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

Highway 654 Rehabilitation
Culvert Replacement
Station 16+927 - TWP of North Himsworth
GWP 5090-05-00

Highway 654
From Highway 534 Easterly 23.1 km to Highway 11

FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

Date: January 10, 2013
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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 the associated temporary protection system required for the culvert replacement. This culvert replacement is located on Highway 654, some 4.0 km West of Highway 11, in the Township of North Himsworth.

The foundation investigation location was specified by the MTO in the RFP/TPM documentation Agreement No. 5010-E-0028. The terms of reference for the scope of work are outlined in LVM | MERLEX's Proposal P-11-151, dated October, 2011. The purpose of this investigation was to determine the subsurface conditions in the area of the culvert 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 foundation investigation for this Corrugated Steel Pipe (CSP) culvert is located at Station 16+927, Township of North Himsworth. The topography at the site is slightly rolling with low terrain and a stream flowing adjacent to the left (north) toe of the embankment. The existing highway embankment currently supports two undivided lanes of highway, running in an east-west direction. The existing highway, at the culvert location, is constructed on a fill embankment some 5.4 m in height above the surrounding grade, with centerline elevation of 216.4 m at the culvert location. The culvert at this location is an 800 mm diameter CSP culvert, some 33.1 m in length. Flow through the culvert is from right to left (i.e. south to north) (see Photo Essay, Appendix 4).

Infrastructure at the culvert location consists of overhead wires on the left (north) 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 general topography on this section of Highway 654 is 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 silt and clay containing varying amounts of sand and gravel.

Bedrock in the area, as indicated on OGS Map 2506, is of the Late Precambrian Era. At the location of this culvert foundation investigation, the bedrock comprises of granitic to syenitic rocks and derived gneisses.

3 INVESTIGATION PROCEDURES

The field work for this investigation was carried out during the period of April 5th to May 22nd, during which five (5) sampled boreholes, and DCPTs, were advanced. For the purposes of foundation design for the culvert replacement, one borehole was advanced through the embankment slightly up chainage from the culvert and one borehole was advanced at each the inlet and outlet ends of the culvert. Two boreholes were advanced through the embankment up and down chainage from the culvert, to provide subsurface data to support the design of a protection system.

The field investigation was carried out using a Bombardier and a truck mounted CME drilling 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. NQ size diamond coring equipment was used to determine the nature of refusal at select boreholes.

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 was backfilled where necessary 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, 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 3 (Figures Nos. L-1 to L-7).

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 Figure 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 specific geological unit. Additional consideration should be given to the fact that subsurface conditions may vary markedly between adjacent boreholes and beyond any specific boring location, and are shown on the drawings for illustration purposes only.

4.1 CULVERT, STATION 16+927, TWP OF NORTH HIMSWORTH

A plan and profile illustrating the borehole locations and stratigraphic sequences is shown on Figure No. 2, Appendix 3. During the course of the exploration program, five (5) sampled boreholes were put down at this site, with Borehole Nos. 1, 2, and 3 advanced through the embankment and Borehole Nos. 4 and 5 advanced at the culvert ends. At the time of the subsurface investigation, the ground surface elevations at Boreholes Nos. 1 to 5 were recorded at 216.4, 216.5, 216.3, 212.8, and 213.9 m, respectively.

4.1.1 Pavement Structure

At Surface at Borehole Nos. 1 and 2, a pavement structure consisting of 50 mm of asphalt and 175 to 200 mm crushed gravel was penetrated. At Borehole No. 3, a pavement structure consisting of 75 mm of asphalt was encountered.

4.1.2 Surficial Organics

At surface at BH No. 4, a layer of surficial organics, some 50 mm thick, was penetrated.

4.1.3 Embankment Fill

Underlying the pavement structure at Borehole Nos. 1 to 3, a deposit of fill consisting of brown sand some silt to silty, trace gravel to gravelly, was penetrated. Occasional cobbles were encountered in this deposit. A buried asphalt layer was encountered in this deposit at Borehole No. 1. The natural moisture content measured on samples of this deposit was in the order of 3 to 17%. Gradation analyses were carried out on five (5) samples of this deposit, the results of which indicated 4 to 39% gravel size particles, 49 to 69% sand size particles, and 10 to 35% silt and clay size particles (Figure No. L-1, Appendix 3). Based on SPT ‘N’ values of 7 to 61 blows per 300 mm penetration, the compactness of this deposit was described as loose to very dense, generally compact. This deposit was encountered to depths of 5.3, 4.6, and 2.9 m below grade at Borehole Nos. 1 to 3, respectively (elevations 211.1, 211.9, and 213.4 m, respectively).

4.1.4 Fill

Underlying the surficial organics at Borehole No. 4, and at surface at Borehole No. 5, a deposit of fill consisting of brown sand some silt trace gravel was penetrated. Occasional cobbles were encountered in this deposit. The natural moisture content measured on samples of this deposit was in the order of 14 to 21%. Based on SPT 'N' values of 16 to 21 blows per 300 mm penetration, the compactness of this deposit was described as compact. This deposit was encountered to depths of 0.3 and 2.1 m below grade at Borehole Nos. 4 and 5, respectively (elevations 212.5 and 211.8 m, respectively). DCPT refusal, likely on a boulder size rock piece, was encountered in this deposit at a depth of 1.9 m at Borehole No. 5 (elevation 212.0 m).

4.1.5 Silty Clay

Underlying the embankment fill at Borehole Nos. 1 and 3, and underlying the fill at Borehole Nos. 4 and 5, a deposit of grey silty clay trace to with sand trace gravel was penetrated. The natural moisture content measured on samples of this deposit was in the order of 23 to 31%. Hydrometer analyses were carried out on two (2) samples of this deposit, the results of which indicated 0 to 9% gravel size particles, 10 to 25% sand size particles, 32 to 62% silt size particles, and 28 to 34% clay size particles (Figure No. L-2, Appendix 3). Atterberg Limits testing was carried out on two (2) samples of this deposit, the results of which indicated a Plastic Limit in the order of 19% and a Liquid Limit in the order of 33 to 34% (Figure No. L-6, Appendix 4). Based on the results of the Atterberg Limits testing, this deposit was described as a silty clay of low plasticity (CL). Based on SPT 'N' values, the consistency of this deposit was estimated as stiff. This deposit was encountered to depths of 6.1, 3.8, 0.9, and 3.2 m below grade at Borehole Nos. 1, 3, 4, and 5, respectively (elevations 210.3, 212.5, 211.9, and 210.7 m, respectively).

4.1.6 Sand and Silt

Underlying the silty clay at Borehole No. 1 and underlying the embankment fill at Borehole No. 2, a deposit of grey sand and silt some to with gravel was penetrated. The natural moisture content measured on samples of this deposit was in the order of 16 to 17%. A hydrometer analysis was carried out on one (1) sample of this deposit, the results of which indicated 21% gravel size particles, 38% sand size particles, 34% silt size particles, and 7% clay size particles (Figure No. L-3, Appendix 3). Atterberg Limits testing was carried out on one (1) samples of this deposit, the results of which indicated a Plastic Limit in the order of 16% and a Liquid Limit in the order of 20% (Figure No. L-6, Appendix 4). Based on the results of the Atterberg Limits testing, this deposit was described as an inorganic sandy silt of slight plasticity (ML). Based on SPT 'N' values of 5 blows per 300 mm penetration, the compactness of this deposit was described as loose. Auger refusal was encountered in this deposit at depths of 6.9 and 6.0 m below grade at Borehole Nos. 1 and 2 respectively (elevations 209.5 and 210.5 m, respectively).

4.1.7 Silt

Underlying the silty clay at Borehole No. 3, a deposit of grey silt trace gravel trace clay was penetrated. The natural moisture content measured on samples of this deposit was in the order of 22 to 28%. A hydrometer analysis was carried out on one (1) sample of this deposit, the results of which indicated 21% gravel size particles, 38% sand size particles, 34% silt size particles, and 7% clay size particles (Figure No. L-4, Appendix 3). Based on STP ‘N’ values of 17 to 18 blows per 300 mm penetration, this deposit was described as compact. Auger refusal was encountered in this deposit at a depth of 5.6 m below grade (elevation 210.7 m).

4.1.8 Sand

Underlying the silty clay at Borehole Nos. 4 and 5, a deposit of grey sand some silt some to with gravel was penetrated. Occasional cobbles were encountered in this deposit at Borehole No. 5. The natural moisture content of measured on samples of this deposit was in the order of 8 to 23%. A gradation analyses was carried out on one (1) sample of this deposit, the results of which indicated 26% gravel size particles, 42% sand size particles, and 16% silt and clay size particles (Figure No. L-5, Appendix 3). Based on STP ‘N’ values of 16 to 52 blows per 300 mm penetration, this deposit was described as compact to dense. Auger refusal was encountered in this deposit at depths of 1.8 and 4.0 m below grade at Borehole Nos. 4 and 5, respectively (elevations 211.0 and 209.9 m, respectively).

4.1.9 Bedrock

Underlying the sand and silt at Borehole No. 1, auger refusal was encountered at a depth of 6.9 m (elevation 209.5 m). Coring was undertaken to determine the nature of auger refusal, which proved to be bedrock. The bedrock was described as a pink to grey gneiss. Based on an RQD of 40 to 77% the bedrock was described as poor to good quality. The borehole was terminated at a depth of 11.4 m below grade (elevation 205.0 m).

4.2 GROUNDWATER DATA

Measurements of the groundwater table and cave-in levels were undertaken, where possible, in the open boreholes during the advance of the individual borings and upon completion. These levels are recorded on the individual Record of Borehole Log Sheets (Appendix B). The groundwater levels in Borehole Nos. 1 to 4 inclusive were measured to vary between elevations 211.4 to 212.2 m, upon completion. Borehole No. 5 was dry upon completion.

The groundwater and stream water levels will fluctuate seasonally.

5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

A foundation investigation was carried for the proposed culvert replacement and to provide subsurface information for design of a protection system as identified in the RFP. This 800 mm CSP culvert is located at Station 16+927 in the Township of North Himsworth.

The existing culvert is an 800 mm CSP culvert some 33.1 m in length. The existing highway embankment currently supports two undivided lanes of highway, running in an east-west direction. 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 a layer of earth fill. The native soils underlying the embankment fill generally consisted of a thin layer of stiff silty clay overlying silts and sands with bedrock encountered at a depth of 6.9 m (elevation 209.5 m.), at Borehole No. 1.

The type of culvert to replace the existing culvert will be based on gravity pipe criteria. 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 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 culverts, a factored bearing resistance at ULS of 175 kPa can be used for a closed culvert (i.e. concrete pipe, CSP, or high density polyethylene (HDPE) culvert). In consideration of the width of the culvert and the depth of overburden, a geotechnical resistance at SLS of 100 kPa can be used for design, in consideration of 25 mm settlement.

