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

Culvert Replacement – Whiskey Jack Culvert
Highway 66
Station 14+791 - Twp. of Cairo
Site No. 47-001
GWP 364-00-00
WP 5290-07-01

FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

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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 at an existing triple centerline culvert site. The site is located at Whiskey Jack Creek on Highway 66, some 0.3 km East of Highway 65, in the Township of Cairo, Site No. 47-001.

The foundation investigation location was specified by the MTO in the Terms of Reference for extra work under Agreement No. 5012-E-0025. The terms of reference for the scope of work are outlined in LVM | MERLEX's Proposal P-13-022, dated February, 2013. The purpose of this investigation was to determine the subsurface conditions in the area of the triple culverts. LVM | MERLEX investigated the foundation area by the drilling of boreholes, carrying out in-situ tests, and performing laboratory testing on select samples.

2 SITE DESCRIPTION

The triple Corrugated Steel Pipe (CSP) culverts are located on Highway 66 at Stations 14+788, 14+791, and 14+794, Township of Cairo. The topography at the site is a low wetland area to the left and right 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 an earth fill embankment some 3.5 m in height, with centerline elevation of 317.2 m at the culvert location. The existing embankment slopes have been established between angles of 1.6H:1V to 2H:1V. The culverts at this location are 2.0 m diameter Corrugated Steel Pipe (CSP) culverts, some 17 m in length. Flow through the culvert is from north to south (left to right) (see Photo Essay, Appendix 4).

Infrastructure at the culvert location consists of overhead wires to the left (north) side of the highway embankment.

2.1 SITE PHYSIOGRAPHY AND SURFICIAL GEOLOGY

This project is located in the Geomorphic Sub-province known as the Temiskaming Clay Plain. The topography on this section of Highway 65 is generally flat. Significant layers of earth overlay the bedrock. Organic materials were also observed. Within the project area native overburden consists primarily of sands and gravels overlying bedrock.

Bedrock in the area, as indicated on OGS Map 2506, is of the Early Precambrian Mafic Metavolcanics, which consists of basaltic and andesitic flows, tuffs, and breccias.

3 INVESTIGATION PROCEDURES

The fieldwork for this investigation was carried out during the period of October 2nd to 17th, 2013 during which time six (6) sampled boreholes, were advanced. Two (2) boreholes were advanced through the embankment at the location of the triple culverts, and two boreholes were advanced at each of the inlet (north) and outlet (south) ends of the culverts.

The field investigation was carried out using a truck mounted CME drilling rig equipped with hollow stem augers, standard augers, casing equipment and routine geotechnical sampling equipment. In order to advance sampled boreholes at the inlet and outlet of the culverts, a mobile B-24 “fly-in” drill rig mounted on a raft was employed equipped with NW casing, NQ coring equipment, and conventional split spoon sampling equipment. Soil samples were obtained at the borehole locations at regular intervals of depth using the standard 50 mm O.D. split spoon sampler advanced in accordance with the Standard Penetration Test (SPT) procedures (ASTM D-1586). The SPT method involves advancing a 50 mm O.D. split spoon sampler with the force of a 63.5 kg hammer freely dropping 760 mm. The number of blows per 300 mm penetration was recorded as the “N” value. When cohesive deposits were encountered, the in-situ strength was measured using an “N” size field vane, vane collar, and calibrated torque meter. When shallow refusal was encountered, NQ size diamond coring equipment was used to determine the nature of shallow refusal. 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. A 19 mm diameter standpipe was installed in Borehole No. 1, prior to backfilling, to allow for further monitoring of the shallow groundwater levels. All other open boreholes were backfilled upon completion with compacted auger cuttings in the general order they were removed and, where necessary, bentonite pellet backfill was added to the boreholes to bring them up to grade in accordance with Ontario Regulation 903. At the borehole(s) through the embankment, the upper portion of the hole, where necessary, was backfilled with an asphalt cold patch to seal the existing asphalt surface. Upon completion of the fieldwork program the standpipe in Borehole No. 1 was decommissioned in accordance with Ontario Reg. 903.

The fieldwork for this investigation was under the full time direction of a senior member of the LVM | Merlex engineering staff, who was responsible for locating the boreholes, clearing the borehole locations of underground services, in-situ sampling and testing operations, logging of the boreholes, labeling and preparation of samples for transport to our North Bay laboratory, plus overall drill supervision. All samples received a visual confirmatory inspection in our laboratory. Laboratory testing of select samples included routine testing for natural moisture content determination and particle size analysis. The results of the laboratory testing are presented on the individual Record of Borehole Sheets (Appendix 2), with a summary of results presented on the laboratory sheets in Appendix 3 (Figures Nos. L-1 to L-4).

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. The borehole elevations are based on a survey carried out by others.

4 SUBSURFACE CONDITIONS

Details of the subsurface conditions revealed by the investigation program are presented on the enclosed Records of Borehole Logs (Appendix 2) and on Drawing No. 2 (Appendix 3). Please note that stratigraphic delineation presented on the borehole logs and soil strata plot are the results of non-continuous sampling, response to drilling progress, the results of SPT, plus field observations. Typically such boundaries represent transitions from one zone to another and are not an exact demarcation of specific geological unit. Additional consideration should be given to the fact that subsurface conditions may vary markedly between adjacent boreholes and beyond any specific boring location, and are shown on the drawings for illustration purposes only.

4.1 CULVERT STATION 14+791, TWP OF CAIRO

A plan and profile illustrating the borehole locations and stratigraphic sequences is shown on Drawing No. 2, Appendix 3. During the course of the exploration program, six (6) sampled boreholes were put down at this site, with Borehole Nos. 1 and 2 advanced through the embankment, Borehole Nos. 3 and 4 advanced at the culvert inlet, and Borehole Nos. 5 and 6 advanced at the culvert outlet. At the time of the subsurface investigation, the ground surface elevations at Boreholes Nos. 1 and 2 were recorded at elevation 317.1 m. The elevations of the creek water surface at Borehole Nos. 3 to 6, inclusive, were recorded at elevation 314.8 m.

4.1.1 Pavement Structure

Borehole Nos. 1 and 2 were advanced from the shoulders where a pavement structure consisting of 50 mm asphalt and 150 mm crushed gravel was penetrated.

4.1.2 Granular Fill

Underlying the pavement structure at Borehole Nos. 1 and 2, a layer of granular fill consisting of brown sand trace silt some to with gravel was penetrated. The natural moisture content measured on samples of this deposit was in the order of 2 to 4%. A gradation analysis was carried out on one (1) sample of this deposit, the results of which indicated 9% gravel size particles, 85% sand size particles, and 6% silt and clay size particles (Figure No. L-1, Appendix 3). Based on SPT ‘N’ values of 31 to 54 blows per 300 mm penetration, the compactness of this deposit was described as dense to very dense. This deposit was encountered to depths of 1.4 and 2.1 m below grade at Borehole Nos. 1 and 2, respectively (elevations 315.7 and 315.0 m, respectively).

4.1.3 Sands and Gravels

At the creek bottom at Borehole Nos. 4, 5, and 6, a deposit of gravel and sand described as grey sand and gravel to gravel with sand trace silt was penetrated. Decomposed wood pieces were encountered in this deposit at varying depths. The natural moisture content measured on samples of this deposit was in the order of 12 to 381%. The elevated moisture contents are due to the wood pieces (organic soils) in the deposit. Gradation analyses were carried out on two (2) samples of this deposit, the results of which indicated 47 and 69% gravel size particles, 30 and 52% sand size particles, and 1% silt and clay size particles (Figure No. L-2, Appendix 3). Based on SPT 'N' values of 2 to 15 blows per 300 mm penetration, this deposit was described as very loose to compact. This deposit was encountered to a depth of 3.1 m below creek water surface at Borehole No. 4 (elevation 311.7 m), where bedrock was encountered. This deposit was encountered to depths of 2.5 and 2.0 m below creek water surface at Borehole Nos. 5 and 6, respectively (elevations 312.3 and 312.8 m, respectively).

4.1.4 **Sands**

Underlying the granular fill at Borehole Nos. 1 and 2, at the creek bottom at Borehole No. 3, and underlying the gravel and sand at Borehole Nos. 5 and 6, a stratum of grey sand some gravel to gravelly trace silt was penetrated. The natural moisture content measured on samples of this deposit was in the order of 3 to 25%. Gradation analyses were carried out on six (6) samples of this deposit, the results of which indicated 9 to 33% gravel size particles, 62 to 90% sand size particles, and 1 to 5% silt and clay size particles (Figure No. L-3, Appendix 3). Based on SPT 'N' values of 5 to 61 blows per 300 mm penetration, this deposit was described as loose to very dense, generally compact. This deposit was encountered to a depth of 2.0 m below creek water surface at Borehole No. 3 (elevation 312.8 m), where bedrock was encountered. Sampling was terminated in this deposit at a depth of 8.7 m below creek water surface at Borehole Nos. 5 and 6 (elevations 307.0 m). Auger refusal was encountered in this deposit at depths of 8.6 and 11.0 m below grade at Borehole Nos. 1 and 2, respectively (elevations 308.5 and 306.1 m).

4.1.5 **Bedrock**

Underlying the sands at Borehole No. 3 and underlying the sand and gravel at Borehole No. 4, bedrock was proven by diamond core drilling. The bedrock was described as black basaltic bedrock. Based on RQD values of 25 to 97% the bedrock was described as poor to excellent quality, generally fair quality. Sampling in the bedrock was terminated at depths of 5.3 and 5.6 m below creek water surface at Borehole Nos. 3 and 4, respectively (elevations 309.5 and 309.2 m, respectively). It should be noted that, when encountered, the underlying bedrock surfaces in this area are very erratic in nature, varying substantially in elevation over short horizontal distances.

4.2 GROUNDWATER DATA

At the time of this investigation, the creek water level in the culvert was measured at elevation 314.8 m at the inlet and outlet.

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. A standpipe was installed in Borehole No. 1 to obtain post borehole completion water levels. These levels are recorded on the individual Record of Borehole Log Sheets (Appendix B).

The water levels were measured between elevations 315.2 to 315.3 m below grade at Borehole Nos. 1 and 2, respectively. The standpipe in Borehole No. 1 was decommissioned in accordance with Ontario Reg. 903 on the last day work was carried out at this site.

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

5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

A foundation investigation was carried for the proposed replacement of the triple culverts as identified in the RFP.

The existing culverts, located at Stations 14+788, 14+791, and 14+794, in the Township of Cairo, are triple 2.0 m diameter CSP culverts some 17 m long. The existing culvert inverts at centerline are at a depth of some 3.5 m (elevation 313.7 m). The existing highway embankment currently supports two undivided lanes of highway, running in a west to east direction. Flow through the culvert is from left to right (north to south). Based on data from this foundation investigation, the embankment supporting the existing pavement structure at this site has been constructed using a granular pavement structure overlying granular fill. The native material, underlying the embankment fill, generally consisted of compact sands.

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

5.2 FOUNDATION CONSIDERATIONS

The founding native compact sands present below the existing embankment are considered adequate for support of a culvert(s) 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 throughout construction, as discussed in Section 5.6.

