



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

**Highway 124 Rehabilitation
Culvert Replacement
Station 11+225 - Twp. of Croft
GWP 5467-09-00**

**Highway 124
From 1.0 km West of West Junction Hwy 520, Easterly 20.7 km to 2.4 km East of
Hwy 510**

FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

Date: May 30, 2013
Ref. N^o: 12/08/12141-F1

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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 an existing culvert and a detour to be used during the culvert replacement under GWP 5467-09-00. This culvert replacement is located on Highway 124, some 1.1 km East of the West Junction with Hwy 520, in the Township of Croft.

The foundation investigation location was specified by the MTO in the RFP/TPM documentation Agreement No. 5011-E-0021. The terms of reference for the scope of work are outlined in LVM | MERLEX's Proposal P-11-151, dated March, 2012. The purpose of this investigation was to determine the subsurface conditions in the area of the culvert and proposed detour 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

This Corrugated Steel Pipe (CSP) culvert is located at Station 11+225, Township of Croft. The topography at the site is a low wet land area with organic terrain to the north (left) of the embankment. The existing highway embankment currently supports two undivided lanes of highway, running in a west-east direction. The existing highway, at the culvert location, is constructed on an embankment consisting of an earth and rock fill mix, some 5.4 m in height, with centerline elevation of 269.9 m at the culvert location. The culvert at this location is a 760 mm diameter CSP culvert, some 40.41 m in length. Flow was not observed in the culvert at the time of this investigation, due to the culvert being buried (see Photo Essay, Appendix 4). Based on culvert inverts, the flow at this culvert location is from south to north, toward the wetland area.

Infrastructure at the culvert location consists of overhead wires on the south (right) side of the highway.

2.1 SITE PHYSIOGRAPHY AND SURFICIAL GEOLOGY

This project is located in the Geomorphic Sub-province known as the Muskoka Ridges and Pockets. The topography on this section of Highway 124 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 silts and silty clays containing varying amounts of sand and gravel. Bedrock outcroppings are present to the east and west of the culvert location.

3 INVESTIGATION PROCEDURES

The fieldwork for this investigation was carried out during the period of August 28th to September 20th, 2012 during which time ten (10) sampled boreholes and DCPTs, were

advanced. For the purposes of foundation design for the culvert replacement, two boreholes were advanced at the culvert outlet, three boreholes were advanced through the embankment slightly up and down chainage from the culvert, and five boreholes were advanced to the south along the toe of the embankment, two of which were advanced at the culvert inlet.

The field investigation was carried out using both a Bombardier and a truck 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. At the 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. When shallow refusal was encountered at the culvert boreholes, NQ size diamond coring equipment was used to determine the nature of shallow refusal. Testpits were advanced using a rubber tired backhoe at select borehole locations, at the toe of embankment slope, to determine the nature of 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-6).

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 CULVERT STATION 11+225, TWP OF CROFT

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, ten (10) sampled boreholes were put down at this site, with Borehole Nos. 3, 9, and 10 advanced through the embankment, and Borehole Nos. 1, 2, 4, and 8 advanced at the culvert ends. Boreholes No. 5 to 7 inclusive were advanced to the south (right) of the existing embankment along the toe to slope. At the time of the subsurface investigation, the ground surface elevations at Boreholes Nos. 1 to 10 were recorded at 265.2, 266.1, 269.9, 265.3, 268.1, 267.1, 269.4, 266.0, 269.9, and 269.9 m, respectively.

4.1.1 Pavement Structure

At surface at Borehole Nos. 3, 9, and 10, a pavement structure consisting of 75 mm of asphalt and 225 to 250 mm crushed gravel was penetrated.

4.1.2 Fill

Underlying the pavement structure base at Borehole Nos. 3, 9, and 10, a deposit of fill consisting of brown sand some silt trace to some gravel was penetrated. The natural moisture content measured on samples of this deposit was in the order of 2 to 4%. Gradation analyses were carried out on two (2) samples of this deposit, the results of which indicated 2 to 18% gravel size particles, 72 to 84% sand size particles, and 10 to 14% silt and clay size particles (Figure No. L-1, Appendix 3). Auger refusal was encountered in this deposit at depths of some 0.8, 0.8, and 0.9 m below grade at Borehole Nos. 3, 9, and 10, respectively (elevations 269.1, 269.1, and 269.0 m, respectively). NQ casing with diamond coring equipment was used to advance past the auger refusal depth.

4.1.3 Earth and Rock Fill Mix

Borehole Nos. 3, 9, and 10 were advanced using NQ sized diamond coring equipment to determine the nature of shallow auger refusal encountered at BH Nos. 3, 9, and 10. Underlying the granular fill (subbase), a deposit of earth (sands and gravels) and rock fill mix was penetrated. This fill deposit was encountered to depths of 4.7, 3.8, and 5.2 m below grade, respectively (elevations 265.2, 266.1, and 264.7 m, respectively).

Refusal of DCPT driven from surface was encountered in this deposit at depths of 3.4 and 3.6 m below grade at Borehole Nos. 3 and 10 (elevations 266.5 and 266.3 m).

4.1.4 Surficial Organics

At surface, at BH Nos. 1 and 5, a layer of surficial organics, some 50 to 100 mm thick, was penetrated.

4.1.5 Silt

Underlying the surficial organics at Borehole Nos. 1 and 5, underlying the embankment fill at Borehole Nos. 3, 9, and 10, and at surface at Borehole Nos. 2, 4, 6, 7, and 8 a deposit of brown to grey silt, trace to with sand, some to with clay, trace gravel was penetrated. Organics were encountered in this deposit at Borehole Nos. 2, 4, and 8. The natural moisture content measured on samples of this deposit was in the order of 20 to 46%. Hydrometer analyses were carried out on seven (7) samples of this deposit, the results of which indicated 0 to 4% gravel size particles, 2 to 37% sand size particles, 55 to 76% silt size particles, and 7 to 25% clay size particles (Figure No. L-2, Appendix 3). Atterberg Limits testing was attempted on seven samples of this deposit, the results of which indicated this deposit is a non-plastic sandy silt to a clayey silt (SM to CL). The plasticity increased with depth at Borehole No. 1, to the point where the lower part of this deposit was classified as silty clay (CI). This deposit was encountered to depths of 1.2, 2.9, 6.1, 0.8, 0.8, 3.0, 5.3, and 6.0 m, at Borehole Nos. 1, 2, 3, 5, 6, 8, 9 and 10 respectively (elevations 264.0, 263.2, 263.8, 267.3, 266.3, 263.0, 264.6, and 263.9 m, respectively). Auger refusal was encountered in the deposit (on bedrock) at depths of 0.8 and 0.2 m, at Borehole Nos. 4 and 7 m, respectively (elevations 264.5 and 269.2 m, respectively).

DCPT refusal was encountered in this deposit (on bedrock) at depths of 0.8, 0.2, and 5.3 m at Borehole Nos. 4, 7, and 9, respectively (elevations 264.5, 269.2, and 264.6 m, respectively).

4.1.6 Silty Clay

Underlying the silt at Boreholes Nos. 2, 3, and 8, transition to a deposit of grey silty clay was encountered. The natural moisture content measured on samples of this deposit was in the order of 30 to 46%. A hydrometer analysis was carried out on one (1) sample of this deposit, the results of which indicated 0% gravel size particles, 1% sand size particles, 54% silt size particles, and 45% clay size particles (Figure No. L-3, Appendix 3). Atterberg Limits testing was carried out on one (1) sample of this deposit, the results of which indicated a Plastic Limit in the order of 22% and a Liquid Limit in the order of 41% (Figure No. L-5, Appendix 4). Based on

results of Atterberg Limits testing, this deposit was described as a silty clay of medium plasticity (CI). Based on SPT 'N' values of 0 (static weight of hammer) to 11 blows per 300 mm, and based on tactile examinations, the consistency of this deposit was estimated as firm to stiff. This deposit was encountered to a depth of 3.8 m below grade at Borehole Nos. 2 and 8 (elevations 262.3 and 262.2 m, respectively). Auger refusal was encountered in this deposit at a depth of 7.3 m below grade at Borehole No. 3 (elevation 262.6 m).

4.1.7 Sand

Underlying the silt deposit at Borehole Nos. 1, 5, and 6, and underlying the silty clay deposit at Borehole Nos. 2 and 8, a deposit of grey sand some silt to silty, some to with gravel was penetrated. The natural moisture content measured on samples of this deposit was in the order of 6 to 26%. Gradation analyses were carried out on three (3) samples of this deposit, the results of which indicated 1 to 25% gravel size particles, 49 to 61% sand size particles, and 14 to 43% silt and clay size particles (Figure No. L-4, Appendix 3). Auger refusal was encountered in this deposit at depths of 2.0, 4.3, 2.0, 1.6, and 4.3, m at Borehole Nos. 1, 2, 5, 6, and 8, respectively (elevations 263.2, 261.8, 266.1, 265.5, and 261.7 m, respectively). DCPT Refusal was encountered in this deposit at depths of 1.7, 4.3, 0.8, 1.6, and 4.3 m below grade at Borehole Nos. 1, 2, 5, 6, and 8, respectively (elevations 263.5, 261.8, 267.3, 265.5, and 261.7 m, respectively).

4.1.8 Bedrock

Underlying the silty clay at Borehole No. 3, and underlying the silt at Borehole Nos. 9 and 10, bedrock was proven by diamond core drilling. The bedrock was described as a pink to grey gneiss. Based on a RQD of 46 to 98% the bedrock was described as good quality. Sampling in the bedrock was terminated at depths of 10.3, 8.3, and 9.0 m below grade at Borehole Nos. 3, 9, and 10 (elevations 259.6, 261.6, and 260.9 m).

The bedrock surface was exposed by advancing testpits at the locations of Borehole Nos. 1, 6, and 7, at depths of 1.5, 0.9, and 0.2 m, respectively (elevations 263.7, 266.2, and 269.2 m, respectively).

4.2 GROUNDWATER DATA

The water level at the culvert inlet and outlet was measured between elevations of 264.8 and 265.1 m (outlet (submerged) and inlet, respectively), 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, 5, and 8 were measured at elevations 264.2, 262.7, 266.3, and 262.2 m upon completion, respectively. Borehole Nos. 3, 4, 6, 7, 9, and 10 were dry upon completion.

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 and design of a detour as identified in the RFP.

