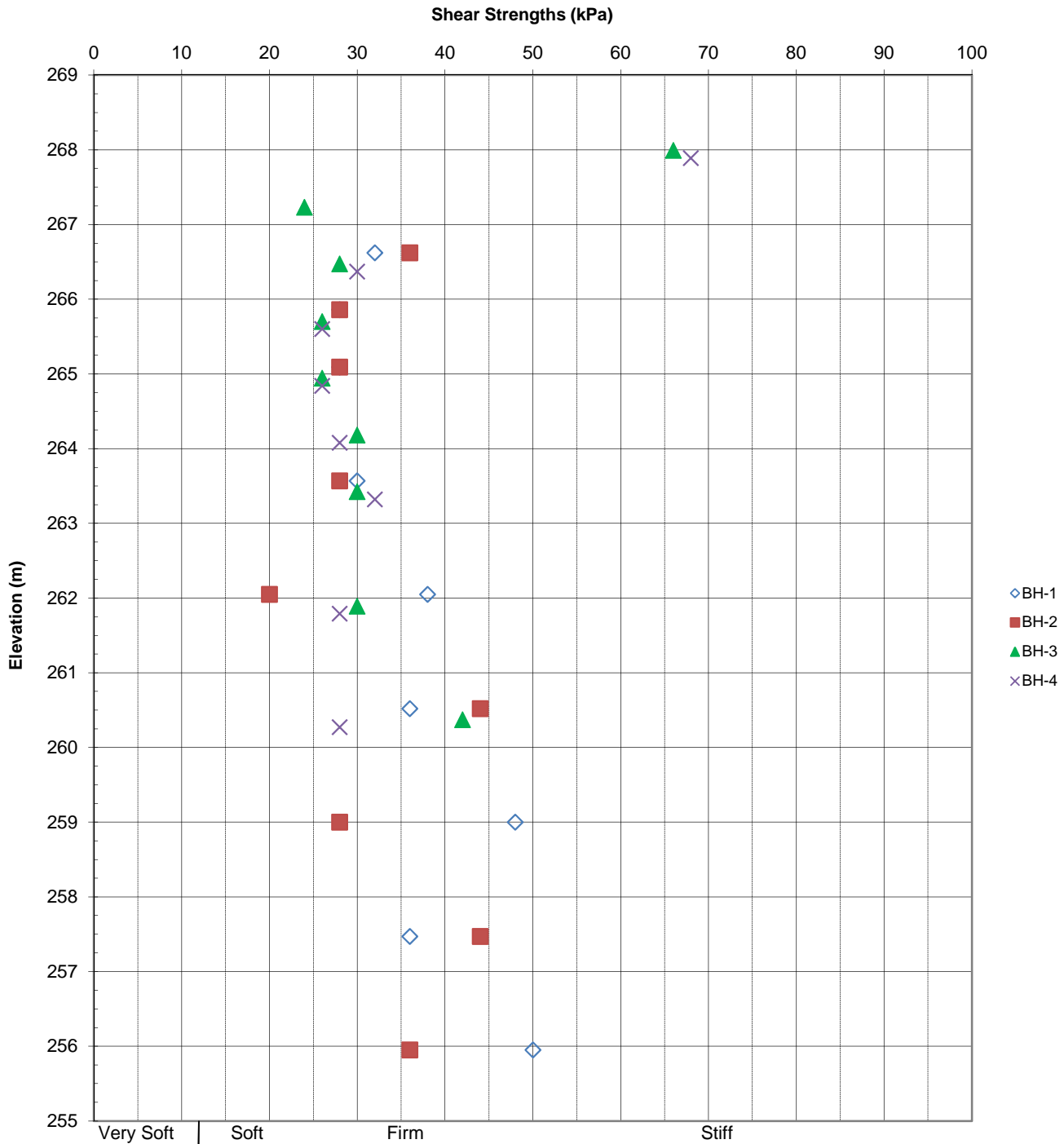
Prep'd: SH

Chkd: MAM

Ref. No.: 13/05/13073-F11

LVM-Merlex, a Division EnGlobe Corp.

