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

Highway 144 Rehabilitation
Culvert Replacement – Site No. 46-413
Halfway Lake Channel Culvert
Station 22+833 – Twp. Of Antrim
GWP 5046-05-00

Highway 144
From Cartier West Entrance (Centre Street)
Northerly 24.8 km

FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

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1.0 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 structure and provide design parameters for a protection system. This culvert structure replacement on Halfway Lake Channel is located on Highway 144, some 24.6 km north of the west entrance to Cartier, in the Township of Antrim.

The foundation investigation location was specified by the MTO in the RFP/TPM documentation Agreement No. 5010-E-0012. The terms of reference for the scope of work are outlined in MEL's proposal P-10-177, dated January, 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.

2.0 SITE DESCRIPTION

The foundation investigation for this culvert structure is located at Station 22+833, Township of Antrim (Site No. 46-413). The topography at the site is generally of low relief. The existing highway embankment currently supports two undivided lanes of highway, running in a north south direction. The existing highway, at the culvert location, is constructed on a fill embankment some 3.5 m in height, with centerline elevation at 411.5 m at the culvert location. The culvert at this location was measured during the structural review and reported to be 3.05 m diameter structural plate corrugated steel pipe (SPCSP) culvert. The culvert invert is at about elevation 408.2 m and, based on Contract Drawing No. 66-121 for WP No.247-64-4, was installed with a zero slope. Rock fill was visible protruding from the embankment slopes.

Infrastructure at the culvert location consists of overhead power and communication wires on the east (right) side of the highway. Halfway Lake is located to the left and right of the highway embankment, down chainage from the channel culvert.

2.1 Site Physiography and Surficial Geology

This project is located in the Geomorphic Sub-province known as the Eastern Sandy Uplands. The topography on this section of Highway 144 is generally rolling and the highway traverses a glaciofluvial outwash plain comprised of sands and silt. 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 sand and gravel containing varying amounts of silt and clay.

Bedrock in the area, as indicated on OGS Map 2506, is of the Early Precambrian Era. At the location of this culvert foundation investigation, the bedrock comprises of Felsic Igneous and Metamorphic Rocks including; granitic rocks, syenite, pegmatite, and unsubdivided migmatite.

3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out between August 31th and October 11th, 2011, during which six (6) sampled boreholes were advanced. For the purposes of foundation design for the culvert replacement and roadway protection, four boreholes were advanced through the embankment, two up chainage and two down chainage from the culvert. Additionally, a borehole was advanced at each the inlet and outlet ends of the culvert.

The field investigation was carried out using a 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.

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) advanced 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 B), with a summary of results presented on the laboratory sheets in Appendix C (Figures Nos. L-1 to L-4).

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.

4.0 SUBSURFACE CONDITIONS

Details of the subsurface conditions revealed by the investigation program are presented on the enclosed Record of Borehole Logs (Appendix B) and on Figure No. 2 (Appendix C). 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 Historical Background Subsurface Information

Historical subsurface information at the Halfway Lake Channel Culvert location was unavailable at the time of this assignment. Based on information obtained from Contract No. 1966-0281, WP No. 247-64-4, the embankment in this area was constructed using rock fill, with granular backfill around the culvert.

4.2 Halfway Lake Channel Culvert, Station 22+833, TWP of Antrim – Site No. 46-413

A plan and profile illustrating the borehole locations and stratigraphic sequences is shown on Figure No. 2, Appendix C. During the course of the exploration program, six (6) sampled boreholes were put down at this site, with Borehole Nos. 1 and 2 advanced off from the ends of the culvert and Borehole Nos. 3 to 6, inclusive, were advanced through the existing embankment. At the time of the subsurface investigation, the ground surface elevations at Boreholes Nos. 1 to 6 inclusive were recorded at 409.5, 409.5, 411.5, 411.5, 411.5, and 411.6 m, respectively.

4.2.1 Pavement Structure

At surface at Borehole Nos. 3 to 6, a surficial pavement structure consisting of 150 to 175 mm of asphalt underlain by 100 to 200 mm of crushed gravel was encountered.

4.2.2 Surficial Deposits

At surface at Borehole No. 1, a deposit of brown sand some silt, some 300 mm thick was penetrated. At Borehole No. 2, a deposit of back silty organics some 100 mm thick was penetrated.

4.2.3 Fill

Underlying the surficial pavement structure at Borehole Nos. 2 to 6, a deposit of fill consisting of brown sand some to with gravel trace to some silt was penetrated. The natural moisture content measured on samples of this deposit was in the order of 2 to 11%. Gradation analyses were carried out on six (6) samples of this deposit, the results of which indicated 22 to 44% gravel size particles, 46 to 68% sand size particles, and 5 to 17% silt and clay size particles (Figure No. L-1, Appendix C). Based on SPT ‘N’ values of 15 to 26 blows per 300 mm penetration, the compactness of this deposit was described as compact. This deposit was encountered to depths of 3.2 and 2.6 m below grade at Borehole Nos. 4 and 5, respectively (elevations 408.3 and 408.9 m, respectively). Auger Refusal was encountered on the underlying rock fill at depths of 1.0 and 0.9 m below grade at Borehole Nos. 3 and 6, respectively (elevations 410.5 and 410.7 m, respectively). A DCPT was driven past the auger refusal on the rock fill deposit at Borehole No. 6 to refusal at a depth of 10.9 m (elevation 400.7 m). The results of the DCPT indicate similar subsurface soil conditions.

4.2.4 Silt

Underlying the surficial deposits at Borehole Nos. 1 and 2, and underlying the fill at Borehole Nos. 4 and 5, a deposit of grey silt trace to some sand trace clay was penetrated. The natural moisture content measured on samples of this deposit was in the order of 18 to 30%. Gradation analyses were carried out on eleven (11) samples of this deposit, the results of which indicated 0% gravel size particles, 0 to 13% sand size particles, and 83 to 98% silt size particles, and 2 to 8% clay size particles (Figure No. L-2, Appendix C). Atterberg Limits Testing was carried out on samples of this deposit, results indicated the silt was non plastic, with one sample indicating a Liquid Limit in the order of 24% and a Plastic Limit in the order of 21% (see Figure No. L-4, Appendix C). Based upon USCS, this deposit was classified as inorganic silt (ML). Based on SPT ‘N’ values of 0 (static weight of hammer) to 16 blows per 300 mm penetration, the compactness of this deposit was described as very loose to compact, generally compact. This deposit was encountered to depths of 8.5, 7.6, 11.3, and 10.6 m below grade at Borehole Nos. 1, 2, 4, and 5, respectively (elevations 401.0, 401.9, 400.2, and 400.9 m, respectively).

4.2.5 Sand

Underlying the silt at Borehole No. 1, 2, 4, and 5, a deposit of grey sand with gravel some silt was penetrated. The natural moisture content measured on samples of this deposit was in the order of 11 to 27%. A gradation analysis was carried out on one (1) sample of this deposit the results of which indicated 30% gravel size particles, 50% sand size particles, and 20% silt and clay size particles (Figure No. L-3, Appendix C). Based on SPT 'N' values of 12 to 26 blows per 300 mm penetration, the compactness of this deposit was described as compact. Auger refusal was encountered in this deposit at depths of 9.6, 8.3, 11.8, and 11.8 m below grade at Borehole Nos. 1, 2, 4, and 5, respectively (elevations 399.9, 401.2, 399.7, and 399.7 m, respectively). DCPT refusal was encountered in this deposit at depths of 9.6, 8.3, 11.8, 11.8, and 10.9 m below grade at Borehole Nos. 1, 2, 4, 5, and 6, respectively (elevations 399.9, 401.2, 399.7, 399.7, and 400.7 m, respectively).

4.3 Groundwater Conditions

The water level in the culvert was encountered at an elevation of 409.1 m, at the time of this investigation. Measurements of the groundwater level and cave-in levels were undertaken, where possible, in the open boreholes during the advance of the individual borings and upon completion. These levels are recorded on the individual Record of Borehole Log Sheets (Appendix B). The ground water level was measured in the embankment, at Borehole Nos. 4 and 5 at elevations 409.0 and 409.1 m, respectively. At Borehole No. 1 and 2, downstream and upstream, respectively, a water level reading in the open borehole was recorded at elevations 408.9 and 408.5 m respectively. The water level at Borehole No. 2 was taken immediately upon completion, and had not stabilized. The groundwater levels will fluctuate seasonally.

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5.0 DESIGN COMMENTS AND RECOMMENDATIONS

5.1 General

A foundation investigation was carried for the proposed replacement of an existing culvert and for a protection system, as identified in the RFP. The 3.05 m diameter SPCSP culvert is located approximately 24.6 km north of the west entrance to Cartier and is identified as Site No. 46-413, at Station 22+833 in the Township of Antrim.

The existing culvert was measured during the structural review by others to be a 3.05 m diameter SPCSP culvert. The existing highway embankment currently supports two undivided lanes of highway, running in a north south direction. Water flow through the culvert was observed from east to west (right to left) at the time of the field drilling operations. Based on data from this foundation investigation and as noted on the contract drawing for WP 247-64-4, the embankment supporting the existing pavement structure at this site has been constructed using rock fills, with granular fill (embedment), generally consisting of sands some gravel, around the culvert. The native material underlying the fill consisted of generally compact silts underlain by sands with auger and/or DCPT refusal at depths of 8.3 to 11.8 m below existing grade (elevations 401.2 to 399.7 m, respectively).

It is understood that the existing culvert will be replaced with a pre-cast concrete box culvert. The box culvert will be 3.0 x 3.0 m and constructed at a similar grade and alignment as the existing culvert.

5.2 Foundation Considerations

The existing 3.05 m diameter SPCSP culvert was supported on a 450 mm sand cushion pad, as per Contract No. 66-281, underlain by the native grey silt stratum, which is in a loose to compact state of compactness. The existing culvert invert is at elevation 408.2 m. Allowing for a 300 mm concrete bottom on the culvert, 300 mm of bedding, and recessing the bottom of the culvert some 300 mm below the bottom of the stream bed for environmental considerations, the underside of bedding will be established at approximately elevation 407.3 m. At this depth the founding stratum will be the generally compact grey silt deposit.

Provide the compact silt subgrade is not disturbed during construction and the bedding is properly placed, as discussed in subsequent sections, a factored bearing resistance at ULS of 400 kPa can be used for a concrete frame **box** culvert some 3 m wide. In consideration of the width of the culvert and depth of overburden, a geotechnical resistance at SLS of 150 kPa can be used for design, in consideration of 25 mm combined immediate and long term settlement.

If a concrete frame **open** culvert (i.e. with wall footings) is considered as a substitute, then a factored bearing resistance at ULS of 85 kPa and a geotechnical resistance at SLS of 50 kPa would apply for design, taking into consideration the limited depth of overburden pressure and smaller footing width.

