



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

**Highway 631 Rehabilitation – GWP 548-00-00  
Culvert Replacement – Culvert No. 80  
Station 10+977 - Twp. of Cooper**

# **FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT**

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**Geocres No. 42C-30**

**LVM | MERLEX**



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## **Final Foundation Investigation and Design Report**

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## 1 INTRODUCTION

LVM | MERLEX has been retained by AECOM Canada Ltd., on behalf of the Ministry of Transportation of Ontario (MTO), to carry out a foundation investigation for the proposed replacement of existing triple culverts under GWP 548-00-00. This culvert replacement is located on Highway 631, some 18.6 km north of the Junction with Hwy 17, in the Township of Cooper.

The foundation investigation location was specified by the MTO in the RFP/TPM documentation Agreement No. 5011-E-0040. The terms of reference for the scope of work are outlined in LVM | MERLEX's Proposal P-12-140, dated September, 2012. The purpose of this investigation was to determine the subsurface conditions in the area of the culverts in order to provide design recommendations. 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 triple cell Asphalt Coated Corrugated Steel Pipe (ACCSP) culverts are located at Station 10+977, Township of Cooper. The topography at the site is a low wet land area with organic terrain to the south (right) of the embankment. The existing highway embankment currently supports two undivided lanes of highway, locally running in a west to east direction. Highway 631 is designated as a south to north highway however, at the culvert location the highway runs predominately in a west to east direction. As such, for the purposes of this report, the highway has been described as oriented in a west to east direction.

The existing highway, at the culvert location, is constructed on an embankment typically consisting of granular fill, some 3.5 m deep. The embankment projects some 1.8 m above surrounding grade, with centerline elevation of 412.4 m at the culvert location. The culverts at this location are identified as triple ACCSP culverts. Each cell is 1.2 m diameter and some 19 m in length. Flow through the culverts, at this location, is from south to north (right to left) (see Photo Essay, Appendix 4).

No above ground infrastructure was observed at this culvert location at the time of this investigation.

### 2.1 SITE PHYSIOGRAPHY AND SURFICIAL GEOLOGY

This project is located in the Geomorphic Sub-province known as the Long Lake Rocky and Limy Drift Uplands. The topography on this section of Highway 631 is generally slightly rolling. There are exposed bedrock ridges. At many locations, significant layers of earth overlay the bedrock. Organic terrain was also observed. Within the project area overburden consists primarily of sands containing varying amounts of silts and gravel.

Bedrock in the area, as indicated on OGS Map 2506, is of the Early Precambrian period. In the area of this culvert foundation investigation, the bedrock comprises of granitic rocks, syenite, pegmatite, and unsubdivided migmatite.

### 3 INVESTIGATION PROCEDURES

The fieldwork for this investigation was carried out during the period of July 19<sup>th</sup> and 20<sup>th</sup>, 2013 during which time three (3) sampled boreholes was advanced. For the purposes of foundation design for the culvert replacement, one borehole were advanced at the outlet of the culverts, one (1) borehole was advanced through the embankment in the area of the culverts, and one boreholes was advanced at the inlet of the culverts.

The field investigation was carried out using a Bombardier mounted CME drill rig equipped with hollow stem augers, standard augers, 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 mounted in a trip (automatic) hammer. 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. When shallow refusal was encountered at the culvert boreholes, NQ size diamond coring equipment was used to determine the nature of shallow refusal.

Groundwater conditions in the open boreholes were observed during the advancement of, and immediately following, completion of the individual boreholes. 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. 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 field work for this investigation was under the full time direction of a senior member of our 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, Atterberg Limits testing, as well as specific gravity testing. 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 C (Figures Nos. L-1 to L-3).

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.

## **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 and Dynamic Cone Penetration Test (DCPT), plus field observations. Typically such boundaries represent transitions from one zone to another and are not an exact demarcation of a 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 CULVERTS STATION 10+977, TWP OF COOPER**

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, three (3) sampled boreholes were put down at this site, with Borehole No. 2 advanced through the embankment, and Borehole Nos. 1 and 3 advanced at the culvert ends. At the time of the subsurface investigation, the ground surface elevations at Boreholes Nos. 1 to 3 were recorded at 410.8, 412.3, and 411.2 m, respectively.

#### **4.1.1 Fill**

At surface at Borehole No. 2, a layer of embankment fill consisting of brown sand trace to some silt trace gravel was penetrated. The natural moisture content measured on samples of this deposit was in the order of 5 to 19%, indicating a dry to wet moisture condition, relative to optimum moisture content. Gradation analyses were carried out on two (2) samples of this layer, the results of which indicated 1 to 2% gravel size particles, 81 to 82% sand size particles, and 16 to 18% silt and clay size particles (Figure No. L-1, Appendix 3). Based on SPT 'N' values of 6 to 29 blows per 300 mm penetration, the compactness of this layer was described as loose to compact, typically compact. The fill layer was encountered to a depth of 3.5 m below grade (elevation 408.8 m).

#### **4.1.2 Peat**

At surface, at Borehole Nos. 1 and 3, a deposit of black to dark brown fine fibrous peat was penetrated. Wood pieces were encountered in this deposit at Borehole No. 1, and rootlets were encountered in this deposit at Borehole No. 3. The natural moisture content measured on samples of this deposit was in the order of 48 to 224%. Several in-situ shear strength tests taken in the peat stratum returned values ranging between 20 to 60 kPa. This deposit was encountered to depths of 2.3 and 1.1 m below grade at Borehole Nos. 1 and 3, respectively (elevations 408.5 and 410.1 m, respectively).

#### 4.1.3 Silt

Underlying the fill at Borehole No. 2, and underlying the peat deposit at Borehole Nos. 1 and 3, a deposit of grey silt trace to some sand trace clay was penetrated. The natural moisture content measured on samples of this deposit was in the order of 14 to 25%, indicating a moist to wet moisture condition, relative to optimum moisture content. Hydrometer analyses were carried out on six (6) samples of this deposit, the results of which indicated 0% gravel size particles, 0 to 4% sand size particles, 92 to 94% silt size particles, and 4 to 7% clay size particles (Figure No. L-2, Appendix 3). Atterberg Limits testing was undertaken on samples of this deposit, the results of which indicated this deposit is non-plastic (NP). A gradation analysis was carried out on one sample of this deposit, the results of which indicated 0% gravel size particles, 13% sand size particles, and 87% silt and clay size particles (see Figure No. L-2, Appendix 3). Based on SPT 'N' values of 9 to 21 blows per 300 mm penetration, the compactness of this deposit was described as loose to compact, generally compact. Sampling was terminated in this deposit at depths of 9.6, 12.6, and 9.6 m below grade at Borehole Nos. 1, 2, and 3, respectively (elevations 401.2, 399.7, and 401.6 m, respectively).

## 4.2 GROUNDWATER DATA

The water level at the culvert inlet and outlet was measured at elevations of 410.6 m at the time of this investigation.

Measurements of the groundwater level and cave-in levels were undertaken, where possible, in the open boreholes during the advance of the individual borings and upon completion. These levels are recorded on the individual Record of Borehole Log Sheets (Appendix B). The water levels in Borehole Nos. 1, 2, and 3 were measured at elevations 410.6, 410.5, and 410.7 m, respectively.

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



## 5 DISCUSSION AND RECOMMENDATIONS

### 5.1 GENERAL

A foundation investigation was carried for a proposed culvert replacement as identified in the RFP.

The existing culverts, located at Station 10+977, in the Township of Cooper, are triple cell 1.22 m diameter Asphalt Coated Corrugated Steel Pipe (ACCSP) culverts some 16.5 m long. At the culvert location the existing highway embankment currently supports two undivided lanes of highway. Highway 631 is designated a south-north highway. However, at the location of the culverts the highway is essentially oriented in a west to east direction. As such, for the purposes of this report, the highway has been described as oriented in a west to east direction.