In-Situ Shear Strengths vs. Depth



Note: Shear strength greater than 100 kPa is shown as >100 kPa

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	0.3	34	58	8		4.0				26			
	2	1.0					3.6				18			
	3	1.8	28	65	8		4.5				45			
	4	2.5					6.6				17			
	5	3.3					33.2				5			
	6	4.0					30.2	43.5	20.4	23.1	8			
	7	4.8					62.6				WH			
	8	5.6					57.0				PM			
	9	6.3					58.4				PM			
	10	7.9					56.2				PM			
	11	9.4					54.0				PM			
	12	10.9					49.6				PM			
	13	12.4					36.5				PM			
	14	14.0					40.4				PM			
	15	15.5					42.9	35.2	19.8	15.4	PM			
2	1	0.3	28	63	9		4.7				23			
	2	1.0					3.9				37			
	3	1.8					3.5				40			
	4	2.5					4.5				43			
	5	3.3	27	63	10		8.0				22			
	6	4.0					34.3				4			
	7	4.8					49.5				WH			
	8	5.6	0	0	25	75	57.0	62.9	22.8	40.1	PM			
	9	6.3					55.9				PM			
	10	7.9					65.6				PM			
	11	9.4					54.5	47.8	20.2	27.6	PM			
	12	10.9					43.0				PM			

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 (%)				
	13	12.42					33.4				PM			
	14	13.95					37.7				PM			
	15	15.5					39.2				PM			
3	1	0.23					50.3				4			
	2	0.99					60.5				WH			
	3	1.75					66.2				PM			
	4	2.5					64.6				PM			
	5	3.3	0	0	26	74	65.0	60.9	22.8	38.1	PM			
	6	4.0					55.1				PM			
	7	4.8					57.6				PM			
	8	6.3					42.4				PM			
	9	7.9					30.7				PM			
4	1	0.2					39.0				5			
	2	0.99					46.5	44.9	25.8	19.1	3			
	3	1.75					66.6				PM			
	4	2.52					64.7				PM			
	5	3.28					62.3				PM			
	6	4.04					64.1				PM			
	7	4.8					51.8				PM			
	8	6.33					53.1	44.7	20.9	23.8	PM			
	9	7.85					40.8				PM			

Appendix 4

Photo Essay

Enclosure No. 6:

Photo Essay

Embankment at Culvert Location – Looking North

Photo: 1



Culvert Inlet – Looking East

Photo: 2



Project: Hwy 112 – Culvert 17+400

Photos Provided By: LVM

Date: September 2014

Beaver Dam at Creek Upstream north of Culvert Inlet– Looking East

Photo: 3



Culvert Outlet – Looking West

Photo: 4



Project: Hwy 112 – Culvert 17+400

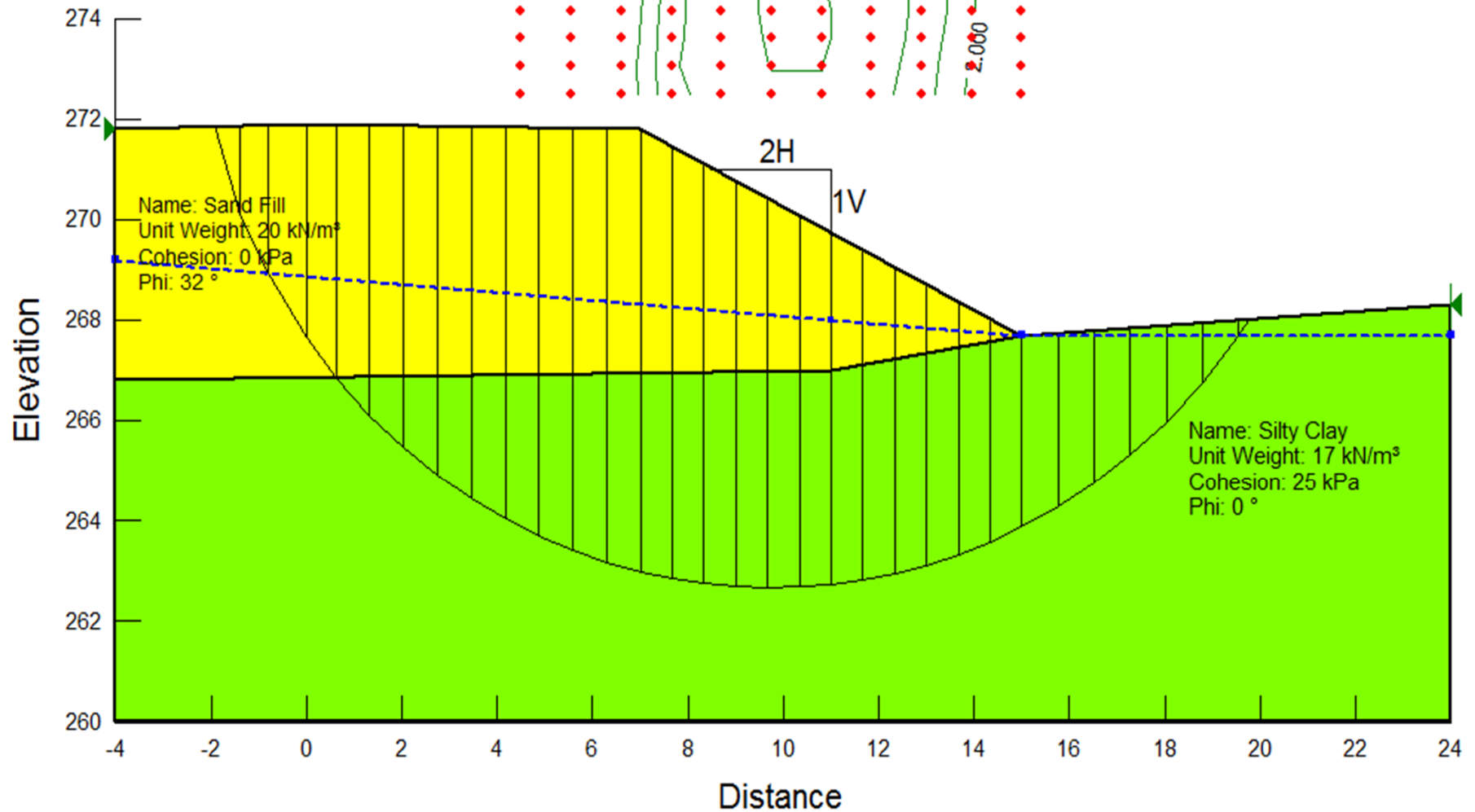
Photos Provided By: LVM

Date: September 2014

Appendix 5 Design Data

Figure No. S-1 and S-2:	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

Stability Analysis
Embankment Stability
Short Term Stability
Failure of Native Material
2H:1V Slopes