If an open culvert (i.e. concrete frame open culvert, with wall footings, or a pipe arch culvert) is considered, then a factored bearing resistance at ULS of 130 kPa, and a geotechnical resistance at SLS or 100 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 for the embankment 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 a standard stable embankment slope established at 2H:1V, for granular fill, over the underlying firm/stiff silty clay deposit. The embankment material was modeled as an earth fill, using a unit weight of 20 kN/m^3 and a friction angle of 30°. The native silty clay was modeled using representative value of unit weight of 16.5 kN/m^3 and a shear strength of 50 kPa. The native silts and sands were modeled using representative values of unit weight of 18 kN/m^3 and a friction angle of 29°. The unit weights and friction angles for the slope calculations are based on general representative values for soil types, obtained through laboratory testing. The results of the analysis indicated a factor of safety in the order of 2.5 against a deep seated global failure through the native silty clay subgrade (see Figure No. S-1, Appendix 5). As, such the stability of the finished embankment slope will not be an issue provided it is constructed in accordance with OPSS and OPSD requirements.

5.3 CULVERT DESIGN, BEDDING, AND EMBEDMENT

The embankment consists of granular and/or earth fills. The results of this investigation indicate that, below the culvert invert, the native soils at Borehole Nos. 1 to 3 consist of generally stiff silty clay underlain by compact silts and sands, underlain by bedrock. A review of the condition of the pavement surface, at the culvert locations, revealed a minor transverse asphalt crack, 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 load on the native soils, 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 of embankment at the culvert location frost tapers should not be required, as per the geotechnical report also prepared by LVM | MERLEX, Ref No. 12/03/12027-P2.

5.3.1 Rigid Concrete Pipe

A concrete pipe culvert 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 should be used, which would aid in dewatering operations. During backfilling the embankment 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 placed to the dimensions as shown on OPSD 802.031.

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, 400 mm thick and extend across the stream bed. Clay seals are generally used where significant head differences exist between the inlet and outlet of a culvert to prevent flow through the embankment. Clay seals are not considered necessary considering the anticipated water levels and flow at this culvert location.

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 embankment fill should be placed in a balanced manner on the outer sides of the pipe 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, 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, 400 mm thick and extend across the stream bed.

5.4 CULVERT INSTALLATION AND CONSTRUCTION STAGING CONSIDERATIONS

The invert elevation of the existing culvert, at centreline, is at 212.2 m, with the top of the embankment at elevation 216.4 m at centerline. As such, the embankment at this location is some 4.2 m in height above the culvert invert at the centerline. Therefore, a minimum 4.5 m deep excavation (i.e. to elevation 211.9 m) will be required, to allow for placement of bedding. The present platform width at this location is some 10.5 m as can be seen on the cross section on Figure 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, unless locally lowering the grade and or sliver widening are undertaken. It is understood that the preferred method of replacing the culvert is to construct a temporary protection system to allow an open cut excavation. Lowering the grade and the use of a protection system are discussed in the following.

5.4.1 Staged Construction

As noted above, the invert elevation of the existing culvert is at 212.2 m, at centerline, with the top of the embankment at elevation 216.4 m at centerline. As such, the embankment at this location is some 4.2 m in height above the culvert inverts at the centerline. The present platform width at this location is some 10.5 m as can be seen on the cross section on Figure No. 2. The platform width at this location, as is, will be insufficient in width to carry out an open excavation using staged construction. To carry out an open cut excavation the grade at the culvert location be can be lowered to elevation 215.7 m to allow for staged construction using open cut staged sequencing and a 24/7 operation with traffic control while limiting traffic flow to one lane (see Figure No. SK-3, Appendix E).

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

- Locally lower the grade at the culvert to an elevation of 215.7 m.

- Limit traffic to a single lane on the left (north) under 24/7 traffic control and/or using traffic signals.
- Open cut excavate, to the right, and install approximately 14 m of new culvert.
- Reconstruct the embankment on the right, with a minimum platform width of 4 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 vertical wall installed along centreline for use as a temporary protection system can be used to carry out the culvert replacement. The installation of a protection system for use in the culvert replacement operation will require penetration through some 5.2 m of embankment fill. The embankment fill is generally underlain by silty clays and silts and sands. One possible method of constructing a temporary vertical wall for roadway protection along the centreline of the highway alignment would be to drive steel sheet piles through the embankment fill into the native material. If a cobble/small boulder size rock is encountered during driving of a sheet section, the individual section could be left high and the cobble/small boulder removed during excavation to allow continued driving. Due to the relatively shallow depth of bedrock at this culvert location, there may not be sufficient penetration to provide toe resistance. As such, a waler and raker system may have to be incorporated in the shoring design. The sheet pile design should be carried out by a structural engineer with experience designing sheet pile walls. Conceptual shoring locations are illustrated on Figure Nos. SK-4 and SK-5, Appendix E.

See Table A, Appendix 5, for advantages and disadvantages for the different type of protection system considered for this site.

Considering the limited depth of excavation, and provided a sheet pile of sufficiently robust section is used, a whaler and raker may be used to span the width of the culvert, however, a tieback system may also be chosen by the contractor. If tiebacks are used, 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):

$R = \sigma z' \, As \, Ls \, \alpha g$ Where: $\sigma z'$ = effective vertical stress at the midpoint of the load carrying length

As = effective unit surface area of the anchor

Ls = effective embedment length of the anchor

αg = 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.

As noted, bedrock was encountered at relatively shallow depths at this culvert location, which will affect the toe resistance of driven sheet piles. As such, consideration can be given to using a micropile system, with micropiles drilled into bedrock, however this shoring system is generally costlier. Alternatively, a caisson wall or soldier piles with lagging can be used. Caissons and or soldier piles should be predrilled and advanced into the bedrock to provide sufficient toe resistance.

Considering the cohesionless nature of the embankment fills (granular pavement structure over essentially granular fills) a rectangular apparent pressure distribution over the height of the cut would be appropriate for design of the temporary shoring. The width of the apparent rectangular pressure distribution, over the height of excavation, can be considered equal to 0.65*Ka*γ*H, where:

Ka = active earth pressure,

γ = unit weight, and

H = height of wall above the base of excavation.

The protection system can be designed using the lateral earth pressure parameters provided in section 5.5 Lateral Earth Pressures.

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 FILL	SSM	NATIVE SILTY CLAY	NATIVE SILTS AND SANDS
Unit Weight (kN/m^3)	22.8	21.2	20	17.5	16.5	18
Angle of Internal Friction	34°	31°	30	30°	-	29°
Shear Strength (kPa)	-	-	-	-	50	-
Coefficient of Active Earth Pressure (Ka)	0.28	0.32	0.33	0.33	-	0.35

PARAMETER	GRANULAR A	GRANULAR B TYPE I	EXISTING FILL	SSM	NATIVE SILTY CLAY	NATIVE SILTS AND SANDS
Coefficient of Passive Earth Pressure (Kp)	3.54	3.12	3.00	3.00	-	2.88
Coefficient of Earth Pressure at Rest (Ko)	0.44	0.48	0.50	0.50	-	0.52

For rigid structures, such as a concrete pipe, deflection cannot occur, as such the “at-rest” condition (Ko) applies. For flexible structures, such as CSP 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, 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. Final (permanent) embankment side slopes in granular/earth fill should be established at the standard angle of 2H:1V.

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. The water level was recorded at approximately elevations 211.4 to 212.2 m, at the time of this investigation. Groundwater control, in accordance with OPSS 517 and 518, will be required to maintain a stable subgrade during culvert installation.

A slight flow was observed through the culvert at the time of the investigation, however, it should be noted that the culvert outlet was above grade at the embankment toe. The water table was at an elevation of up to 212.2 m. An excavation to elevation 211.8 m would be required to install the culvert and bedding. As such, a head of water must be controlled during excavation and culvert installation.

During construction, local temporary sandbagging, combined with installation of filtered sumps and pumping from the base of the excavation will, at a minimum, be required to maintain the excavation in an dewatered condition during subgrade preparation. A sand bag cofferdam or possibly temporary sheet pile type cofferdam can also be considered for controlling stream flow depending upon anticipated flow at time of construction. By-pass pumping through a separate diversion pipe through the embankment should be considered for diverting stream flow.

Ultimately, the method of dewatering and stream 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 earth fill embankment and the generally shallow groundwater table, 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

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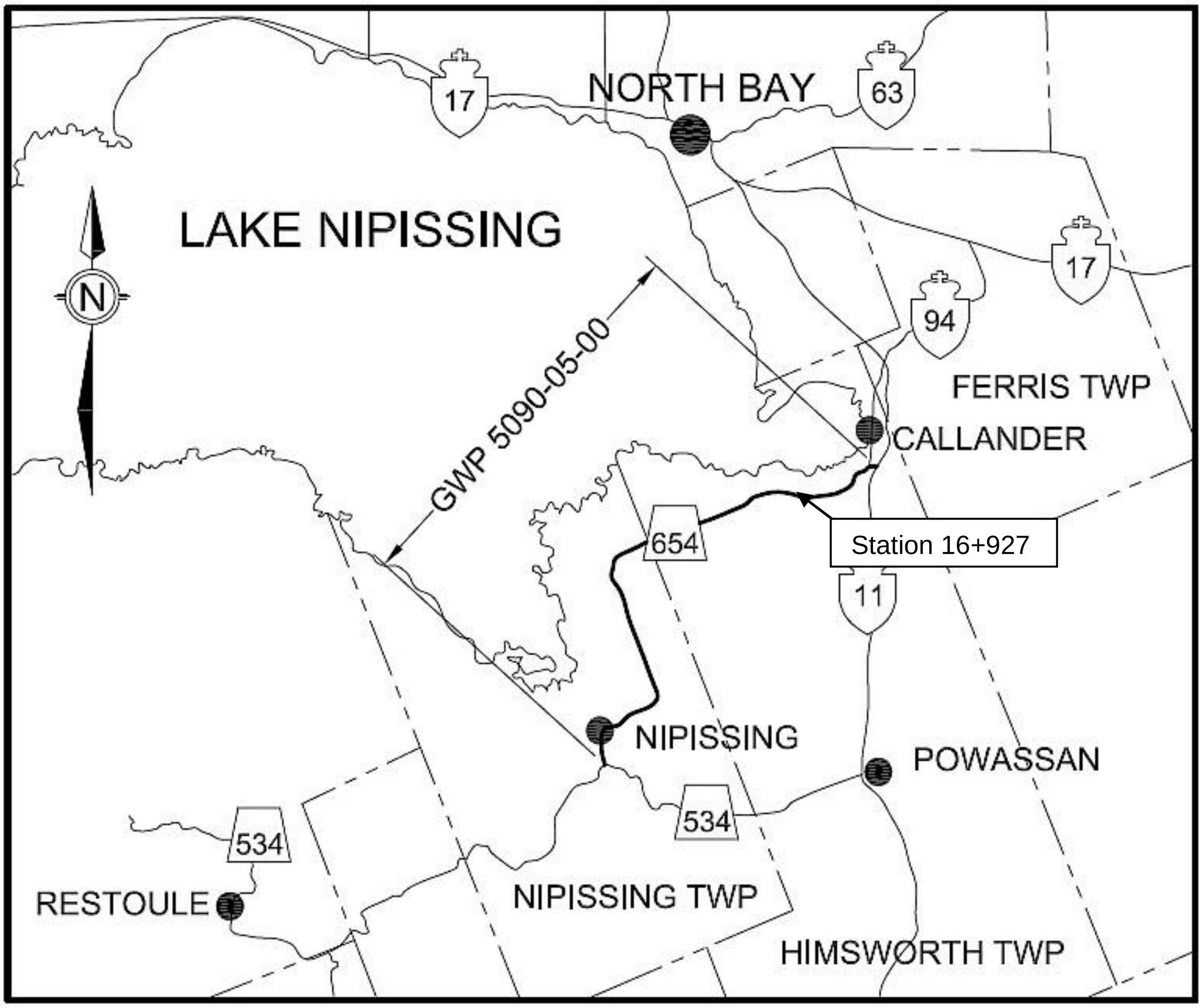
KEY PLAN **Drawing No. 1**