Based on the above a box culvert is most appropriate for this site from a foundation point of view (see Table B, Appendix E).

5.2.1 Slope Stability

The maximum height of fill above surrounding grade for the embankment at this location is some 3.5 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 embankment slope established at 2H:1V. The embankment was modeled with 1 m of granular fill over 2.5 m of rock fill. The Granular B Type I was modeled using a unit weight of 20 kN/m^3 and a friction angle of 30°, and the rock fill was modeled using a unit weight of 18.5 kN/m^3 and a friction angle of 43°. The native compact silts were modeled using representative values of unit weight at 18.5 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, evaluated through field and laboratory testing. The results of the analysis indicated a factor of safety in the order of 1.6 against failure through the native silt subgrade with the water table at elevation 409.0 m (see Figure No. S-1, Appendix E). As such, the stability of the finished embankment slope will not be an issue provided it is properly constructed.

5.3 Culvert Design, Bedding, and Embedment

The embankment, at the channel culvert, consists of granulars (pavement structure) overlying a sand and gravel embankment fill (embedment material) which contains occasional cobble and boulder size rock fill. The results of this investigation indicates that, below the culvert invert, the native soils consist of generally compact silts overlying silty sands. A review of the condition of the pavement surface, at the culvert location, revealed minor longitudinal and transverse asphalt cracking, however, in general, the embankment appears to have performed well (see Photo Essay, Appendix D).

It is understood that the existing SPCSP culvert will be replaced with a 3.0 x 3.0 m pre-cast rigid frame concrete box culvert. Bedding for a rigid frame concrete box culvert should consist of Granular A with a thickness of 300 mm. The bedding under the middle third of the box unit base should be loosely placed and uncompacted. The upper 75 mm portion of the bedding should be uncompacted throughout the width of the box and incorporated as the top levelling course in conformance with OPSS 422.07.08. Alternatively, specifically if open cut excavation is carried out, a 19 mm clear stone bedding can be used, which would to aid in groundwater control. Prior to the placement of the bedding, a Class II geotextile with a FOS of 50 to 100 um should be placed over the exposed subgrade. During backfilling the embankment fill should be placed in a balanced manner on the outer sides of the box unit. The elevation difference of the backfill on either side of the box unit must be a maximum 300 mm. Backfilling and construction of pre-cast concrete box culverts shall be in accordance with OPSS 422. Cover material for concrete box culverts can consist of Granular A and placed to the dimensions as shown on MTOD-803.021.

The joints between precast box units should be covered with a strip of Non-Woven Class II Geotextile 600 mm in width, centered over the joint, covering the top of the culvert and extending halfway down the sides of the culvert to prevent the infiltration of fines. Since the culvert will be founded on silts, which have previously supported a similar size culvert, and there will not be a grade raise at the culvert location, installing the culvert on a camber will not be necessary. Since the soils have been preloaded and no significant load increases are anticipated, there should be minimum embankment settlement.

Apron (cut-off) walls, 1.2 m deep, must be provided at the ends of the rigid box culverts in accordance with the MTO Concrete Culvert Design Manual. It is understood that, at this time the concrete box culvert will not have wing walls at the culvert ends, and therefore a 600 mm thick apron of rock protection will be required. If wing walls are used, an apron of rock protection may not be required. Clay seals along the length of the culvert are not considered necessary considering the anticipated flow at this culvert location and the pervious nature of the embankment fill.

Frost tapers will not be required at this proposed box culvert considering the depth and type of existing embankment fill at the culvert location.

5.4 Culvert Installation and Construction Staging Considerations

The existing culvert is established in a granular fill embankment some 3.5 m in height. The embankment up and down chainage consists of a layer of granular fill overlying some 2.5 m of rock fill. The embankment material is considered a Type 3 soil as defined in the Occupational Health and Safety Act and Regulations for Construction Projects. Temporary open excavations will be stable above the groundwater table 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.

The invert elevation of the existing culvert is at approximately 408.2 m, at both the inlet and outlet, with the top of the embankment at elevation 411.5 m at centerline. As such, the embankment at this location is some 3.3 m in height above the culvert invert at the centerline. Therefore, a 4.2 m deep excavation (i.e. to elevation 407.3 m) will be required, allowing for the box to be placed a distance equal to 10% of the box height below the stream bed level and allowing the culvert bottom thickness and for a minimum of 300 mm of bedding below the culvert. The present platform width at this location is some 9.0 m, as can be seen on the cross section on Figure No. 2. The platform width at this location, as is, is insufficient to carry out an open excavation (parallel to centerline) using staged construction. It is understood that, due to environmental and other issues, a detour will not be constructed to divert traffic during culvert replacement. As such, a temporary protection system will be required to carry out the culvert replacement and maintain an active lane of traffic.

5.4.1 Protection System

A protection system is required to maintain an active traffic lane during the culvert replacement operation, and will require penetration through some 3.5 m of embankment (granular and rock fill) into the underlying compact silt stratum. The embankment fill at the culvert location varies from granular backfill, immediately adjacent to the culvert, with a transition to rock fill, at an estimated lateral distance of some 2.5 m from the centre of the culvert. Considering the presence of rock fill in the embankment, advancing a temporary retaining system (i.e. driven sheet piles) through the rock fill will be problematic. Several approaches to construct a protection system are described in the following.

In consideration of the water level, in the culvert and embankment, steel sheet piles should be considered for the protection system, as the penetration of sheet piles will aid in ground water control and maintaining a stable subgrade. As noted above, driving sheet piles through the rock fill may be problematic. For steel sheet piles to be considered, a sheet pile with a sufficiently robust cross section should be used. The operation to advance the sheet piles should consider excavating small lifts of the rock fill (some 1 m) then advancing the sheet piles and supporting the sheet piles with a whaler and raker system. Once the sheet piles have been advanced through the rock fill, the sheet piles can be driven into the native silt a sufficient distance to offer toe resistance and cut off ground water flow. Tiebacks should be considered for supporting a sheet pile wall as the excavation progresses.

The contractor should consider driving sheet piles, parallel to the culvert, through the granular embedment material, and around the culvert ends to allow work on one half of the culvert length within an enclosed cofferdam. Obstructions to driving the sheet piles due to the presence of rock fill should be minimal if driving through the culvert embedment material. This approach of enclosing the full perimeter of the excavation is also a positive method of controlling groundwater flow and dewatering during culvert installation.

Alternately, 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, 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 sheeting 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. Temporary shoulder widening may be required to accommodate single lane traffic with traffic lights.

Another alternative of providing a protection system would be to penetrate the rock fill with H piles (soldier piles) extending into the underlying silts and install lagging. Pre-drilling will likely be required to advance the H piles through the rock fill. 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):

$\mathbf{R = \sigma_z' A_s L_s \alpha_g}$ 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.

The contractor's shoring/protection system design must be carried out by a geostructural engineer with appropriate experience.

A table outlining the possible temporary excavation protection/flexible retaining systems and their relative advantages, disadvantages and costs, as well as comments on the viability of the methods is provided in Table A, Appendix E. Conceptual shoring locations are illustrated on Figure No. SK-3, Appendix E.

The protection system can be designed using the following lateral earth pressure parameters:

Elevation (m)	Soil Type	Unit weight (KN/m^3) γ	Angle of Internal Friction (degrees)	Active earth pressure (Ka)
411.5 – 410.7*	Fill – Sand some to with gravel trace to some silt	20	30	0.29
410.7 – 408.9**	Rock Fill	18.5	43	0.19
408.9 – 400.2	Silt – Sand trace to with gravel trace silt	18.5	29	0.35

* Fill depth varies, backfill was encountered to native silt at the culvert location (elevation 408.8 m), while refusal on rock fill was encountered at a depth of 0.9 m (elevation 410.7 m) some 8 m up and down chainage from the culvert
** Rock fill was not encountered next to existing culvert. The rock fill could not be penetrated with standard auger, as such depth to the base of the rock fill is estimated based on the borehole data adjacent to the culvert.

Considering the cohesionless nature of the embankment fills (granular pavement structure over rock fill and 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 $0.65{*}K_a{*}\gamma{*}H$, where:

Ka = 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 roadway protection and traffic volume, a performance level 2 is considered appropriate.

5.5 Lateral Earth Pressures

Lateral earth pressures for culvert design 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:

Soil Type	Unit weight (KN/m^3) ɣ	Angle of Internal Friction (degrees)	Active earth pressure (Ka)	At-rest Earth Pressure (Ko)
Granular A	22	35	0.27	0.43
Granular B Type I/ Existing Backfill Material	20	30	0.29	0.46
Rock Fill	18.5	43	0.19	0.32
Native Silts	18.5	29	0.35	0.52

For rigid structures, such as precast concrete box, deflection cannot occur, as such the “at-rest” condition (Ko) applies.

5.6 Excavation, Dewatering, and Embankment Reconstruction

All excavations greater than 1.2 m in depth must be sloped or shored in accordance with the Occupational Health and Safety Act Regulations for Construction Projects. Temporary open excavations will be stable above the groundwater table at an angle of 1H:1V, as the embankment soils are considered a Type 3 soil as defined in the Occupational Health and Safety Act and Regulations for Construction Projects. Final embankment earth slopes 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 the founding subgrade. The groundwater level was recorded at elevations 408.5 to 409.1 m, at the time of this investigation. A method of controlling groundwater would be to fully enclose one half of the excavation with closed interlocking sheet piles, driven to a minimum depth below the base of the excavation equal to the height of the groundwater level above the excavation base at the time of excavation. Temporary stream flow will be required through a temporary centerline culvert. Groundwater control, in accordance with OPSS 517 and 518, will be required to maintain a stable subgrade during culvert installation. If an enclosed excavation is carried out, the sheeting design must ensure the depth of sheeting is sufficient to prevent piping and degradation of the compact silt subgrade. Generally, a minimum, advancing sheeting to a depth below grade equal or greater than that of the height of water above grade is required to prevent piping.

During culvert replacement it will be necessary to by-pass the stream flow. The contractor must have sufficient pumping capacity, with a backup system, to handle the anticipated flows as specified by the hydrology report, elsewhere in the contract.

If the contractor does not completely enclose the culvert excavation with a sheet pile cofferdam and instead chooses to use a linear centerline protection system for active traffic lane protection combined with open cut methods for advancing the excavation, then a cofferdam will be required at the inlet and outlet, along with temporary diversion of the stream flow. This decision will be partially dependent upon the depth of water at the time of construction. During construction, local temporary sandbagging, combined with installation of filtered sumps extending below the base of the excavation and pumping from the base of the excavation will, at a minimum, be required to maintain the excavation in a dewatered condition during subgrade preparation. This method of dewatering to maintain a stable subgrade is only effective if the groundwater head is less than some 1.0 m. The native subgrade is loose/compact silt which, when wet, can be disturbed easily by worker foot traffic and equipment. As such, bedding should be placed immediately after excavating to grade to aid in maintaining a stable subgrade.