The existing culvert, located at Station 11+225 in the Township of Croft, is a 760 mm diameter CSP culvert some 40.41 m long. The existing highway embankment currently supports two undivided lanes of highway, running in an east-west direction. Based on culvert inverts, flow through the culvert is from right to left (i.e. south to north). 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 an earth and rock fill mix. The native material, underlying the fill, generally consisted of silts with varying sand and clay content underlain by silty clays and sands with bedrock (proven by diamond core drilling, at the location of Borehole Nos. 3, 9, and 10) at elevations 262.6 to 264.6 m. Based on testpits advanced at Borehole Nos. 1, 6, and 7, refusal at these boreholes was on bedrock (see Photo Essay, Appendix 4).

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

5.2 FOUNDATION CONSIDERATIONS

The founding native compact silts and firm to stiff silty clays present below the existing embankment are considered adequate for support of a culvert and for a conventional highway embankment of this height. 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 silty clay subgrade present below the culvert, the response of the existing embankment, and a founding elevation similar to that of the existing culvert, a factored Bearing Resistance at ULS of 125 kPa can be used for a closed culvert (i.e. precast concrete frame box culvert 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 125 kPa can be used for design, in consideration of less than 25 mm settlement and preloading associated with the existing embankment.

If an open culvert (i.e. concrete frame open culvert, with wall footings, or a pipe arch culvert on footings) is considered, then a factored Bearing resistance at ULS of 85 kPa, and a geotechnical reaction at SLS of 85 kPa would apply for design, taking into consideration the limited depth of overburden and smaller footing width. Considering the relatively small culvert

size we do not consider an open box culvert practical for this site, in consideration of the footing depth required for frost cover and scour protection.

5.2.1 Slope Stability

The maximum height of fill above surrounding grade of the embankment at this location is some 5.4 m at the culvert location. 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 earth fill. The embankment was modeled as an earth fill at the culvert location, as per backfilling recommendation in Section 5.6, and in consideration of the existing 2H:1V embankment slopes. The embankment material was modeled using an upper granular fill, with a unit weight of 21 kN/m^3 and a friction angle of 31° , and an earth fill, using a unit weight of 17.5 kN/m^3 and a friction angle of 30° . The native silts were modeled using a representative value of unit weight of 17.5 kN/m^3 and a friction angle of 27° . The silty clays were modeled using representative values of unit weight of 16.5 kN/m^3 and a shear strength of 30 kPa. The native sands were modeled using a unit weight of 18 kN/m^3 and a friction angle of 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 1.3 against failure through the underlying native silt subgrade (see Figure No. S-1, Appendix 5). As such, the stability of the finished embankment will not be an issue provided it is properly constructed as outlined in Section 5.6.

5.3 CULVERT DESIGN, BEDDING, AND EMBEDMENT

The embankment consists of granular fills overlying an earth and rock fill mix. The results of this investigation indicate that, below the culvert invert, the native soils at Borehole No. 3 consist of firm to stiff silty clay, underlain by bedrock. A review of the condition of the pavement surface, at the culvert locations, revealed minor asphalt cracking, however, in general, the embankment appears to have performed well. The existing embankment has preloaded the soils at the culvert locations and since there will be no change in the height of the embankment, and therefore no 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. 12/08/12141.

5.3.1 Rigid Concrete Culvert

A concrete pipe can be considered for culvert replacement at this site. A Class B Bedding for the concrete pipe 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 pipe can consist of Granular A and placed to the dimensions as shown on OPSD 802.031.

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 be 3 m in width, 500 mm thick and extend across the stream bed and up the embankment to the culvert. 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

A flexible culvert (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.

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. However, the inlet and outlet stream bed shall be protected with a rip-rap (R-50 size as per OPSS 1004) apron. The apron shall be 3 m in width, 500 mm thick and extend across the width of the stream bed.

5.4 CULVERT INSTALLATION AND CONSTRUCTION STAGING CONSIDERATIONS

The invert elevation of the existing culvert is at 263.9 m, with the top of the embankment at elevation 269.9 m at centerline. As such, the embankment at this location is some 6.0 m in height above the culvert invert at the centerline. Therefore, a minimum 6.3 m deep excavation (i.e. to elevation 263.6 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 10 m as can be seen on the cross section on Drawing No. 2. The platform width at this location, as is, will not be sufficient in width to carry out an open excavation using staged construction.

Consideration could be given to constructing a vertical wall for use as a protection system, however, due to the rock fill mixed with earth fill in the embankment at this culvert location, installing a protection system will be problematic. It is understood that the preferred method of replacing the culvert under consideration is to construct a detour to the south (right) of the existing embankment to allow an open cut excavation for culvert replacement.

5.4.1 Detour

As noted, it is understood that a detour may be used to allow culvert replacement using open cut excavation methods. It is understood that it is proposed to construct a detour which will consist of a temporary road constructed to the south (right) of the existing embankment, to

accommodate traffic while an open cut excavation is carried out to allow replacement of the culvert. It is anticipated that the detour will be temporary and greater than 1.2 m in height and, as such, it will not be necessary to strip the topsoil/organics however the tree and shrub cover should be cut. Based on the results of this investigation, the existing soils are considered acceptable to support the proposed detour embankment, which may consist of up to some 5 m of fill, depending upon design speed.

The proposed detour can be constructed using rock fill, granular fill, or earth fill (provided that it is at a moisture content that will allow compaction). Embankment fill should be placed in regular lifts in accordance with OPSS 206.07.07 and compacted to 95% Standard Proctor Dry Density (SPDD). The pavement structure on the detour should consist of a 300 mm subbase with a 100 mm base. The final lifts of Granular A and Granular B Type I should be compacted to 100% SPDD.

5.4.1.1 **Detour Slope Stability**

A stability analysis, using the GEO-SLOPE computer program, Slope/W was carried out at this location for a detour to the south of the existing embankment. The detour was modelled as an earth fill embankment with standard stable embankment slopes of 2.0H:1.0V. The earth fill material was modeled using a unit weight of 17.5 kN/m^3 and a friction angle of 30° . The results of the analysis indicated a factor of safety in the order of 1.3 against failure through the underlying native silt subgrade (see Figure Nos. S-2, Appendix 5). The stability of the temporary detour will not be an issue provided it is constructed at a 2H:1V slope.

5.4.2 **Protection System**

As noted above, consideration could also be given to constructing a vertical wall for use as a temporary protection system. The installation of a protection system for use in the culvert replacement operation will require penetration through up to 4.3 m of earth and rock fill mix. The embankment fill is generally underlain by compact silts, and silty clays, overlying bedrock. Considering the presence of rock fill in the embankment, advancing a temporary retaining system (i.e. driven sheet piles) through the rock fill may be problematic. Several approaches to constructing a protection system are described in the following. See Table A, Appendix 5, for advantages and disadvantages for the different type of protection system considered for this site. Conceptual shoring locations are illustrated on Figure No. SK-4, Appendix 5.

One method to construct a protection system would be to penetrate the rock fill in the embankment with H piles (soldier piles) extending into the underlying silts and/or bedrock and install lagging. Pre-drilling will likely be required to advance the H piles through the rock fill and into the underlying the bedrock. The H piles would be installed at an interval of 2.5 to 3 m apart and the lagging would be installed as the excavation progresses. A waler and raker system or tie back anchor system would have to be installed as the excavation advances. The contractor must be prepared to address large pieces of rock fill and control groundwater as the excavation progresses, without compromising the adjacent active lane of traffic.

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

$$R = \sigma'_z * A_s * L_s * \alpha_g \quad \text{Where:}$$

σ'_z = effective vertical stress at the midpoint of the load
carrying length

A_s = effective unit surface area of the anchor

L_s = effective embedment length of the anchor

α_g = anchorage coefficient use 1.0 for granular backfill

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

Alternatively, a drilled micropile system with an intermediate support system of reinforced shotcrete, to act as lagging, could be considered for roadway protection at this site. One method of constructing this system would be to drill in micropiles, advancing to either side of the culvert below the invert several meters into the compact silts or probably into bedrock, depending upon the size and capacity of the micropiles. Over the actual culvert location, the piles would be carried down to top of culvert grade followed by bracing, with a suitably sized waler and anchorage system, tied into the full depth piling at the culvert sides, in order to provide support at the top of the piling over the culvert barrel. Depending on the section properties of the retaining structure, walers and bracing struts or ground anchor support systems will probably be required. As the excavation progresses downward in 1 to 1.2 m lifts, a reinforced shotcrete, tied into the piles, is applied. Once one half of the box culvert construction is complete, a system of buried anchors could be installed to tie back the micropiles as the highway fill is brought up to grade. When the excavation on the opposite side reaches the anchor depths, a support waler, if required, can be placed and tensioned to support the shotcrete as specified in the contractor's approved shoring design.

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 E. Conceptual shoring locations are illustrated on Figure No. SK-4, Appendix E.

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

Considering the cohesionless nature of the embankment fills (granular pavement structure over an earth fill and rock fill mix) 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,

γ = unit weight, and

H = height of wall above the base of excavation.

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	GRANUL AR A	GRANUL AR B TYPE I	ROCK FILL	SSM/ EARTH FILL	NATIVE SILT	NATIVE SILTY CLAY	NATIVE SAND
Unit Weight (kN/m ³)	23.0	21.0	18.5	17.5	17.5	16.5	18
Angle of Internal Friction	34°	31°	43°	30°	27	-	30
Shear Strength (kPa)	-	-	-	-	-	30	-
Coefficient of Active Earth Pressure (K_a)	0.28	0.32	0.19	0.33	0.38	-	0.33
Coefficient of Passive Earth Pressure (K_p)	3.54	3.12	5.29	3.00	2.66	-	3.00
Coefficient of Earth Pressure at Rest (K_o)	0.44	0.48	0.32	0.50	0.55	-	0.50

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

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 an earth fill or Select Subgrade Material (SSM) up to the underside of the pavement structure. An SSM material must be used within the depth of frost penetration. A non-woven class II geotextile shall be placed over the existing excavations slopes prior to placement of the backfill, see Figure SK-2, Appendix 5. Final (permanent) embankment side slopes in earth or granular fills should be established at the standard angle of 2H:1V. A granular sheeting, some 300, mm thick should be placed over slopes in earth fill/SSM.

Bedrock was not encountered within the anticipated depth of excavation, therefore bedrock excavation and/or blasting operations are not anticipated. However, bedrock was encountered within a shallow depth below the base of the required excavation.

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 between elevations 264.8 and 265.1 m at the outlet and inlet, respectively, at the time of this investigation and excavations to an approximate elevation 263.6 m would be required to install the culvert and bedding. As such dewatering will be required during excavation and culvert installation.

Considering the negligible flow, based on visual assessment at the time of investigation (see Photos Appendix 4) it is likely that constructing a cofferdam, with bypass pumping, will be adequate to control the anticipated flow during construction. A cofferdam may be considered to control ground water at the culvert outlet. It should be noted that refusal was encountered at a shallow depth (2.0 m below grade) at the culvert inlet. As such, there may be insufficient depth for a sheet pile type cofferdam. Therefore, a sand bag cofferdam should be considered at the culvert inlet.