NOT TO SCALE



FINAL
FOUNDATION INVESTIGATION
AND DESIGN REPORT
GWP 5090-05-00
Highway 654

From Highway 534, Northerly 23.1 km
To The Highway 11 Interchange

Reference No: 12/03/12027-F2 January 2013

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Appendix 2 Subsurface Data

Enclosure No. 1	List of Abbreviations and Symbols
Enclosure Nos. 2 to 6	Record of Borehole Sheet

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LIST OF ABBREVIATIONS & DESCRIPTION OF TERMS

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

1. ABBREVIATIONS

AS Auger Sample
CS Chunk Sample
DS Denison type sample
FS Foil Sample
NFP No Further Progress
PH Sampler advanced by hydraulic pressure
PM Sampler advanced by manual pressure
RC Rock core with size & percentage of recovery
SS Split Spoon
ST Slotted Tube
TO Thin-walled, open
TP Thin-walled, piston
WS Wash Sample

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.

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

METRIC

RECORD OF BOREHOLE NO. 1

L|V|M

REFERENCE 12/03/12027-F2	DATUM Geodetic	LOCATION N 5116287.6 E 312448.1 - North Himsworth Township	ORIGINATED BY JL
PROJECT GWP 5090-05-00, Highway 654		BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers	COMPILED BY AT
CLIENT AECOM Inc.		DATE (Started) 5 April 2012 DATE (Completed) 5 April 2012 TIME (Completed) 12:20:00 PM	CHECKED BY MAM

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20, 40, 60, 80, 100
SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%): 20, 40, 60
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA (SI CL)

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR SA (SI CL)
216.4	Ground Surface					
0.0	50 mm Asphalt 200 mm Crushed Gravel FILL - brown sand some silt to silty some gravel to gravelly occasional cobbles	1	AS			
	(loose/dense)	2	SS	29		15 50 (35)
	asphalt layers present in fill deposit	3	SS	42		
		4	SS	18		
		5	SS	7		39 51 (10)
		6	SS	15		
		7	SS	7	∇	
211.1 5.3	SILTY CLAY - grey silty clay trace sand (stiff)	8	SS	9	Cave in	0 10 62 28
210.3 6.1	SAND and SILT - grey sand and silt some gravel occasional cobbles	9	SS	36/175 mm		
209.5 6.9	BEDROCK pink to grey gneiss	10	RC	Rec= 90% RQD= 45%		
		11	RC	Rec= 93% RQD= 40%		

ELEVATION SCALE: 216, 215, 214, 213, 212, 211, 210, 209, 208, 207

Continued Next Page

COMMENTS

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

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

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

	Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1)	5/4/12 12:20:00 PM	5	5.5
2)		-	-
3)		-	-

MEL-GEO 11209 - AREA 2 - BOREHOL LOGS.GPJ MEL-GEO.GDT 11/1/13

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

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

METRIC

RECORD OF BOREHOLE NO. 1

LVM

REFERENCE	12/03/12027-F2	DATUM	Geodetic	LOCATION	N 5116287.6 E 312448.1 - North Himsworth Township
ORIGINATED BY	JL	PROJECT	GWP 5090-05-00, Highway 654	BOREHOLE TYPE	Track Mounted CME 45B - Hollow Stem Augers
COMPILED BY	AT	CLIENT	AECOM Inc.	DATE (Started)	5 April 2012
DATE (Completed)	5 April 2012	TIME (Completed)	12:20:00 PM	CHECKED BY	MAM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES						
	Continued from Previous Page										
			12	RC	Rec= 100% RQD= 77%		206				
205.0 / 11.4	End of Borehole						205				

MEL-GEO 11209 - AREA 2 - BOREHOL LOGS.GPJ MEL-GEO.GDT 11/1/13

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

METRIC

RECORD OF BOREHOLE NO. 2

LVM

REFERENCE 12/03/12027-F2 DATUM Geodetic LOCATION N 5116284.5 E 312439.6 - North Himsworth Township ORIGINATED BY JL

PROJECT GWP 5090-05-00, Highway 654 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT

CLIENT AECOM Inc. DATE (Started) 15 May 2012 DATE (Completed) 15 May 2012 TIME (Completed) CHECKED BY MAM

ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
216.5	Ground Surface						
0.0	50 mm Aspalt 175 mm Crushed Gravel FILL - brown sand some to with silt trace to some gravel occasional cobbles (compact/dense)		1	AS			
			2	SS	37		
			3	SS	29		19 57 (24)
			4	SS	19		
			5	SS	18		4 67 (29)
			6	SS	14	▽	
211.9 4.6	SAND AND SILT - grey sand and silt with gravel trace organics (loose)		7	SS	5		21 38 34 7
210.5 6.0	Auger Refusal End of Borehole						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

UNIT WEIGHT γ kN/m³

ELEVATION SCALE: 216, 215, 214, 213, 212, 211

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)	15/5/12 11:45:00 AM	4.3	5.9
2)		-	-
3)		-	-

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

MEL-GEO 11209 - AREA 2 - BOREHOL LOGS.GPJ MEL-GEO.GDT 11/1/13

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

METRIC

RECORD OF BOREHOLE NO. 3

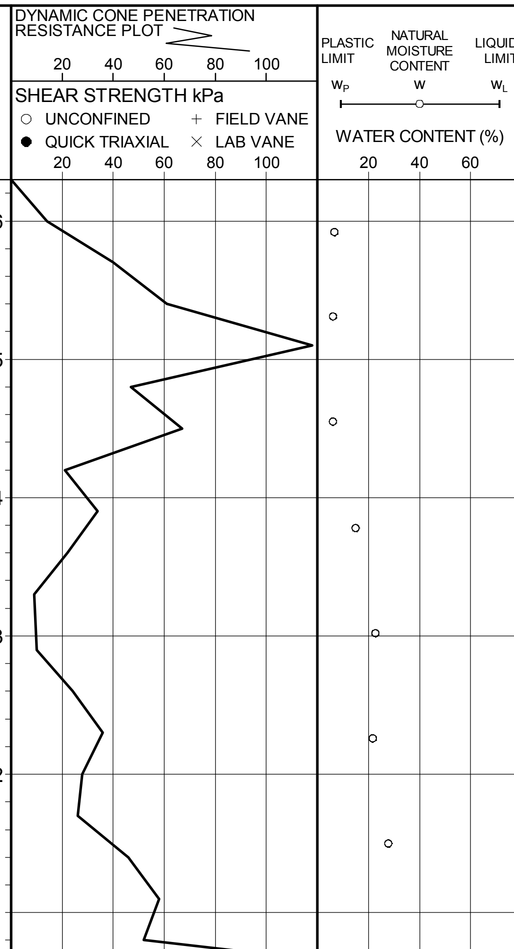
LVM

REFERENCE 12/03/12027-F2 DATUM Geodetic LOCATION N 5116277.8 E 312458.4 - North Himsworth Township ORIGINATED BY JL

PROJECT GWP 5090-05-00, Highway 654 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT

CLIENT AECOM Inc. DATE (Started) 15 May 2012 DATE (Completed) 15 May 2012 TIME (Completed) CHECKED BY MAM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	NATURAL MOISTURE CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
216.3	Ground Surface						
0.0	±75 mm Asphalt						
	FILL - brown gravelly sand some silt occasional cobbles	1	AS			o	
	(compact/very dense)	2	SS	61		o	
		3	SS	58		o	35 49 (16)
		4	SS	29		o	
213.4 / 2.9	SILTY CLAY - grey silty clay	5	SS	10		o	
212.5 / 3.8	SILT - brown to grey silt some sand trace clay	6	SS	17		o	0 10 86 4
	(compact)				▽ (water level) ⊠ (cave in)		
		7	SS	18		o	
210.7 / 5.6	DCPT Refusal Auger Refusal End of Borehole						



COMMENTS

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

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

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

	Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1)	15/5/12 3:20:00 PM	4.4	4.6
2)		-	-
3)		-	-

MEL-GEO 11209 - AREA 2 - BOREHOL LOGS.GPJ MEL-GEO.GDT 11/1/13

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

RECORD OF BOREHOLE NO. 4

METRIC

LVM

REFERENCE 12/03/12027-F2 DATUM Geodetic LOCATION N 5116303.5 E 312457.2 - North Himsworth Township ORIGINATED BY JL

PROJECT GWP 5090-05-00, Highway 654 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT

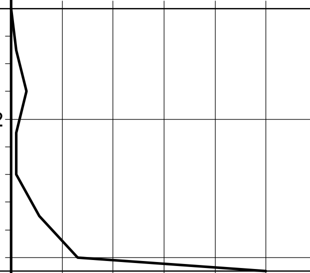
CLIENT AECOM Inc. DATE (Started) 22 May 2012 DATE (Completed) 22 May 2012 TIME (Completed) 11:30:00 AM CHECKED BY MAM

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	NATURAL MOISTURE CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
212.8	Ground Surface							
0.0	FILL - brown fine to medium sand some silt trace gravel occasional cobbles							
212.5 0.3	SILTY CLAY - grey/brown silty clay	1	AS				o	
211.9 0.9	SAND - grey sand some silt with gravel (compact)	2	SS	16	▽	212	o	26 58 (16)
		3	SS	50/150 mm			o	
211.0						211		
210.9 1.9	Auger Refusal DCPT Refusal End fo Borehole							

Advanced Auger Probe 1.3 m W of BH 4. Auger Refusal at 1.6 m depth.

Advanced Auger Probe 1.5 m N and 1.3 m W of BH 4. Auger Refusal at 1.8 m depth.