Flow through the culvert is from south to 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 typically granular embankment fill. The native material, underlying the fill, generally consisted of silts. Refusal was not encountered within the depth of this investigation (i.e. to elevation 399.7 m).

The type of culvert(s) (precast box, concrete pipe, CSP, or High Density Polyethylene (HDPE)) to be used to replace the existing culverts is currently unknown. However, the new culverts will likely be constructed at a similar vertical alignment and skew to the existing culverts. The final vertical and horizontal alignment of the highway will remain essentially the same.

### 5.2 FOUNDATION CONSIDERATIONS

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

Based on the characteristics of the native silt subgrade present below the culvert, the response of the existing embankment, and a founding elevation similar to that of the existing culverts, a factored Geotechnical Resistance at ULS of 350 kPa can be used for **closed** culverts (i.e. precast concrete frame box culvert, structural plate corrugated steel pipe arch (SPCSPA) or CSP/concrete pipe culvert). In consideration of the width/diameter of the culvert and the depth of overburden, a geotechnical reaction at SLS of 115 kPa can be used for design, in consideration of less than 25 mm settlement and preloading associated with the existing embankment.

If **open** culverts (i.e. concrete frame open culvert, with wall footings, or a pipe arch culvert on footings) are considered, then a factored Geotechnical resistance at ULS of 100 kPa, and a geotechnical reaction at SLS of 75 kPa would apply for design, taking into consideration the limited depth of overburden and smaller footing width. Considering the relatively small culvert

size an open (footing type) culvert is not considered practical for this site, in consideration of the footing depth required for frost cover and scour protection.

### 5.2.1 Slope Stability

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 stable embankment slopes of 2H:1V in granular fill. The embankment was modeled as a granular fill at the culvert location, as per backfilling recommendation in Section 5.6, and inconsideration of the existing 2H:1V embankments slopes. For the purposes of these analyses, the materials were modeled using the following parameters;

PARAMETER	MATERIAL		
	EMBANKMENT FILL	PEAT	SILTS
Unit Weight (kN/m <sup>3</sup> )	20.0	10.0	17.5
Effective Friction Angle (degrees)	32	-	28
Cohesion (kPa)	-	30	-

The unit weights and friction angles for the slope calculations are based on general representative values for soil types, obtained through laboratory testing and tactile analysis. The results of the analysis indicated a factor of safety in the order of 2.0 against failure through the underlying native silt subgrade (as shown below on Figure No. S-1). As such, the stability of the finished embankment will not be an issue provided it is properly constructed as outlined in Section 5.6.

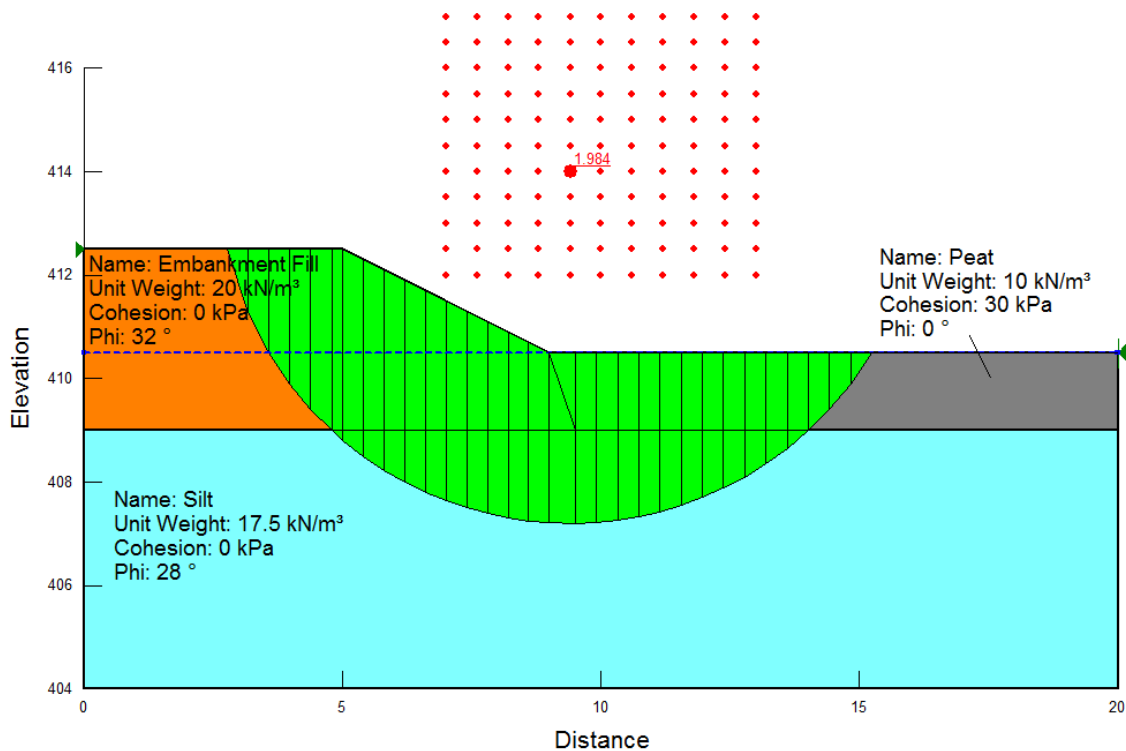


Figure S-1: Slope Stability, Station 10+977, Twp of Cooper

## 5.3 CULVERT DESIGN, BEDDING, AND EMBEDMENT

The embankment typically consists of a pavement structure overlying a granular fill embankment. The results of this investigation indicate that, below the culvert invert, the native soils at Borehole No. 2 consist of compact silts. 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 or width of the embankment, and therefore no increase in embankment load, no appreciable settlement of the embankment is anticipated. As such, installing the culvert on a camber will not be required at this site.

Due to the height and composition of the embankment at the culvert location frost tapers shall not be required, as per the geotechnical report also by LVM | MERLEX, Ref No. 13/03/13042.

### 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 200 mm. Alternatively, specifically if construction is carried out under wet conditions, a 19 mm clear stone bedding could be used, which would aid in dewatering operations. During backfilling, the embedment fill should be placed in a balanced manner on each side of the pipe. The elevation difference of the

backfill on either side of the pipe must be a maximum 200 mm. Cover material for concrete pipes can consist of Granular A and be placed to the dimensions as shown on OPSD 802.031.

Precast concrete rigid frame box culverts 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 below the outer one-third of the box unit base should be compacted to 100% Standard Proctor Dry Density, whereas the bedding under the middle 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. Alternatively, specifically if construction is carried out under wet conditions, a 19 mm clear stone bedding and levelling course could be used, which may 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 600 mm in width, centered over the joint, covering the top of the culvert and extending halfway 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 full apron of Rip Rap (R-50 size as per OPSS 1004). The apron shall extend 3 m beyond the culvert openings, be 500 mm thick and extend across the stream bed and up the embankment to 500 mm above the high water level mark. Clay seals are generally used where significant head differences exist between the inlet and outlet of a culvert to prevent flow through the embankment. Considering the anticipated culvert slope, at this location, clay seals are not required.

## 5.3.2 Flexible Steel Culvert

Flexible culverts (i.e. CSP/SPCSP/HDPE) can also be considered for culvert replacement at this site. If a flexible pipe is used for replacement, embedment material could consist of Granular B Type I provided the maximum size of stone inclusions is limited to 25 mm or less in size and placed in accordance with OPSD 802.010 for a Type 3 soil. The material in the haunch area must be compacted to 100% Standard Proctor Dry Density prior to placing the remainder of the embedment material. During backfilling, the embedment fill should be placed in a balanced manner on the outer sides of the culvert unit. The elevation difference of the backfill on either side of the culvert must be a maximum 200 mm.

The inlet and outlet stream bed shall be protected with a Rip Rap (R-50 size as per OPSS 1004) apron. The apron shall extend 3 m beyond the culvert openings, be 500 mm thick and

extend across the width of the stream bed and up the foreslope to 500 mm above the high water level. Considering the porous nature of the embankment fill and Rip Rap apron, inlet clay seals along the culvert or outlet cut-off walls are not required.