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

Constructing a new embankment for a one lane (with temporary lights) or two lane detour is feasible from a foundation point of view but would require additional property and environmental clearance. Construction of a protection system along centreline will be difficult due to the up to 4.3 m of rock fill in the existing embankment. We do not anticipate any major construction difficulties during construction of the detour and culvert replacement if proper dewatering is carried out.

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.

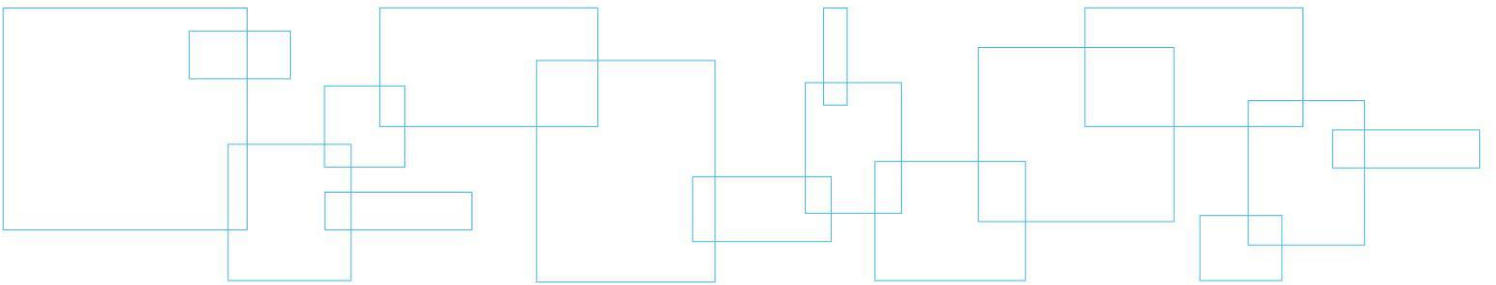
The comments in this report are intended solely for the guidance of the design engineer and address the geotechnical conditions only. The number of boreholes required to determine the localized conditions between boreholes directly affecting construction costs, equipment, scheduling, etc. would in fact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

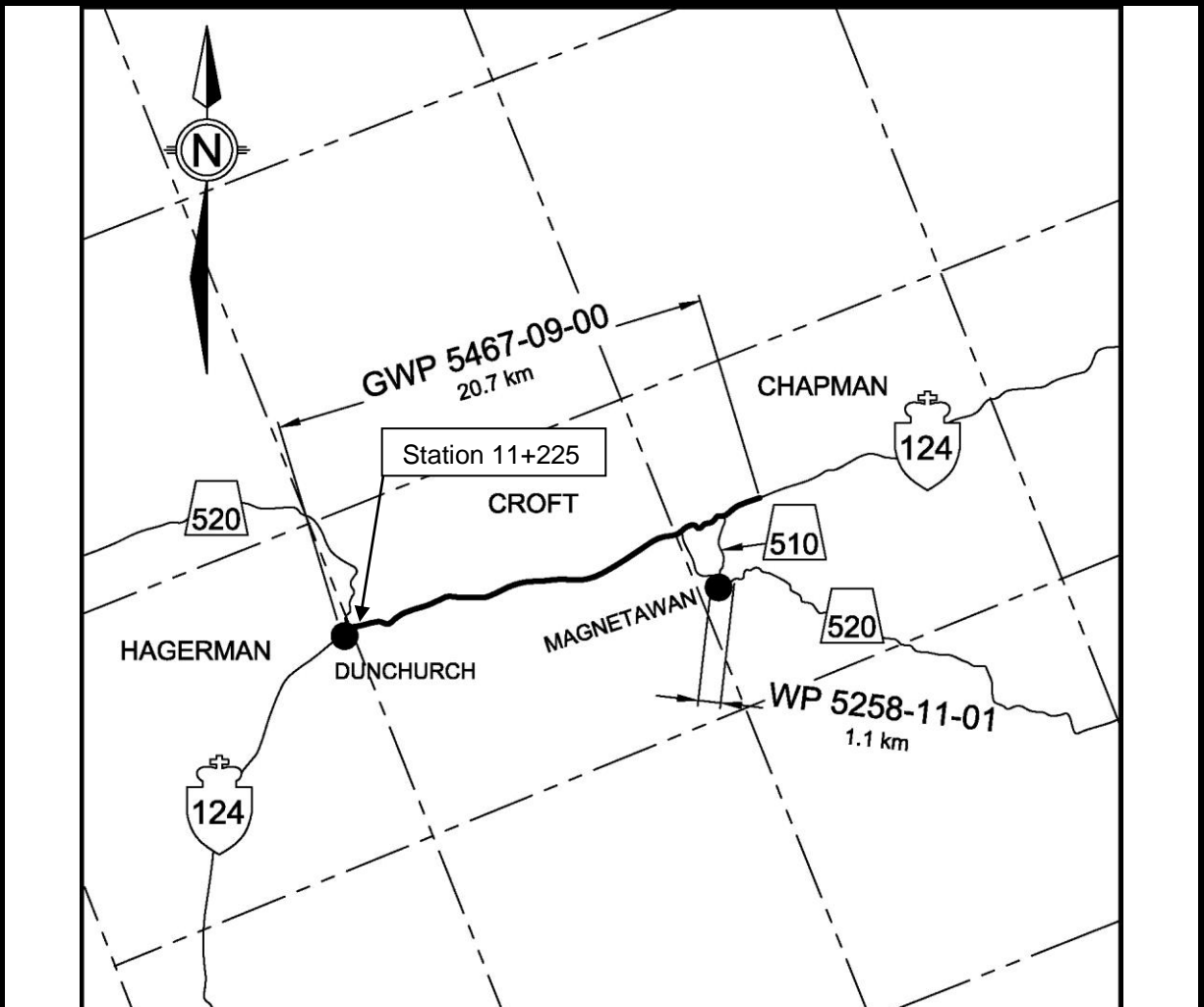
Key Plan



KEY PLAN

Drawing No. 1

NOT TO SCALE



FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

GWP 5467-09-00
Highway 124

From 1.0 km West of West Junction Hwy 520,
Easterly 20.7 km to 2.4 km East of Hwy 510

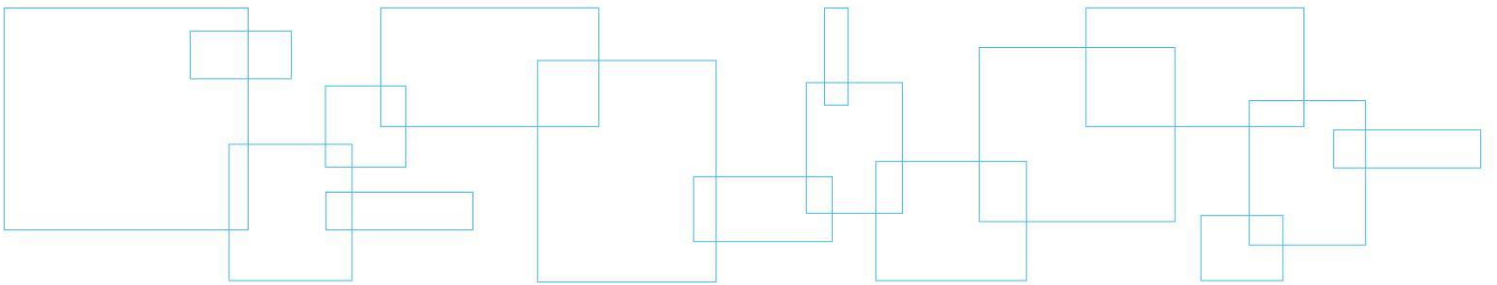
Reference No: 12/08/12141-F1

May 2013

LVM | MERLEX

Appendix 2 Subsurface Data

Enclosure No. 1	List of Abbreviations and Symbols
Enclosure Nos. 2 to 11	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

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) *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.

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/or boulders frequency is an estimate based on drill response and field observations:

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

5. LABORATORY TESTS

P	Standard Proctor Test
A	Atterberg Limit Test
GS	Grain Size Analysis
H	Hydrometer Analysis
C	Consolidation

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. 01



REFERENCE 12/08/12141-F1 DATUM Geodetic LOCATION N 5057100.9 E 278954.2 - Township of Croft ORIGINATED BY JL
 PROJECT GWP 5467-09-00, Highway 124 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT
 CLIENT AECOM Inc. DATE (Started) 28 August 2012 TIME
 DATE (Completed) 28 August 2012 (Completed) 1:45:00 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								
265.2	Ground Surface											
0.0	100 mm organics											
	SILT - brown and grey silt trace sand some clay trace gravel		1	AS								
	plasticity increasing with depth (compact)		2	SS	17							4 2 76 18
264.0												
1.2	SAND - grey sand some silt some gravel (compact)											
263.5												
1.7	DCPT Refusal		3	SS	60/275 mm							
263.2												
2.0	Auger Refusal End of Borehole											

COMMENTS		WATER LEVEL RECORDS	
Testpit advanced at borehole location. Bedrock encountered at 1.5 m.		Date (dd/mm/yy)/Time	Water Depth (m)
The stratification lines represent approximate boundaries. The transition may be gradual.		1) 28/8/12 1:38:00 PM	0.9
		2) 31/8/12 8:00:00 AM	1
		3)	-

MEL-GEO 12141 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 4/6/13



METRIC

RECORD OF BOREHOLE NO. 02



REFERENCE 12/08/12141-F1 DATUM Geodetic LOCATION N 5057134.7 E 278945.6 - Township of Croft ORIGINATED BY JL
 PROJECT GWP 5467-09-00, Highway 124 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT
 CLIENT AECOM Inc. DATE (Started) 11 September 2012 TIME 11 September 2012
 DATE (Completed) 11 September 2012 (Completed) 2:05:00 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								
266.1	Ground Surface												
0.0	SILT - brown silt trace to with sand some clay trace gravel trace organics		1	AS									
	brown		2	SS	2								1 23 66 10
	grey												
	(very loose/ loose)		3	SS	10								
			4	SS	9								0 9 77 14
263.2	SILTY CLAY - grey silty clay												
2.9	medium plasticity		5	SS	WH								0 1 54 45
	(firm)												
262.3	SAND - grey sand some silt some gravel		6	SS	25/25 mm								
3.8	Auger Refusal												
262.1													
4.0													
261.8	DCPT Refusal												
4.3	End of Borehole												
COMMENTS								+ 3, × 3 : Numbers on right refer to Sensitivity Numbers on left refer to values greater than 120 kPa ○ 3% STRAIN AT FAILURE					
								WATER LEVEL RECORDS Date (dd/mm/yy)/Time 1) 11/9/12 2:00:00 PM 2) 3)					
								Water Depth (m) 3.4 - -					
								Cave In (m) 3.9 - -					