Based on the characteristics of the native sand subgrade present below the culverts, the response of the existing embankment, and a founding elevation similar to that of the existing culverts, a factored bearing resistance at ULS of 450 kPa can be used for a closed culvert (i.e. precast concrete frame box culvert or CSP culvert). In consideration of the width of the culvert, depth of overburden, and response of the existing embankment, a geotechnical reaction at SLS of 75 kPa can be used for design, in consideration of 25 mm settlement.

If open culverts (i.e. concrete frame open culverts, with wall footings, or pipe arch culverts on footings) are considered, then a factored bearing resistance at ULS of 115 kPa, and a geotechnical reaction at SLS of 75 kPa would apply for design, in consideration of 25 mm settlement and taking into consideration the limited depth of overburden and smaller footing width.

Under both types of foundations, the magnitude of settlement is related to the thickness of overburden above the unyielding bedrock. As such, settlement, if it develops, would be greater at the outlet end in consideration of the shallow bedrock at the inlet end.

5.2.1 Slope Stability

The maximum height of the embankment above the stream bed at this location is some 3.5 m. A stability analysis, using the GEO-SLOPE computer program, Slope/W (GeoStudio 2007, version 7.17, Geo-Slope International Ltd.), was carried out at this location with standard embankment slopes of 2.0H:1.0V in granular fill. For the purposes of these analyses, the materials were modeled using the following parameters;

PARAMETER	MATERIAL		
	EMBANKMENT FILL	GRAVEL AND SAND	SANDS
Unit Weight (kN/m^3)	20	18.5	18
Effective Friction Angle (degrees)	32	30	29

The unit weights and friction angles for the slope calculations are based on general representative values for the various soil types, obtained through laboratory testing and tactile analysis. The results of the analyses indicated a factor of safety for the new embankment in the order of 1.3 (see Figure No. S-1, Appendix 5). Lower factors of safety will occur during excavation and backfilling as discussed in Section 5.5. Short term stability should not be an issue if construction is carried out as described herein. The long term stability of the new embankment will not be an issue provided it is properly constructed.

5.3 CULVERT DESIGN, BEDDING, AND EMBEDMENT

The embankment consists of granular fills. The results of this investigation indicate that, below the culvert inverts, the native soils at Borehole Nos. 1 and 2 generally consists of loose sands. A review of the condition of the pavement surface, at the culvert locations, revealed minor transverse asphalt cracking, however, in general, the embankment appears to have performed well. The existing embankment has preloaded the soils at the culvert locations and since there will be no change in the height of the embankment, and therefore no increases in embankment load, no appreciable settlement of the embankment is anticipated. As such, installing the culverts on a camber will not be required at this site.

5.3.1 Rigid Concrete Culvert

Concrete pipes can be considered for culvert replacement at this site. A Class B Bedding for the concrete pipes shall consist of Granular A with a thickness of 300 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 embedment fill should be placed in a balanced manner on each side of the pipe. The elevation difference of the backfill on either side of the pipe must be limited to a maximum 200 mm. Cover material for concrete pipes can consist of Granular A and placed to the dimensions as shown on OPSD 802.031. If circular concrete pipes are used, compaction of the haunch is critical and should be in accordance with OPSS 501.

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 5 m in length, 400 mm thick and extend across the stream bed to 5 m beyond the outside edges of the culvert. Clay seals are generally used where significant head differences exist between the inlet and outlet of the culverts to prevent flow through the bedding/embedment granulars. Considering the anticipated water levels and flow at this culvert location, clay seals are not considered necessary.

5.3.2 Flexible Culvert

Flexible culverts (i.e. CSP/SPCSP/HDPE) can also be considered for culvert replacement at this site. If flexible pipes are used for replacement, embedment material should consist of Granular B Type I provided the maximum size of stone inclusions is limited to 25 mm or less in size and placed in accordance with OPSD 802.010 for a Type 3 soil. The material in the haunch area must be compacted to 100% Standard Proctor Dry Density prior to placing the remainder of the embedment material. During backfilling, the embedment fill should be placed in a balanced manner on the outer sides of the culvert units. The elevation difference of the backfill on either side of the culvert must be limited to 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 5 m in length, 400 mm thick and extend across the stream bed to 5 m beyond the outside edges of the culvert.

5.4 CULVERT INSTALLATION AND CONSTRUCTION STAGING CONSIDERATIONS

The invert elevation of the existing culverts is at 313.7 m, with the top of the embankment at elevation 317.2 m at centerline. As such, the embankment at this location is some 3.5 m in height above the culvert invert at the centerline. Therefore, a minimum 3.8 m deep excavation (i.e. to elevation 313.4 m) will be required in consideration of a 300 mm thick layer of bedding/embedment material. The present platform width at this location is some 11 m as can be seen on the cross section on Drawing No. 2. The platform width at this location, as is, will not be sufficient to carry out an open excavation using staged construction unless local lowering of the grade and/or sliver widening is undertaken. Consideration can be given to constructing a vertical wall for use as a protection system. It is suggested that locally lowering the grade be considered to allow an open cut staged excavation.

5.4.1 Staged Construction

As noted, the platform at this location, as is, is of insufficient width to carry out an open excavation using staged construction, unless temporarily lowering the vertical alignment is carried out. To carry out an open cut excavation, locally lowering the grade to allow for staged construction using staged sequencing and limiting traffic flow to one lane would be required (see Figure No. SK-3, Appendix 5).

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

- Locally lower the grade at the culverts to an elevation of approximately 316.1 m.
- Limit traffic to a single lane on the left, with a minimum platform width of 5 m, under 24/7 traffic control.
- Open cut excavate, to the right, and install approximately 8 m of new culvert.
- Reconstruct the embankment on the right, with a minimum platform width of 5 m for traffic.
- Divert the single lane of traffic to the right and continue open excavation to install the remainder of the culvert on the left.
- As the width of the platform increases on the right, the vertical alignment can be raised, and the traffic can revert back to two lanes when sufficient width permits.

5.4.2 Protection System

As noted above, consideration could also be given to constructing a vertical wall, along centerline, for use as a temporary protection system. The installation of a protection system for use in the culvert replacement operation will require penetration through some 3.5 m of granular fill. The embankment fill is generally underlain by loose to compact sands. The embankment generally consists of granular fill, as such, the recommended method of constructing a temporary vertical wall for a protection system along the centreline of the highway alignment would be to drive steel sheet piles through the embankment fill into the underlying native soils. Conceptual shoring locations and sections are illustrated on Figure Nos. SK-4 and SK-5, Appendix 5.

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

Ka = active earth pressure coefficient, as described in Section 5.5,

ɣ = unit weight, as described in Section 5.5, and

H = height of wall above the base of excavation.

Surcharge loads from the active lane of traffic must also be considered during design of the temporary shoring system.

The 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 5. Conceptual shoring location is illustrated on Figure No. SK-4, Appendix 5.

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

The temporary protection system should be designed and constructed to comply with OPSS 539. In consideration of the location of the protection system and traffic volume, a Performance Level 2 is considered appropriate.

5.5 LATERAL EARTH PRESSURES

Lateral earth pressures should be computed in accordance with the Canadian Highway Bridge Design Code (CHBDC). The design parameters for the bedding/embedment and backfill materials are as follows:

PARAMETER	GRANULAR A	GRANULAR B TYPE I	EMBANKMENT FILL	GRAVEL AND SAND	SAND
Unit Weight (kN/m^3)	22.8	21.2	20	18.5	18
Angle of Internal Friction	34°	31°	32	30	29
Coefficient of Active Earth Pressure (Ka)	0.28	0.32	0.31	0.33	0.34
Coefficient of Passive Earth Pressure (Kp)	3.54	3.12	3.25	3.00	2.88
Coefficient of Earth Pressure at Rest (Ko)	0.44	0.48	0.47	0.50	0.52

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

5.6 EXCAVATION, DEWATERING, AND EMBANKMENT RECONSTRUCTION

All excavations greater than 1.2 m in depth must, at a minimum, be sloped or shored in accordance with the Occupational Health and Safety Act Regulations for Construction Projects. The embankment material, above the water table, is considered a Type 3 soil as defined in the Occupational Health and Safety Act and Regulations for Construction Projects. Temporary open excavations above the groundwater table, could be cut back at an angle of 1H:1V, provided they are monitored continuously, however, below the groundwater table, the side slopes will have to be cut back to an angle of 2H:1V, possibly shallower, dependent upon the Contractors' chosen method of controlling the groundwater. Temporary open cuts with a slope of 1H:1V cannot be left unattended (i.e. overnight, during breakdowns, etc.). If work must stop for extended periods of time, the temporary slopes must be flattened to a minimum angle of 2H:1V.

The excavation backfill should consist of Select Subgrade Material (SSM), at a minimum, up to the underside of the pavement structure. An SSM material must be used within the depth of frost penetration. Final (permanent) embankment side slopes in granular fills should be established to match the existing slopes or as per OPSD 200.010. Final slopes should be treated with a mulch and seed to prevent ravelling.

Bedrock was not encountered at the borehole locations within the anticipated depth of excavation, therefore bedrock excavation and/or blasting operations are not anticipated. It should be noted that, when encountered, the underlying bedrock surfaces in this area are very erratic in nature, varying substantially in elevation over short horizontal distances. Excavations must be maintained in a dewatered condition during excavation and foundation construction, and every reasonable effort must be made to prevent disturbing (piping/boiling) at the founding subgrade. Groundwater control, in accordance with OPSS 517 and 518, will be required to maintain a stable subgrade during culvert installation.

The water level in the creek was recorded at elevation 314.8 m at the time of this investigation and excavations to an approximate elevation 313.4 m will be required to install the culvert and bedding. As such dewatering will be required during excavation and culvert installation.

During construction, installation of filtered sumps and pumping from the base of the excavation will, at a minimum, be required to maintain the excavation in a dewatered condition during subgrade preparation and culvert installation. This method of groundwater control is generally only effective when the groundwater in the excavation is less than a depth of some 1 m above the final base of the excavation. To effectively lower the groundwater to a greater depth, a more sophisticated groundwater control system, such as a well points or closed sheeting, would have to be considered. To provide a stable working surface the water level must be controlled to below the base of excavation. When wet, silty/sandy subgrades can become easily disturbed, and can lose a significant portion of its natural bearing capacity.

A cofferdam, constructed of earth fill, sand bags, or water filled bag (i.e. aquadam) can be considered at this site. The presence of bedrock at the inlet end would limit the penetration of a steel sheet pile type cofferdam. However, at the outlet of the culvert, auger refusal was not encountered within the depth of investigation. As such, steel sheet piles may be considered for controlling stream flow at the culvert outlet. For base design, sheet piles should extend a minimum depth below base of proposed excavation equal to the height of water above the base of excavation. By-pass pumping can be carried out to divert the stream flow at the time of construction. Since this site has triple culverts, by-pass pumping/diversion through one of the culverts can be carried out, while the adjacent culverts are being replaced.

Ultimately, the method of excavation, dewatering, and stream flow diversion will be the choice of the contractor; however the importance of maintaining the subgrade in a dewatered stable condition during excavation and construction operations cannot be stressed enough.