## 5.4 CULVERT INSTALLATION AND CONSTRUCTION STAGING CONSIDERATIONS

The invert elevation of the existing culvert is at 409.8 m, with the top of the embankment at elevation 412.4 m at centerline. As such, the embankment at this location is some 2.6 m in height above the culvert invert at the centerline. Therefore, a minimum 2.9 m deep excavation (i.e. to elevation 409.8 m) will be required in consideration of some 300 mm thick layer of bedding/embedment material. The present platform width at this location is some 12 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 in width to carry out an open excavation using staged construction without lowering the platform or sliver widening. Consideration could be given to constructing a vertical wall for use as a protection system. In consideration of the existing embankment geometry, open cut excavation with locally lowering the grade is recommended.

### 5.4.1 Staged Construction

The present platform width, at this location, is some 12 m as can be seen on the cross section on Figure No. 2. As such, a staged construction operation carried out by locally lowering the grade using open cut staged sequencing and a 24/7 operation for traffic control while limiting traffic flow to one lane is recommended for culvert replacement at this location (see Figure No. SK-3, Appendix 5).

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

- Locally lower the platform grade by a minimum 0.8 m
- Limit traffic to a single lane on the left under 24/7 traffic control.
- Open cut excavate, to the right, and install approximately 8 m of new culvert.
- Reconstruct the embankment on the right, with a minimum platform width of 5 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 to two lanes when sufficient width permits.

### 5.4.2 Protection System

As noted above, a temporary protection system consisting of a vertical wall can be considered for use during culvert replacement at this site. The installation of a protection system for use in the culvert replacement operation will require penetration through up to 3.5 m of typically granular embankment fill. The embankment fill is generally underlain by compact silts. 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 are illustrated on Figure No. SK-4, Appendix 5.

Considering the cohesionless nature of the embankment fills (granular pavement structure over earth 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,

$\gamma$  = unit weight, and

$H$  = height of wall above the base of excavation.

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 in Table A, Appendix 5. Conceptual shoring location is illustrated on Figure No. SK-4, Appendix 5.

The protection system can be designed using the lateral earth pressure parameters as outlines in Section 5.5.

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.

## 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	EXISTING EMBAKMENT FILL/SSM	NATIVE SILT
Unit Weight (kN/m <sup>3</sup> )	23.0	21.0	020.0	17.5
Angle of Internal Friction	35°	33°	32°	28°
Shear Strength (kPa)	-	-	-	-
Coefficient of Active Earth Pressure ( $K_a$ )	0.27	0.29	0.31	0.38

PARAMETER	GRANULAR A	GRANULAR B TYPE I	EXISTING EMBAKMENT FILL/SSM	NATIVE SILT
Coefficient of Passive Earth Pressure (Kp)	3.69	3.39	3.25	2.66
Coefficient of Earth Pressure at Rest (Ko)	0.43	0.46	0.47	0.55

For rigid structures, such as a precast concrete culvert, deflection cannot occur, as such the “at-rest” condition (Ko) applies. For flexible structures, such as CSP/HDPE culverts, deflection can occur, as such the “active” condition (Ka) 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.

The excavation backfill should consist of granular fill, to match the existing embankment, up to the underside of the pavement structure. Final (permanent) embankment side slopes in granular fills should be established to match the existing embankment or as per OPSD 200.010. Final slopes should be treated with a mulch and seed to prevent erosion.

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

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

The water level at the location of the culvert inlet and outlet was recorded at Elevation 410.6 m at the time of this investigation and excavations to an approximate elevation 409.5 m would 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. To provide a stable working surface the water level must be controlled to below the base of excavation. When wet, silty subgrades can

become easily disturbed, and can lose a significant portion of its natural bearing capacity. If an excavation greater than some 1 m below the prevailing ground water table is required, which would be the case if an open footing type culvert is considered at this site, a more sophisticated unwatering system, such as vacuum well points will have to be considered.

A sand bag cofferdam, aquadam, or a temporary sheet pile type cofferdam can be considered for controlling stream flow depending upon anticipated flow at time of construction. Considering the low anticipated head of water to be diverted, at the inlet and outlet, a gravity type cofferdam (sandbag or aquadam) is the most appropriate to temporarily control flow through the culverts. By-pass pumping can be carried out to divert the stream flow at the time of construction. Since this site has three culverts, by-pass pumping/diversion through one of the culverts can be carried out, while the adjacent culverts are being replaced.

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 foundation construction cannot be stressed enough.

## **5.7 CONSTRUCTION CONCERNS**

Considering the nature of the granular fill embankment, 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 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 not be involved during the full construction phase, our liability is strictly limited to the factual information contained herein only.

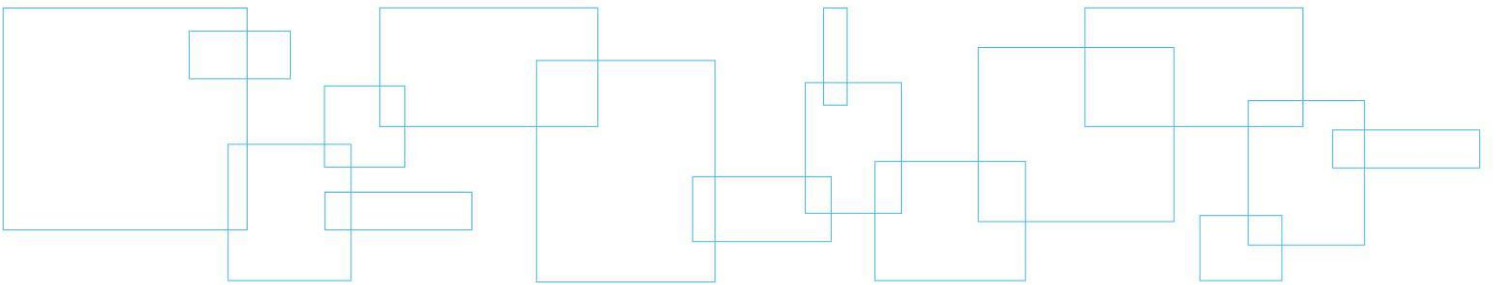
The comments in this report are intended solely for the guidance of the design engineer and address the geotechnical conditions only. The number of boreholes required to determine the localized conditions between boreholes directly affecting construction costs, equipment, scheduling, etc. would in fact 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