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

MEL-GEO 12141 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 4/6/13



METRIC

RECORD OF BOREHOLE NO. 03



REFERENCE 12/08/12141-F1 DATUM Geodetic LOCATION N 5057120.5 E 278944.8 - Township of Croft ORIGINATED BY JL
 PROJECT GWP 5467-09-00, Highway 124 BOREHOLE TYPE Truck Mounted CME 45B - Hollow Stem Augers and NQ casing COMPILED BY AT
 CLIENT AECOM Inc. DATE (Started) 19 September 2012 TIME (Completed) 5:00:00 PM CHECKED BY MAM
 DATE (Completed) 19 September 2012

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								
269.9	Ground Surface												
0.0	75 mm Asphalt 250 mm Crushed Gravel FILL - brown sand some silt trace gravel		1	AS									2 84 (14)
269.1	Auger Refusal EARTH AND ROCK FILL MIX advanced NQ size casing through earth and rock fill mix												
0.8													
266.5	DCPT Refusal EARTH AND ROCK FILL MIX												
3.4													
265.2	SILT - grey sandy silt to silty sand trace clay trace gravel (very loose/loose)		2	SS	4								1 37 55 7
4.7			3	SS	WH								
263.8	SILTY CLAY - grey silty clay trace to some sand (firm)		4	SS	11								
6.1													
262.6	BEDROCK - pink to grey gneiss		5	RC	Rec=100% RQD=89%								
7.3			6	RC	Rec=95% RQD=87%								
259.6	End of Borehole												
10.3													

COMMENTS		WATER LEVEL RECORDS	
Advanced hole with NW Casing and NQ size coring equipment below 0.8 m depth		Date (dd/mm/yy)/Time	Water Depth (m)
The stratification lines represent approximate boundaries. The transition may be gradual.		1) 19/9/12 4:45:00 PM	2.5
		2)	-
		3)	-

MEL-GEO 12141 - AREA 1 - BOREHOLE LOGS.GPJ MEL-GEO.GDT 4/6/13



METRIC

RECORD OF BOREHOLE NO. 04



REFERENCE 12/08/12141-F1 DATUM Geodetic LOCATION N 5057101.5 E 278960.2 - Township of Croft ORIGINATED BY JL
 PROJECT GWP 5467-09-00, Highway 124 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT
 CLIENT AECOM Inc. DATE (Started) 29 August 2012 TIME
 DATE (Completed) 29 August 2012 (Completed) 8:45:00 AM 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	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							
265.3	Ground Surface										
0.0	SILT - brown silt some sand trace clay trace organics occasional cobbles/boulders		1	AS		265					
264.5	(loose)										
0.8	Auger Refusal DCPT Refusal End of Borehole										

COMMENTS	+ 3, × 3 : Numbers on right refer to Sensitivity Numbers on left refer to values greater than 120 kPa ○ 3% STRAIN AT FAILURE	WATER LEVEL RECORDS		
		Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
The stratification lines represent approximate boundaries. The transition may be gradual.		1)	-	-
		2)	-	-
		3)	-	-

MEL-GEO 12141 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 4/6/13



METRIC

RECORD OF BOREHOLE NO. 05



REFERENCE 12/08/12141-F1 DATUM Geodetic LOCATION N 5057103.8 E 279000.2 - Township of Croft ORIGINATED BY JL
 PROJECT GWP 5467-09-00, Highway 124 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT
 CLIENT AECOM Inc. DATE (Started) 11 September 2012 TIME 11 September 2012 (Completed) 9:30:00 AM CHECKED BY MAM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES								
268.1	Ground Surface												
0.0	50 mm organics		1	AS			268						
267.3	SILT - brown silt some sand some clay (loose)		2	SS	12		267						1 56 (43)
0.8	SAND - brown sand some silt to silty trace to with gravel (compact/very dense)		3	SS	85								25 61 (14)
266.1	Auger Refusal End of Borehole												
2.0													

COMMENTS		WATER LEVEL RECORDS	
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	Date (dd/mm/yy)/Time	Water Depth (m)
		1) 11/9/12 9:25:00 AM	1.8
		2)	-
		3)	-

MEL-GEO 12141 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 4/6/13



METRIC

RECORD OF BOREHOLE NO. 06



REFERENCE 12/08/12141-F1 DATUM Geodetic LOCATION N 5057104.4 E 278931.1 - Township of Croft ORIGINATED BY JL
 PROJECT GWP 5467-09-00, Highway 124 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT
 CLIENT AECOM Inc. DATE (Started) 28 August 2012 TIME
 DATE (Completed) 28 August 2012 (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	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L WATER CONTENT (%)	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE						
267.1	Ground Surface									
0.0	SILT - brown silt with sand trace clay trace gravel (loose/compact)		1	AS						3 28 59 10
266.3										
0.8	SAND - brown silty sand some gravel (dense/very dense)		2	SS	59					13 49 (38)
265.5										
1.6	Auger Refusal DCPT Refusal End of Borehole		3	SS	50/50					

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	
Testpit advanced at borehole location. Bedrock encountered at 0.9 m.				Date (dd/mm/yy)/Time	Water Depth (m)
				1) 28/8/12 3:30:00 PM	DRY
				2)	
				3)	
					Cave In (m)
					1.4

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

MEL-GEO 12141 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 4/6/13



METRIC

RECORD OF BOREHOLE NO. 07



REFERENCE 12/08/12141-F1 DATUM Geodetic LOCATION N 5057105.3 E 278896.1 - Township of Croft ORIGINATED BY JL
 PROJECT GWP 5467-09-00, Highway 124 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT
 CLIENT AECOM Inc. DATE (Started) 28 August 2012 TIME
 DATE (Completed) 28 August 2012 (Completed) 4:00:00 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	20	40	60	80					
269.4	Ground Surface															
269.2	SILT - brown silt some sand trace clay trace organics		1	AS												
0.2	Auger Refusal DCPT Refusal End of Borehole															

COMMENTS		WATER LEVEL RECORDS		
Testpit advanced at borehole location. Bedrock encountered at 0.2 m.		+ 3, × 3 : Numbers on right refer to Sensitivity Numbers on left refer to values greater than 120 kPa ○ 3% STRAIN AT FAILURE		
Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)		
1)	-	▽		
2)	-	▽		
3)	-	▽		

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

MEL-GEO 12141 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 4/6/13



METRIC

RECORD OF BOREHOLE NO. 08



REFERENCE 12/08/12141-F1 DATUM Geodetic LOCATION N 5057134.8 E 278950.5 - Township of Croft ORIGINATED BY JL
 PROJECT GWP 5467-09-00, Highway 124 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT
 CLIENT AECOM Inc. DATE (Started) 11 September 2012 TIME
 DATE (Completed) 11 September 2012 (Completed) 3:20:00 PM CHECKED BY MAM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)												
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES																		
266.0	Ground Surface																						
0.0	SILT - brown silt trace to with sand trace to some clay		1	AS																			
	organic layer		2	SS	WH																		
	(very loose/compact)																						
	brown																						
	grey		3	SS	17						0 31 (69)												
			4	SS	9						0 6 69 25												
263.0																							
3.0	SILTY CLAY - grey silty clay (firm)		5	SS	WH																		
262.2																							
3.8	SAND - grey sand some silt (dense)		6	SS	28/75 mm																		
261.8																							
264.7	Auger Refusal																						
4.3	DCPT Refusal End of Borehole																						
COMMENTS								+ 3, × 3 : Numbers on right refer to Sensitivity Numbers on left refer to values greater than 120 kPa ○ 3% STRAIN AT FAILURE															
								WATER LEVEL RECORDS <table border="1"> <thead> <tr> <th>Date (dd/mm/yy)/Time</th> <th>Water Depth (m)</th> <th>Cave In (m)</th> </tr> </thead> <tbody> <tr> <td>1) 11/9/12 3:10:00 PM</td> <td>3.8</td> <td>3.9</td> </tr> <tr> <td>2)</td> <td>-</td> <td>-</td> </tr> <tr> <td>3)</td> <td>-</td> <td>-</td> </tr> </tbody> </table>				Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)	1) 11/9/12 3:10:00 PM	3.8	3.9	2)	-	-	3)	-	-
Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)																					
1) 11/9/12 3:10:00 PM	3.8	3.9																					
2)	-	-																					
3)	-	-																					

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

MEL-GEO 12141 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 4/6/13



METRIC

RECORD OF BOREHOLE NO. 09



REFERENCE 12/08/12141-F1 DATUM Geodetic LOCATION N 5057115.5 E 278930.9 - Township of Croft ORIGINATED BY JL
 PROJECT GWP 5467-09-00, Highway 124 BOREHOLE TYPE Truck Mounted CME 45B - Hollow Stem Augers and NQ casing COMPILED BY AT
 CLIENT AECOM Inc. DATE (Started) 20 September 2012 TIME (Completed) 8:25:00 AM CHECKED BY MAM
 DATE (Completed) 20 September 2012

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								
269.9	Ground Surface												
0.0	75 mm Asphalt 225 mm Crushed Gravel FILL - brown sand some silt trace gravel		1	AS									
269.1	Auger Refusal												
0.8	EARTH AND ROCK FILL MIX - earth (sand and gravel) and rock fill mix (compact)		2	SS	14								
			3	SS	27								
			4	SS	50/150 mm								
266.1	SILT - brown to grey silt with sand (compact)		5	SS	13								
			6	SS	35/100 mm								
264.6	DCPT Refusal												
5.3	BEDROCK - pink to grey gneiss		7	RC	Rec = 95% RQD = 85%								
			8	RC	Rec = 98% RQD = 98%								
261.6	End of Borehole												
8.3													

COMMENTS		WATER LEVEL RECORDS	
Advanced hole with NW Casing and NQ size coring equipment		Date (dd/mm/yy)/Time	Water Depth (m)
The stratification lines represent approximate boundaries. The transition may be gradual.		1) 20/9/12 8:25:00 AM	0.7
		2)	-
		3)	-

MEL-GEO 12141 - AREA 1 - BOREHOLE LOGS.GPJ MEL-GEO.GDT 4/6/13



METRIC

RECORD OF BOREHOLE NO. 10



REFERENCE 12/08/12141-F1 DATUM Geodetic LOCATION N 5057116.0 E 278955.9 - Township of Croft ORIGINATED BY JL
 PROJECT GWP 5467-09-00, Highway 124 BOREHOLE TYPE Truck Mounted CME 45B - Hollow Stem Augers and NQ casing COMPILED BY AT
 CLIENT AECOM Inc. DATE (Started) 20 September 2012 TIME (Completed) 8:45:00 AM CHECKED BY MAM
 DATE (Completed) 20 September 2012