5.7 CONSTRUCTION CONCERNS

Considering the nature of the granular fill embankment, no major construction concerns are anticipated if construction is carried out in general conformance with the above discussion.

6 STATEMENT OF LIMITATIONS

The design recommendations given in this geotechnical report are applicable only to the project described in the text and only if constructed substantially in accordance with details of alignment and elevations stated in the report. Since all details of the design may not be known, in our analysis certain assumptions had to be made. The actual conditions may however, vary from those assumed, in which case changes and modifications may be required to our geotechnical recommendations. We recommend, therefore, that we be retained and provided the opportunity during the design stage to review the design drawings, site survey information, proposed elevations, etc. to verify that they are consistent with our recommendations or the assumptions made in our analysis. It is further recommended that we be retained to review the final design drawings and specifications relative to the geotechnical recommendations.

If, during construction, conditions in the field vary from those assumed at the design stage, an engineer from this office must be notified immediately.

Proper subgrade preparation, groundwater control, compaction, etc. are all critical aspects of the bearing capacity of native soils. It must be noted that different aspects of the geotechnical design are based on the assumption that LVM | Merlex Ltd. will be retained during site preparation and construction of the proposed works to ensure that both the geotechnical site characteristics and the construction operations/techniques are consistent with our recommendations. Should LVM | Merlex Ltd. not be involved during the full construction phase, our liability is strictly limited to the factual information contained herein only.

The comments in this report are intended solely for the guidance of the design engineer and address the geotechnical conditions only. The number of boreholes required to determine the localized conditions between boreholes directly affecting construction costs, equipment, scheduling, etc. would in fact be greater than what has been carried out for design purposes. Therefore, contractors bidding on this project or undertaking this work should make their own interpretations of the factual borehole results and carry out further work as they deem necessary to assess the scope of the project.

Section 5 of this reported is intended for the use of the client and the design team only and is not intended to be included in the tender documents. Inclusion of the factual information (Sections 1 to 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.

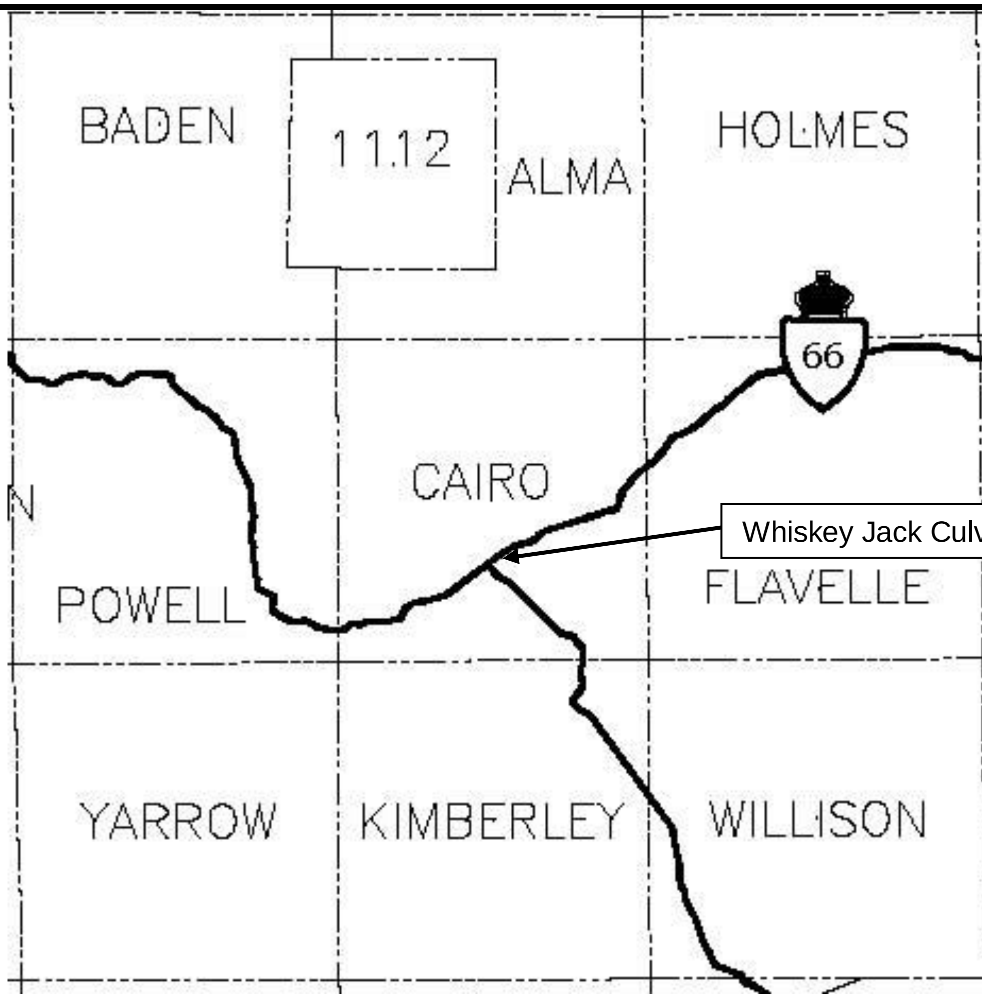
Appendix 1 Key Plan

Drawing No. 1	Key Plan

LVM | MERLEX

KEY PLAN **Drawing No. 1**

NOT TO SCALE



FINAL
FOUNDATION INVESTIGATION
AND DESIGN REPORT
GWP 364-00-00
Highway 66

Whiskey Jack Creek Culvert

Reference No: 13/05/13073-F3 May 2014

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Appendix 2 Subsurface Data

Enclosure No. 1	List of Abbreviations and Symbols
Enclosure Nos. 2 to 7	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
Rec % recovery from individual run of rock core
RQD Rock quality designation (%)

2. PENETRATION RESISTANCE/"N"

Dynamic Cone Penetration Test (DCPT):

A continuous profile showing the number of blows for each 300 mm of penetration of a 50 mm diameter 60° cone attached to AW rod driven by a 63 kg hammer falling 760 mm.

Plotted as ——•——•——•——•

Standard Penetration Test (SPT) or "N" Values

The number of blows of a 63 kg hammer falling 760 mm required to advance a 50 mm O.D. drive open sampler 300 mm.

3. SOIL DESCRIPTION

a) *Cohesionless Soils:*

"N" (blows/0.3 m)	*Relative Density*
0 to 4	very loose
4 to 10	loose
10 to 30	compact
30 to 50	dense
over 50	very dense

b) *Cohesive Soils:*

Undrained Shear Strength (kPa)	*Consistency*
Less than 12	very soft
12 to 25	soft
25 to 50	firm
50 to 100	stiff
100 to 200	very stiff
over 200	hard

3. SOIL DESCRIPTION (Cont'd)

c) *Cohesive Soils:*

RQD (%)	*Classification*
Less than 25	Very poor quality
25 to 50	Poor quality
50 to 75	Fair quality
75 to 90	Good quality
90 to 100	Excellent quality

d) *Method of Determination of Undrained Shear Strength of Cohesive Soils:*

+ 3.2 - Field Vane test in borehole. The number denotes the sensitivity to remoulding.

D - Laboratory Vane Test

¨ - Compression test in laboratory

For a saturated cohesive soil the undrained shear strength is taken as one-half of the undrained compressive strength.

e) *Soil Moisture:*

Moisture	*Described as*
Dry	Below optimum moisture content
Moist	Near optimum moisture content
Wet	Above optimum moisture content

4. TERMINOLOGY

Terminology used for describing soil strata is based on the proportion of individual particle sizes present in the samples (please note that, with the exception of those samples subject to a grain-size analysis, all samples were classified visually and the accuracy of visual examination is not sufficient to determine exact grain sizing):

Trace, or occasional	Less than 10%
Some	10 to 20%
With	20 to 30%
Adjective (i.e. silty or sandy)	30 to 40%
And (i.e. sand and gravel)	40 to 60%

Terminology for cobbles and boulders is based on auger response and field observations:

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

SAMPLE DESCRIPTION NOTES:

1. **FILL:** The term fill is used to designate all man-made deposits of natural soil and/or waste materials. The reader is cautioned that fill materials can be very heterogeneous in nature and variable in depth, density and degree of compaction. Fill materials can be expected to contain organics, waste materials, construction materials, shot rock, rip-rap, and/or larger obstructions such as boulders, concrete foundations, slabs, abandoned tanks, etc.; none of which may have been encountered in the borehole. The description of the material penetrated in the borehole therefore may not be applicable as a general description of the fill material on the site as boreholes cannot accurately define the nature of fill material. During the boring and sampling process, retrieved samples may have certain characteristics that identify them as 'fill'. Fill materials (or possible fill materials) will be designated on the Borehole Logs. If fill material is identified on the site, it is highly recommended that testpits be put down to delineate the nature of the fill material. However, even through the use of testpits defining the true nature and composition of the fill material cannot be guaranteed. Fill deposits often contain pockets or seams of organics, organically contaminated soils or other deleterious material that can cause settlement or result in the production of methane gas. It should be noted that the origins and history of fill material is frequently very vague or non-existent. Often fill material may be contaminated beyond environmental guidelines and the material will have to be disposed of at a designated site (i.e. registered landfill). Unless requested or stated otherwise in this report, fill material on this site has not been tested for contaminants however, environmental testing of the fill material can be carried out at your request. Detection of underground storage tanks cannot be determined with conventional geotechnical procedures.

2. **TILL:** The term till indicates a material that is an unstratified, glacial deposit, heterogeneous in nature and, as such, may consist of mixtures and pockets of clay, silt, sand, gravel, cobbles and/or boulders. These heterogeneous deposits originate from a geological process associated with glaciation. It must be noted that due to the highly heterogeneous nature of till deposits, the description of the deposit on the borehole log may only be applicable to a very limited area and therefore, caution must be exercised when dealing with a till deposit. When excavating in till, contractors may encounter cobbles/boulders or possibly bedrock even if they are not indicated on the borehole logs. It must be appreciated that conventional geotechnical sampling equipment does not identify the nature or size of any obstruction.

3. **BEDROCK:** Auger refusal may be due to the presence of bedrock, but possibly could also be due to the presence of very dense underlying deposits, boulders or other large obstructions. Auger refusal is defined as the point at which an auger can no longer be practically advanced. It must be appreciated that conventional geotechnical sampling equipment does not differentiate between nature and size of obstructions that prevent further penetration of the boring below grade. Bedrock indicated on the borehole logs will be labeled 'possibly' or 'probable' etc. based on the response of the boring and sampling equipment, surrounding topography, etc. Bedrock can be proven at individual borehole locations, at your request, by diamond core drilling operations or, possibly, by testpits. It must also be appreciated that bedrock surfaces can be, and most times are, very erratic in nature (i.e. sheer drops, isolated rock knobs, etc.) and caution must be used when interpreting subsurface conditions between boreholes. A bedrock profile can be more accurately estimated, at the clients' request, through a series of closely positioned unsampled auger probes combined with core drilling.