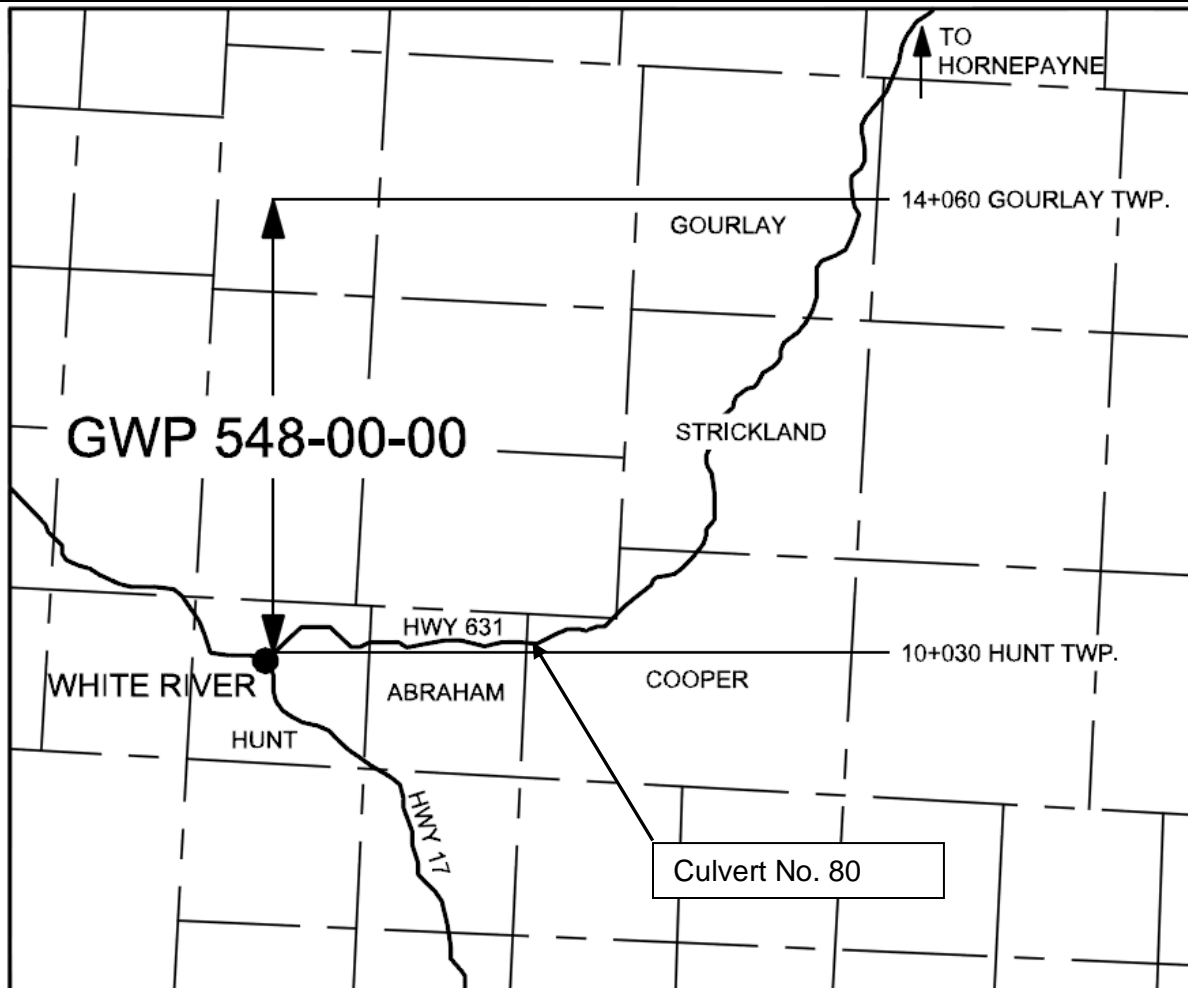
Key Plan



# KEY PLAN

Drawing No. 1

NOT TO SCALE



**FINAL  
FOUNDATION INVESTIGATION  
AND DESIGN REPORT**

**GWP 548-00-00**

Highway 631

Culvert No. 80

**LVM | MERLEX**

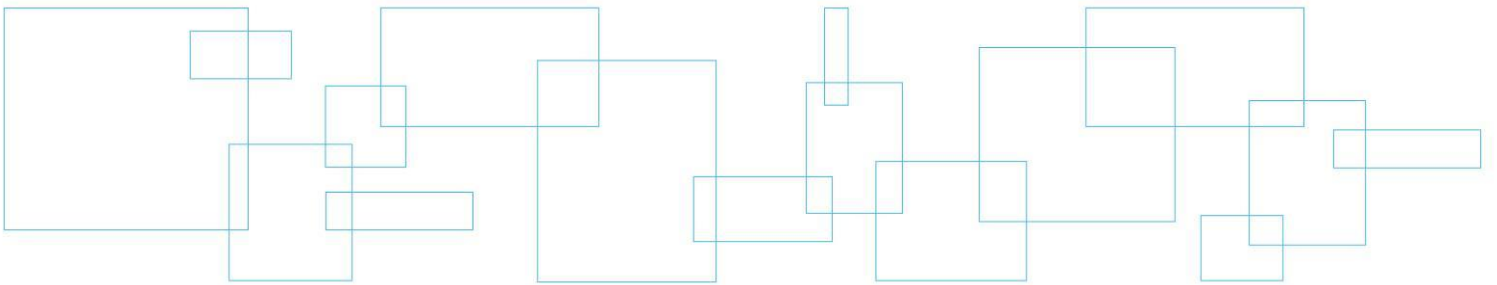
Reference No: 13/03/13042-F3

March 2014

## Appendix 2    Subsurface Data

Enclosure No. 1  
Enclosure Nos. 2 to 4

List of Abbreviations and Symbols  
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
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 13/03/13042-F3 DATUM Geodetic LOCATION N 5386536.2 E 227633.7 - Cooper Township, Culvert No. 80 ORIGINATED BY JL

PROJECT GWP 548-00-00, Highway 631 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT

CLIENT AECOM DATE (Started) 2013 July 19 TIME  CHECKED BY MAM

DATE (Completed) 2013 July 19 (Completed)

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 $\gamma$	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			20	40						60	80
410.8	Ground Surface															
0.0	PEAT - fibrous peat with wood pieces black to dark brown		1	SS	1											117
			2	SS	5											144
			3	SS	WH											224
408.5	SILT - trace sand grey, wet (compact)		4	SS	13											
2.3			5	SS	11											
			6	SS	14											
			7	SS	18											
			8	SS	18											
			9	SS	12											
			10	SS	12											
401.2	End of Sampling End of Borehole															
9.6																
COMMENTS								$+3, \times 3$ : Numbers on right refer to Sensitivity Numbers on left refer to values greater than 120 kPa $\circ$ 3% STRAIN AT FAILURE		WATER LEVEL RECORDS						
								Date (dd/mm/yy)/Time		Water Depth (m)		Cave In (m)				
								1) 13/7/19 3:20:00 PM		1.8		2.7				
								2) 13/7/19 5:35:00 PM		0.5		2.7				
								3) 13/7/20 11:00:00 AM		0.2		2.4				

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

MEL-GEO 13042 - BOREHOLE LOGS - SITE C.GPJ MEL-GEO.GDT 14/3/11

**METRIC**

REFERENCE	<u>13/03/13042-F3</u>	DATUM	<u>Geodetic</u>	LOCATION	<u>N 5386547.4 E 227640.8 - Cooper Township - Culvert No. 80</u>	ORIGINATED BY	<u>JL</u>
PROJECT	<u>GWP 548-00-00, Highway 631</u>			BOREHOLE TYPE	<u>Truck Mounted CME 45B - Hollow Stem Augers</u>	COMPILED BY	<u>AT</u>
CLIENT	<u>AECOM</u>	DATE (Started)	<u>2013 July 20</u>	TIME	<u></u>	CHECKED BY	<u>MAM</u>
		DATE (Completed)	<u>2013 July 20</u>	(Completed)	<u></u>		

[illegible]



## METRIC

## RECORD OF BOREHOLE NO. 2



REFERENCE 13/03/13042-F3 DATUM Geodetic LOCATION N 5386547.4 E 227640.8 - Cooper Township - Culvert No. 80 ORIGINATED BY JL

PROJECT GWP 548-00-00, Highway 631 BOREHOLE TYPE Truck Mounted CME 45B - Hollow Stem Augers COMPILED BY AT

CLIENT AECOM DATE (Started) 2013 July 20 TIME  CHECKED BY MAM

DATE (Completed) 2013 July 20 (Completed)

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	$w_p$	$w$	$w_L$		
	Continued from Previous Page																
	SILT - trace sand trace clay grey, wet (compact)		11	SS	12		402										
							401										
399.7			12	SS	15		400										
12.6	End of Sampling End of Borehole																

MEL-GEO 13042 - BOREHOLE LOGS - SITE C.GPJ MEL-GEO.GDT 14/3/11

## METRIC

## RECORD OF BOREHOLE NO. 3



REFERENCE 13/03/13042-F3 DATUM Geodetic LOCATION N 5386259.9 E 227632.7 - Cooper Township - Culvert No. 80 ORIGINATED BY JL

PROJECT GWP 548-00-00, Highway 631 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT

CLIENT AECOM DATE (Started) 2013 July 19 TIME  CHECKED BY MAM

DATE (Completed) 2013 July 19 (Completed)