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								
269.9	Ground Surface												
0.0	75 mm Asphalt 250 mm Crushed Gravel FILL - brown sand some silt some gravel		1	AS									18 72 (10)
269.0	Auger Refusal												
0.9	EARTH AND ROCK FILL MIX - earth (sands and gravels) and rock fill mix (compact/dense)		2	SS	15								
			3	SS	21								
			4	SS	44								
266.3	DCPT Refusal												
3.6	EARTH AND ROCK FILL MIX												
264.7	SILT - brown and grey silt (compact)		5	SS	22								
263.9	BEDROCK - grey gneiss		6	RC	Rec = 95% RQD = 77%								
6.0			7	RC	Rec = 85% RQD = 46%								
260.9	End of Borehole												
9.0													

COMMENTS

Advanced hole with NW Casing and NQ size coring equipment below 0.9 m depth below 0.8 m depth

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

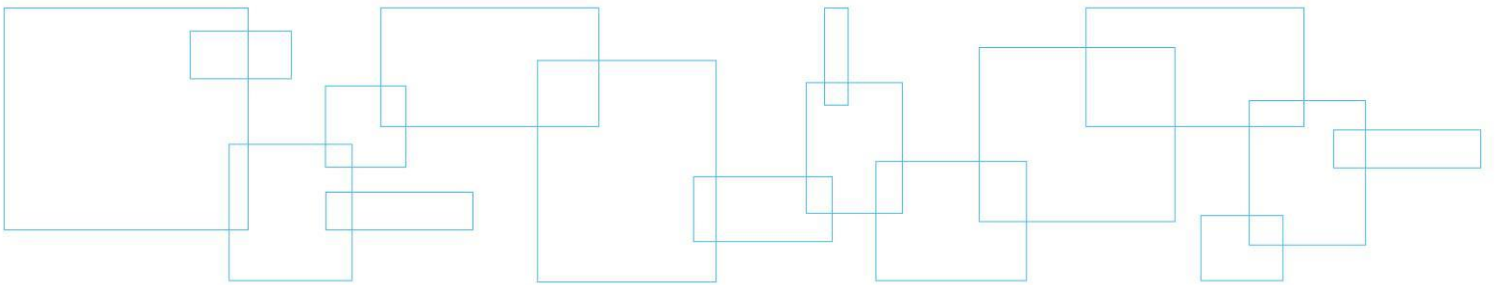
Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1) 20/9/12 8:45:00 AM	DRY	0.7
2)	-	-
3)	-	-

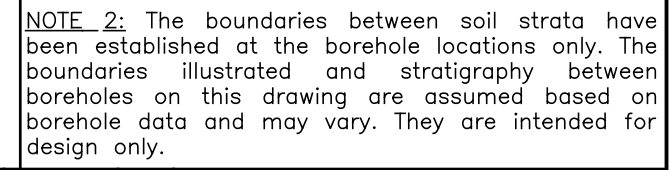
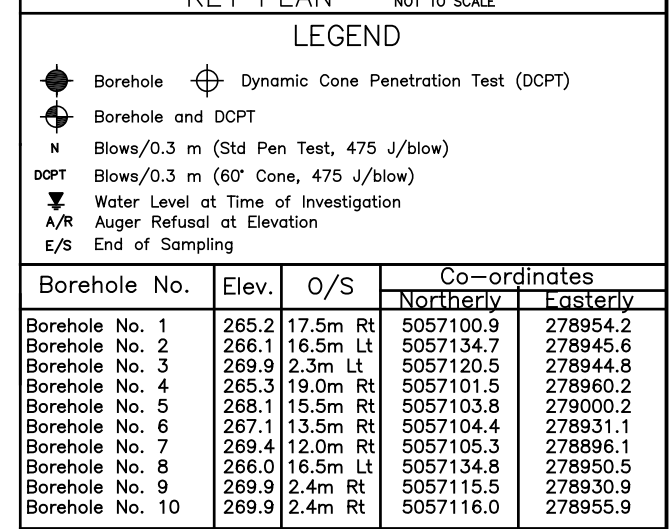
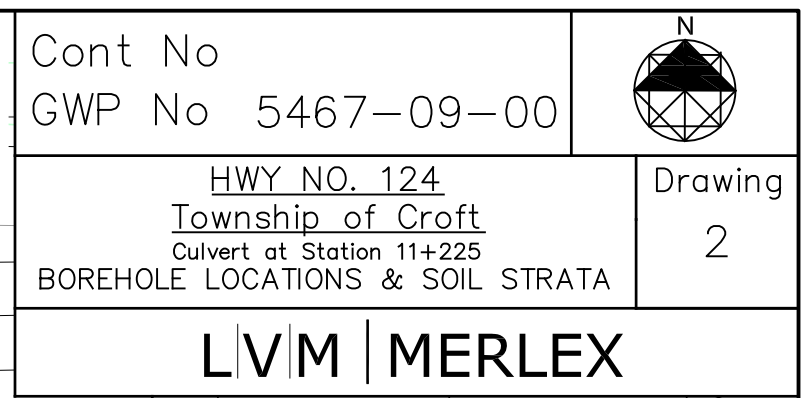
MEL-GEO 12141 - AREA 1 - BOREHOL LOGS.GPJ MEL-GEO.GDT 4/6/13



Appendix 3 Borehole Plan and Lab Data

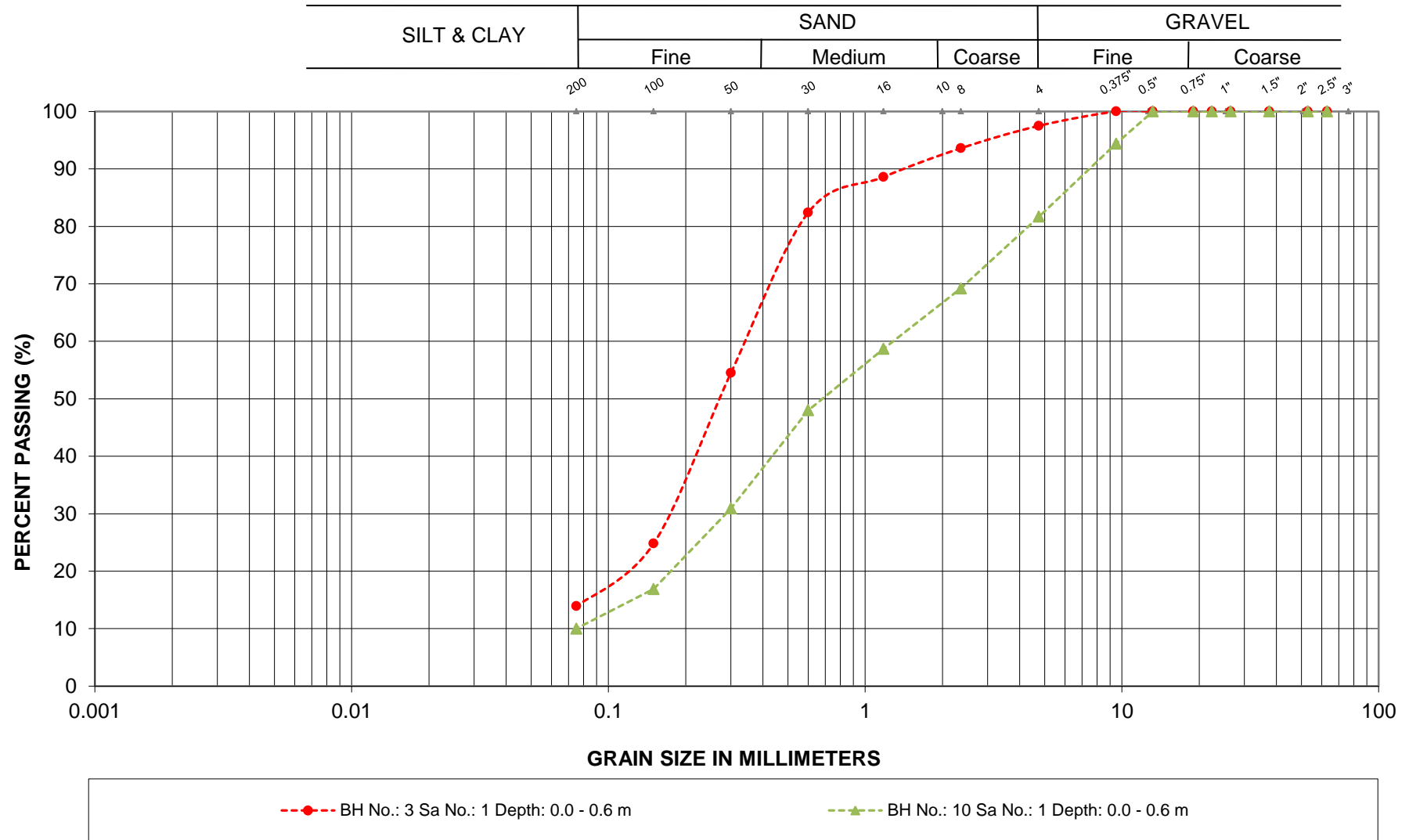
Drawing No. 2: Borehole Location and Soil Strata
Figure Nos. L-1 to L-4: Grain Size Distribution Curves
Figure No. L-5: Atterberg Limits Sheet
Figure No. L-6: Lab Test Summary Sheet





REVISIONS	DATE	BY	DESCRIPTION
	Jan 2013	IK	DRAFT
	May 2013	MCM	FINAL
<div> <div>HWY No. 124 – Croft Twp – Culvert at Station 11+225</div> <div>REF 12141 – F1</div> </div>			
SUBM'D		GEOCRETS 31E-322A	SITE
DRAWN IK		CHK MAM	DATE January 2013
			DWG 2