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100)



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

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

UNIT WEIGHT γ kN/m³

COMMENTS

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

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

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1) 22/5/12 11:45:00 AM	0.9	1.2
2)	-	-
3)	-	-

MEL-GEO 11209 - AREA 2 - BOREHOL LOGS.GPJ MEL-GEO.GDT 11/1/13

ENCLOSURE NO.:6 (Pg. 1 of 1)

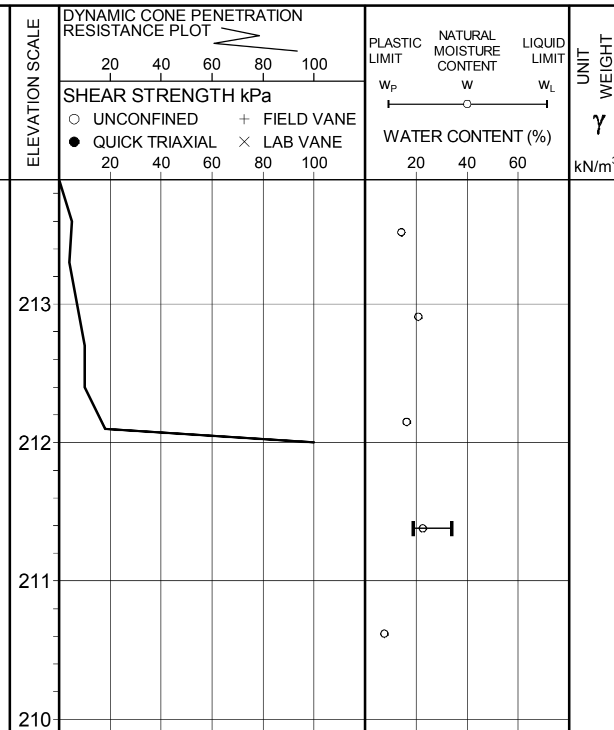
METRIC

RECORD OF BOREHOLE NO. 5

LVM

REFERENCE 12/03/12027-F2	DATUM Geodetic	LOCATION N 5116270.4 E 312443.1 - North Himsworth Township	ORIGINATED BY JL
PROJECT GWP 5090-05-00, Highway 654		BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers	COMPILED BY AT
CLIENT AECOM Inc.		DATE (Started) 22 May 2012 / DATE (Completed) 22 May 2012 / TIME (Completed) 4:00:00 PM	CHECKED BY MAM

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRATA PLOT	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
213.9	Ground Surface						
0.0	±50 mm Organics FILL - brown sand trace silt trace gravel occasional cobbles and boulders		1	AS			
			2	SS	21		
212.0			3	SS	16		
211.8 / 1.9	DCPT Refusal						
2.1	SILTY CLAY - grey silt clay with sand trace gravel		4	SS	10		9 25 32 34
210.7 / 3.2	SAND - grey fine sand some silt some gravel occasional cobbles (dense)		5	SS	52		
209.9 / 4.0	Auger Refusal End of Borehole						



COMMENTS
DCPT refusal likely encountered on boulder size rock, moved Borehole 1 m to the west

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) 22/5/12 3:50:00 PM	DRY	3.7
2)	-	-
3)	-	-

MEL-GEO 11209 - AREA 2 - BOREHOL LOGS.GPJ MEL-GEO.GDT 11/1/13

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Appendix 3 Borehole Plan and Lab Data

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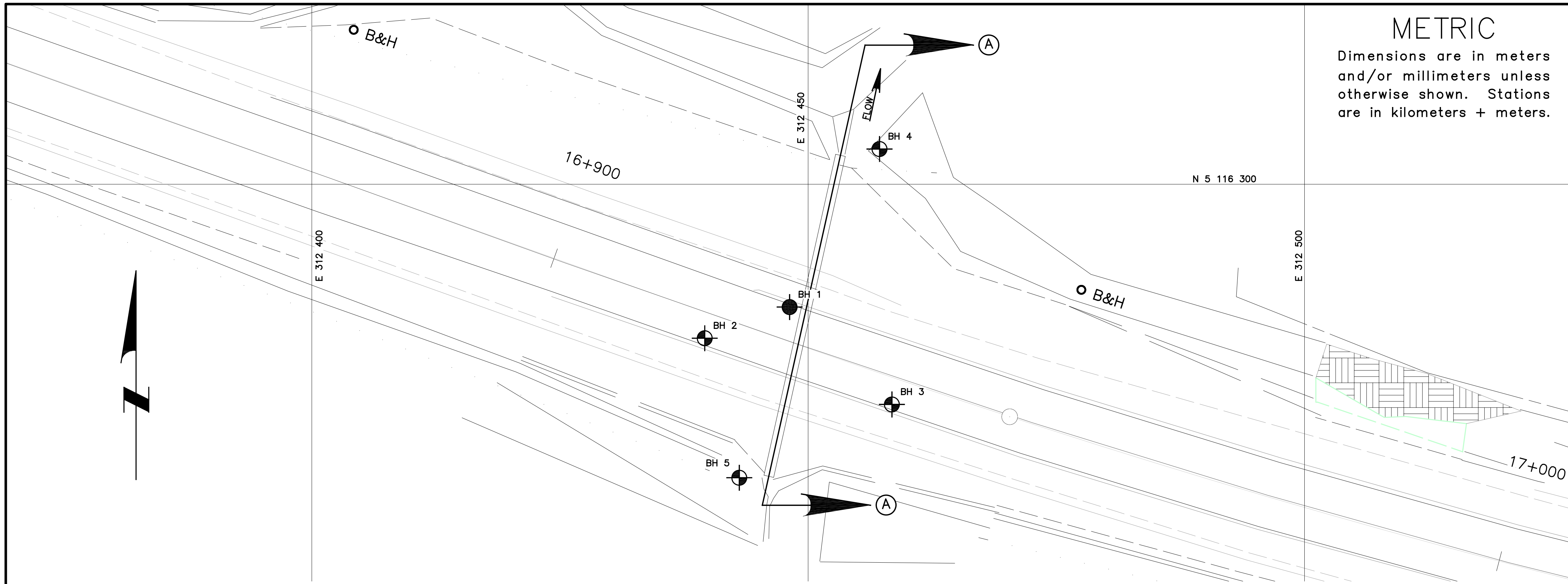
SITE No	
WP No	
GWP No	5090–05–00
Geocres	31L–167

HWY NO. 654 –
Township of North Himsworth
Culvert at Station 16+927
BOREHOLE LOCATIONS & SOIL STRATA

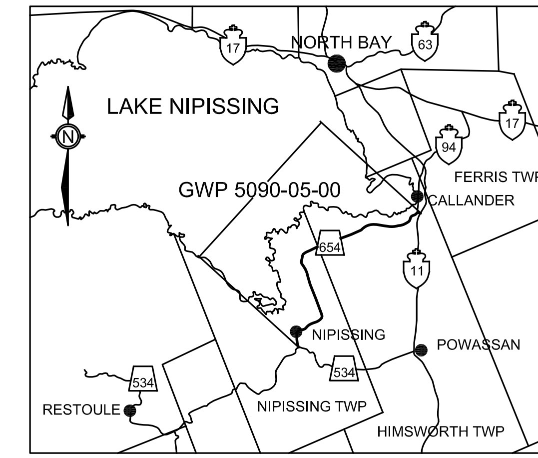
Drawing 2

LVM | MERLEX

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



PLAN
5m SCALE 5m



KEY PLAN – NOT TO SCALE

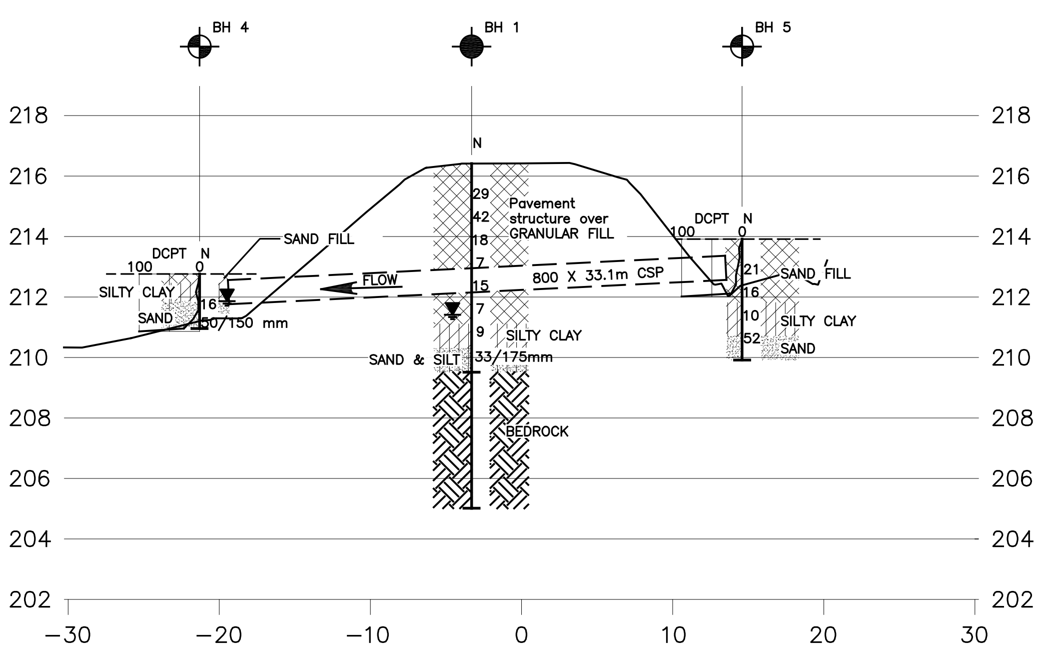
LEGEND

- Borehole
- Dynamic Cone Penetration Test (DCPT)
- Borehole and DCPT
- N — Blows/0.3 m (Std Pen Test, 475 J/blow)
- DCPT — 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

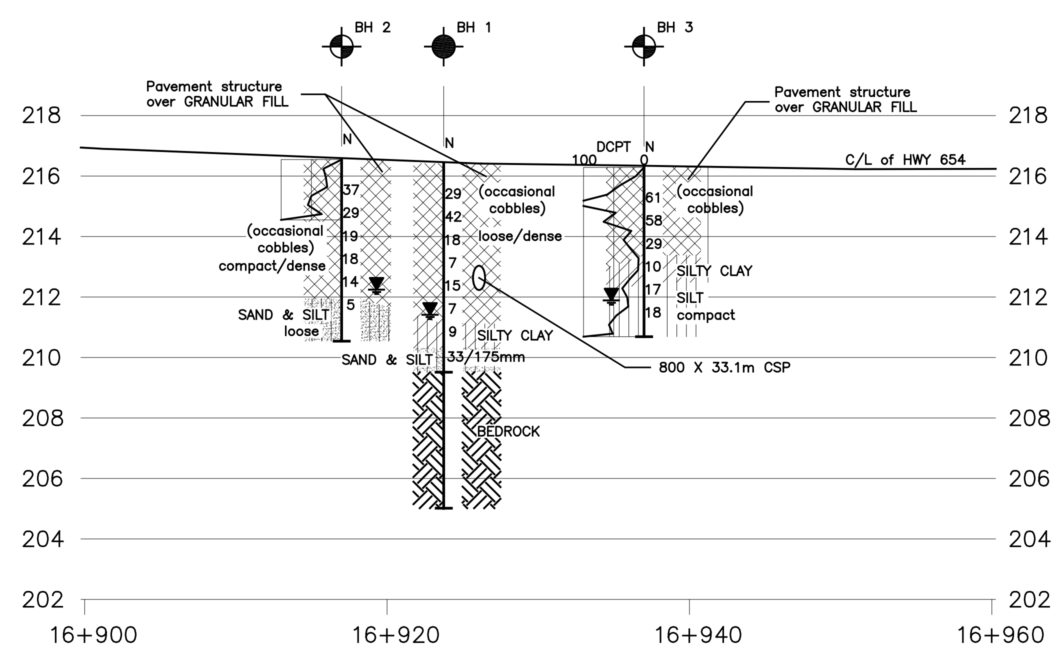
Borehole No.	Elev.	O/S	Co–ordinates Northerly	Co–ordinates Easterly
Borehole No. 1	216.4	3.3m Lt	5116287.6	312448.1
Borehole No. 2	216.5	2.5m Rt	5116284.5	312439.6
Borehole No. 3	216.3	2.6m Rt	5116277.8	312458.4
Borehole No. 4	212.8	21m Rt	5116303.5	312457.2
Borehole No. 5	213.9	15m Lt	5116270.4	312443.1

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.