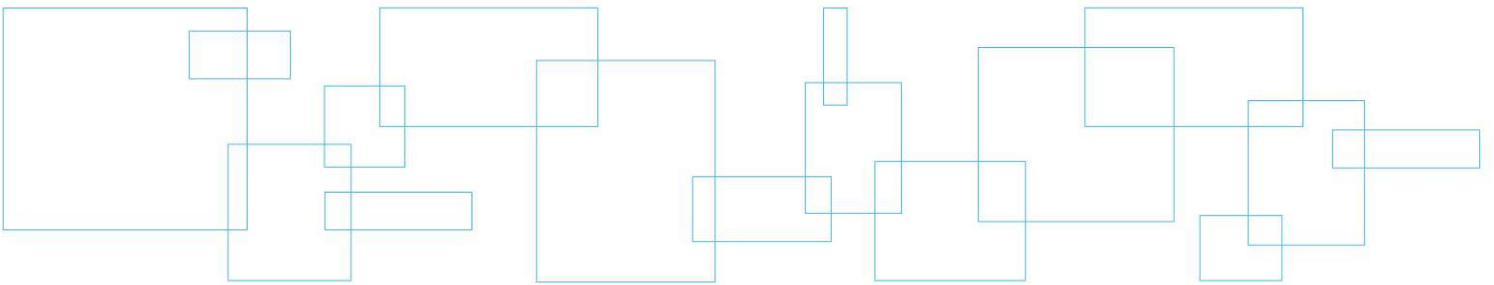
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES			20	40					
411.2	Ground Surface													
0.0	PEAT - fibrous peat trace rootlets black		1	SS	2									
410.1			2	SS	12									
1.1	SILT - trace to some sand trace clay grey, wet (loose/compact)		3	SS	21									
			4	SS	11									
			5	SS	11									
			6	SS	9									
			7	SS	15									
			8	SS	15									
			9	SS	16									
			10	SS	15									
401.6	End of Sampling End of Borehole													
9.6														
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) 13/7/19 5:35:00 PM		2.4		3.2		
								2) 13/7/20 11:05:00 AM		0.5		1.1		
								3)		-		-		

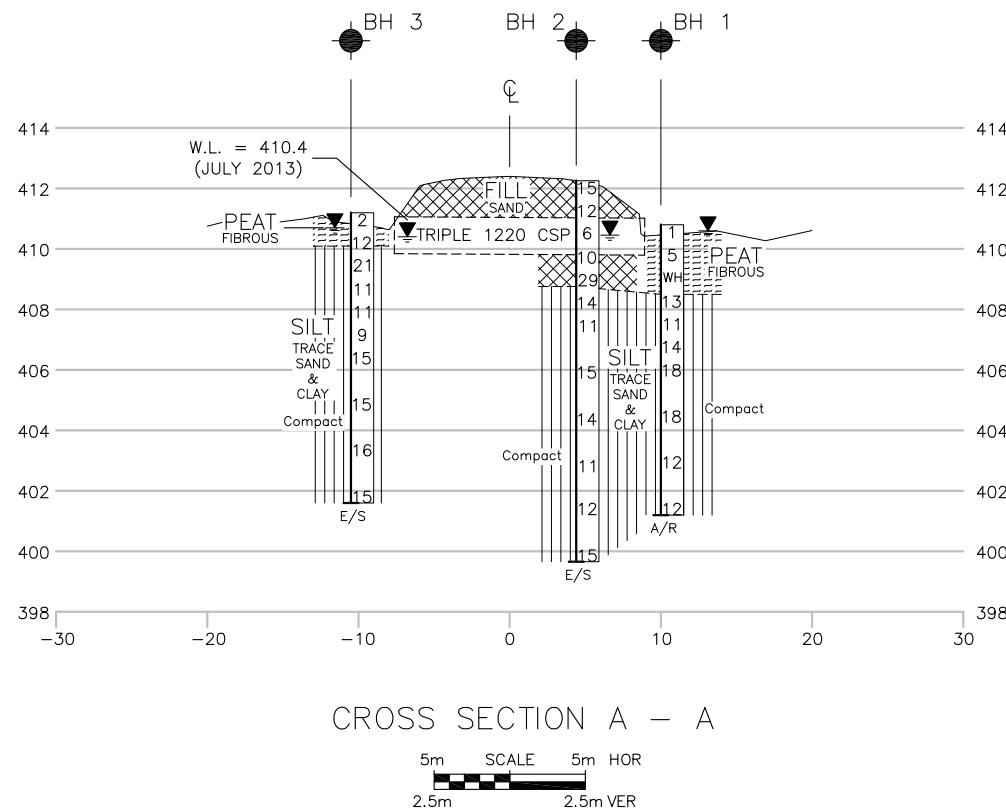
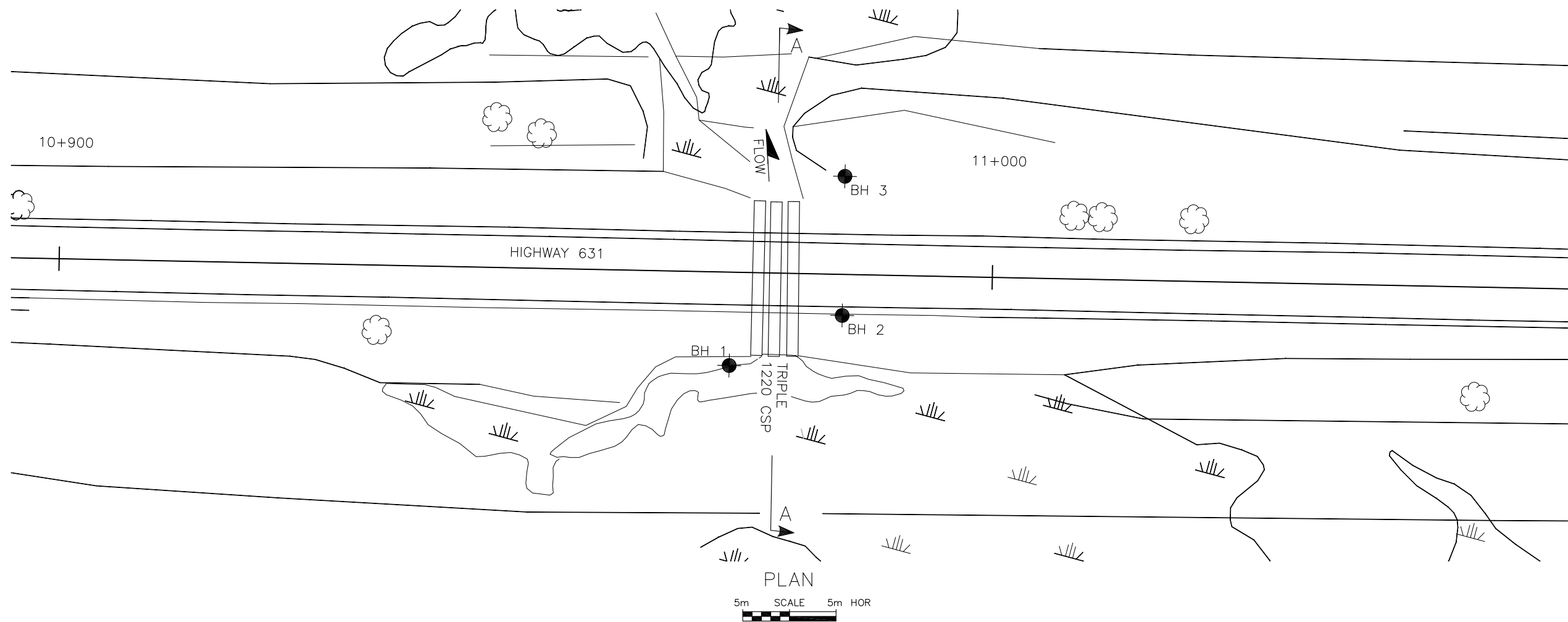
The stratification lines represent approximate boundaries. The transition may be gradual.