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

The presence of rock fill in the embankment, as noted on the borehole logs and plan/profile will be encountered during installation of a centreline protection system, and groundwater control must be carried out during construction. Various methods to address these issues are discussed above, however the method used will depend upon the individual contractor's expertise, equipment, and material availability.

6.0 CLOSURE

Information provided in this report is valid only at the locations described above. Any assumptions of continuity of soil stratigraphy between boreholes, as shown on the enclosed cross-sections, is intended as an aid for design purposes only and does not constitute a statement of existing conditions for contractual or construction purposes. Field investigation was carried out using a CME drill rig mounted on a Bombardier carrier owned by Chrisdamat Management Ltd. The report was prepared by Mr. J. R. Berghamer, P. Eng and reviewed by the firm's principal and MTO designate Mr. M. A. Merleau, P. Eng.

Details of the investigation, the material analysis and recommendation in this report are considered to be complete. However, should any questions arise, please do not hesitate to contact the undersigned.

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M. A. Merleau, P. Eng.
Principal Engineer
MTO Designate

J. R. Berghamer, P. Eng.
Regional Manager

Z:\PROJECT FILES\2011\11101 - PAV & FDN, Hwy 144 GWP 5046-05-00 (AECOM)\`FOUNDATION\Reports\FINAL\F2 - Area 7 - Halfway Lake\11101-F2 - FINAL FIDR, Hwy 144 GWP 5046-05-00 - Halfway lake.doc

Appendix A Key Plan

Figure No. 1: Key Plan

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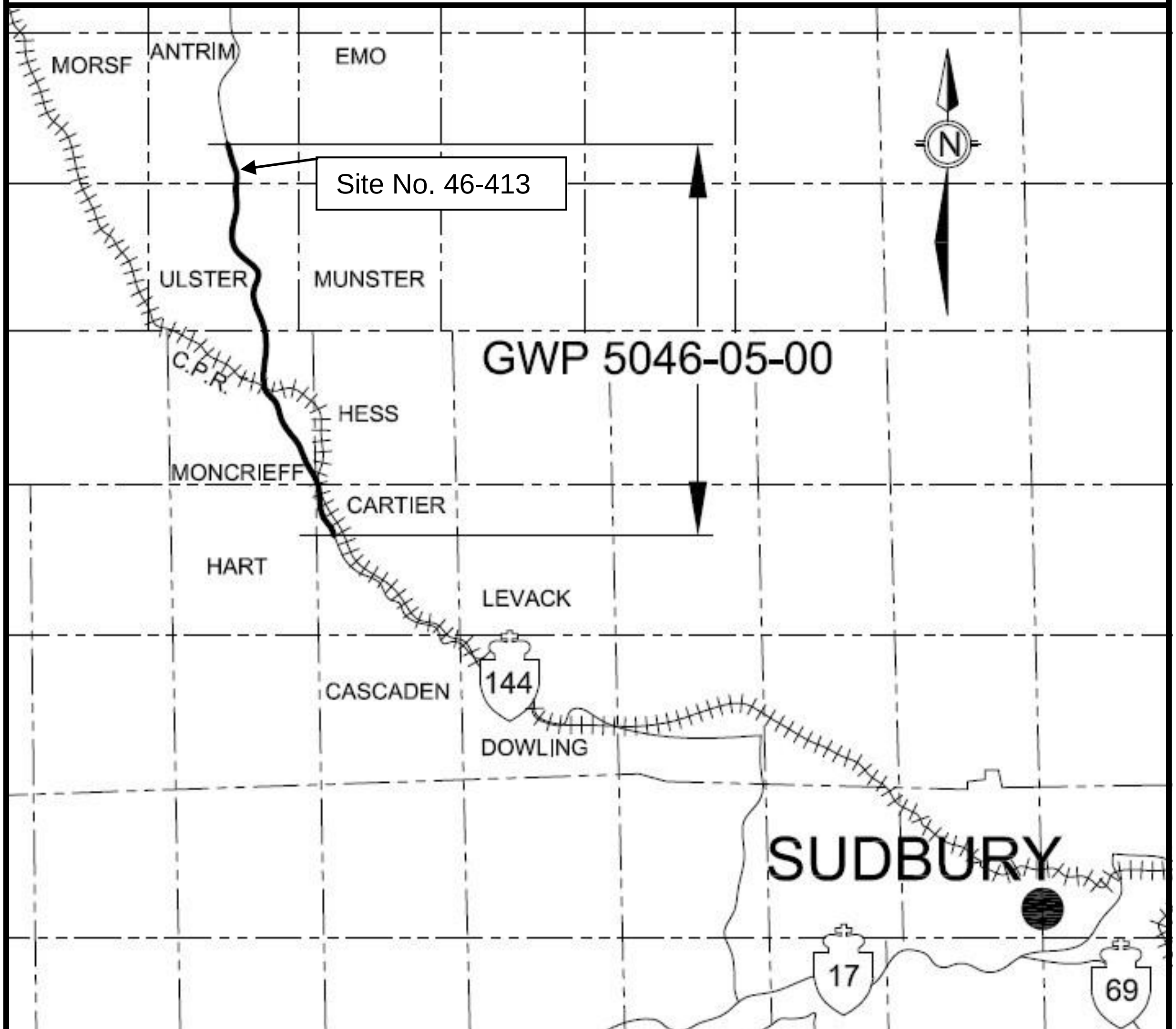
KEY PLAN

Figure No. 1

NOT TO SCALE



FINAL
FOUNDATION INVESTIGATION
AND DESIGN REPORT
GWP 5046-05-00

Highway 144

From Cartier West Entrance (Centre Street)
Northerly 24.8 km

Ref. No.: 11/06/11101-F2 September 2012

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Appendix B Abbreviations
Record of Borehole Sheets

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

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LIST OF ABBREVIATIONS AND 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
NP Non Plastic
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

3. SOIL DESCRIPTION (Cont'd)

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

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%

5. LABORATORY TESTS

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

LIST OF ABBREVIATIONS AND DESCRIPTION OF TERMS

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 1)

METRIC

RECORD OF BOREHOLE NO. 1

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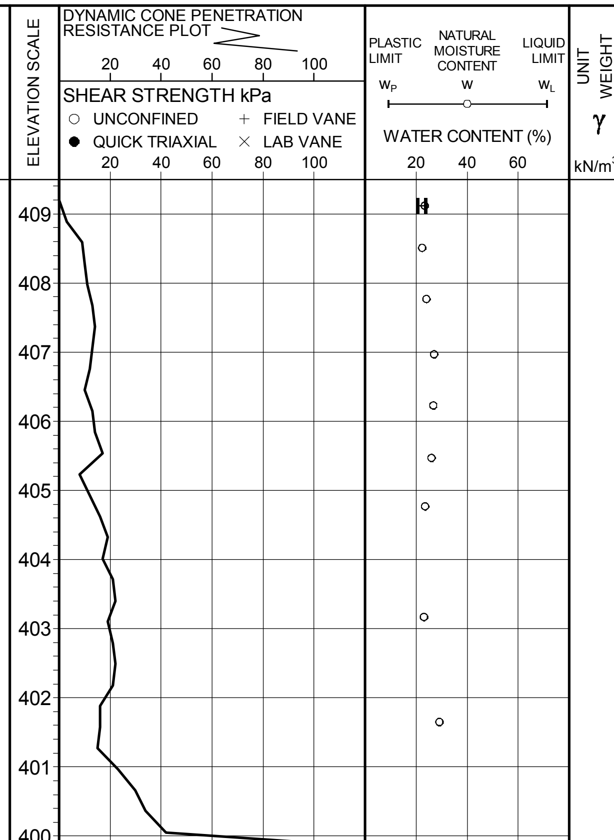
REFERENCE	11/06/11101-F2	DATUM	Geodetic	LOCATION	N5196207.2 E256742.5 - Antrim Township
ORIGINATED BY	JL				
PROJECT	GWP 5046-05-00, Highway 144 - Site No. 46-413	BOREHOLE TYPE	Track Mounted CME 45B - Hollow Stem Augers	COMPILED BY	MCM
CLIENT	AECOM Inc.	DATE (Started)	August 31, 2011		
		DATE (Completed)	August 31, 2011	TIME (Completed)	5:20:00 PM
CHECKED BY	MAM				

ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
409.5	Ground Surface						
0.0	300 mm brown sand some silt		1	AS		▽	0 2 93 5
	SILT - grey silt trace to some sand trace clay		2	SS	11	▽	
	(very loose/compact)		3	SS	8		0 12 85 3
			4	SS	6		
			5	SS	11		
			6	SS	4		0 1 97 2
			7	SS	11		
			8	SS	10		
			9	SS	WH		
401.0 / 8.5	SAND - grey sand with gravel some silt		10	SS	50/125mm		30 50 (20)
399.9 / 9.6	Auger Refusal DCPT 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) 8/31/11 5:20:00 PM	1	5.9
2) 9/1/11 8:15:00 AM	0.6	-
3)	-	-

MEL-GEO 11101 - AREA 7 - BOREHOLE LOGS - HALFWAY LAKE.GPJ MEL-GEO.GDT 5/8/12

LVM | MERLEX

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

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

RECORD OF BOREHOLE NO. 2

METRIC

LVM | MERLEX

REFERENCE 11/06/11101-F2 DATUM Geodetic LOCATION N5196207.1 E256765.5 - Antrim Township ORIGINATED BY JL

PROJECT GWP 5046-05-00, Highway 144 - Site No. 46-413 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY MCM

CLIENT AECOM Inc. DATE (Started) September 1, 2011 DATE (Completed) September 1, 2011 TIME (Completed) 11:20:00 AM CHECKED BY MAM

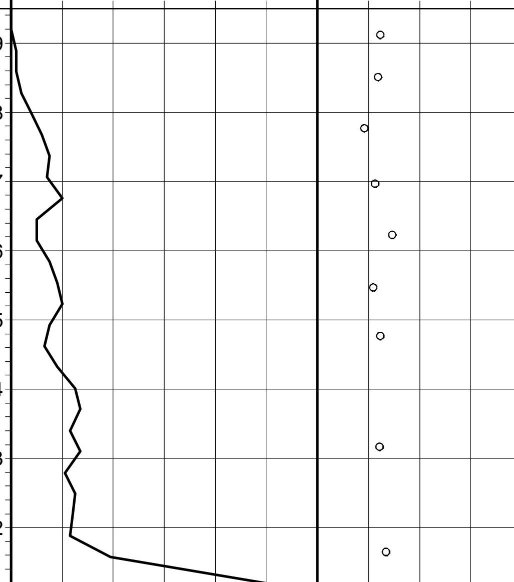
ELEV DEPTH	SOIL PROFILE – DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
409.5	Ground Surface							
0.0	100 mm black silty organics		1	AS	N/A		409	
	SILT - grey silt trace to some sand trace clay		2	SS	11	∇		0 1 96 3
	(loose/compact)		3	SS	14		408	
			4	SS	15		407	
			5	SS	8		406	0 11 87 2
			6	SS	10			
			7	SS	11		405	0 0 98 2
						Cave in	404	
			8	SS	7		403	
401.9 7.6	SAND - grey sand with gravel some silt (compact)		9	SS	26		402	
401.2 8.3	Auger Refusal DCPT 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