GRAIN SIZE ANALYSIS

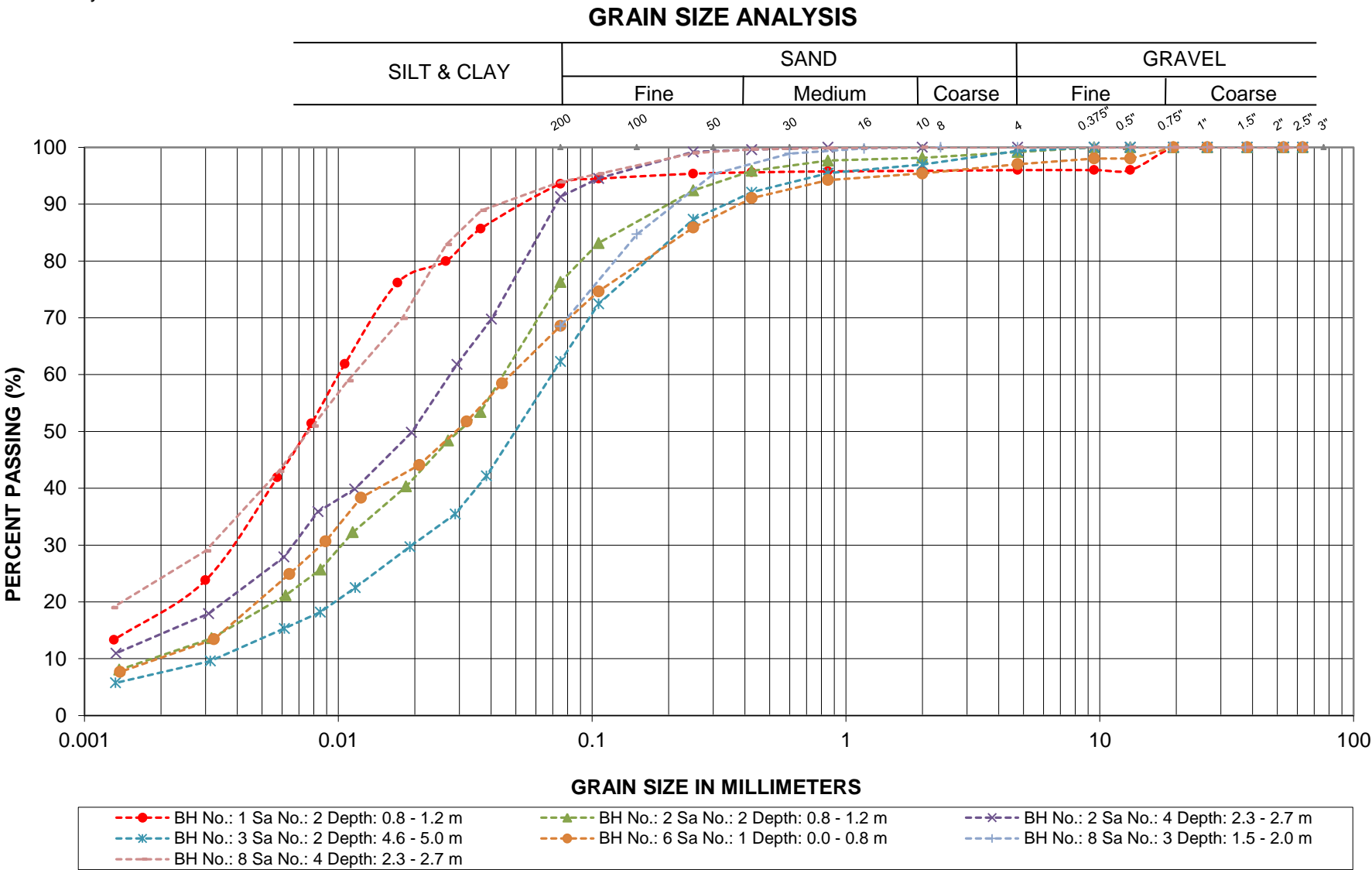


G.W.P.: 5467-09-00
LOCATION: Hwy 124

GRANULAR FILL

LVM | MERLEX

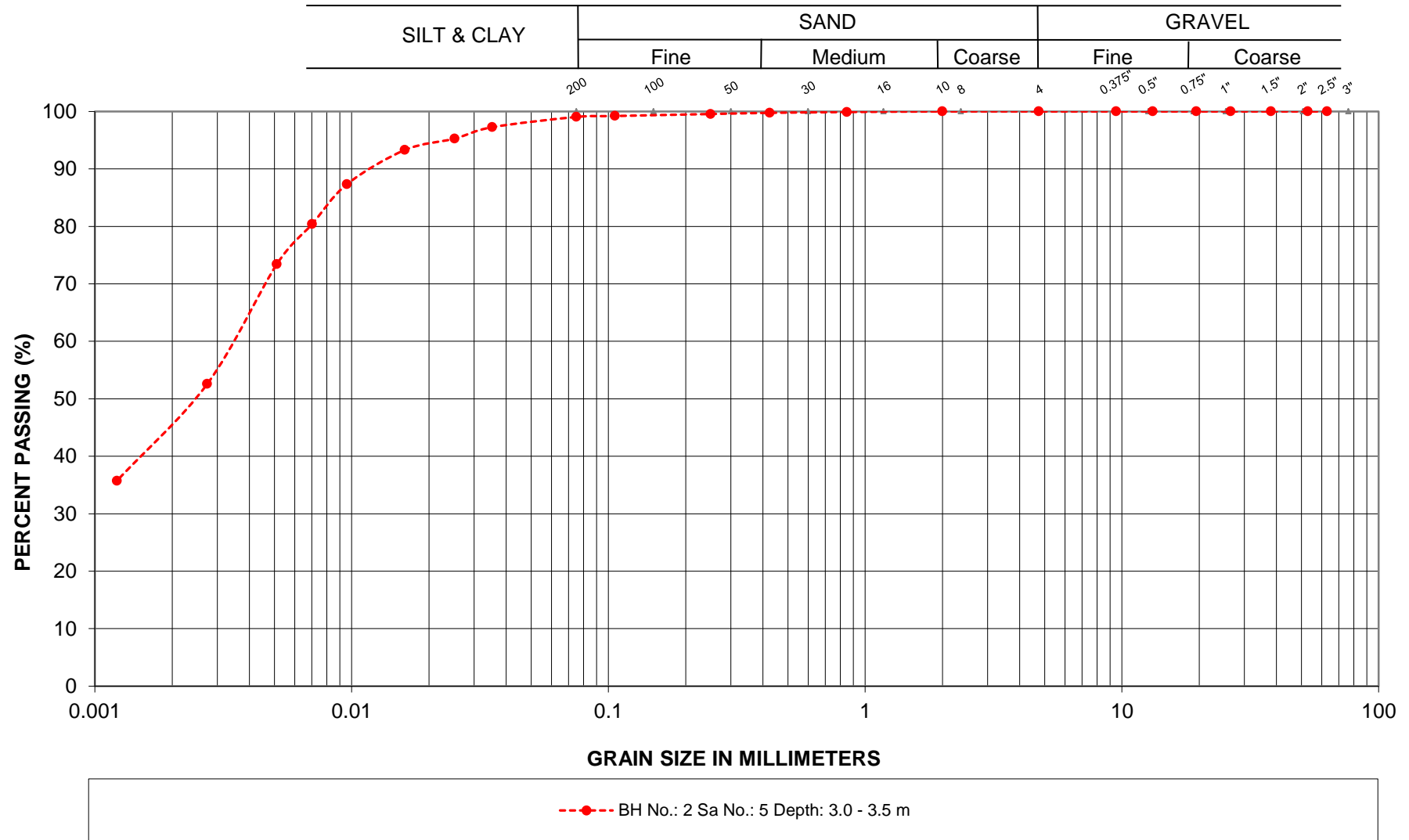
FIGURE L-1



G.W.P.: 5467-09-00
LOCATION: Hwy 124

SILT

GRAIN SIZE ANALYSIS



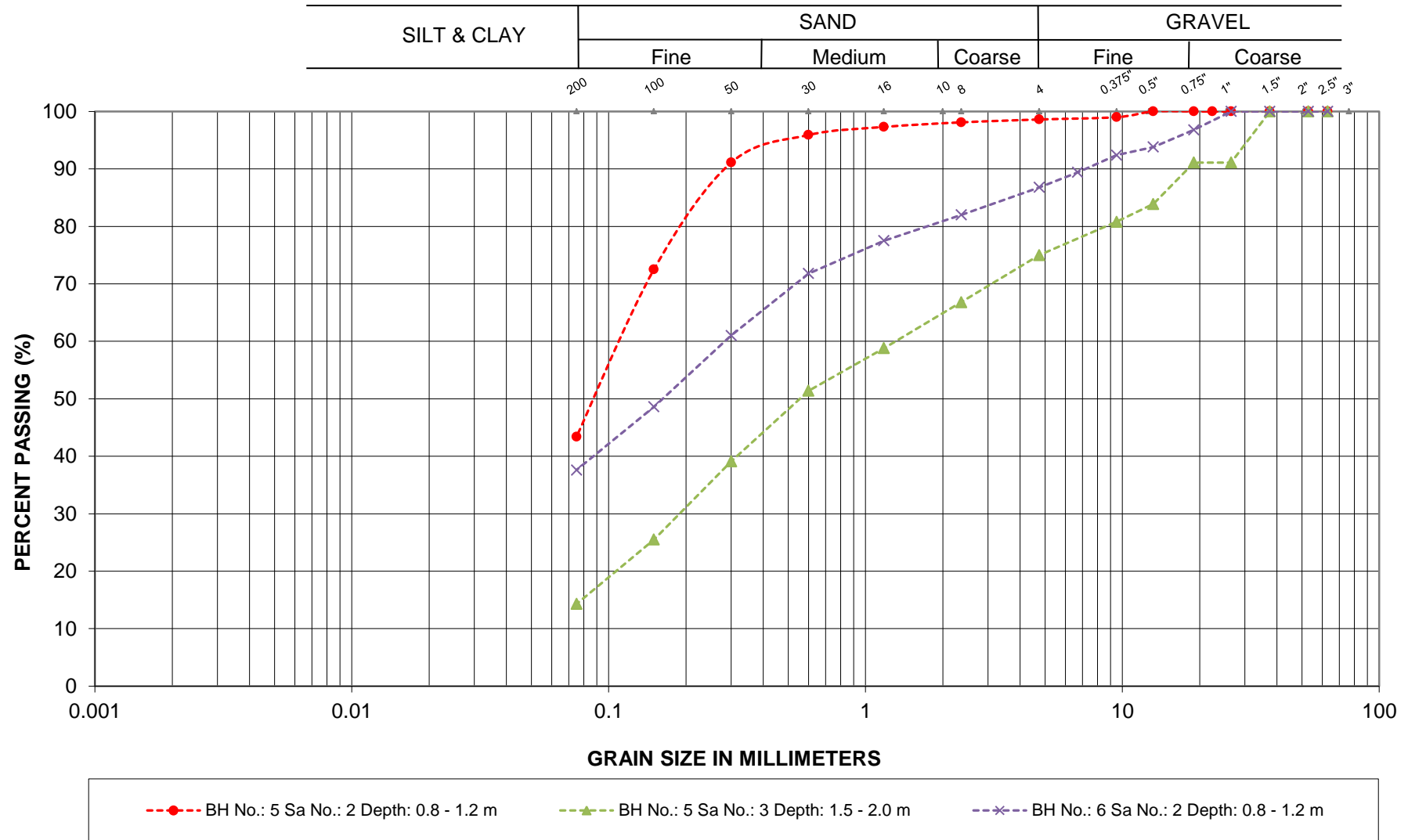
G.W.P.: 5467-09-00
LOCATION: Hwy 124

SILTY CLAY

LVM | MERLEX

FIGURE L-3

GRAIN SIZE ANALYSIS

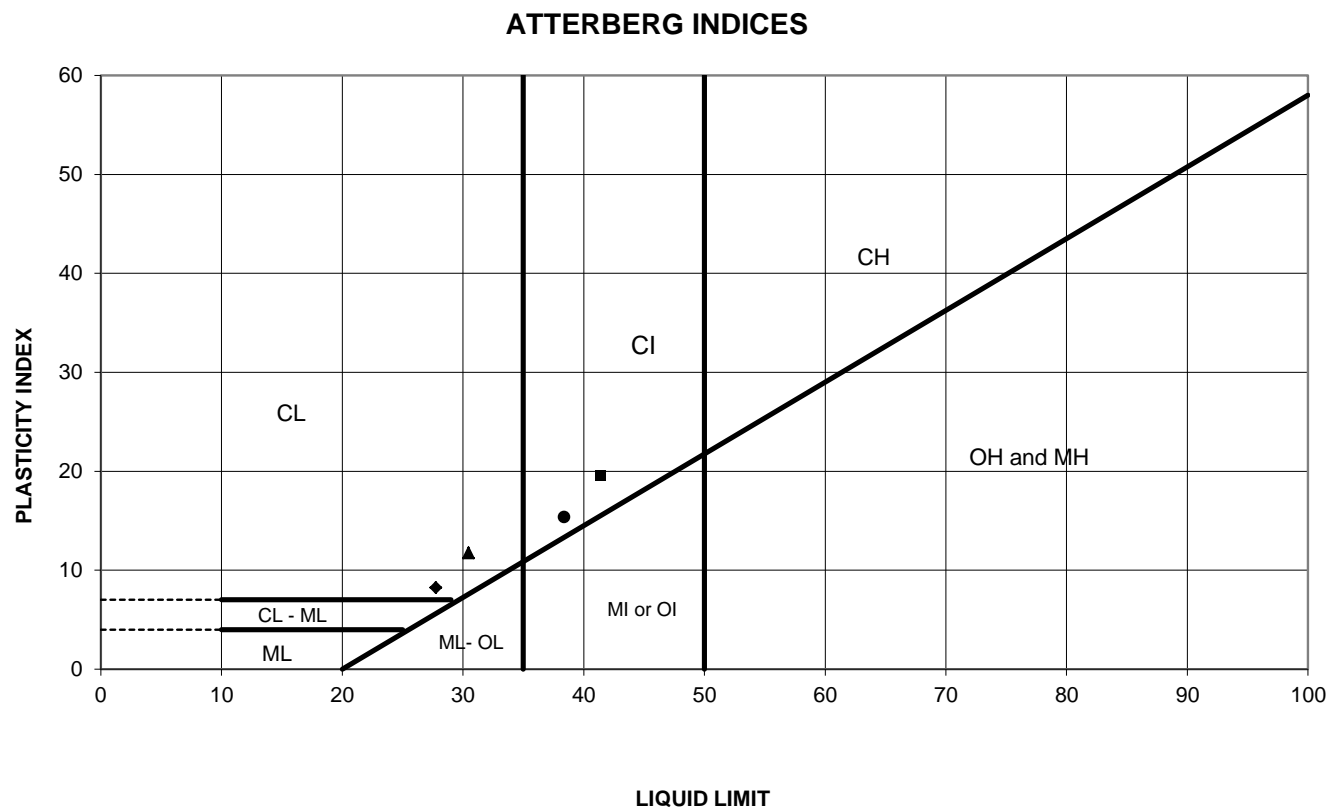


G.W.P.: 5467-09-00
LOCATION: Hwy 124

SAND

ATTERBERG LIMITS TEST RESULTS

FIGURE L-5



SYMBOL	BH	Sa. No.	Depth(m)	Elev.(m)	Liquid Limit	Plastic Limit	Plasticity Index	NMC %
●	1	2	0.8	264.4	38.4	23.0	15.3	24.2
◆	2	4	2.3	263.8	27.8	19.5	8.2	26.3
■	2	5	3.0	263.1	41.5	21.9	19.6	43.6
▲	8	4	2.3	263.7	30.5	18.7	11.8	27.6

Date: May-13
Project: Hwy 124
G.W.P: 5467-09-00

Prep'd: AT
Chkd: MAM
Ref. No.: 12/08/12141-F1

LVM | MERLEX

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					26.8				N/A			
	2	0.8	4	2	76	18	24.2	38.4	23.0	15.3	17			
	3	1.5					18.6				60/275 mm			
2	1	0.0					21.2				N/A			
	2	0.8	1	23	66	10	38.4				2			
	3	1.5					22.1				10			
	4	2.3	0	9	77	14	26.3	27.8	19.5	8.2	9			
	5	3.1	0	1	54	45	43.6	41.5	21.9	19.6	WH			
	6	3.8					24.4				25/25 mm			
3	1	0.0	2	84	14		4.0				N/A			
	2	4.6	1	37	55	7	23.5				4			
	3	5.3					30.9				WH			
	4	6.1									11			