MEL-GEO 13042 - BOREHOLE LOGS - SITE C.G.P.J MEL-GEO.GDT 14/3/11

## Appendix 3    Borehole Plan and Lab Data

Drawing No. 2:            Borehole Location and Soil Strata  
Figure Nos. L-1 and L-2:   Grain Size Distribution Curves  
Figure No. L-3:            Lab Test Summary Sheet





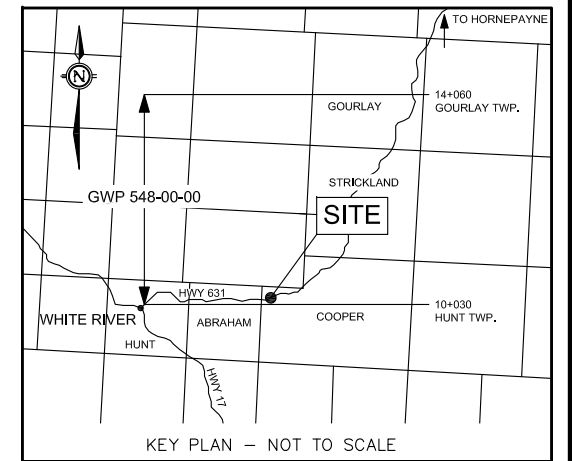
CONT. No.  
XXXX-XXXX

GWP. No.  
548-00-00

N

DRAWING  
2

HWY 631  
CULVERT #80  
STA. 10+977 - COOPER TOWNSHIP  
BOREHOLE LOCATIONS & SOIL STRATA



LEGEND

- Borehole
- N Blows/0.3 m (Std Pen Test, 475 J/blow)
- CONE 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

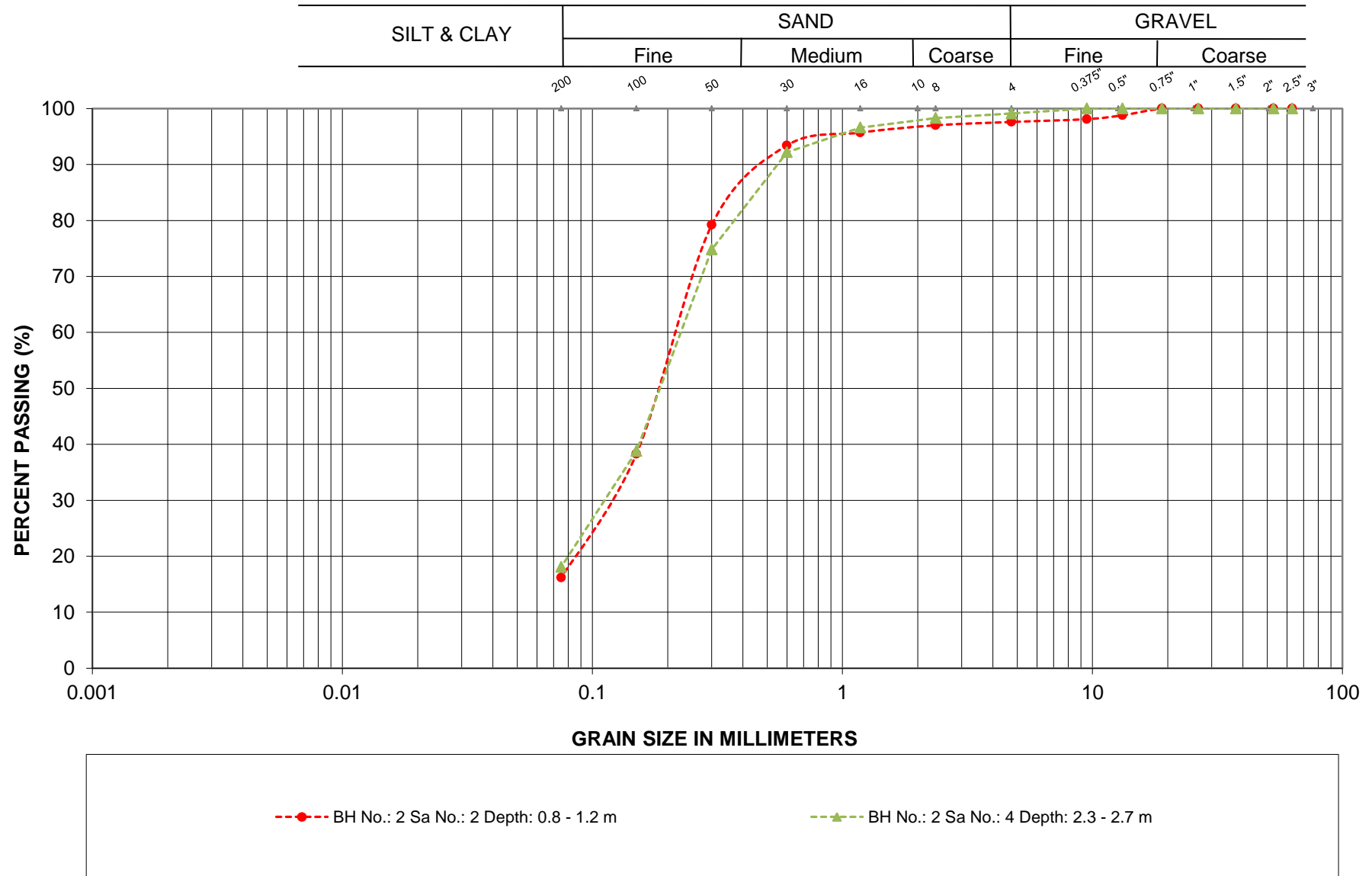
Borehole No.	Elev.	O/S	Co-ordinates	
			Northerly	Easterly
Borehole No. 1	410.8	10.0 m Rt	5386536.2	227633.7
Borehole No. 2	412.3	4.4 m Rt	5386547.4	227640.8
Borehole No. 3	411.2	10.5 m Lt	5386259.9	227632.7

NOTE 1: This drawing is for subsurface information only. Surface details and features are for conceptual illustration. The proposed structure location is shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

NOTE 2: 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.