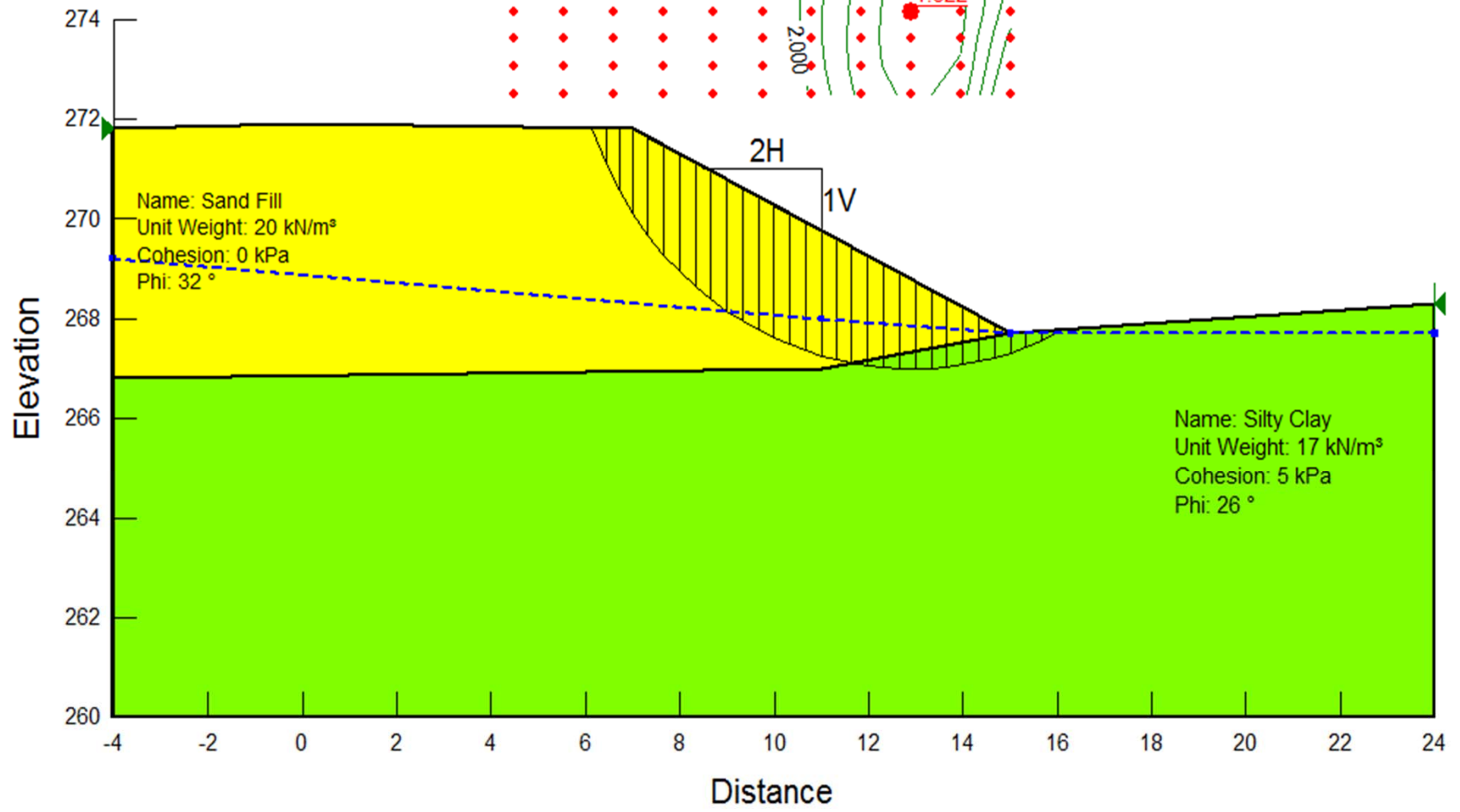


Station 17+400
 Township of Boston

Project: Hwy 112, Unamed Creek Culvert
 Location: Twp. of Boston

Figure No. S-1

Stability Analysis
Embankment Stability
Long Term Stability
Failure of Native Material
2H:1V Slopes