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) 9/1/11 11:40:00 AM	1	5.6
2)	-	-
3)	-	-

MEL-GEO 11101 - AREA 7 - BOREHOLE LOGS - HALFWAY LAKE.GPJ MEL-GEO.GDT 5/8/12

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

METRIC

RECORD OF BOREHOLE NO. 3

LVM | MERLEX

REFERENCE 11/06/11101-F2 DATUM Geodetic LOCATION N5196204.0 E256756.8 - Antrim Township ORIGINATED BY JL

PROJECT GWP 5046-05-00, Highway 144 - Site No. 46-413 BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers COMPILED BY AT

CLIENT AECOM Inc. DATE (Started) August 31, 2011 DATE (Completed) August 31, 2011 TIME (Completed) 5:20:00 PM CHECKED BY MAM

ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
411.5	Ground Surface										
0.0	150 mm Asphalt 200 mm Crushed Gravel		1	AS	N/A		411		o		
410.5 1.0	FILL - grey sand with gravel some silt		2	SS					o		30 59 (11)
	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

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)	-	-
2)	-	-
3)	-	-

MEL-GEO 11101 - AREA 7 - BOREHOLE LOGS - HALFWAY LAKE.GPJ MEL-GEO.GDT 5/8/12

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

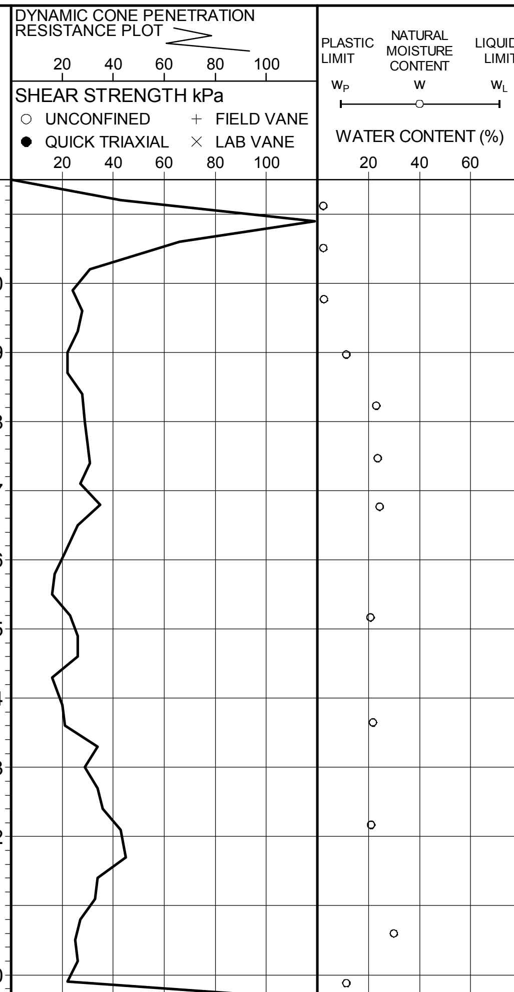
METRIC

RECORD OF BOREHOLE NO. 4

LVM | MERLEX

REFERENCE	11/06/11101-F2
DATUM	Geodetic
LOCATION	N5196211.5 E256756.6 - Antrim Township
ORIGINATED BY	JL
PROJECT	GWP 5046-05-00, Highway 144 - Site No. 46-413
BOREHOLE TYPE	Track Mounted CME 45B - Hollow Stem Augers
COMPILED BY	AT
CLIENT	AECOM Inc.
DATE (Started)	September 1, 2011
DATE (Completed)	September 1, 2011
TIME (Completed)	11:40:00 AM
CHECKED BY	MAM

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
411.5	Ground Surface					
0.0	175 mm Asphalt 200 mm Crushed Gravel	1	AS	N/A		
	FILL - brown sand with gravel trace silt occasional cobbles/boulders (compact)	2	SS	23		30 64 (6)
		3	SS	20		
		4	SS	15	▽	27 68 (5)
408.3 / 3.2	SILT grey silt trace sand trace clay (loose/compact)	5	SS	12		
		6	SS	11		0 2 93 5
		7	SS	10		
		8	SS	15		
		9	SS	10		0 1 91 8
		10	SS	6		
		11	SS	11		
400.2 / 11.3	SAND - grey sand with gravel some silt	12	SS			
399.7 / 11.8	Auger Refusal DCPT 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) 10/11/11 3:45:00 PM	2.5	2.6
2)	-	-
3)	-	-

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

METRIC

RECORD OF BOREHOLE NO. 5

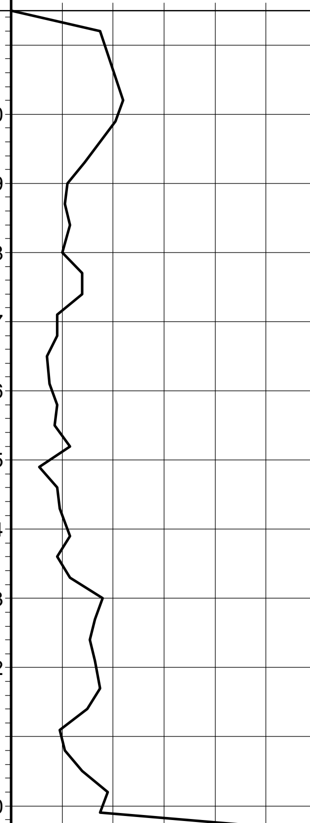
LVM | MERLEX

REFERENCE 11/06/11101-F2	DATUM Geodetic	LOCATION N5196215.4 E256752.0 - Antrim Township	ORIGINATED BY JL
PROJECT GWP 5046-05-00, Highway 144 - Site No. 46-413		BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers	COMPILED BY AT
CLIENT AECOM Inc.		DATE (Started) October 12, 2011 / DATE (Completed) October 12, 2011 / 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)
411.5	Ground Surface						
0.0	150 mm Asphalt 100 mm Crushed Gravel FILL - brown sand some gravel to gravelly trace to some silt (compact)		1	AS	N/A		39 54 (7)
			2	SS	26		
			3	SS	25		
408.9			4	SS	23	∇	22 61 (17)
2.6	SILT - grey silt trace to some sand trace clay (very loose/compact)						0 13 83 4
			5	SS	16		
			6	SS	9		
			7	SS	2		
			8	SS	9		
			9	SS	8		0 1 95 4
			10	SS	12		
400.9							
10.6	SAND - grey sand with gravel some silt (compact)		11	SS	12		
399.7			12	SS			
11.8	Auger Refusal DCPT Refusal End of Borehole						

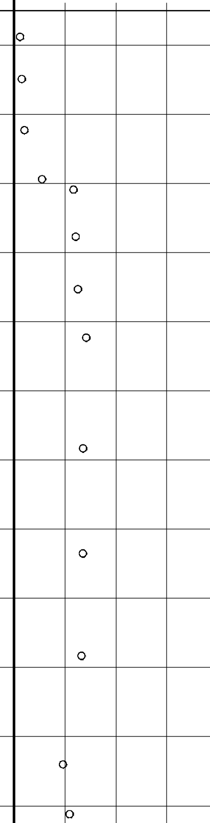
DYNAMIC CONE PENETRATION RESISTANCE PLOT

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE



PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%)



UNIT WEIGHT γ kN/m³

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) 10/12/11 11:15:00 AM	2.4	5.8
2)	-	-
3)	-	-

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

MEL-GEO 11101 - AREA 7 - BOREHOLE LOGS - HALFWAY LAKE.GPJ MEL-GEO.GDT 5/8/12

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ENCLOSURE NO.:7 (Pg. 1 of 1)

RECORD OF BOREHOLE NO. 6

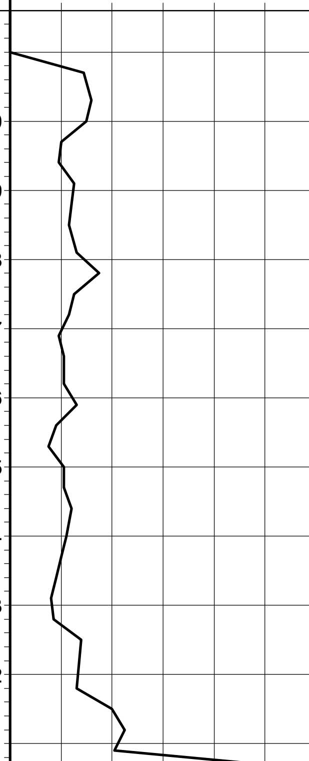
METRIC

LVM | MERLEX

REFERENCE 11/06/11101-F2	DATUM Geodetic	LOCATION N5196223.4 E256752.0 - Antrim Township	ORIGINATED BY JL
PROJECT GWP 5046-05-00, Highway 144 - Site No. 46-413		BOREHOLE TYPE Track Mounted CME 45B - Hollow Stem Augers	COMPILED BY AT
CLIENT AECOM Inc.		DATE (Started) October 11, 2011 / DATE (Completed) October 11, 2011 / TIME (Completed) 3:45:00 PM	CHECKED BY MAM

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	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)
411.6	Ground Surface									
0.0	150 Asphalt 100 Crushed Gravel FILL - brown sand and gravel trace silt		1	AS	N/A		411	o		
			2	SS				o		44 46 (10)
410.7 0.9	Auger Refusal						410 – 401			
400.7 10.9	DCPT 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



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)	-	-
2)	-	-
3)	-	-

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Appendix C Borehole Location Plan Labwork

Figure No. 2: Borehole Location and Soil Strata
Figure Nos. L-1 to L-3: Summary Grain Size Analysis Graph
Figure No. L-4: Atterberg Limits Summary Sheet
Figure No. L-5: Lab Test Summary Sheet