4. **GROUNDWATER:** Although the groundwater table may have been encountered during this investigation and the elevation noted in the report and/or on the record of boreholes, it must be appreciated that the elevation of the groundwater table will fluctuate based upon seasonal conditions, localized changes, erratic changes in the underlying soil profile between boreholes, underlying soil layers with highly variable permeabilities, etc. These conditions may affect the design and type and nature of dewatering procedures. Cave-in levels recorded in borings give a general indication of the groundwater level in cohesionless soils however, it must be noted that cave-in levels may also be due to the relative density of the deposit, drilling operations etc.

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

METRIC

RECORD OF BOREHOLE NO. 01

LVM

REFERENCE 13/0513073-F3 DATUM Geodetic LOCATION N 5313213.4 E 335043.5 - Cairo Township - Station 14+784, 2.2 m Rt ORIGINATED BY JL

PROJECT GWP 364-00-00, Hwy 66 - Whiskey Jack Culvert BOREHOLE TYPE Truck Mounted CME 45B - Hollow Stem Augers COMPILED BY RG

CLIENT AECOM Inc. DATE (Started) 2013 October 2 DATE (Completed) 2013 October 2 TIME (Completed) 2:45:00 PM CHECKED BY AT

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
317.1	Asphalt Surface					
0.0	± 50 mm Asphalt ± 150 mm Crushed Gravel FILL - sand trace silt some to with gravel brown, dry	1	AS	N/A	○	
	(dense)	2	SS	31	○	
315.7 / 1.4	SAND some gravel to gravelly trace silt brown, dry (loose/very dense)	3	SS	17	○	23 73 (4)
	moist/wet	4	SS	13	○	23 72 (5)
		5	SS	18	○	
	grey	6	SS	16	○	33 62 (5)
		7	SS	9	○	20 76 (4)
		8	SS	5	○	
		9	SS	61	○	
308.5 / 8.6	Auger Refusal End of Borehole					

Chart headings: SOIL PROFILE; SAMPLES; STRATA PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (317, 316, 315, 314, 313, 312, 311, 310, 309); 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 (yy/mm/dd)/Time	Water Depth (m)	Cave In (m)
1) 13/10/2 2:45:00 PM	1.9	2.2
2) 13/10/18 8:00:00 AM	2.4	-
3)	-	-

MEL-GEO 13073-F3 - BOREHOLE LOGS - WHISKEY JACK CULVERT.GPJ MEL-GEO.GDT 14/5/26

RECORD OF BOREHOLE NO. 02

METRIC

LVM

REFERENCE	13/0513073-F3	DATUM	Geodetic
LOCATION	N 5313221.3 E 335053.8 - Cairo Township - Station 14+797, 2.2 m Lt	ORIGINATED BY	JL
PROJECT	GWP 364-00-00, Hwy 66 - Whiskey Jack Culvert	BOREHOLE TYPE	Truck Mounted CME 45B - Hollow Stem Augers
COMPILED BY	RG	CLIENT	AECOM Inc.
DATE (Started)	2013 October 2	DATE (Completed)	2013 October 2
TIME (Completed)	5:30:00 PM	CHECKED BY	AT

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
317.1	Asphalt Surface
0.0	± 50 mm Asphalt ± 150 mm Crushed Gravel FILL - sand trace silt trace to some gravel brown, dry (dense/very dense)
315.0 / 2.1	SAND trace silt some to with gravel brown, wet (loose/compact) grey

Continued Next Page

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
1	AS	N/A	9 85 (6)
2	SS	54	
3	SS	39	
4	SS	11	
5	SS	8	
6	SS	4	
7	SS	4	
8	SS	8	
9	SS	12	
10	SS	6	

GROUND WATER CONDITIONS

ELEVATION SCALE: 317, 316, 315, 314, 313, 312, 311, 310, 309, 308

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 (yy/mm/dd)/Time	Water Depth (m)	Cave In (m)
1)	13/10/2 5:30:00 PM	1.8	2.1
2)		-	-
3)		-	-

MEL-GEO 13073-F3 - BOREHOLE LOGS - WHISKEY JACK CULVERT.GPJ MEL-GEO.GDT 14/5/26

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

ENCLOSURE NO.:3 (Pg. 2 of 2)

METRIC

RECORD OF BOREHOLE NO. 02

LVM

REFERENCE	13/0513073-F3	DATUM	Geodetic	LOCATION	N 5313221.3 E 335053.8 - Cairo Township - Station 14+797, 2.2 m Lt
ORIGINATED BY	JL	PROJECT	GWP 364-00-00, Hwy 66 - Whiskey Jack Culvert	BOREHOLE TYPE	Truck Mounted CME 45B - Hollow Stem Augers
COMPILED BY	RG	CLIENT	AECOM Inc.	DATE (Started)	2013 October 2
DATE (Completed)	2013 October 2	TIME (Completed)	5:30:00 PM	CHECKED BY	AT

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	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)	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)
	Continued from Previous Page										
	SAND trace silt some to with gravel grey, wet (loose/compact)						307				
306.1			11	SS	8/150mm 50/50mm				○		
11.0	Auger Refusal End of Borehole										

MEL-GEO 13073-F3 - BOREHOLE LOGS - WHISKEY JACK CULVERT.GPJ MEL-GEO.GDT 14/5/26

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

METRIC

RECORD OF BOREHOLE NO. 03

LVM

REFERENCE 13/0513073-F3 DATUM Geodetic LOCATION N 5313223.4 E 335042.1 - Cairo Township - Station 14+789, 11.4 m L ORIGINATED BY JL

PROJECT GWP 364-00-00, Hwy 66 - Whiskey Jack Culvert BOREHOLE TYPE Raft Mounted B-24 - NW Casing & NQ Core COMPILED BY RG

CLIENT AECOM Inc. DATE (Started) 2013 October 15 DATE (Completed) 2013 October 16 TIME (Completed) 11:45:00 AM CHECKED BY AT

ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
314.8	Water Surface					▽		
0.0	Water						314	
313.6 / 1.2	SAND trace silt with gravel brown, wet		1	SS	32		313	
312.8 / 2.0	BEDROCK - black basaltic rock (poor quality)		2	SS	50/25mm			
	(fair quality)		3	RC	Rec=100% RQD=25%		312	
			4	RC	Rec=100% RQD=70%		311	
309.5			5	RC	Rec=100% RQD=73%		310	
5.3	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. Sample 1: water content approx. 20%.

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 (yy/mm/dd)/Time	Water Depth (m)	Cave In (m)
1) 13/10/16	0	-
2)	-	-
3)	-	-

MEL-GEO 13073-F3 - BOREHOLE LOGS - WHISKEY JACK CULVERT.GPJ MEL-GEO.GDT 14/5/26

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

METRIC

RECORD OF BOREHOLE NO. 04

LVM

REFERENCE 13/0513073-F3 DATUM Geodetic LOCATION N 5313229.7 E 335048.7 - Cairo Township - Station 14+798, 12.0 m L ORIGINATED BY JL

PROJECT GWP 364-00-00, Hwy 66 - Whiskey Jack Culvert BOREHOLE TYPE Raft Mounted B-24 - NW Casing & NQ Core COMPILED BY RG

CLIENT AECOM Inc. DATE (Started) 2013 October 16 DATE (Completed) 2013 October 16 TIME (Completed) 6:15:00 PM CHECKED BY AT

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
314.8	Water Surface						
0.0	Water						
313.9 / 0.9	SAND AND GRAVEL trace silt, grey, (very loose/loose)	1	SS	8	314		47 52 (1)
		2	SS	2	313		
	decomposed wood pieces encountered at depth	3	SS	HW/300mm 25/0mm	312	381	
311.7 / 3.1	BEDROCK - black basaltic rock (good quality)	4	RC	Rec= 100% RQD= 78%	311		
	(excellent quality)	5	RC	Rec= 100% RQD= 97%	310		
309.2 / 5.6	End of Borehole						

Ground water conditions: ▽ (at surface)

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 (yy/mm/dd)/Time	Water Depth (m)	Cave In (m)
1) 13/10/16	0	-
2)	-	-
3)	-	-

MEL-GEO 13073-F3 - BOREHOLE LOGS - WHISKEY JACK CULVERT.GPJ MEL-GEO.GDT 14/5/26

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

METRIC

RECORD OF BOREHOLE NO. 05

LVM

REFERENCE 13/0513073-F3 DATUM Geodetic LOCATION N 5313209.6 E 335062.7 - Cairo Township - Station 14+797, 12.4 m Rt ORIGINATED BY JL

PROJECT GWP 364-00-00, Hwy 66 - Whiskey Jack Culvert BOREHOLE TYPE Raft Mounted B-24 - NW Casing & NQ Core COMPILED BY RG

CLIENT AECOM Inc. DATE (Started) 2013 October 17 DATE (Completed) 2013 October 17 TIME (Completed) CHECKED BY AT

ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	(SI CL)
314.8	Water Surface					▽						
0.0	Water											
313.9 / 0.9	GRAVEL AND SAND trace silt and decomposed wood pieces grey, wet (loose/compact)		1	SS	3		314	128				
			2	SS	15		313	○		69	30	(1)
312.3 / 2.5	SAND trace silt trace to with gravel grey, wet (compact)		3	SS	14		312	○				
			4	SS	16		311	○		9	90	(1)
			5	SS	11		310	○				
			6	SS	13		309	○				
			7	SS	15		308	○		23	76	(1)
307.0 / 7.8	End of Sampling End of Borehole						307					

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
REMARKS & GRAIN SIZE DISTRIBUTION (%)

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 (yy/mm/dd)/Time	Water Depth (m)	Cave In (m)
1) 13/10/17	0	-
2)	-	-
3)	-	-

MEL-GEO 13073-F3 - BOREHOLE LOGS - WHISKEY JACK CULVERT.GPJ MEL-GEO.GDT 14/5/26

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

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

METRIC

RECORD OF BOREHOLE NO. 06

LVM

REFERENCE 13/0513073-F3	DATUM Geodetic	LOCATION N 5313203.4 E 335054.8 - Cairo Township - Station 14+787, 12.6 m Rt	ORIGINATED BY JL
PROJECT GWP 364-00-00, Hwy 66 - Whiskey Jack Culvert		BOREHOLE TYPE Raft Mounted B-24 - NW Casing & NQ Core	COMPILED BY RG
CLIENT AECOM Inc.		DATE (Started) 2013 October 17; DATE (Completed) 2013 October 17; TIME (Completed) 5:35:00 PM	CHECKED BY AT

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT (approx. %)
314.8	Water Surface					
0.0	Water				314	
313.6 / 1.2	GRAVEL AND SAND trace silt with decomposed wood pieces; grey, wet; (loose)	1	SS	4		~40
312.8 / 2.0	SAND trace silt trace gravel; grey, wet; (loose/compact)	2	SS	10	313	~23
		3	SS	10	312	~30
		4	SS	9	311	~28
	moist	5	SS	6	310	~25
		6	SS	10	309	~27
		7	SS	17	308	~25
307.0 / 7.8	End of Sampling; End of Borehole				307	

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRATA PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); 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)

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 (yy/mm/dd)/Time	Water Depth (m)	Cave In (m)
1) 13/10/17	0	-
2)	-	-
3)	-	-