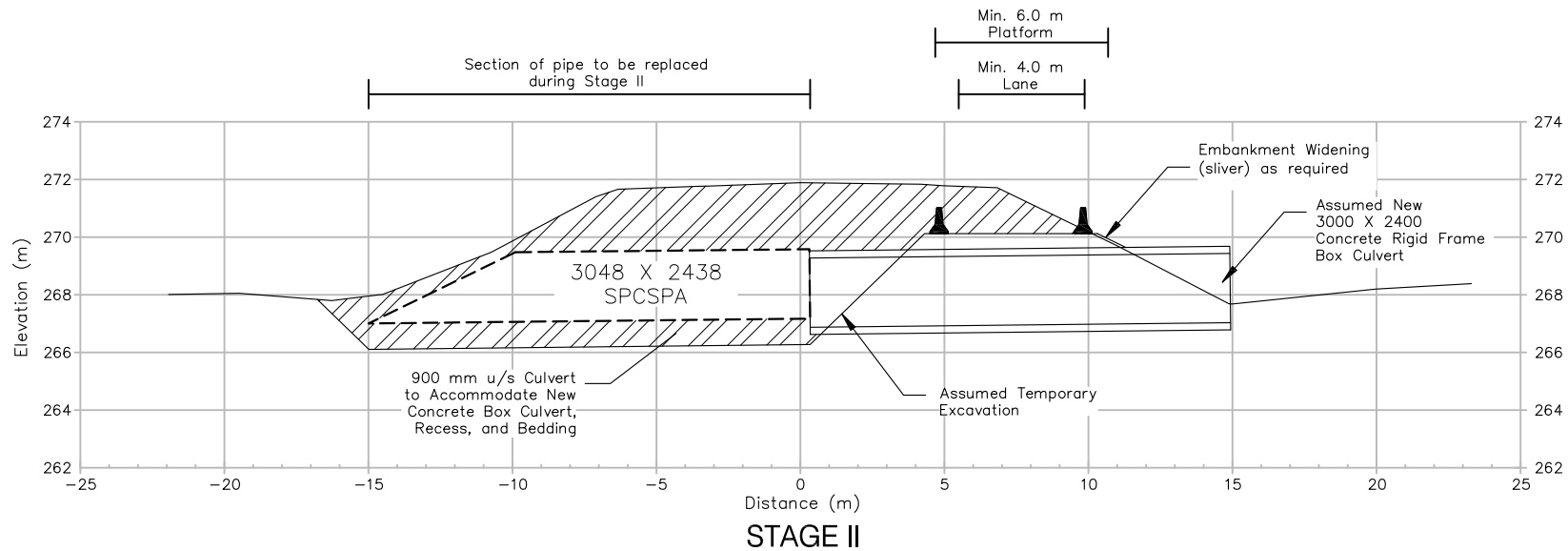
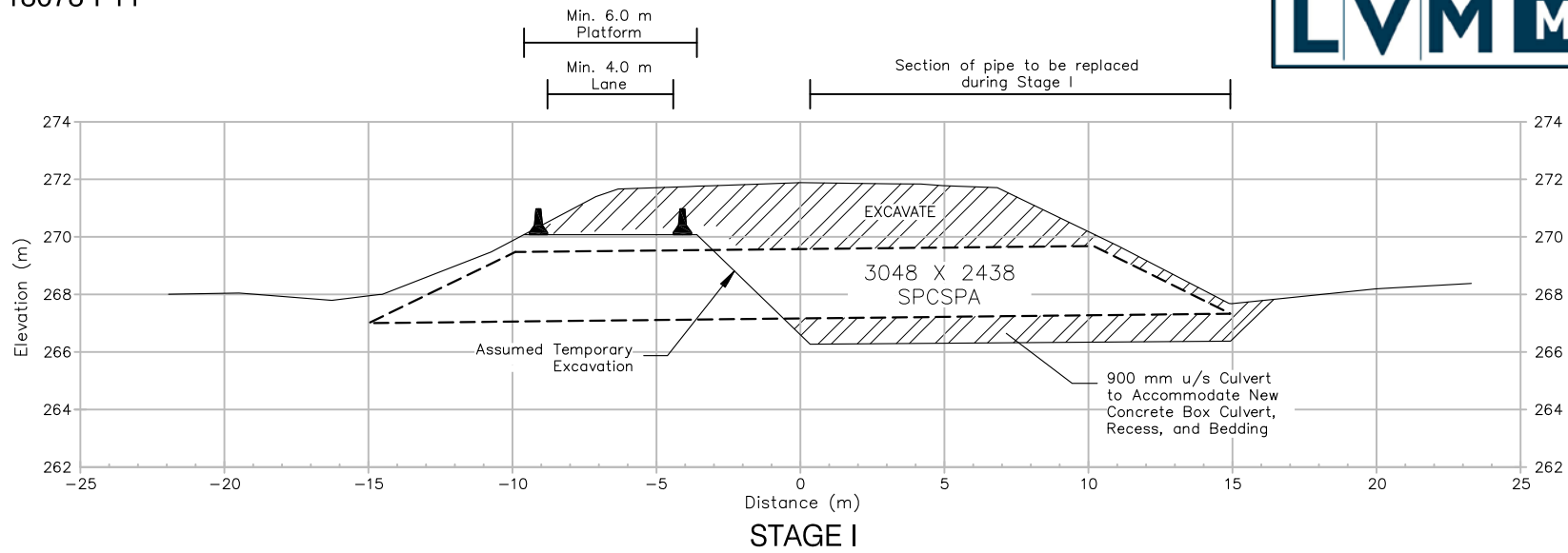
Station 17+400
 Township of Boston

Project: Hwy 112, Unnamed Creek Culvert
 Location: Twp. of Boston

Figure No. S-2

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 cobble/boulders present in native soils.	\$ 650/m ²
Steel Sheet Piles	5 – 21	-High strength, continuous, -Readily available	-Limited by soil conditions (i.e. obstructions)	Recommended for temporary protection, provided sufficiently robust cross section pile is used.	\$ 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	
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



Note:
Geometry of temporary cut slopes based on assumption of adequate groundwater control carried out by the Contractor during excavation.