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METRIC

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

SITE No	46–413
WP No	5046–05–00
Geocres	421–291

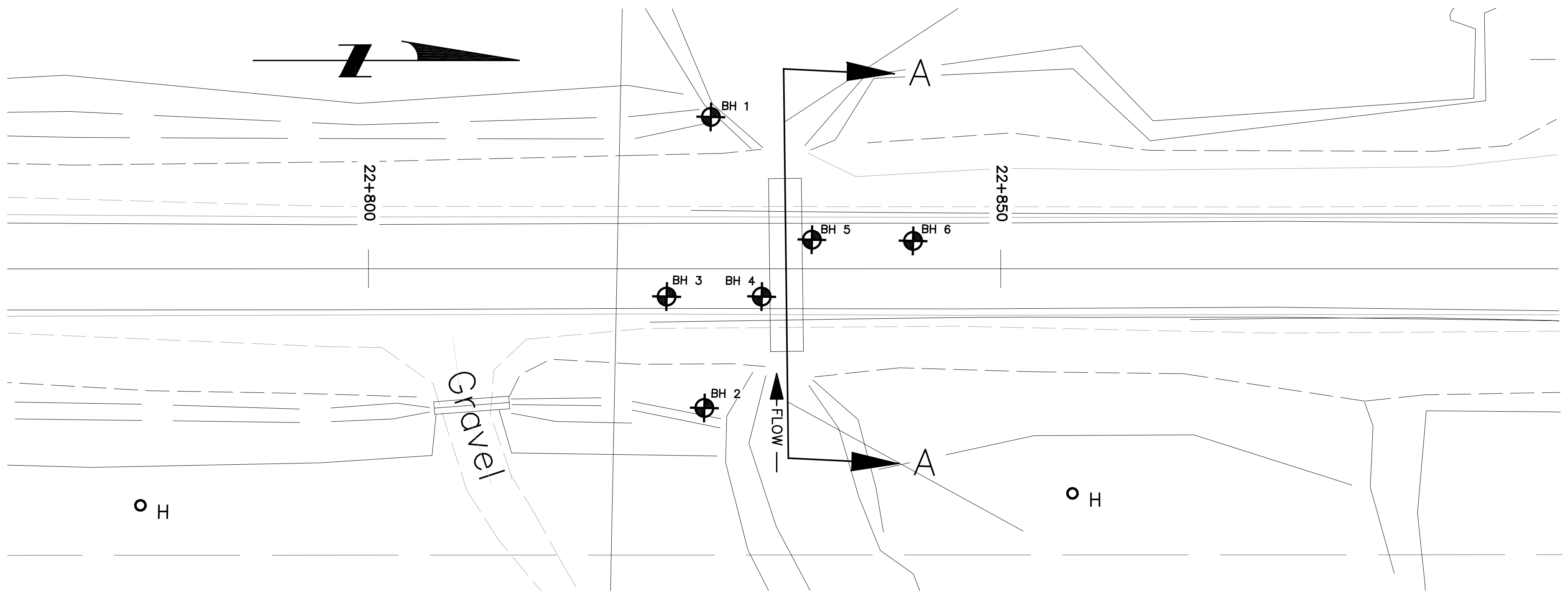
HWY NO. 144 – Township of Antrim

Halfway Lake Channel Culvert – Station 22+833
Culvert Replacement

BORHOLE LOCATIONS & SOIL STRATA

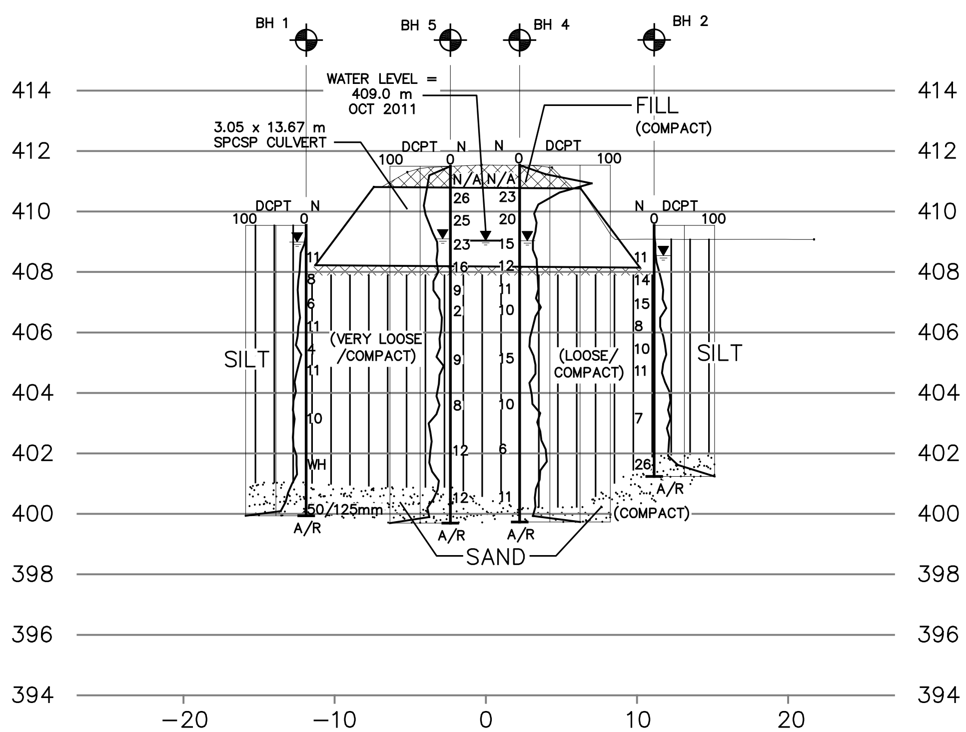
Figure 2

LVM | MERLEX



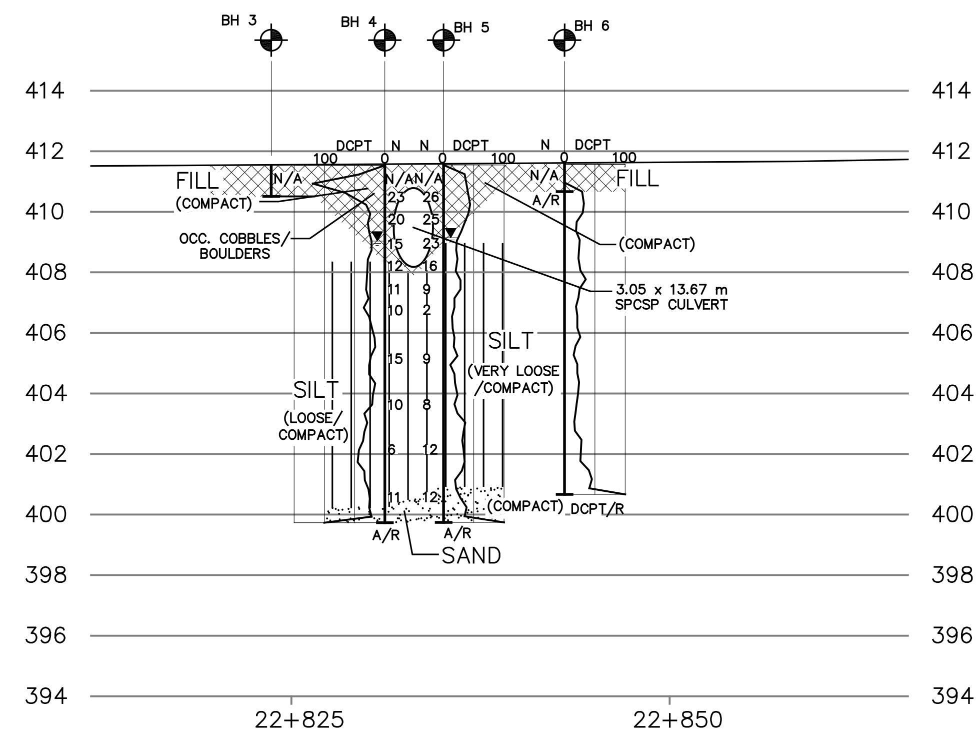
PLAN

SCALE 5m 5m



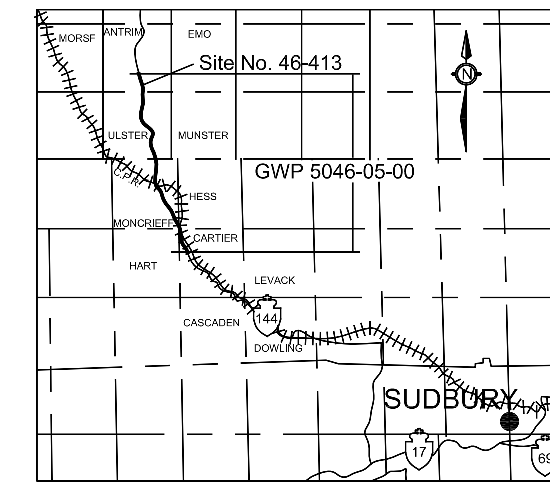
SECTION A–A

SCALE 5m 5m HOR 2.5m 2.5m VER



℄ PROFILE

SCALE 5m 5m HOR 2.5m 2.5m VER



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	409.5	12.0m Rt	5196207.2	256742.5
Borehole No. 2	409.5	11.0m Lt	5196207.1	256765.5
Borehole No. 3	411.5	2.2m Rt	5196204.0	256756.8
Borehole No. 4	411.5	2.2m Rt	5196211.5	256756.6
Borehole No. 5	411.5	2.3m Lt	5196215.4	256752.0
Borehole No. 6	411.6	2.2m Lt	5196223.4	256752.0

NOTE 1:
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 purposes only.