MEL-GEO 13073-F3 - BOREHOLE LOGS - WHISKEY JACK CULVERT.GPJ MEL-GEO.GDT 14/5/26

Appendix 3 Borehole Plan and Lab Data

Drawing No. 2:	Borehole Location and Soil Strata
Figure Nos. L-1 and L-3:	Grain Size Distribution Curves
Figure No. L-4:	Lab Test Summary Sheet

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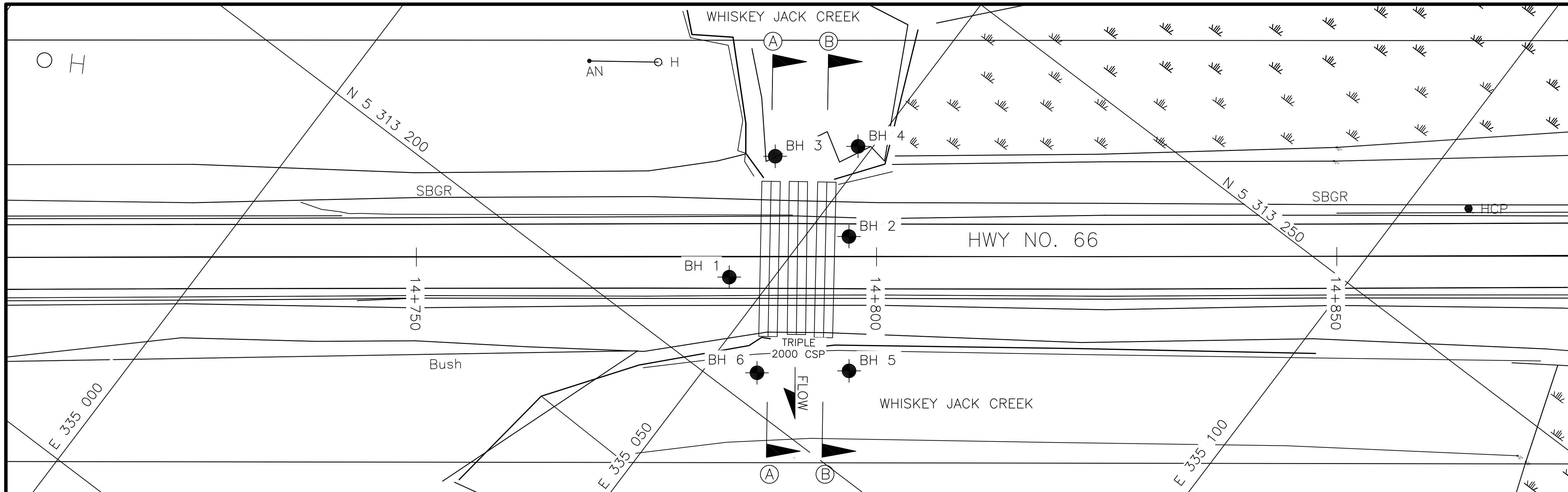
CONT. No. XXXX–XXXX

GWP. No. 364–00–00

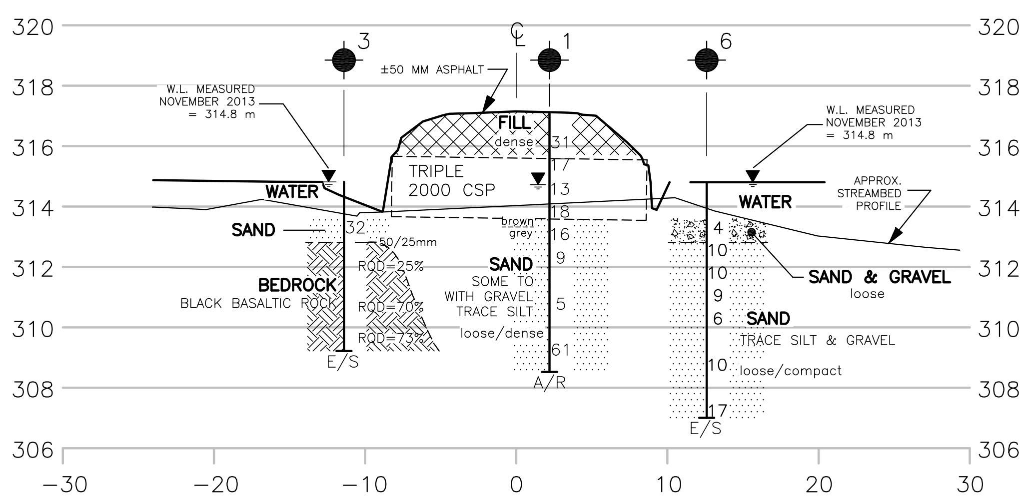
DRAWING 2

HWY 66
WHISKEY JACK CULVERT (SITE 47–001)
CAIRO TOWNSHIP
BOREHOLE LOCATIONS & SOIL STRATA



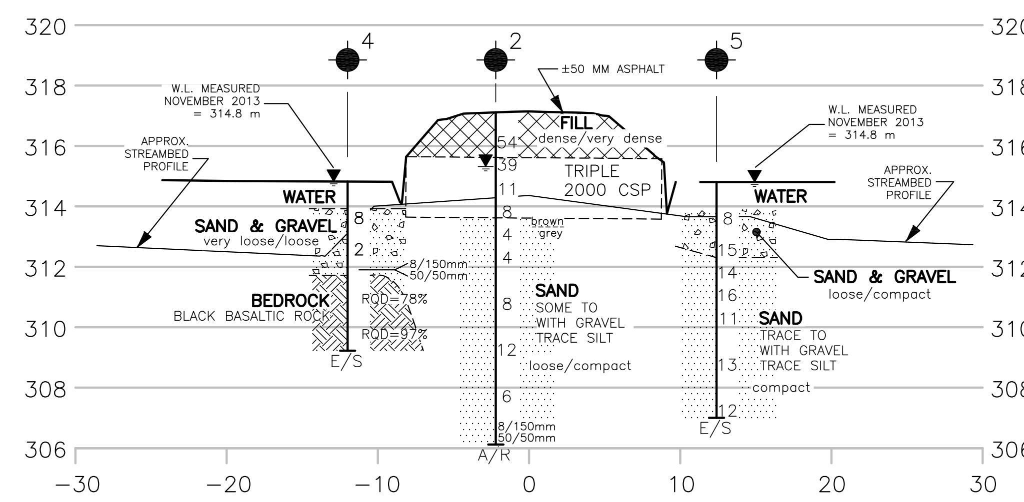
PLAN

5m SCALE 5m



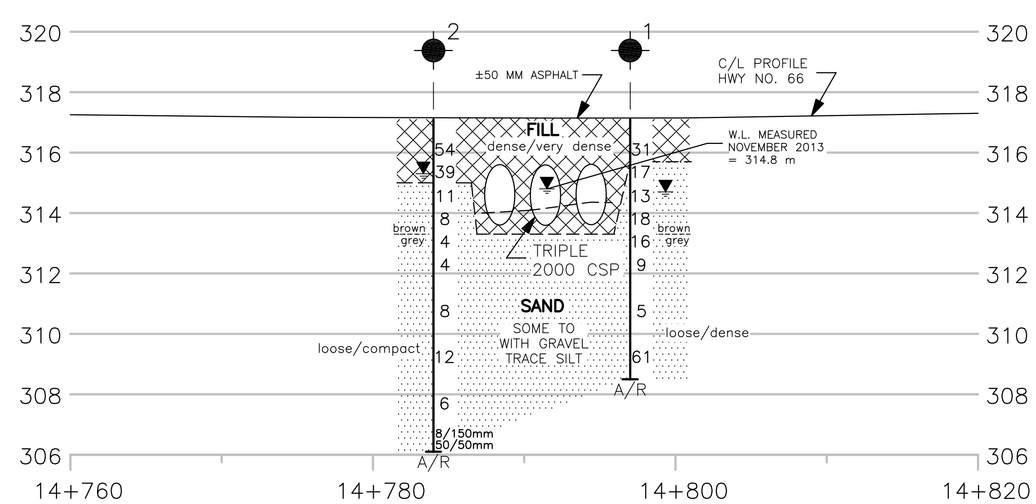
CROSS SECTION Ⓐ – Ⓐ

5m SCALE 5m HOR; 2.5m 2.5m VER



CROSS SECTION Ⓑ – Ⓑ

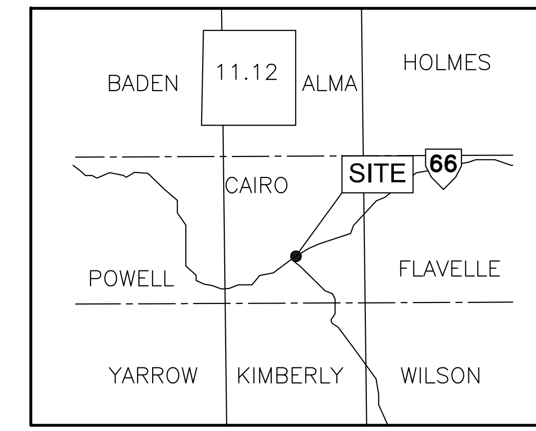
5m SCALE 5m HOR; 2.5m 2.5m VER



C/L PROFILE

5m SCALE 5m HOR; 2.5m 2.5m VER

LVM



KEY PLAN – NOT TO SCALE

LEGEND

- ● Borehole
- 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
- E/S End of Sampling

Borehole No.	Elev.	O/S	Co–ordinates	
			Northerly	Easterly
Borehole No. 1	317.1	2.2 m Rt	5313213.4	335043.5
Borehole No. 2	317.1	2.2 m Lt	5313221.3	335053.8
Borehole No. 3	314.8	11.4 m Lt	5313223.4	335042.1
Borehole No. 4	314.8	12.0 m Lt	5313229.7	335048.7
Borehole No. 5	314.8	12.4 m Rt	5313209.6	335062.7
Borehole No. 6	314.8	12.6 m Rt	5313203.4	335054.8

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

NOTE 2: The boundaries between soil strata have been established at the borehole locations only. The boundaries illustrated and stratigraphy between boreholes on this drawing are assumed based on borehole data and may vary. They are intended for design only.