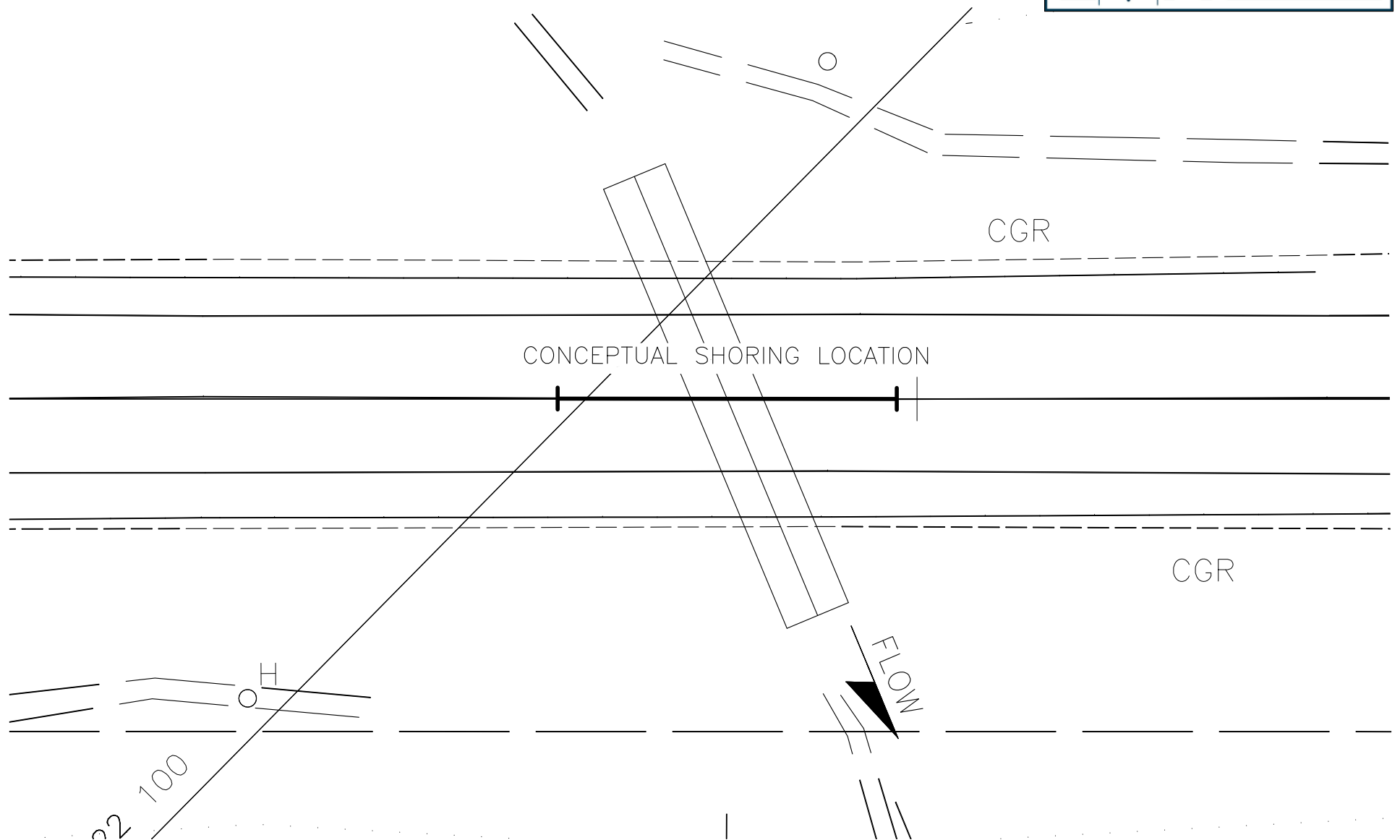
METRIC

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



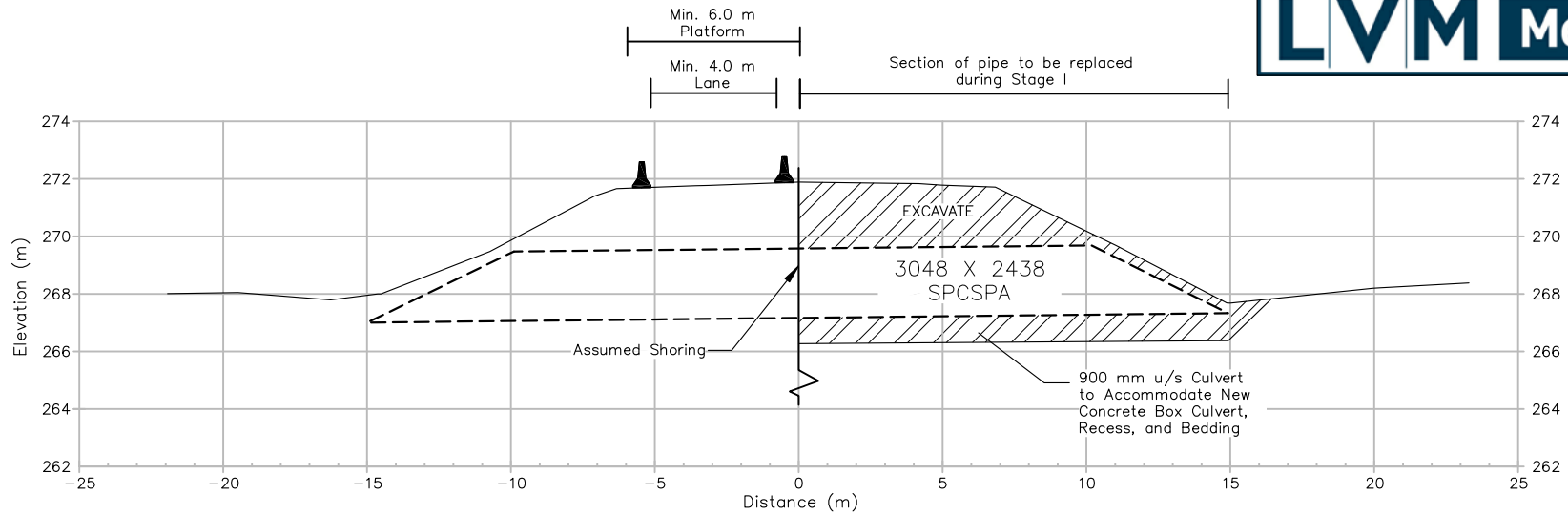
Highway 112, Township of Boston - Culvert at Station 17+400
Conceptual Staging

FIGURE SK-3

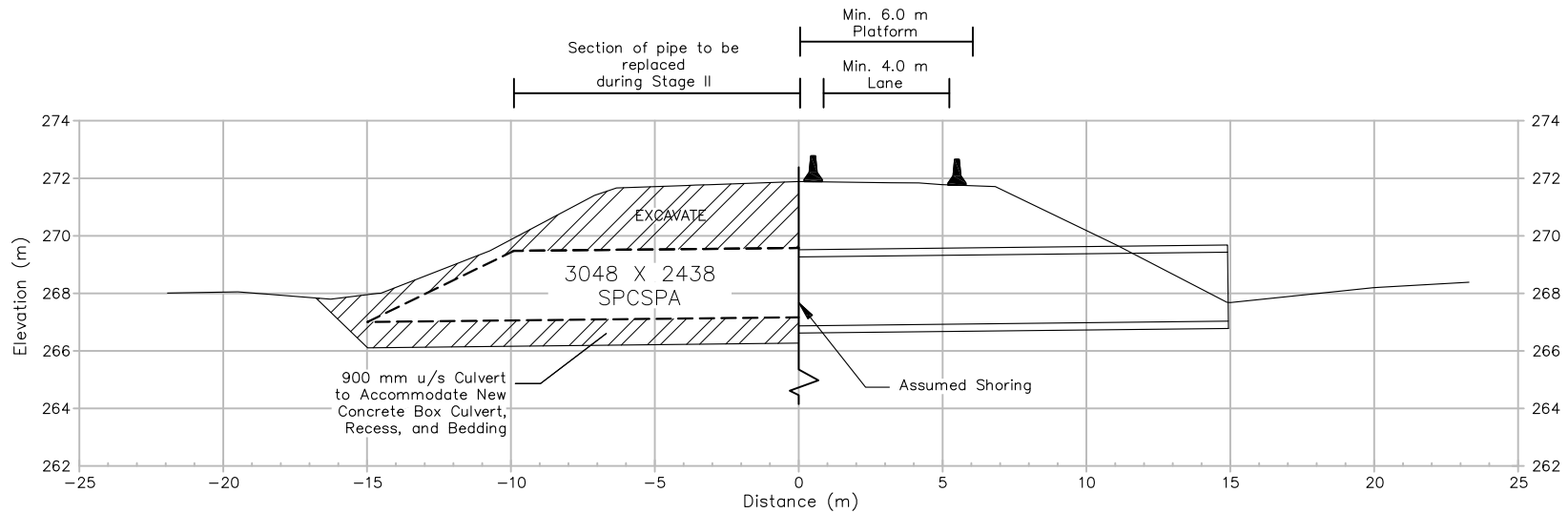


Highway 112, Township of Boston - Culvert at Station 17+400
Conceptual Shoring Location

FIGURE SK-4



STAGE I



STAGE II

Note:

Geometry based on assumption of adequate groundwater control carried out by the Contractor during excavation.

METRIC

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