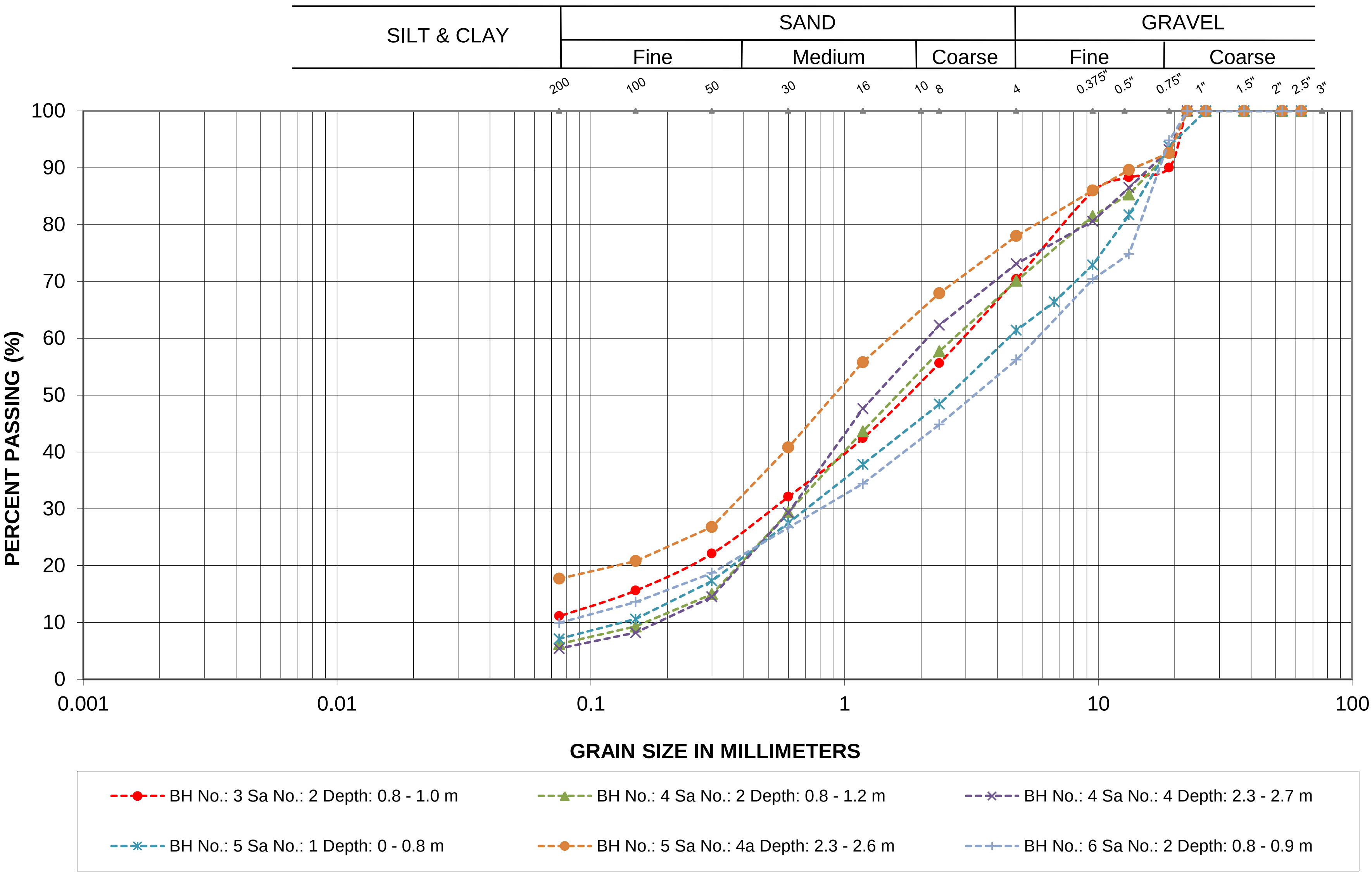
REVISIONS

DATE	BY	DESCRIPTION
Jan 2012	MCM	DRAFT
Aug 2012	RG	FINAL

HWY No. 144 – Antrim Twp. – Halfway Lake Culv.			REF 11101
SUBM'D			SITE 46–413
DRAWN MCM	CHK MAM	DATE JANUARY 2012	FIG 2

Reference No.: 11/06/11101-F2
Date: September 2012

GRAIN SIZE ANALYSIS



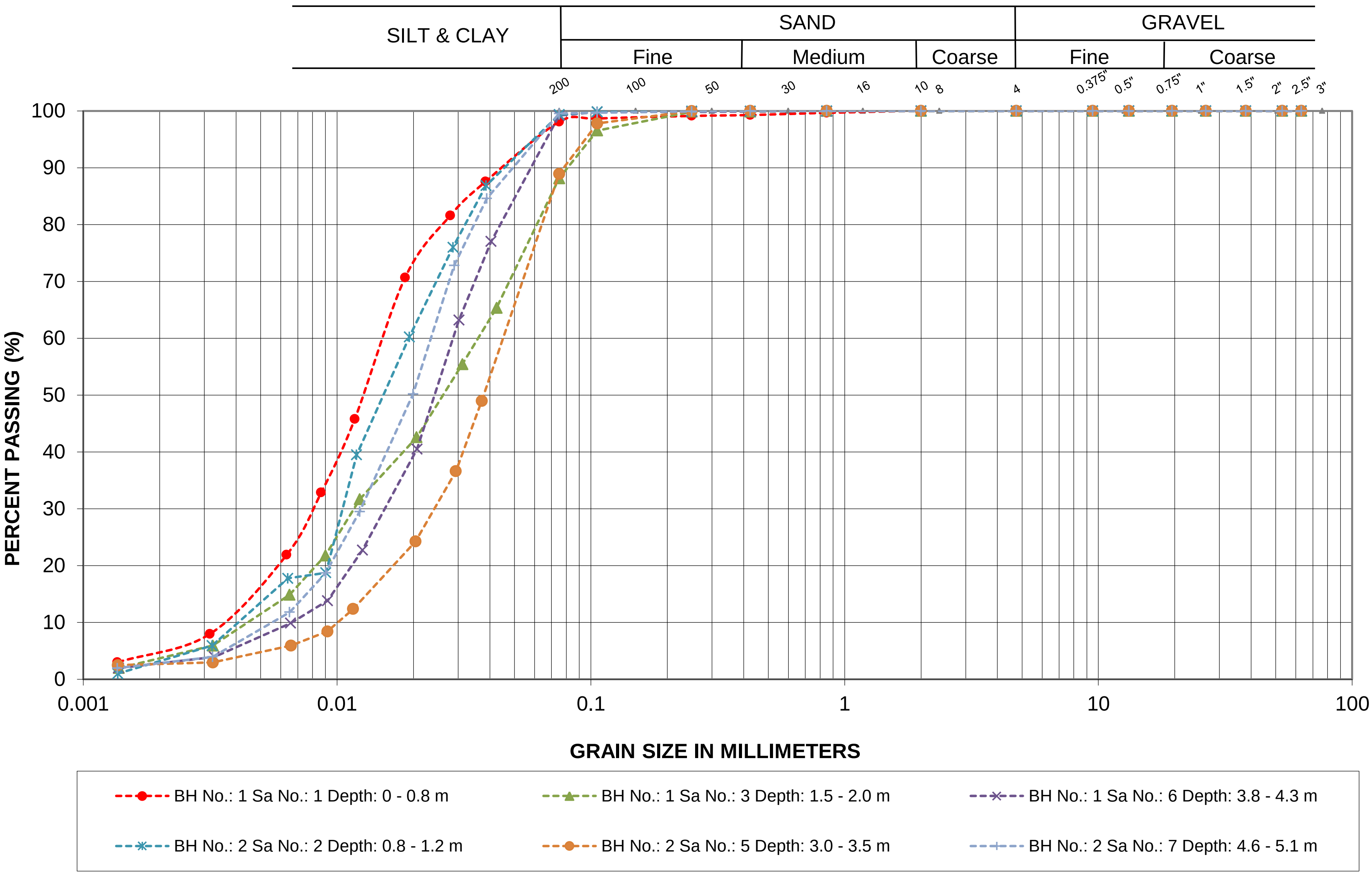
G.W.P.: 5046-05-00
LOCATION: Hwy 144
SITE: 46-413

FILL

Reference No.: 11/06/11101-F2
Date: September 2012

LVM | MERLEX

GRAIN SIZE ANALYSIS



G.W.P.: 5046-05-00
LOCATION: Hwy 144
SITE: 46-413

SILT

Reference No.: 11/06/11101-F2
Date: September 2012

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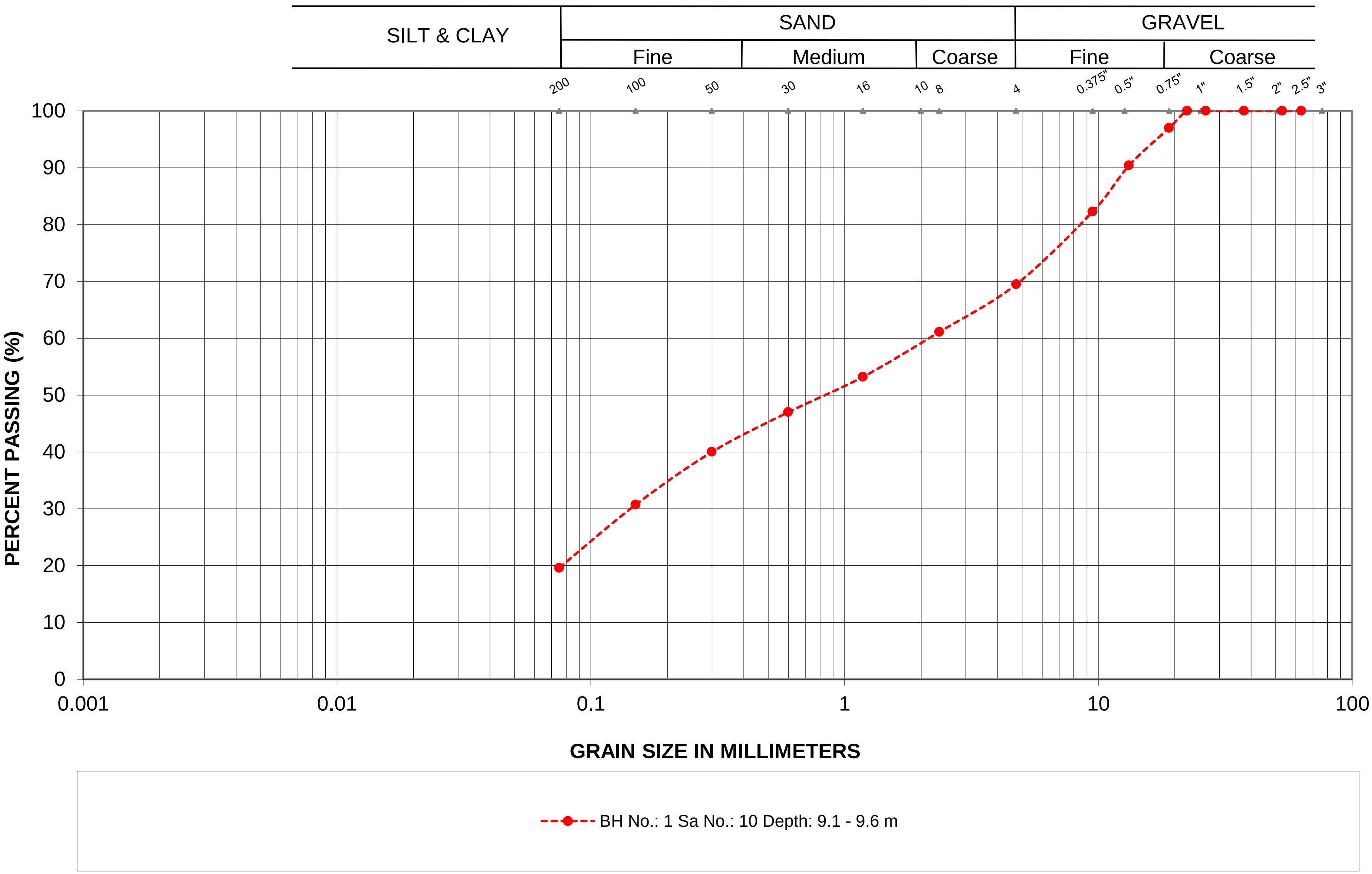
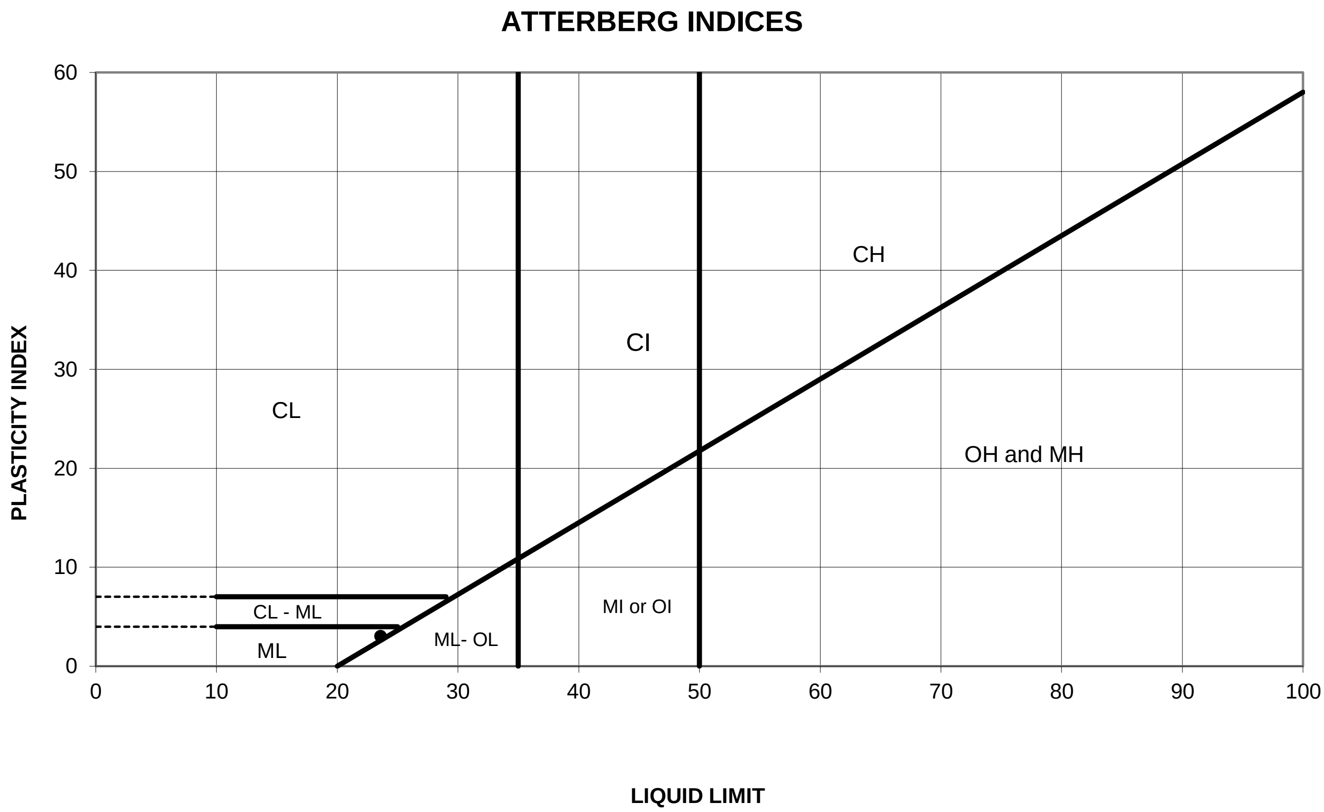
GRAIN SIZE ANALYSIS