REVISIONS DATE	BY	DESCRIPTION
MAY 2014	IK	REVISION 1

HWY NO. 66 – CAIRO TOWNSHIP

GEOCRES NO.: 41P–56

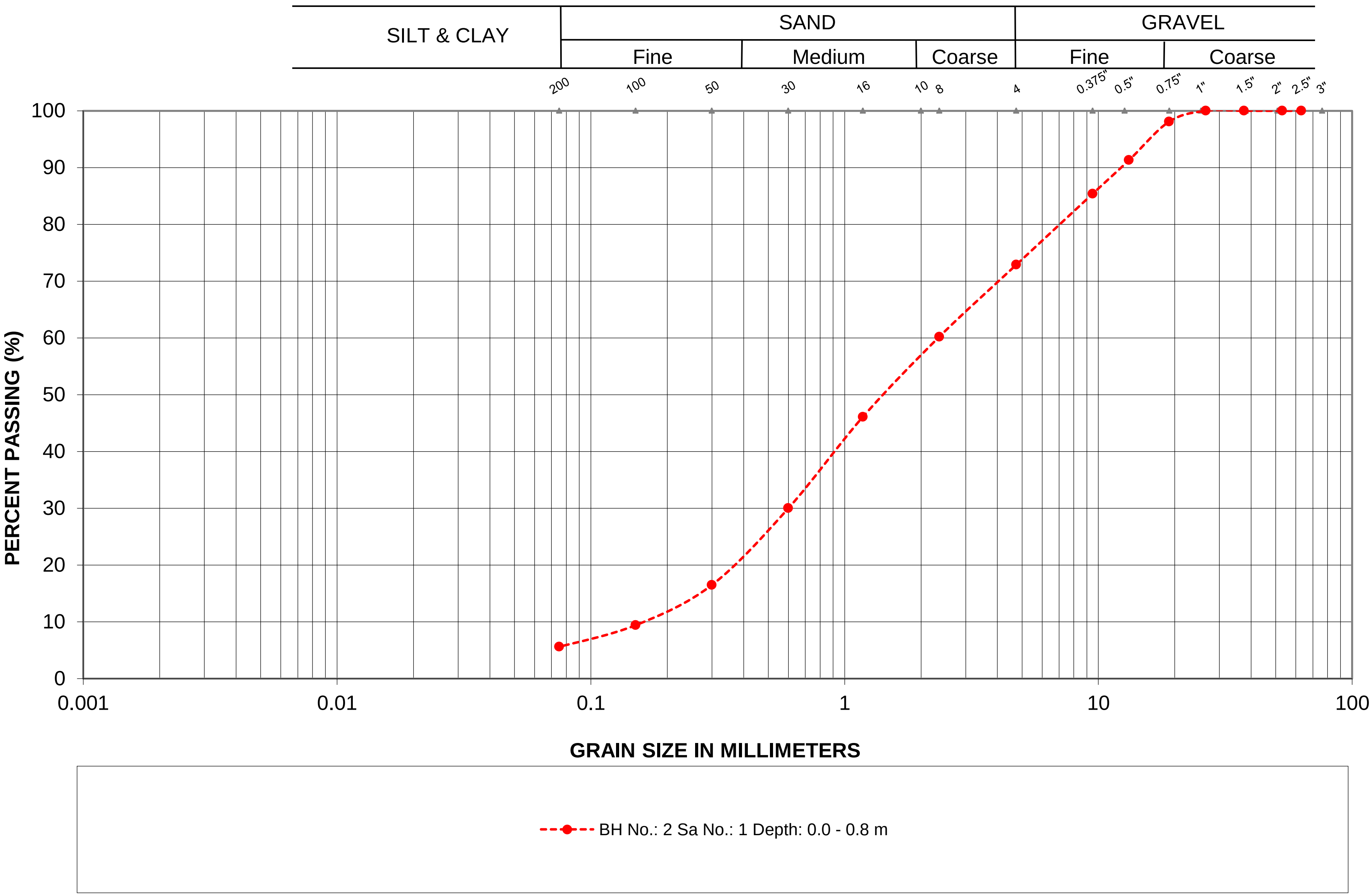
L|V|M REF. NO.: 13/05/13073–F3

DRAWN: RG | CHECKED: AT | DATE: JANUARY 2014

Reference No.: 13/05/13073-F3
Date: May 2014

LVM | MERLEX

GRAIN SIZE ANALYSIS



G.W.P.: 364-00-00
LOCATION: Hwy 65, Whiskey Jack Creek

EMBANKMENT FILL

Reference No.: 13/05/13073-F3
Date: May 2014

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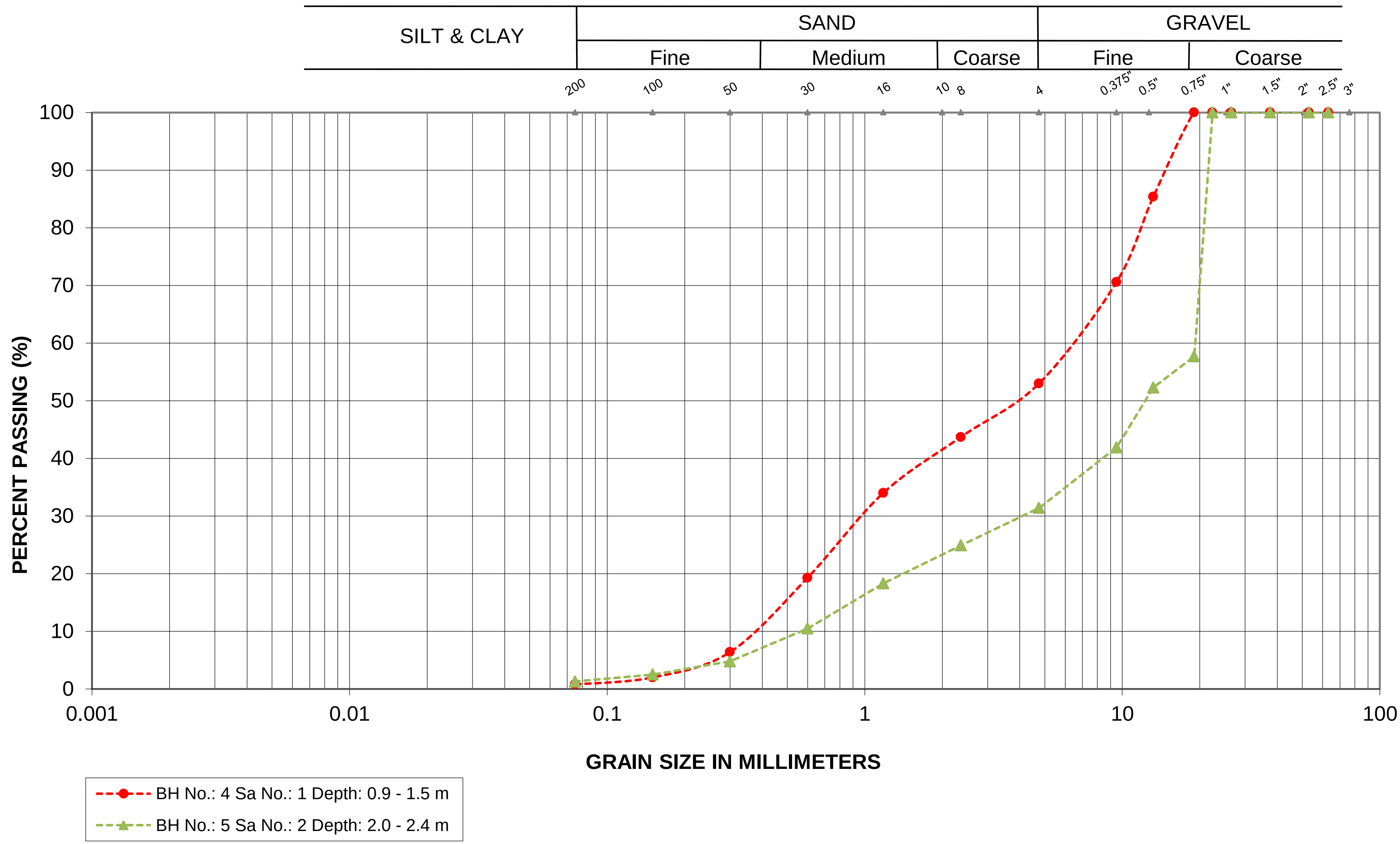
GRAIN SIZE ANALYSIS



G.W.P.: 364-00-00
LOCATION: Hwy 65, Whiskey Jack Creek

SAND AND GRAVEL

Reference No.: 13/05/13073-F3
Date: May 2014

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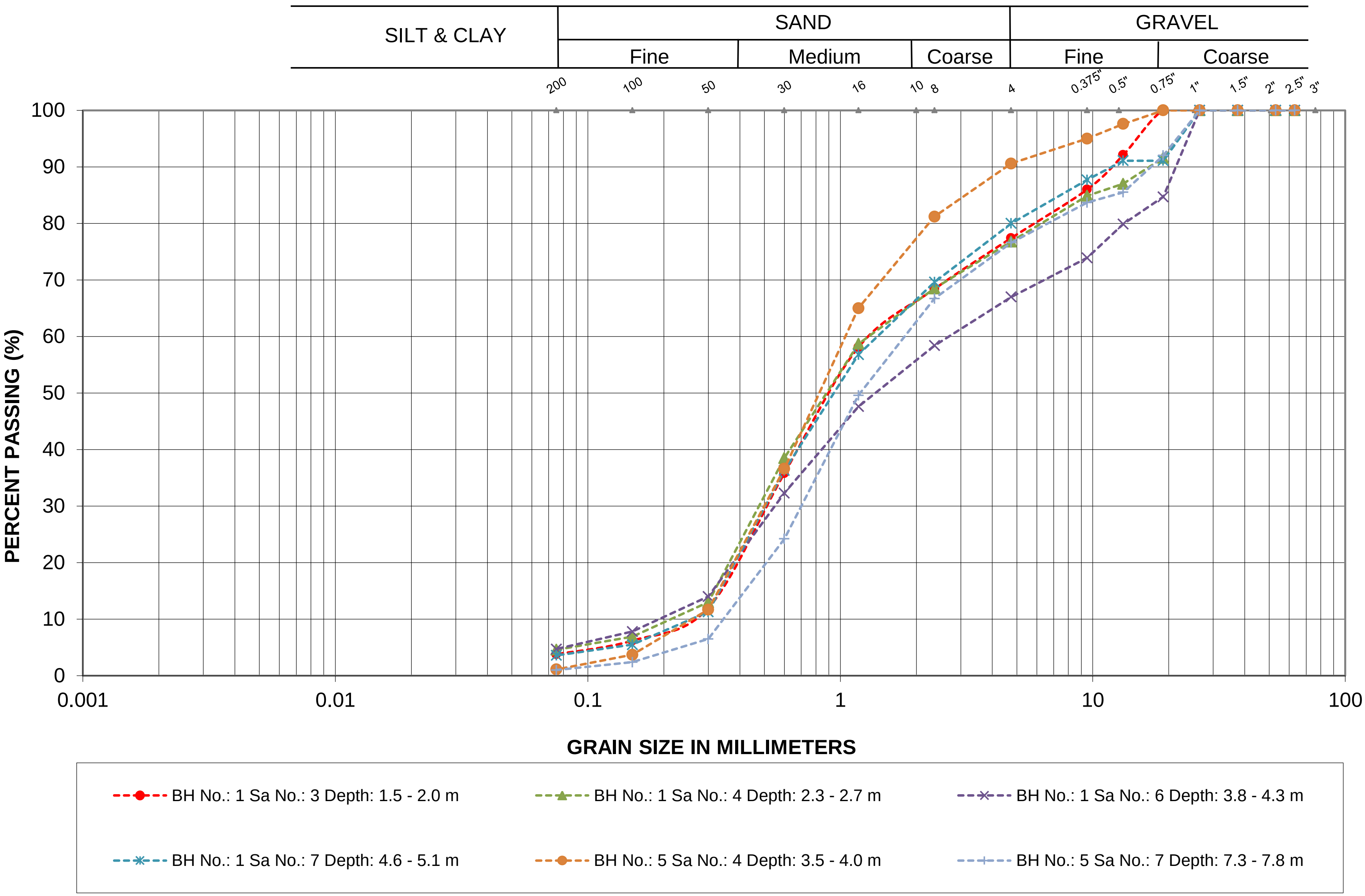
GRAIN SIZE ANALYSIS