4	1	0.0					32.5				N/A			
5	1	0.0					20.2				N/A			
	2	0.8	1	56	43		16.9				12			
	3	1.5	25	61	14		11.5				85			
6	1	0.0	3	28	59	10	27.6				N/A			
	2	0.8	13	49	38		10.4				59			
	3	1.5					6.0				50/50 mm			
7	1	0.0					34.3				N/A			
8	1	0.0					24.7				N/A			
	2	0.76					46.0				WH			
	3	1.52	0	31	69		19.9				17			
	4	2.3	0	6	69	25	27.6	30.5	18.7	11.8	9			
	5	3.1					46.4				WH			
	6	3.8					25.9				28/75 mm			

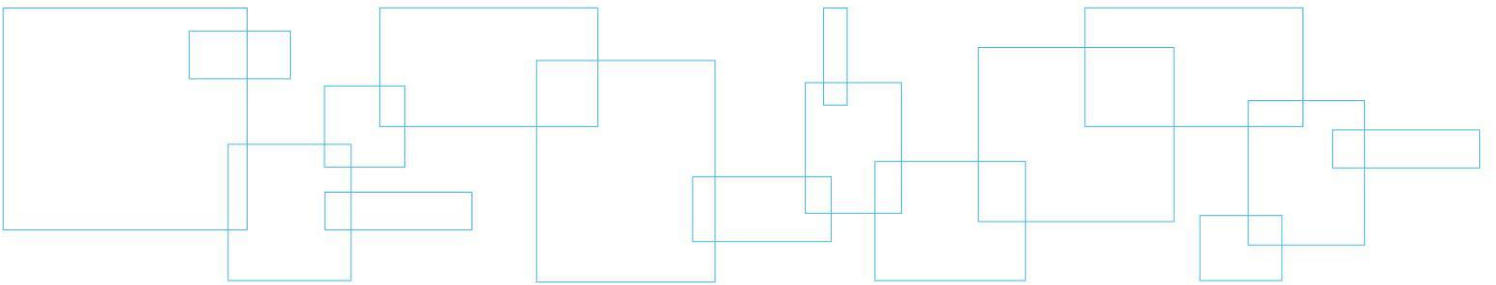
Laboratory Tests - Summary Sheet

[illegible]

Appendix 4 Photo Essay

Enclosure No. 12:

Photo Essay



South Embankment Slope – Looking West

Photo: 1

Location of culvert inlet



Culvert Inlet

Photo: 2



Project: Hwy 124 – Station 11+225, Twp of Croft

Photos Provided By: LVM

Date: September 2012

Testpit at Borehole No. 1 (Culvert Inlet)

Photo: 3



South Embankment Slope and Side Road – Looking East

Photo: 4



Project: Hwy 124 – Station 11+225, Twp of Croft

Photos Provided By: LVM

Date: September 2012

View of North Embankment Slope From Embankment - Looking North

Photo: 5



Location of Borehole No. 2 – Looking North

Photo: 6



Project: Hwy 124 – Station 11+225, Twp of Croft

Photos Provided By: LVM

Date: September 2012

Appendix 5

Design Data

Figure Nos. S-1 and S-2:

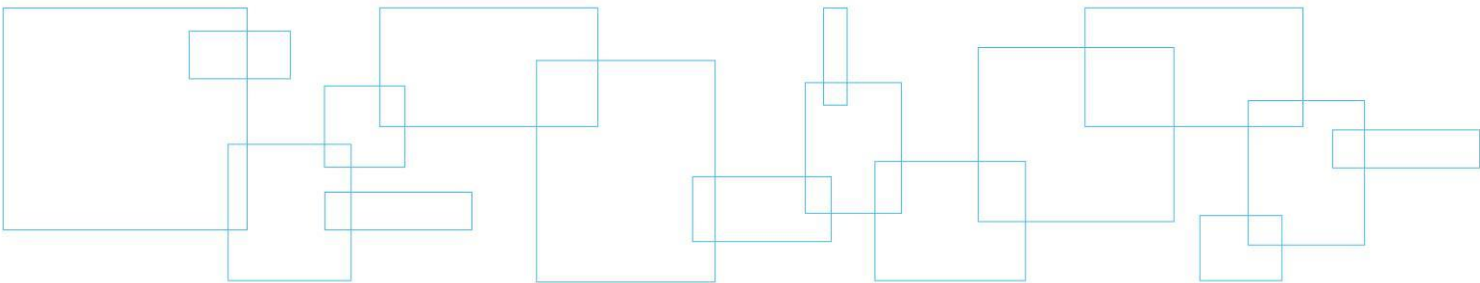
Slope Stability

Table A:

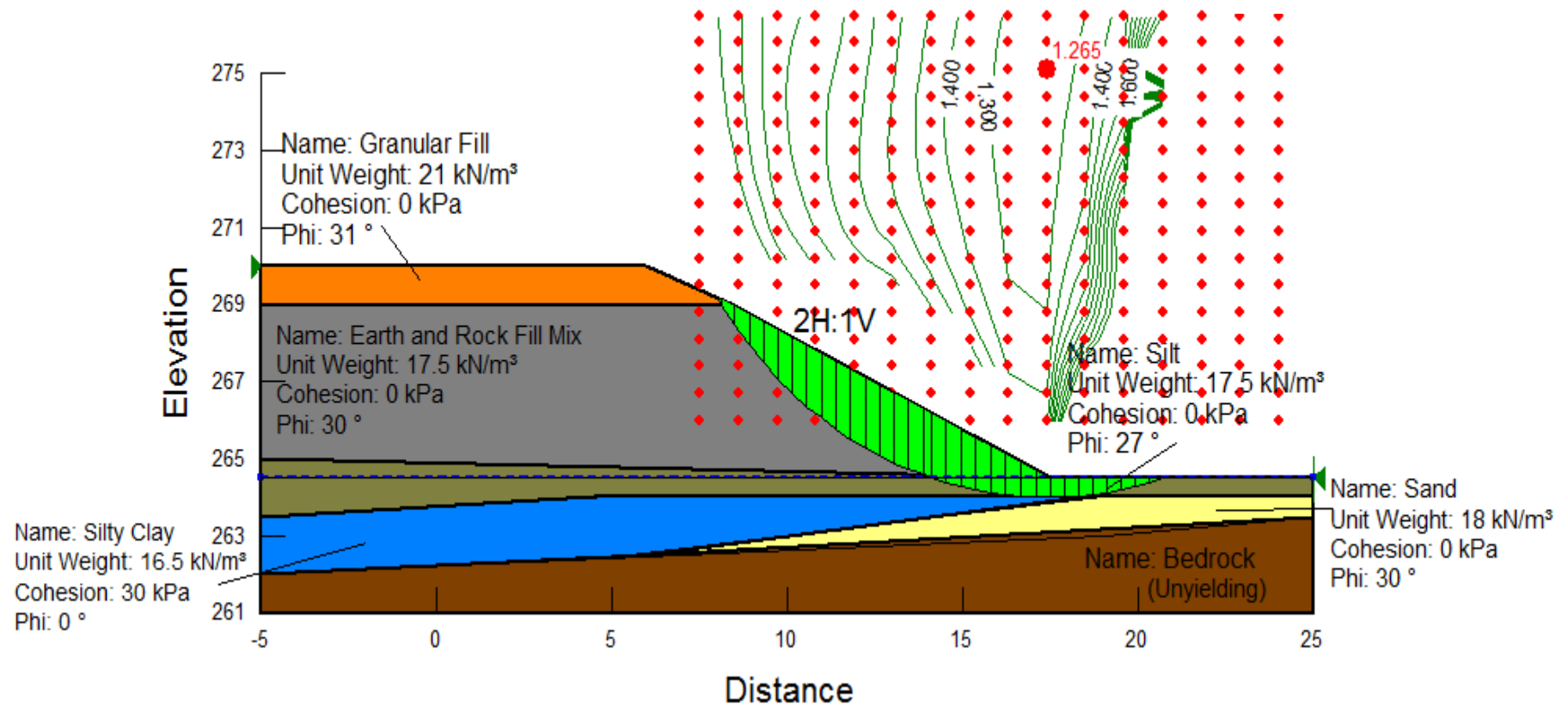
Comparison of Shoring Alternatives

Figure SK-4:

Conceptual Shoring Location



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

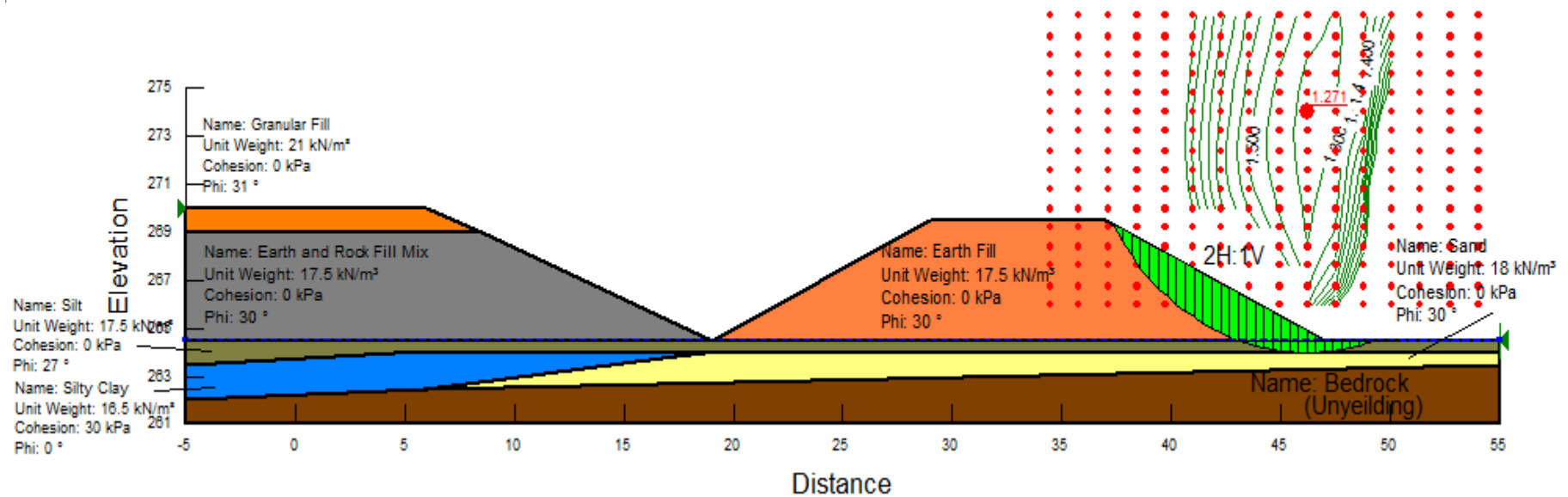


Stability Analysis
 Station 11+225
 TWP of Croft

Project: G.W.P 5467-09-00
 Location: Hwy 124

Figure No. S-1

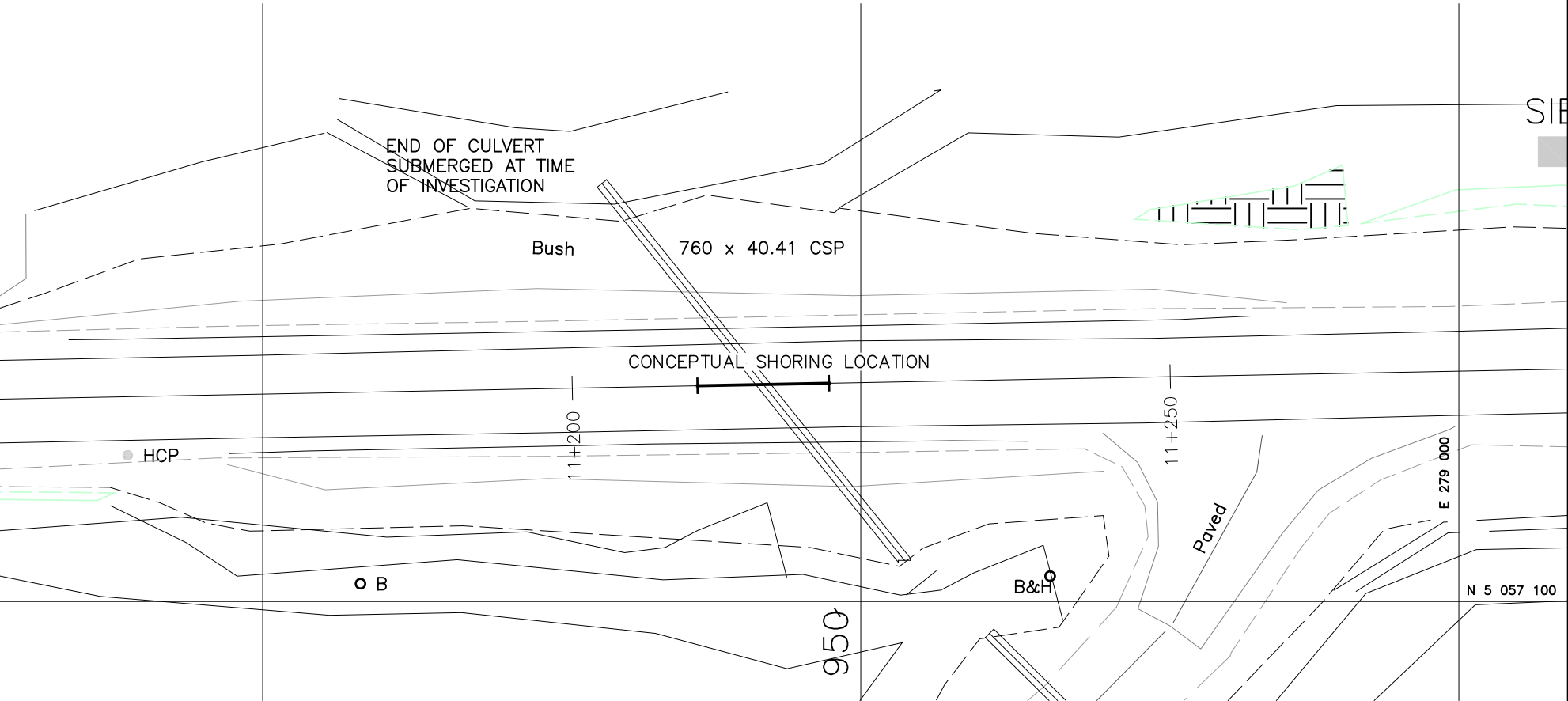
**Stability Analysis
Embankment Stability
Temporary Detour
Failure of Native Material
2H:1V Slopes**



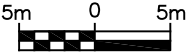
Stability Analysis
Station 11+225
TWP of Croft

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 considered due to rock fill embankment	
Steel Sheet Piles	5 – 21	-High strength, continuous, -Readily available	-Limited by soil conditions (i.e. obstructions)	Not considered due to rock fill embankment	
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 ground conditions and higher cost	
Soldier piles	5 – 25	-Easy installation -Readily available -Adaptable to various ground conditions	-Pre-drilling may be required -Possible ground loss	Recommended for protection system at this site	\$ 725/m ² Predrilling \$ 1,500/m ²
Tangent/ Secant/ Staggered Drilled Piles	10 – 18	-Readily available -Adaptable to various ground conditions	-Possible ground loss and/or seepage -Poor alignment tolerance	Considered for excavations requiring a protection system at this site	
Concrete Diaphragm	10 – 30	-High Strength -Durable -Can be permanent	-High cost -Requires specialized equipment/control	Not Considered due to ground conditions and higher costs	
Micropiles with reinforced shotcrete face		-Can be installed in various ground conditions -High strength -Good tolerance	-High Cost -Requires specialized equipment	Considered for excavations requiring a protection system at this site	\$ 1,200 – 1,500/m ²



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



HWY 124 - Township of Dunchurch - Culvert at 11+225
Conceptual Shoring Location

FIGURE SK-4