G.W.P.: 5046-05-00
LOCATION: Hwy 144
SITE: 46-413

SAND

ATTERBERG LIMITS TEST RESULTS	FIGURE L-4



SYMBOL	BH	Sa. No.	Depth(m)	Elev.(m)	Liquid Limit	Plastic Limit	Plasticity Index	NMC %
●	1	2	0.1	-0.1	23.6	20.6	3.0	23.3

Date: Sep-12
Project: Hwy 144 - Site 46-413
G.W.P: 5046-05-00

Prep'd: AT
Chkd: RG
Ref. No.: 11/06/11101-F2

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Reference No.: 11/06/11101-F2
Date: September 2012

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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	0	0	93	5	23.3	23.6	20.6	3.0	N/A			
	2	0.8					22.3				11			
	3	1.5	0	12	85	3	24.0				8			
	4	2.3					27.0				6			
	5	3.0					26.7				11			
	6	3.8	0	1	97	2	26.0				4			
	7	4.5					23.5				11			
	8	6.1					23.0				10			
	9	7.6					29.1				WH			
	10	9.1	30	50	20						50/125mm			
2	1	0.0					24.6				N/A			
	2	0.8	0	1	96	3	23.7				11			
	3	1.5					18.3				14			
	4	2.3					22.5				15			
	5	3.0	0	11	87	2	29.3				8			
	6	3.8					21.9				10			
	7	4.5	0	0	98	2	24.6				11			
	8	6.1					24.3				7			
	9	7.6					26.8				26			
3	1	0.0					2.2				N/A			
	2	0.8	30	59	11		1.6							
4	1	0.0					2.3				N/A			
	2	0.76	30	64	6		2.3				23			
	3	1.5					2.5				20			
	4	2.3	27	68	5		11.3				15			
	5	3.04					23.0				12			
	6	3.8	0	2	93	5	23.6				11			

Project: Hwy 144
Location: Halfway Lake Culvert

Laboratory Tests - Summary Sheet

Borehole No.	Sample No.	Depth	Grain Size Analysis: Gravel Size (%)	Sand Size (%)	Silt Size (%)	Clay Size (%)	NMC	Atterberg Limits: LL (%)	PL (%)	IP (%)	SPT 'N'	USCS	Unit Weight (kN/m3)	Remarks
4	7	4.5					24.3				10			
	8	6.1					20.7				15			
	9	7.62	0	1	91	8	21.7				10			
	10	9.1					21.0				6			
	11	10.67					29.9				11			
	12	11.43					11.3							
5	1	0	39	54	7		2.3				N/A			
	2	0.76					3.0				26			
	3	1.5					4.1				25			
	4a	2.3	22	61	17		11.0				23			
	4b	2.3	0	13	83	4	23.3				23			
	5	3.04					24.2				16			
	6	3.8					25.0				9			
	7	4.5					28.3				2			
	8	6.1					27.1				9			
	9	7.62	0	1	95	4	27.0				8			
	10	9.1					26.4				12			
	11	10.67					19.2				12			
	12	11.58					21.8							
6	1	0					2.1				N/A			
	2	0.76	44	46	10		1.7							

Appendix D Photo Essay

Enclosure No. 8: Photo Essay

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Top: Embankment at culvert, looking north Bottom: Stream at culvert inlet, looking east	Photo: 1 - 2

Reference Number: 11/06/11101-F2 Project: Hwy 144 – Halfway Lake Channel Culvert – Site No. 46-413	Provided By: LVM | MERLEX Date: August 2011

Top: Stream at culvert outlet, looking west Bottom: Looking through culvert, looking east	Photo: 3 - 4

Reference Number: 11/06/11101-F2	Provided By: LVM | MERLEX
Project: Hwy 144 – Halfway Lake Channel Culvert – Site No. 46-413	Date: August 2011

Appendix E Design Data

Figure No. S-1:	Slope Stability
Sketch Nos. SK-3:	Conceptual Shoring Location
Sketch No. SK-4:	Staged Construction Section
Table A:	Comparison of Shoring Alternatives
Table B:	Culvert Replacement Options

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Reference No.: 11/06/11101-F2
Date: September 2012

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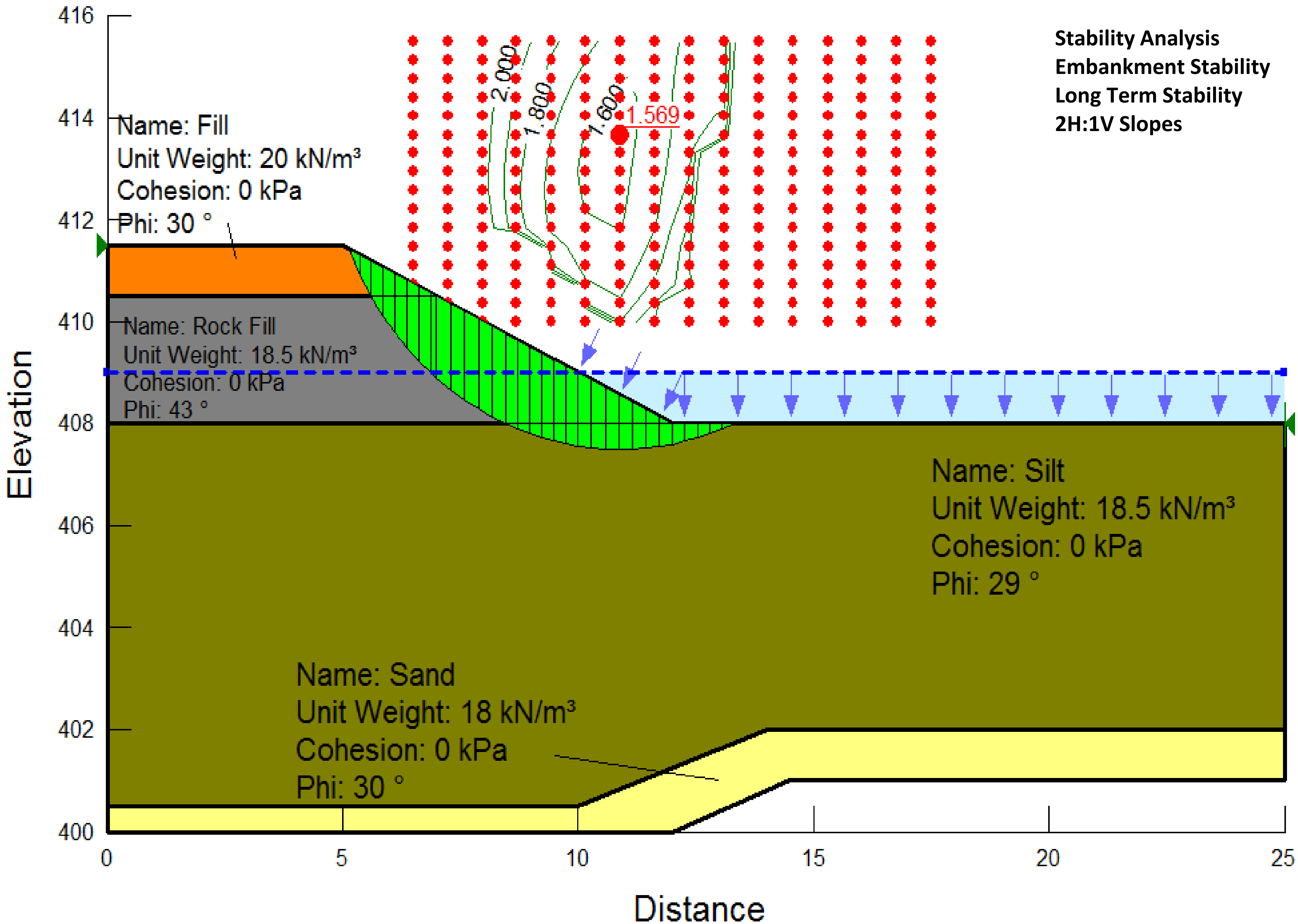