G.W.P.: 364-00-00
LOCATION: Hwy 65, Whiskey Jack Creek

SAND

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					2.3				N/A			
	2	0.8					3.8				31			
	3	1.5	23	73	4		3.4				17			
	4	2.3	23	72	5		14.2				13			
	5	3.1					10.1				18			
	6	3.8	33	62	5		14.2				16			
	7	4.6	20	76	4		20.8				9			
	8	6.1					20.6				5			
	9	7.6					11.3				61			
2	1	0.0	9	85	6		3.6				N/A			
	2	0.8					3.3				54			
	3	1.5					3.0				39			
	4	2.3					13.2				11			
	5	3.1					18.3				8			
	6	3.8					18.6				4			
	7	4.6					23.2				4			
	8	6.1					15.6				8			
	9	7.6					22.7				12			
	10	9.1					16.6				6			
	11	10.7					16.5				8/150mm			
3	1	1.2					19.4				32			
	2	2									50/25mm			
	3	2.0												Rec= 100% RQD= 25%
	4	3.5												Rec= 100% RQD= 70%
	5	4.7												Rec= 100% RQD= 73%

Reference No.: 13/05/13073-F3
Date: May 2014

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 (%)				
4	1	0.9	47	52	1		18.3				8			
	2	2.0					34.0				2			
	3	2.7					381.0							
	4	3.1												Rec= 100% RQD= 78%
	5	4.4												Rec= 100% RQD= 97%
5	1	0.9					128.0				3			
	2	2.0	69	30	1		12.6				15			
	3	2.7					15.4				14			
	4	3.5	9	90	1		24.7				16			
	5	4.3					23.7				11			
	6	5.8					20.9				13			
	7	7.3	23	76	1		17.9				15			
6	1	1.2					39.68				4			
	2	2					4.94				10			
	3	2.74					18.74				10			
	4	3.51					15.64				9			
	5	4.27					8.3				6			
	6	5.8					13.28				10			
	7	7.32					9.23				17			

Project: Hwy 66, Whiskey Jack Creek
Location: Station 14+791

Figure No. L-4

Appendix 4 Photo Essay

Enclosure No. 8: Photo Essay

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Existing Embankment, North Side – Looking West	Photo: 1

Existing Embankment, South Side – Looking East	Photo: 2

Project: Hwy 66 – Stations 14+791, Twp of Cairo	Photos Provided By: LVM Date: October 2013

Culvert Inlet – Looking South East	Photo: 3
	
Culvert Outlet, Center and East Culverts – Looking South	Photo: 4
	
Project: Hwy 66 – Stations 14+791, Twp of Cairo	Photos Provided By: LVM Date: July 2013

Appendix 5 Design Data

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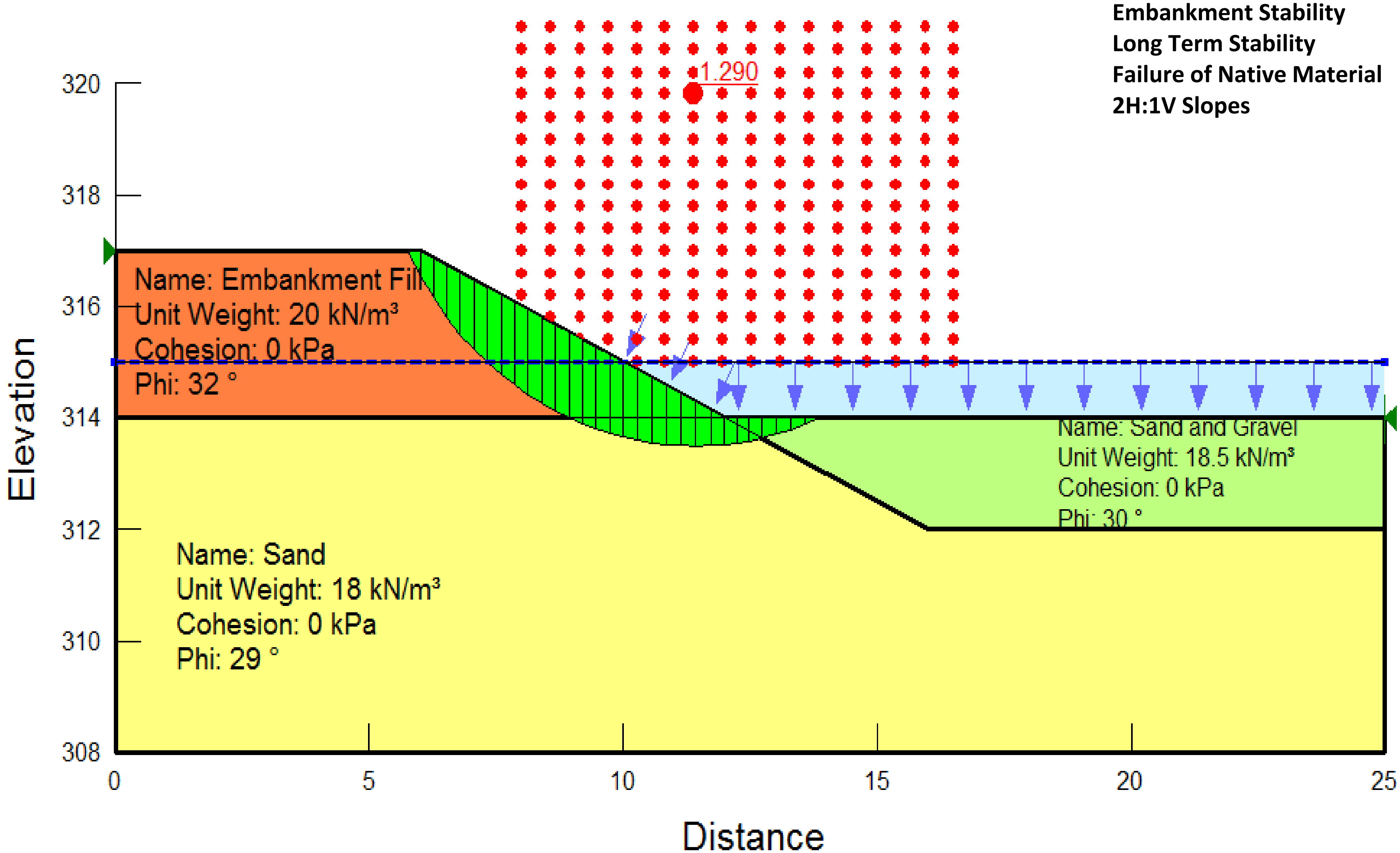
Stability Analysis
Embankment Stability
Long Term Stability
Failure of Native Material
2H:1V Slopes



Stability Analysis
Station 14+791
TWP of Cairo

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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.	$ 650/m^2
Pre-cast concrete panels	3 – 10	-Durable -Assists in minimizing seepage	-Limited depths -Can be damaged during installation -Limited by soil conditions (i.e. obstructions)	Not considered due to higher cost.	
Soldier piles	5 – 25	-Easy installation -Readily available -Adaptable to various ground conditions	-Pre-drilling may be required -Possible ground loss	Not considered due to higher cost	
Tangent/ Secant/ Staggered Drilled Piles	10 – 18	-Readily available -Adaptable to various ground conditions	-Possible ground loss and/or seepage -Poor alignment tolerance	Not Considered due to higher costs	
Concrete Diaphragm	10 – 30	-High Strength -Durable -Can be permanent	-High cost -Requires specialized equipment/control	Not Considered due to higher costs	
Micropiles with reinforced shotcrete face		-Can be installed in various ground conditions -High strength -Good tolerance	-High Cost -Requires specialized equipment	Not Considered due to higher costs	

REF.: 13073-F3

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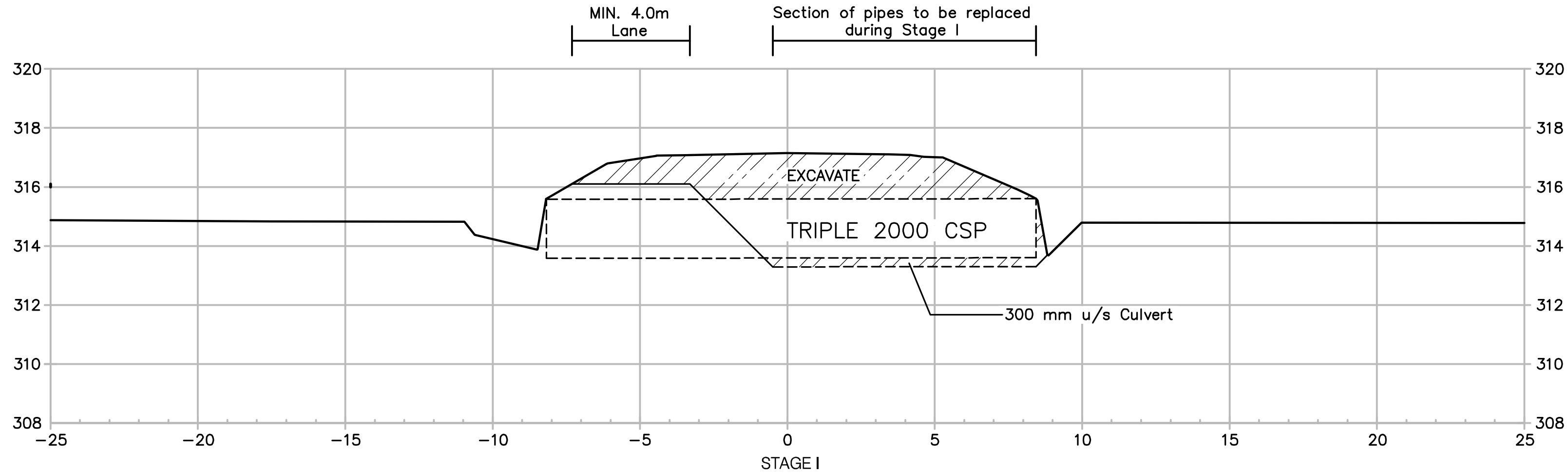