SECTION AT CULVERT Ⓐ – Ⓐ
5m SCALE 5m HOR
2.5m 2.5m VER



℄ PROFILE
5m SCALE 5m HOR
2.5m 2.5m VER

REVISIONS DATE	BY	DESCRIPTION
Aug 2012	RG	DRAFT
Jan 2013	RG	FINAL

HWY No. 654 – North Himsworth Twp – Culvert at Station 16+927

SUBM'D		REF 12027–F2	SITE
DRAWN RG	CHK MAM	DATE August 2012	FIG 2

Reference No.: 12/03/12027-F2
Date: January 2013

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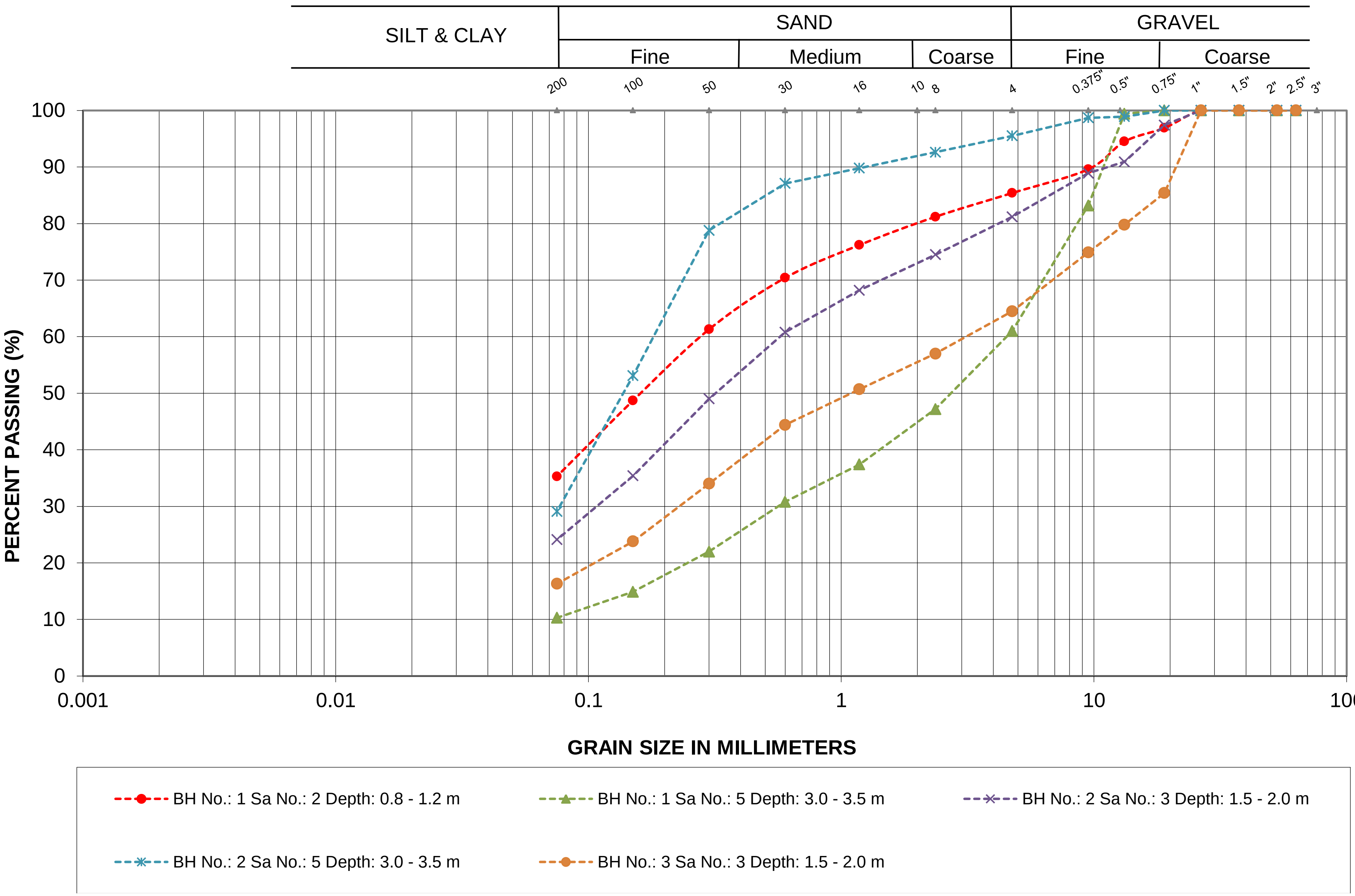
GRAIN SIZE ANALYSIS



EMBANKMENT FILL
SANDS
varying silt content

G.W.P.: 5090-05-00
LOCATION: Hwy 654

Reference No.: 12/03/12027-F2
Date: January 2013

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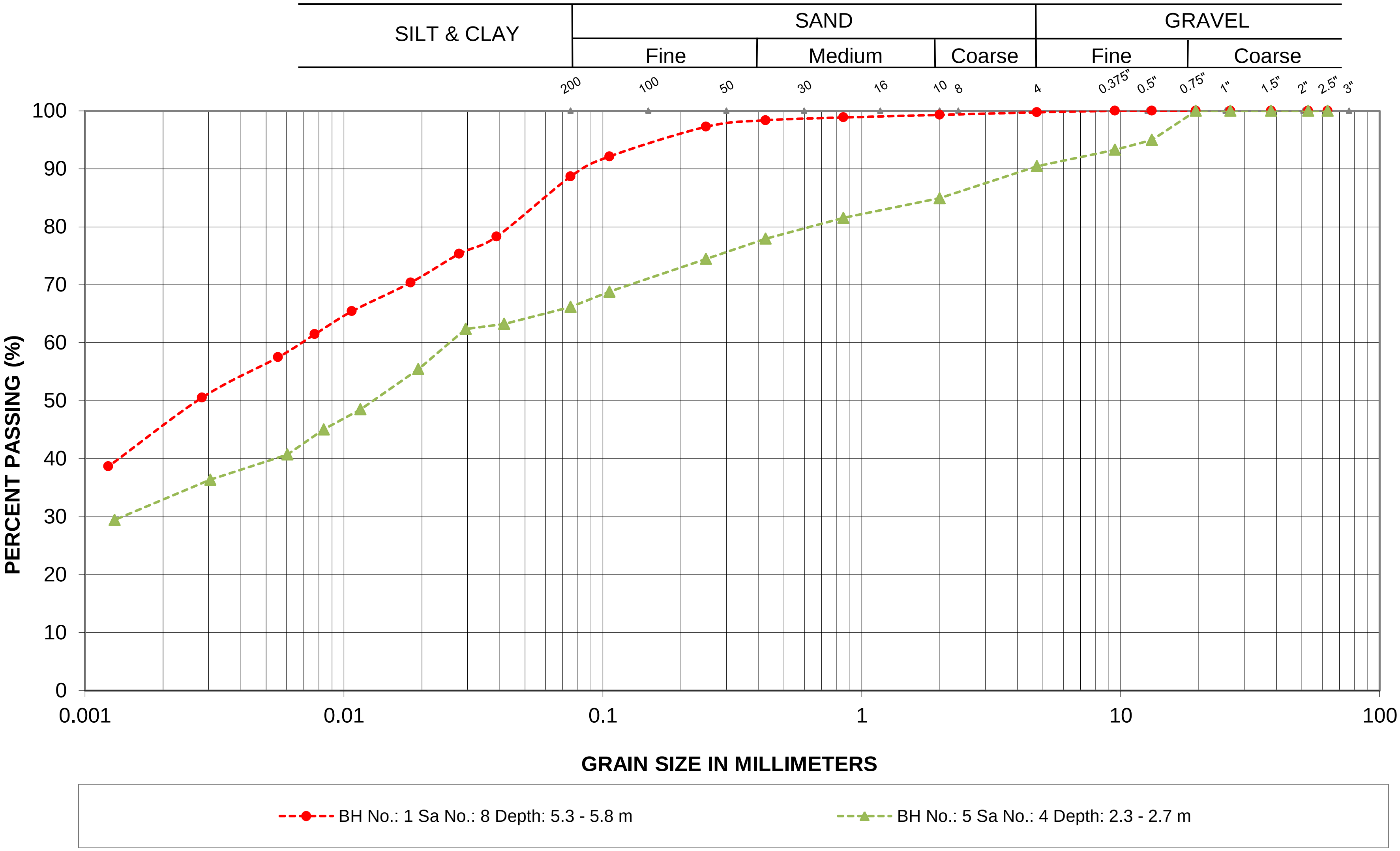
GRAIN SIZE ANALYSIS