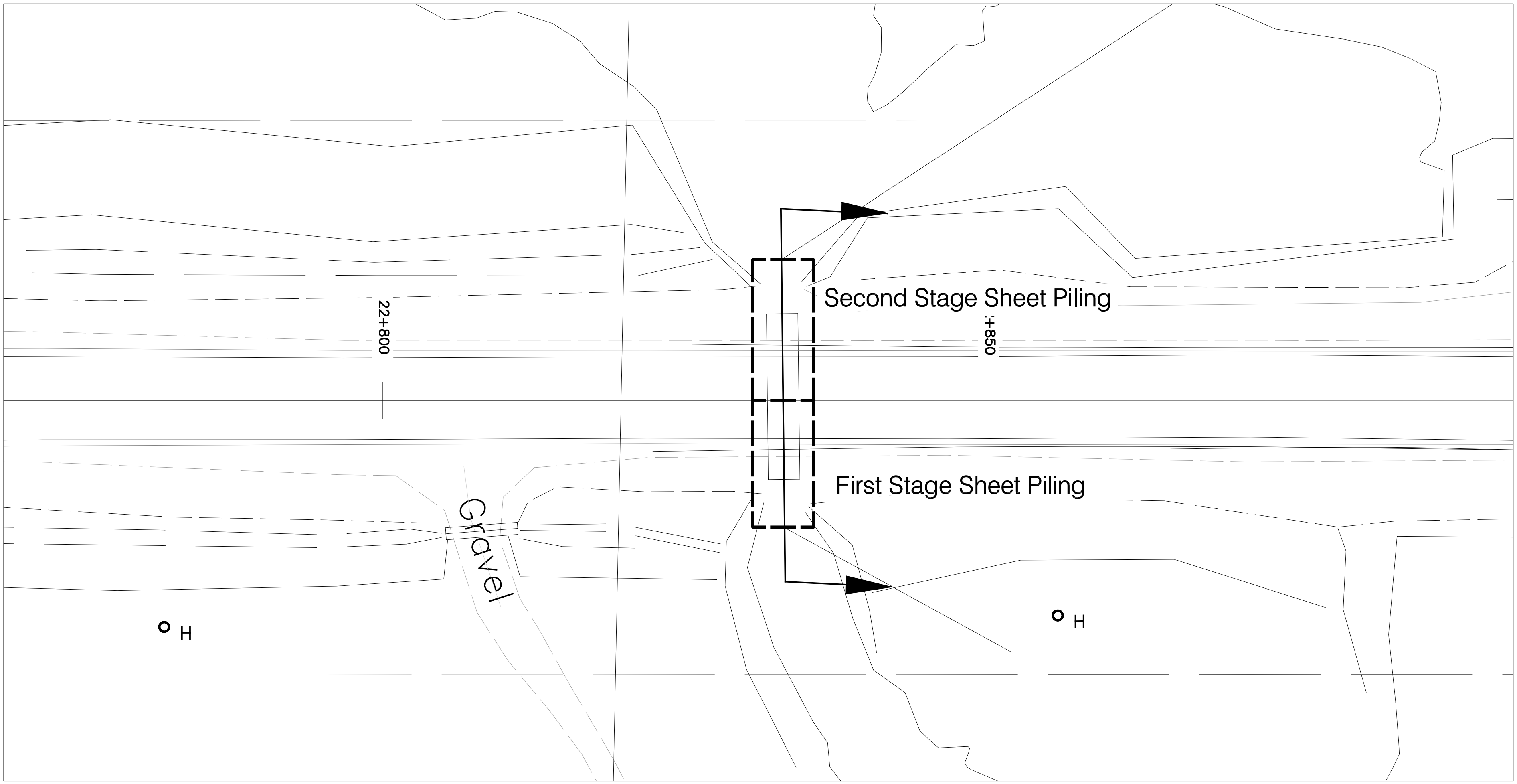
Stability Analysis
Station 22+833
TWP of Antrim

Project: G.W.P 5046-05-00
Location: Hwy 144, Halfway Lake Channel Culvert

Figure No. S-1

LVM | MERLEX

REF: 11101-F2



HWY 144 - Township of Antrim - Site 46-413

Conceptual Shoring and Sheet Piles Cofferdam Locations - Halfway Lake Channel Culvert

FIGURE SK-3

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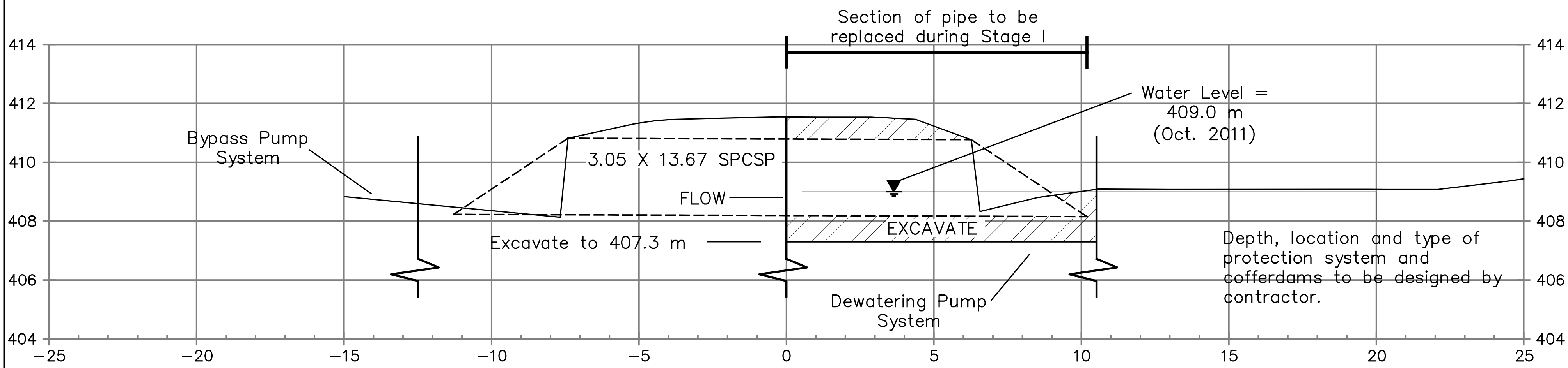
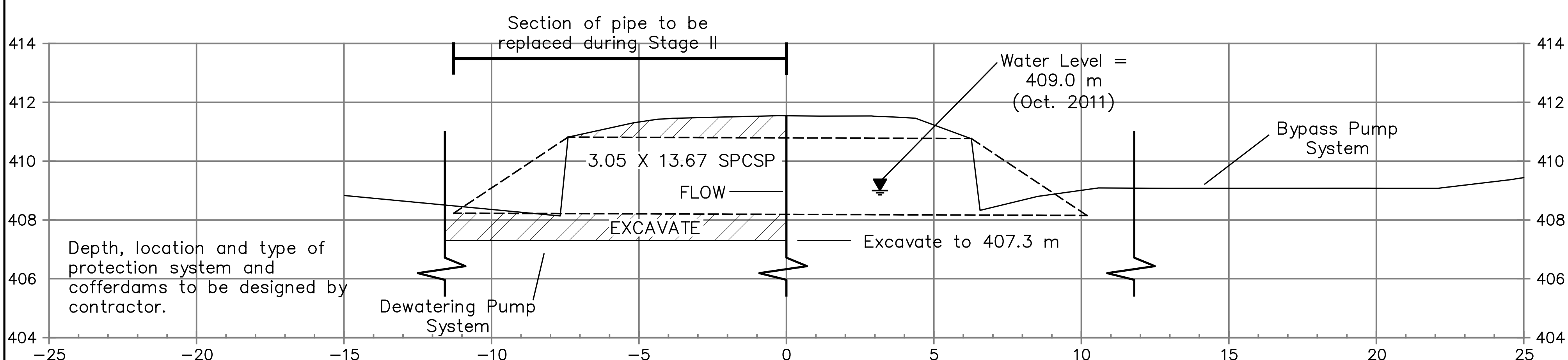
REF: 11101-F2



STAGE I



STAGE II

HWY 144 - Township of Antrim - Site 46-413 Conceptual Shoring and Sheet Piles Cofferdam Locations - Halfway Lake Channel Culvert	FIGURE SK-4

Table A – Protection Systems

Retaining System	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 ground conditions and depths required	
Steel Sheet Piles	5 – 21	-High strength, continuous, -Readily available	-Limited by soil conditions (i.e. obstructions)	Considered for protection system at this site, provided driving and excavation of rock fill can be carried out	$ 650/m^2
Pre-cast concrete panels	3 – 10	-Durable -Assists in minimizing seepage	-Limited depths -Can be damaged by driving -Limited by soil conditions (i.e. obstructions)	Not considered due to limited depth required and higher costs and presence of rock fill	
Soldier piles With lagging	5 – 25	-Easy installation -Readily available -Adaptable to various ground conditions	-Pre-drilling may be required -Possible ground loss	Considered for protection system at this site due to ground conditions	$ 725/m^2
Tangent/ Secant/ Staggered Drilled Piles	10 – 18	-Readily available -Adaptable to various ground conditions	-Possible ground loss and/or seepage -Poor alignment tolerance	Not Considered due to limited depths required and higher costs	
Concrete Diaphragm	10 – 30	-High Strength -Durable -Can be permanent	-High cost -Requires specialized equipment/control	Not Considered due to limited depths required 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 due to limited depth required and rock fill stratum	N/A

Table B – Culvert Replacement

Culvert Options	Advantages	Disadvantages	Remarks
Concrete Frame Box Culvert (Non-rigid or rigid)	-Increased bearing of closed culvert on marginal soils (i.e. loose sands/silt and soft clays) -Design life generally 75 years		
Concrete Frame Open Culvert (Non-rigid or rigid)	-Design life generally 75 years	-Reduced bearing on strip footings on marginal soils (i.e. loose sands/silt and soft clays) -Deeper excavations required for footings -Risk of scour around footings	
Corrugated Steel Pipe (CSP)Culvert	-Increased bearing of closed culvert on marginal soils (i.e. loose sands/silt and soft clays) -High tolerance to differential settlements	Poor performance of galvanized pipe culverts in Northeast Region	
Corrugate Steel Pipe Open Arch Culvert		-Reduced bearing on strip footings on marginal soils (i.e. loose sands/silt and soft clays) -Deeper excavations required for footings -Risk of scour around footings -Poor performance of galvanized pipe culverts in Northeast Region	