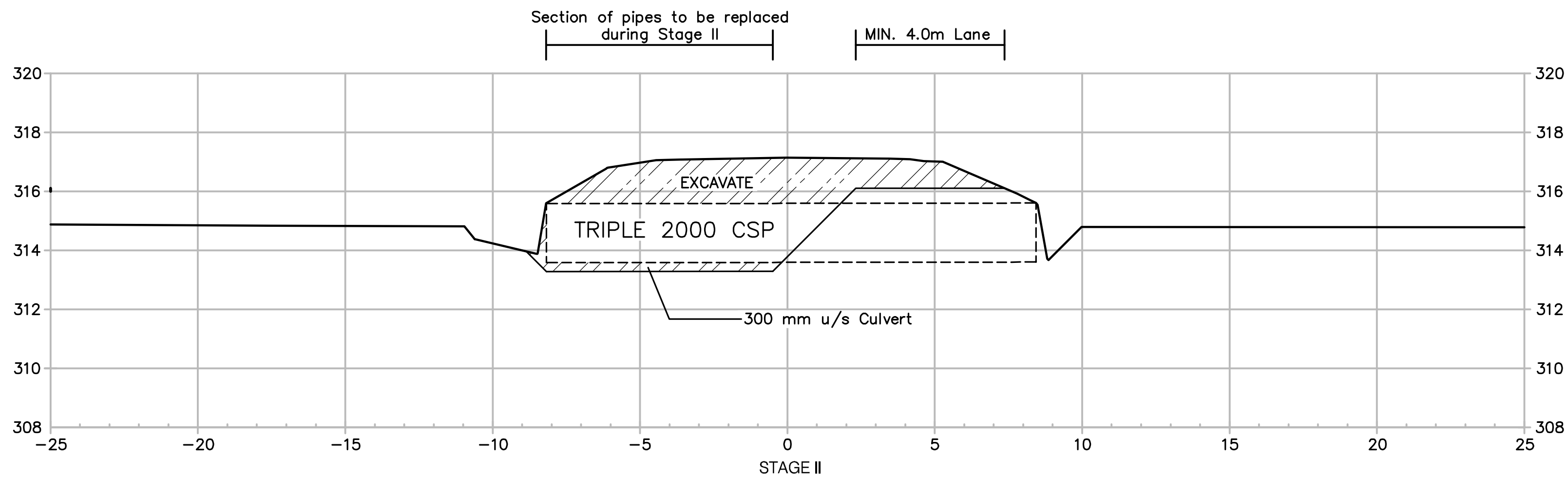

METRIC

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

2.5m 0 5m

HWY 66 - Station 14+791, Township of Cairo - Whiskey Jack Creek Culvert
Conceptual Staging

FIGURE SK-3

REF.: 13073-F3

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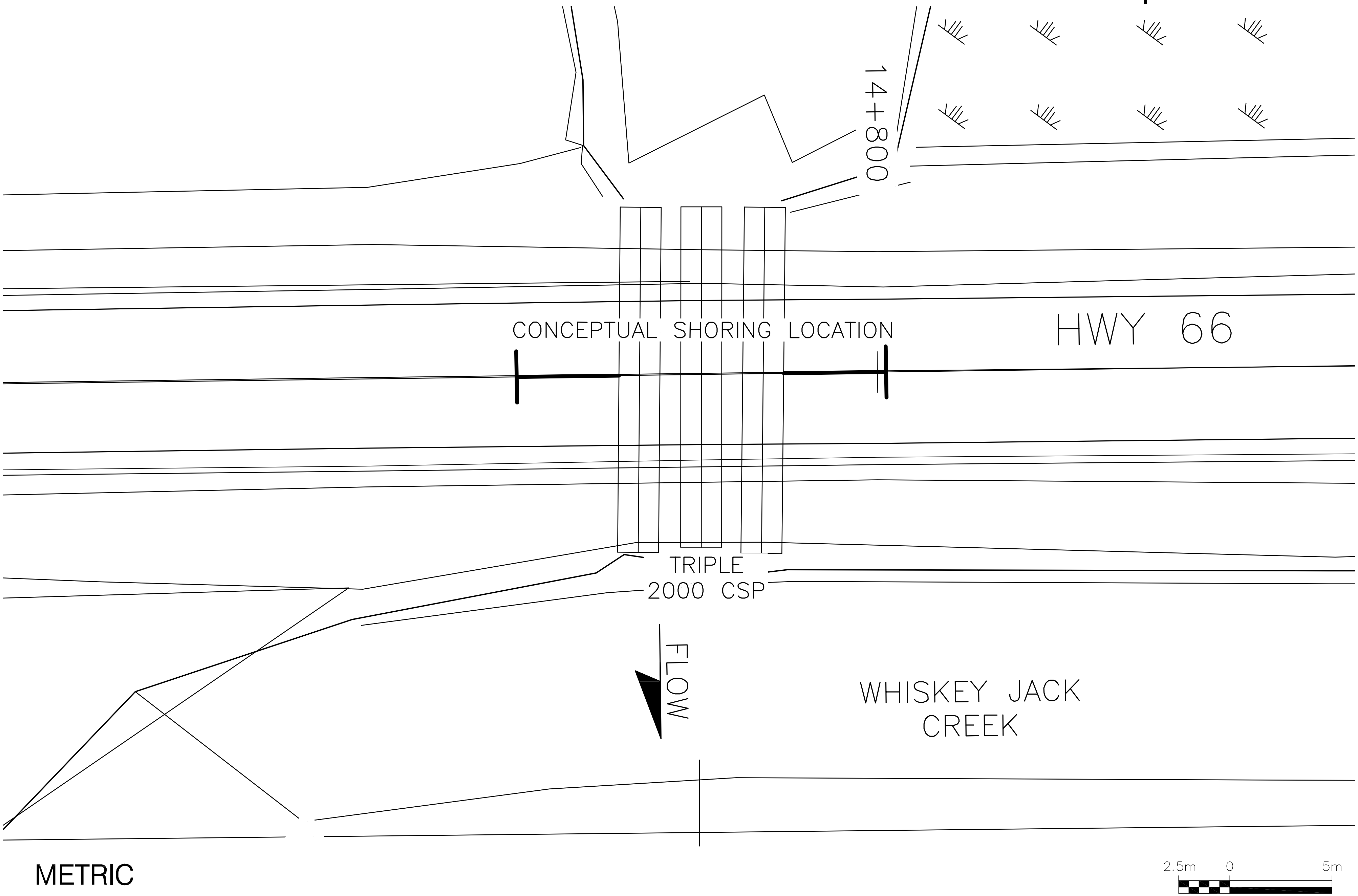


METRIC

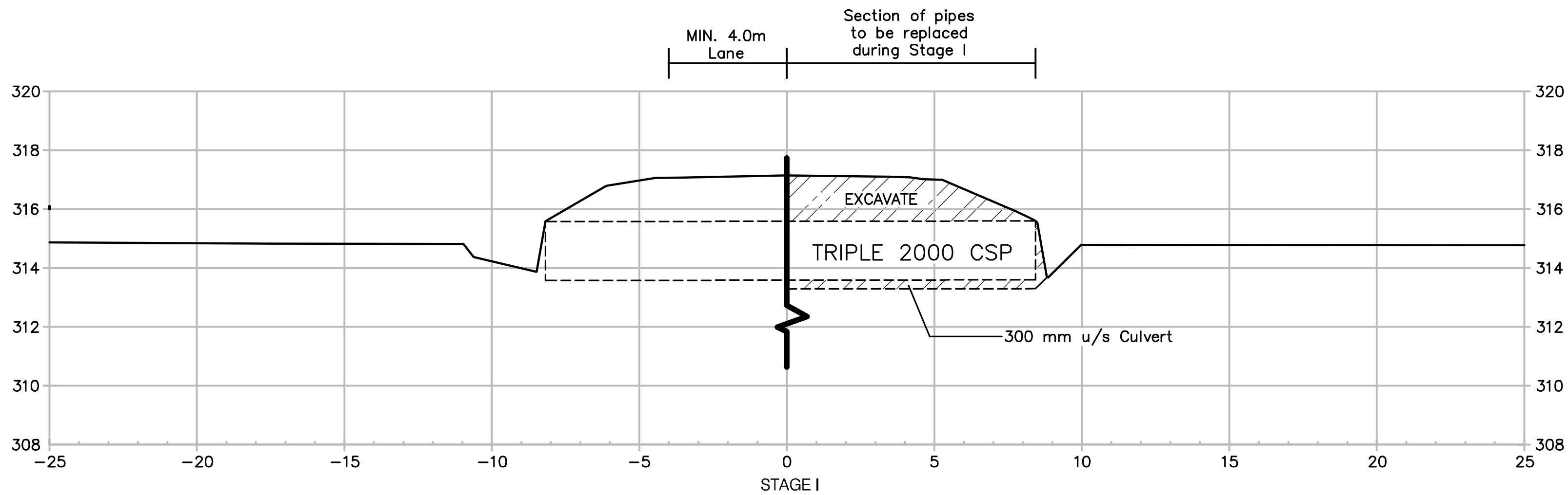
Dimensions are in meters and/or millimeters unless otherwise shown. Stations are in kilometers + meters.

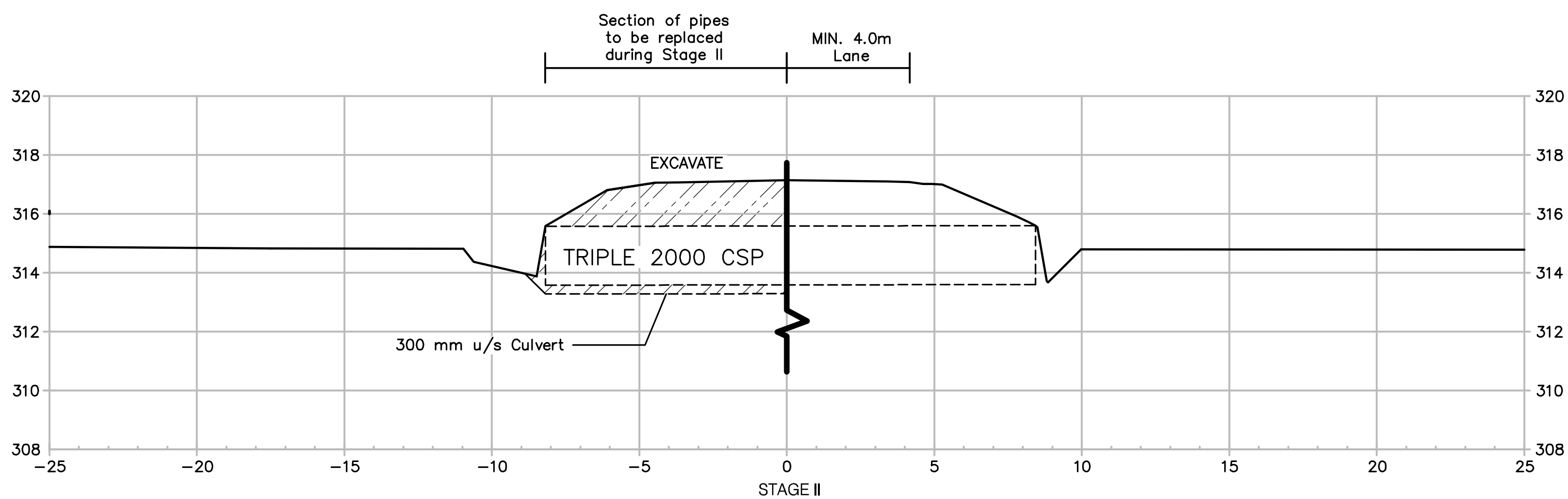
HWY 66 - Station 14+791, Township of Cairo - Whiskey Jack Creek Culvert
Conceptual Shoring Plan

FIGURE SK-4

REF.: 13073-F3

LVM | MERLEX





METRIC

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

2.5m 0 5m

HWY 66 - Station 14+791, Township of Cairo - Whiskey Jack Creek Culvert
Conceptual Shoring Section

FIGURE SK-5