G.W.P.: 5090-05-00
LOCATION: Hwy 654

SILTY CLAY

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FIGURE L-2

Reference No.: 12/03/12027-F2
Date: January 2013

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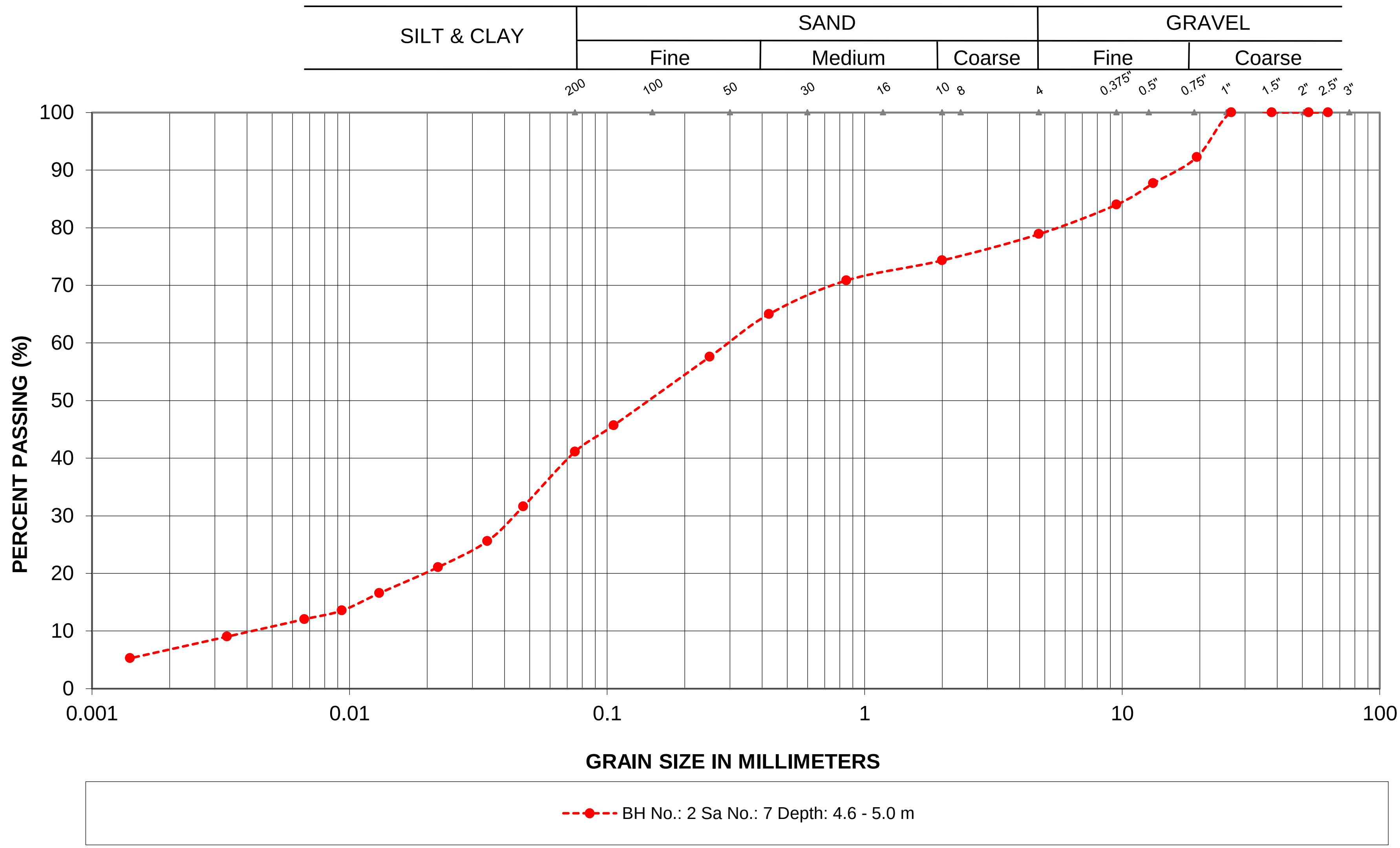
GRAIN SIZE ANALYSIS



G.W.P.: 5090-05-00
LOCATION: Hwy 654

SAND AND SILT

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FIGURE L-3

Reference No.: 12/03/12027-F2
Date: January 2013

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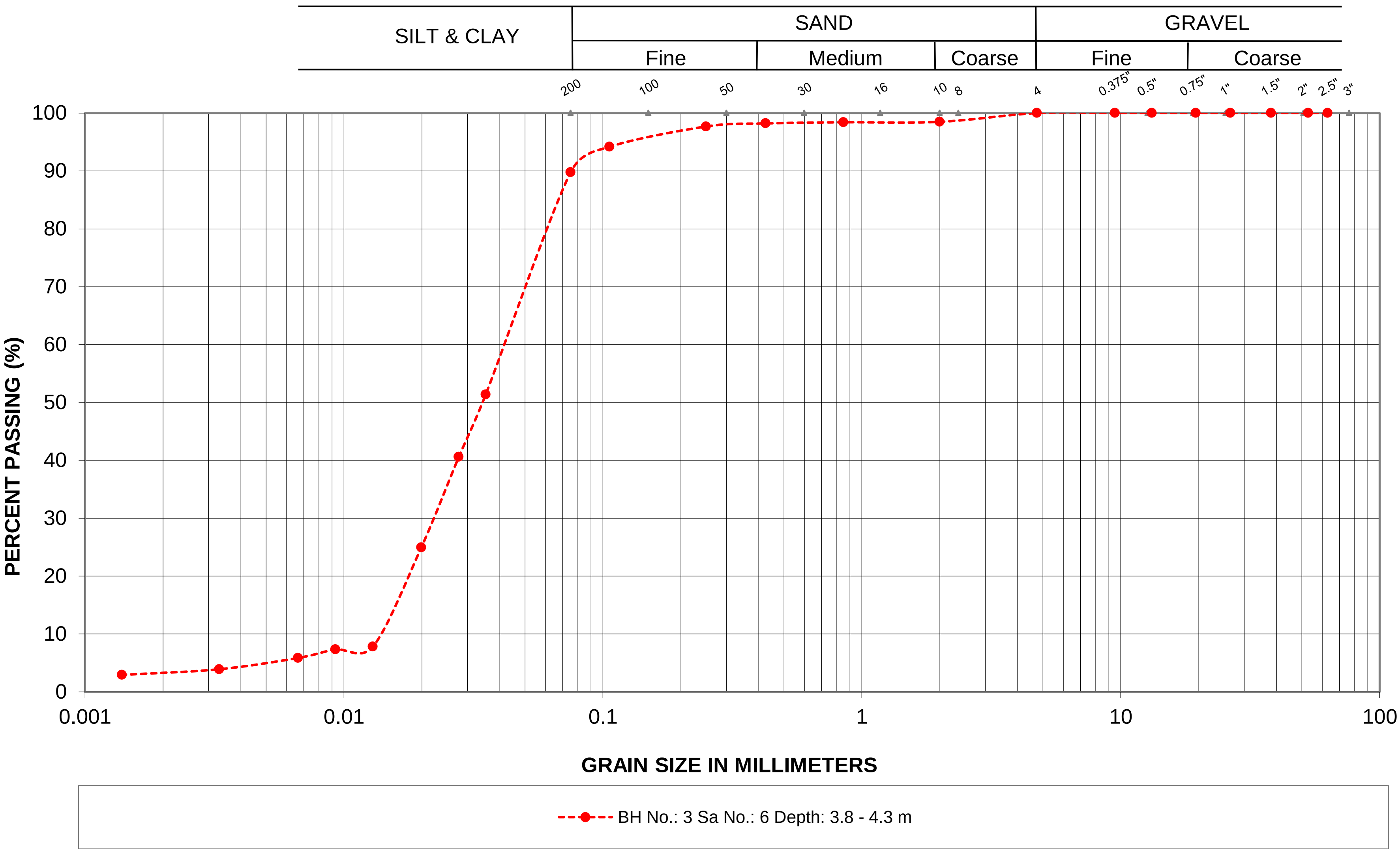
GRAIN SIZE ANALYSIS



G.W.P.: 5090-05-00
LOCATION: Hwy 654

SILT

Reference No.: 12/03/12027-F2
Date: January 2013

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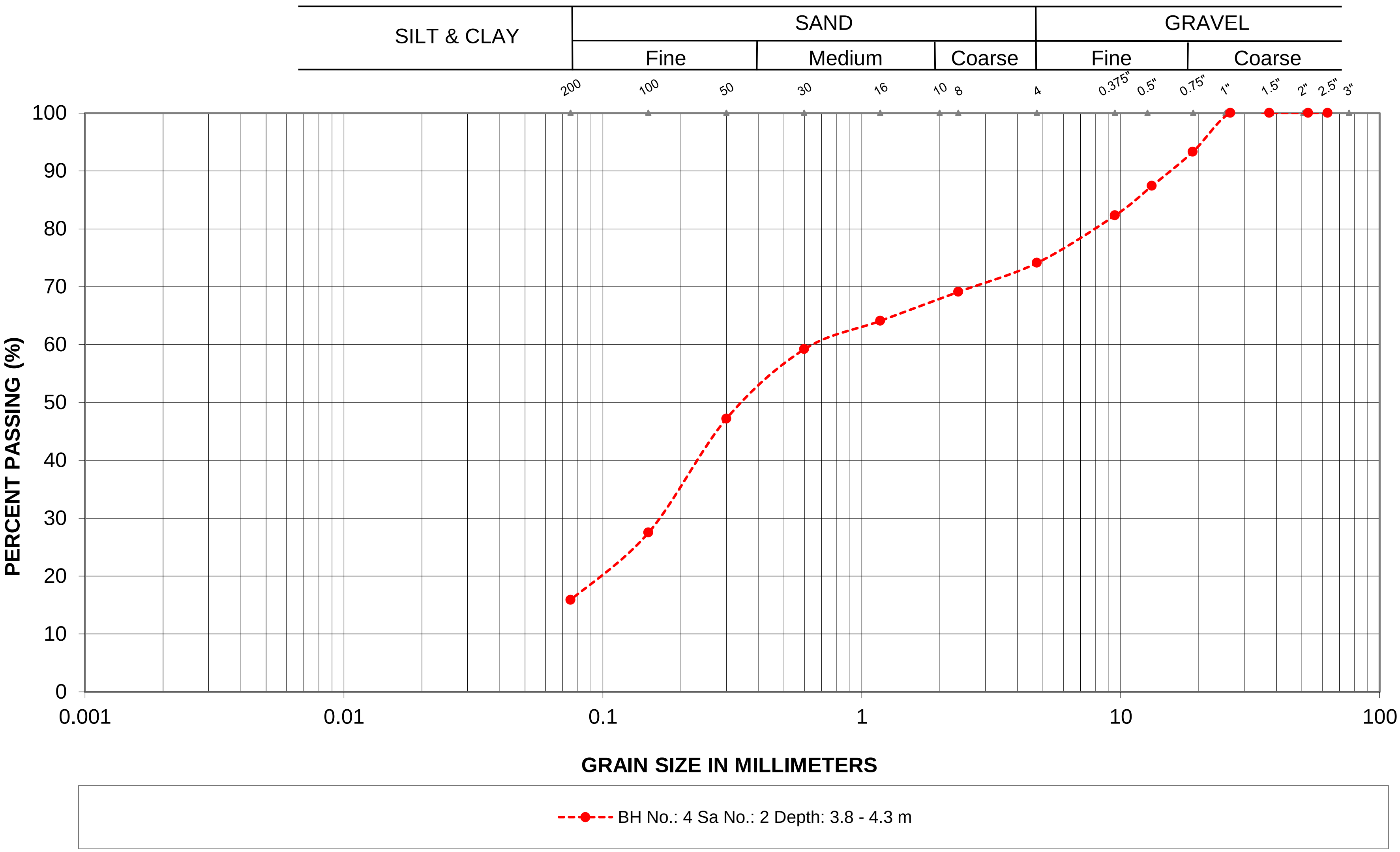
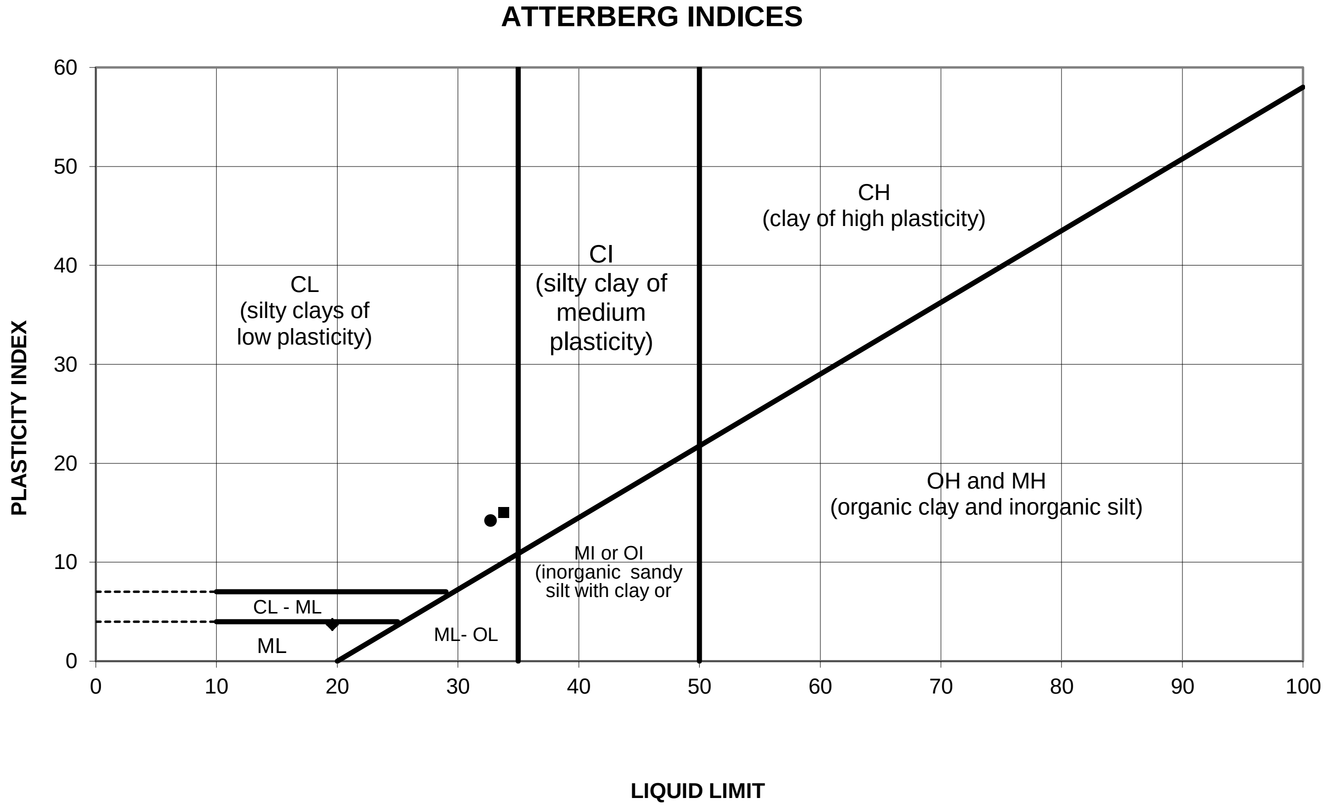
GRAIN SIZE ANALYSIS