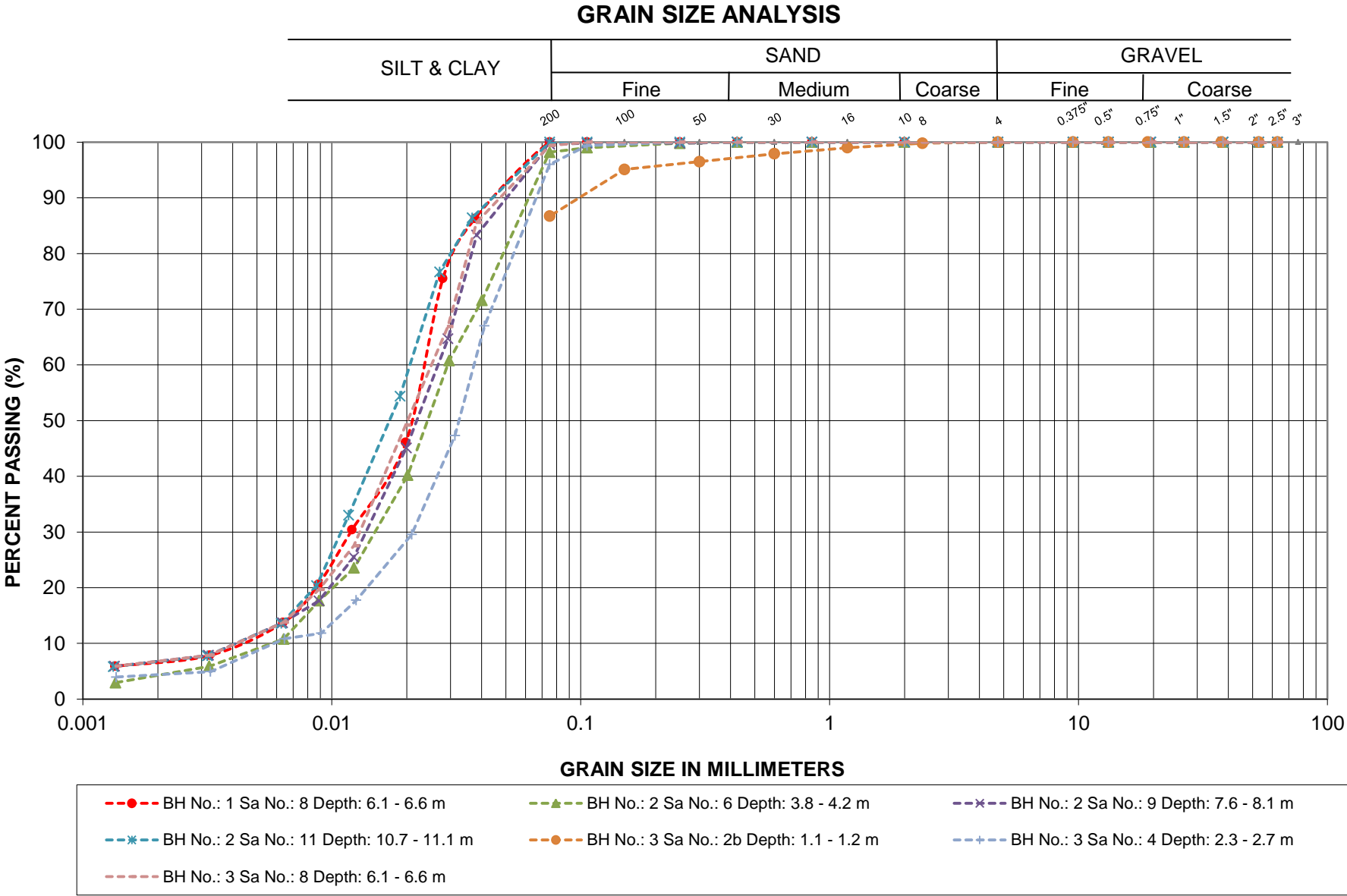
REVISIONS	DATE	BY	DESCRIPTION
	FEB 2014	RG	Revisions for Final, Add GEOCREs #
HWY NO. 631 - COOPER TOWNSHIP			
GEOCREs NO.: 42C-30			
L V M REFERENCE NO.: 13/13/13042			
DRAWN: RG		CHECKED: AT	DATE: DECEMBER 2013

# GRAIN SIZE ANALYSIS



G.W.P.: 548-00-00  
LOCATION: Hwy 631, Culvert No. 80

EMBANKMENT FILL



G.W.P.: 548-00-00  
LOCATION: Hwy 631, Culvert No. 80

SILT

## 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					116.9				1			
	2	0.8					144.0				5			
	3	1.5					223.7				WH			
	4	2.3					22.1				13			
	5	3.1					20.6				11			
	6	3.8					25.5				14			
	7	4.6					24.2				18			
	8	6.1	0	0	93	7	21.9				18			Non-Plastic
	9	7.6					16.1				12			
	10	9.1					19.7				12			
2	1	0.0					5.1				15			
	2	0.8	2	82	16		9.9				12			
	3	1.5					19.1				6			
	4	2.3	1	81	18		17.1				10			
	5	3.1					14.8				29			
	6	3.8	0	2	94	4	15.6				14			Non-Plastic
	7	4.6					14.0				11			
	8	6.1					15.2				15			
	9	7.6	0	0	93	7	17.3				14			Non-Plastic
	10	9.1					16.6				11			
	11	10.7	0	0	93	7	24.1				12			Non-Plastic
	12	12.19					15.7				15			
3	1	0.0					69.8				2			
	2a	0.8					48.2				12			
	2b	1.0	0	13	87		18.1				12			

## Laboratory Tests - Summary Sheet

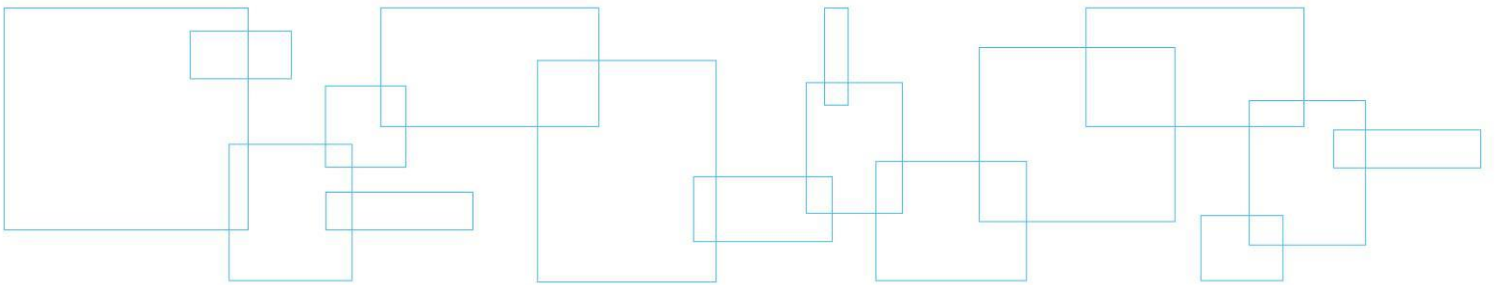
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## Appendix 4 Photo Essay

Enclosure No. 5:

Photo Essay



Left Side of Existing Embankment, Drilling Borehole No. 3 – Looking East

Photo: 1



Culvert Inlet – Looking North

Photo: 2



Project: Hwy 631 – Culvert No. 80

Photos Provided By: LVM

Date: June 2013

Culvert Outlet – Looking East

Photo: 3



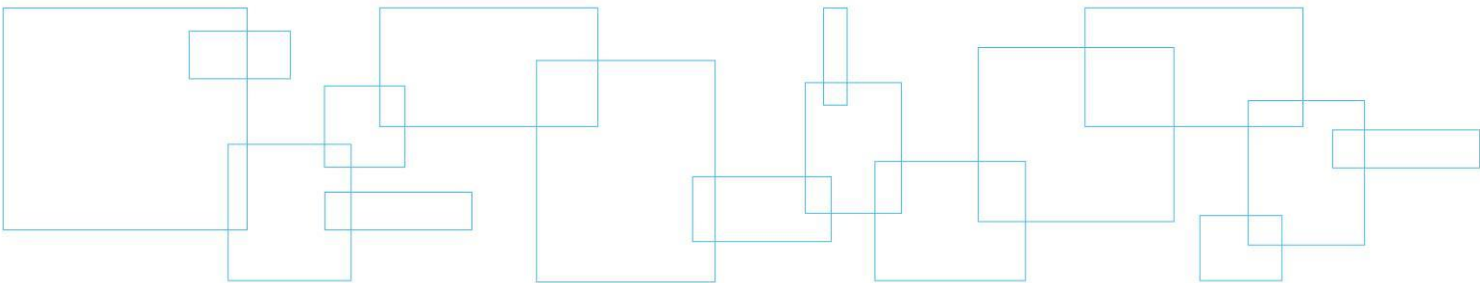
Project: Hwy 631 – Culvert No. 80

Photos Provided By: LVM

Date: June 2013

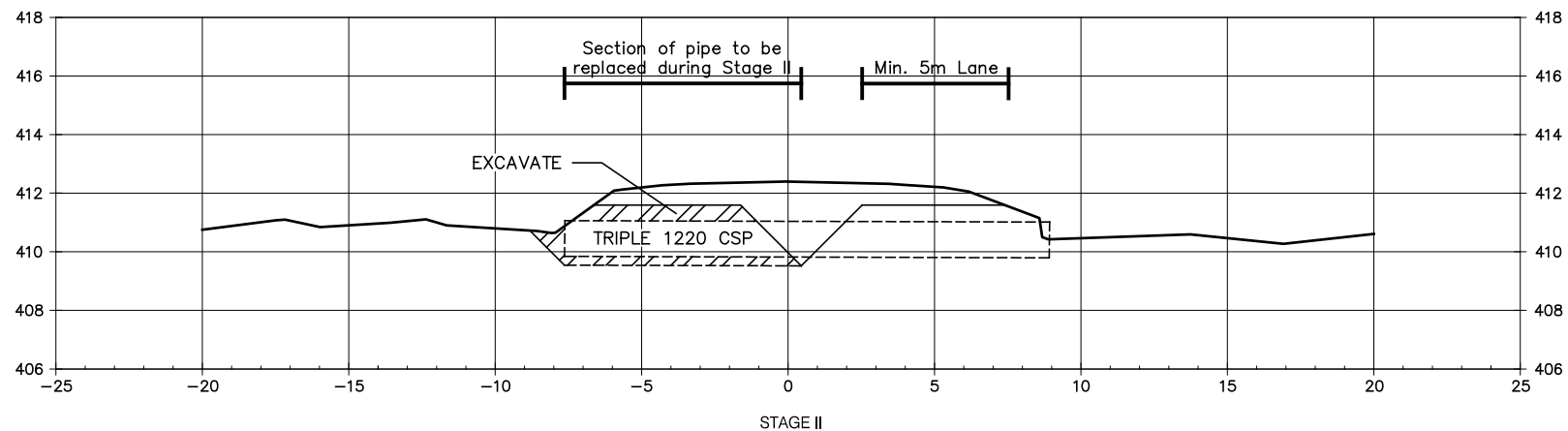
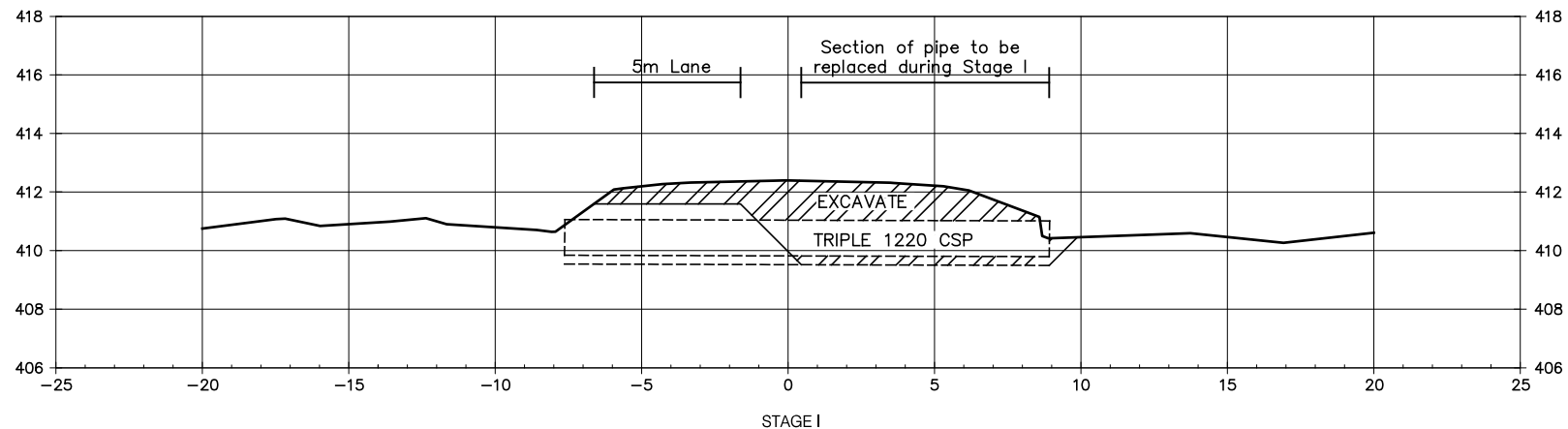
**Appendix 5      Design Data**

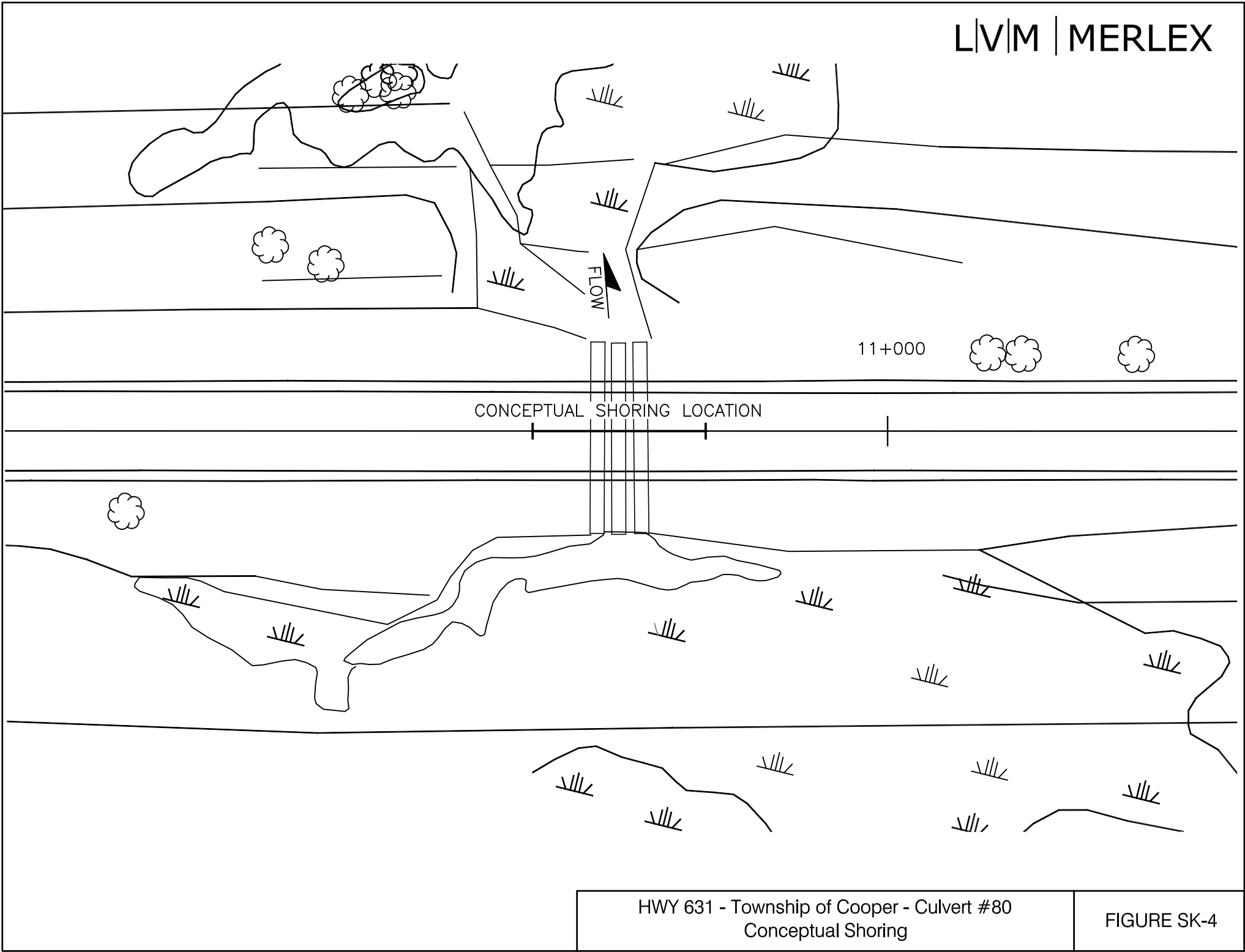
Table A:	Comparison of Shoring Alternatives
Figure SK-3:	Conceptual Staging Plan
Figure SK-4:	Conceptual Shoring Location



**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 for protection system.	\$ 650/m <sup>2</sup>
Steel Sheet Piles	5 – 21	-High strength, continuous, -Readily available	-Limited by soil conditions (i.e. obstructions)	Recommended for temporary protection.	\$ 650/m <sup>2</sup>
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	





HWY 631 - Township of Cooper - Culvert #80  
Conceptual Shoring

FIGURE SK-4