G.W.P.: 5090-05-00
LOCATION: Hwy 654

SAND

ATTERBERG LIMITS TEST RESULTS	FIGURE L-6



SYMBOL	BH	Sa. No.	Depth(m)	Elev.(m)	Liquid Limit	Plastic Limit	Plasticity Index	NMC %
●	1	8	5.3	211.1	32.7	18.5	14.2	29.9
◆	2	7	4.6	211.9	19.6	15.9	3.7	16.2
■	5	4	2.3	211.6	33.8	18.8	15.0	22.6

Date: January 2013
Project: Hwy 654
G.W.P: 5090-05-00

Prep'd: AT
Chkd: MAM
Ref. No.: 12/03/12027-F2

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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					9.2				N/A			
	2	0.8	15	50	35		8.9				29			
	3	1.5					7.0				42			
	4	2.3					5.7				18			
	5	3.1	39	51	10		5.2				7			
	6A	3.8					10.9				15			
	6B	3.8					2.5				15			
	7	4.6					9.9				7			
	8	5.3	0	10	62	28	29.9	32.7	18.5	14.2	9			
	9	6.1					17.7				36/175mm			
2	1	0.0					6.7				N/A			
	2	0.8					9.9				37			
	3	1.5	19	57	24		7.1				29			
	4	2.3					8.8				19			
	5	3.1	4	67	29		9.7				18			
	6	3.8					16.5				14			
	7	4.6	21	38	34	7	16.2	19.6	15.9	3.7	5			
3	1	0.0					6.6				N/A			
	2	0.8					6.1				61			
	3	1.5	35	49	16		6.1				58			
	4	2.3					14.9				29			
	5	3.1					22.7				10			
	6	3.81	0	10	86	4	21.6				17			
	7	4.57					27.7				18			
4	1	0.0					30.6				N/A			
	2	0.8	26	42	16		23.0				16			
	3	1.5					11.5				50/150mm			

Laboratory Tests - Summary Sheet

Borehole No.	Sample No.	Depth	Grain Size Analysis				NMC	Atterberg Limits			SPT 'N'	USCS	Unit Weight (kN/m3)	Remarks
			Gravel Size (%)	Sand Size (%)	Silt Size (%)	Clay Size (%)		LL (%)	PL (%)	IP (%)				
5	1	0.0					14.2				N/A			
	2	0.8					20.8				21			
	3	1.5					16.2				16			
	4	2.3	9	25	32	34	22.6	33.8	18.8	15.0	10			
	5	3.1					7.5				52			

Appendix 4 Photo Essay

Enclosure No. 7: Photo Essay

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Existing Embankment – Left Side, Looking North-East	Photo: 1

Embankment at Culvert Outlet – Looking South	Photo: 2

Reference No. 12/03/12027-F2 Project: Hwy 654 – Station 16+627	Photos Provided By: LVM Date: March 2012

Culvert Outlet – Looking South	Photo: 3

Culvert Inlet – Looking South	Photo: 4

Reference No. 12/03/12027-F2 Project: Hwy 654 – Station 16+627	Photos Provided By: LVM Date: March 2012

Appendix 5 Design Data

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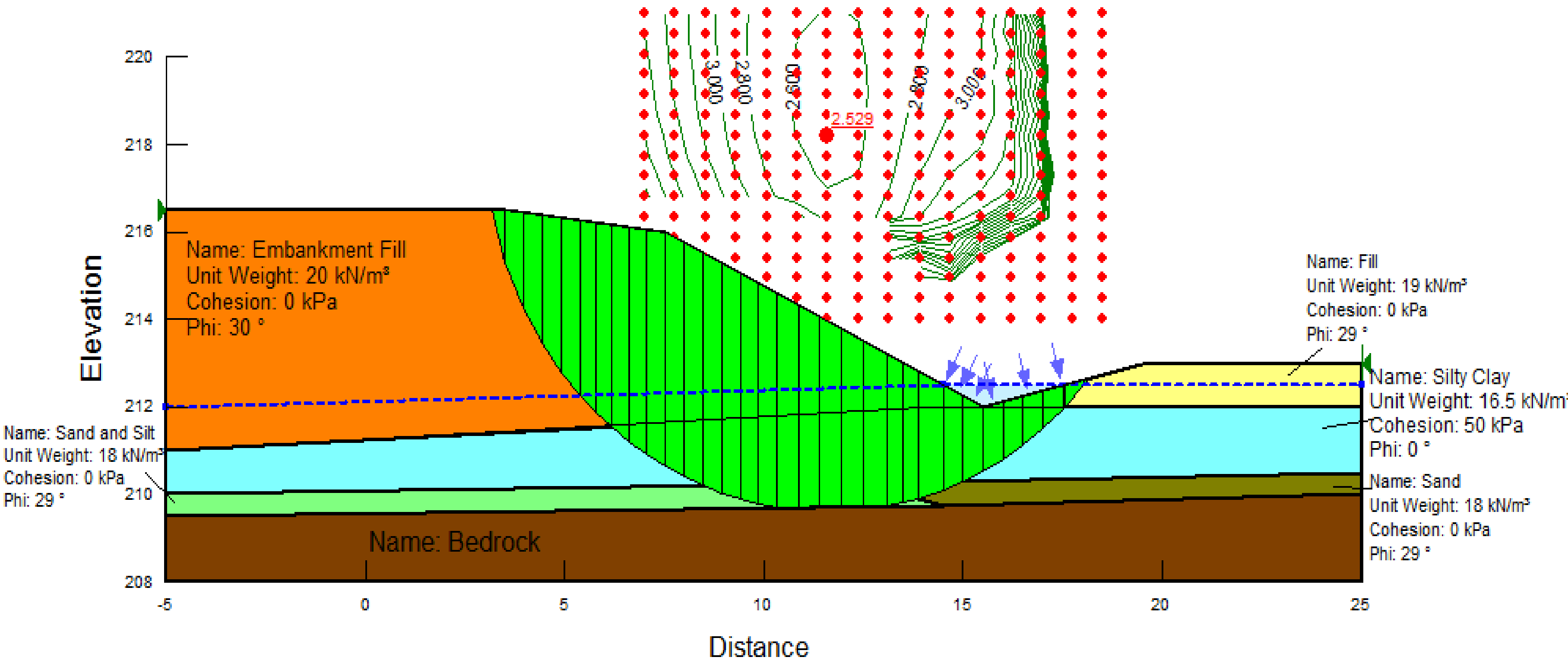
Stability Analysis
Embankment Stability
Long Term Stability
Failure of Native Material
2H:1V Slopes



Stability Analysis
Station 16+927
TWP of North Himsworth

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^2
Steel Sheet Piles	5 – 21	-High strength, continuous, -Readily available	-Limited by soil conditions (i.e. obstructions)	Recommended for temporary protection. Pinning the toe of sheeting may be required due to shallow bedrock.	$ 650/m^2
Pre-cast concrete panels	3 – 10	-Durable -Assists in minimizing seepage	-Limited depths -Can be damaged during installation -Limited by soil conditions (i.e. obstructions)	Not considered due to higher cost.	
Soldier piles	5 – 25	-Easy installation -Readily available -Adaptable to various ground conditions	-Pre-drilling may be required -Possible ground loss	Considered for protection system penetrating into bedrock, (i.e. if greater toe resistance is required).	$ 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	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	$ 1,200 – 1,500/m^2

REF.: 12027-F2

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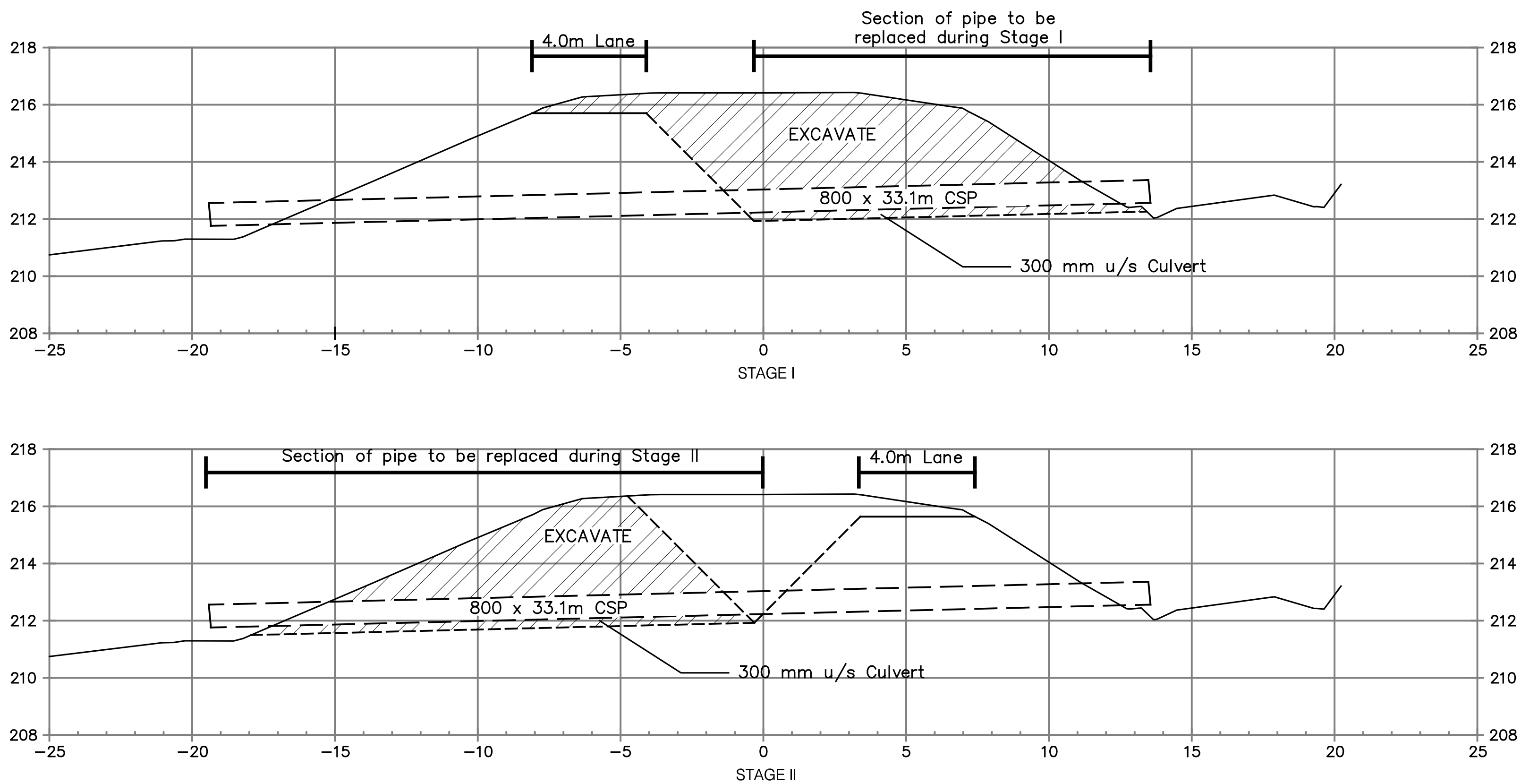

2.5m 0 5m

METRIC

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

HWY 654- Township of North Himsworth - Culvert at Station 16+927
Conceptual Staging - Typical Sections

FIGURE SK-3

REF.: 12027-F2

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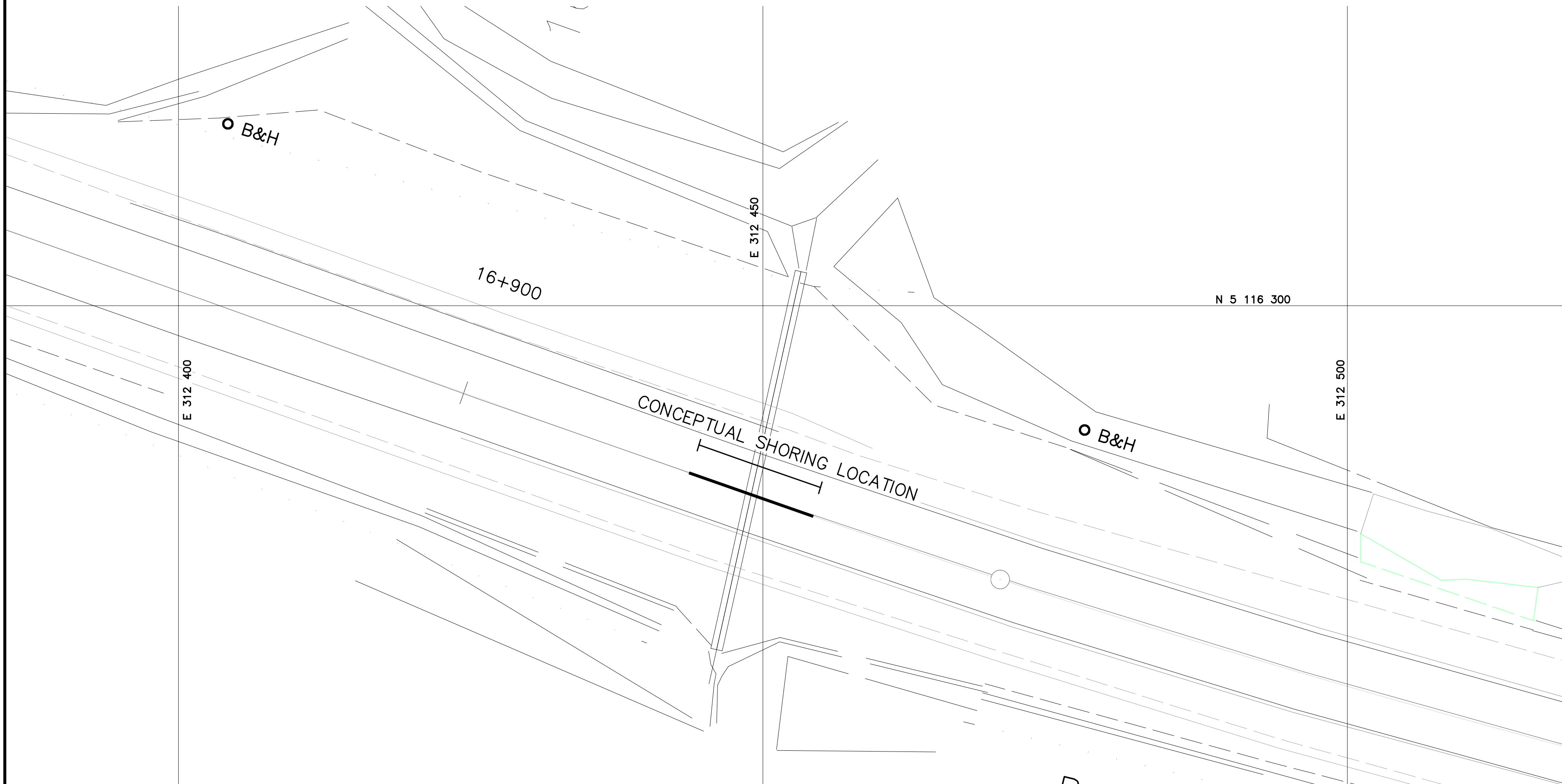

5m 0 10m

METRIC

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

HWY 654- Township of North Himsworth - Culvert at Station 16+927
Conceptual Shoring Locations

FIGURE SK-4

REF.: 12027-F2

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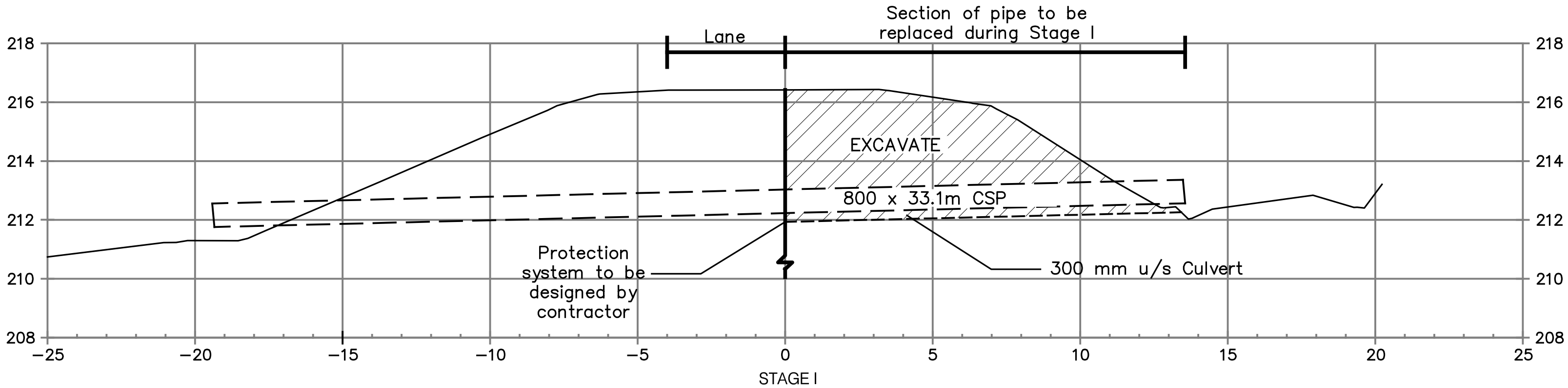

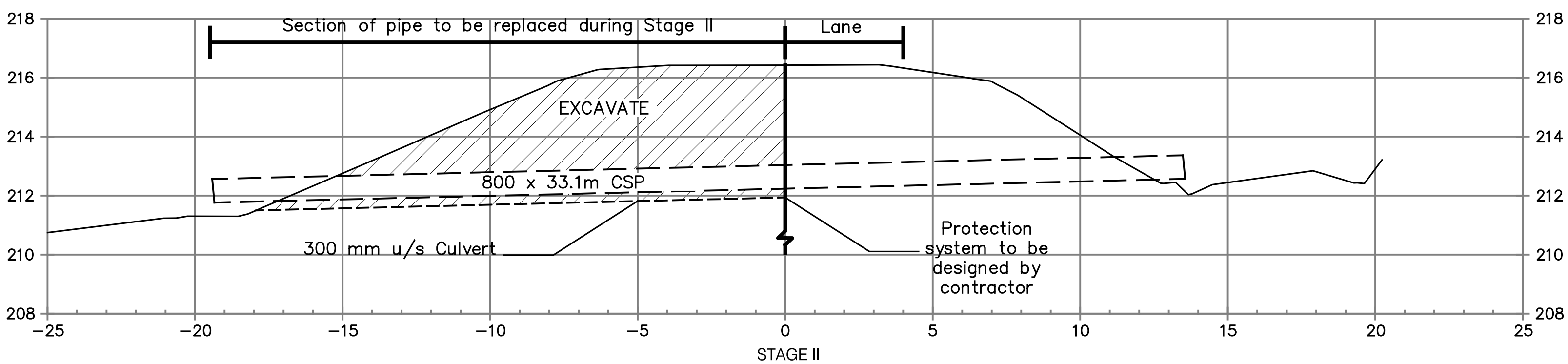

2.5m 0 5m

METRIC

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

HWY 654- Township of North Himsworth - Culvert at Station 16+927
Protection System - Typical Sections

FIGURE SK-5