Englobe
Soils Materials Environment

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
Highway 60
Station 11+698 - Twp. of Chaffey
GWP 5005-05-00

FINAL FOUNDATION INVESTIGATION AND DESIGN REPORT

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Final Foundation Investigation and Design Report

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1 INTRODUCTION

EnGlobe Corp. (Englobe), formerly LVM-Merlex, a Division of Englobe Corp., 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 centreline culvert site. The site is located at Station 11+698 in the Township of Chaffey on Highway 60, approximately 0.8 km west of King William Street.

The foundation investigation location was specified by the MTO in the Terms of Reference for Change Order No. 3 under Agreement No. 5013-E-0032 – GWP 5005-05-00. The terms of reference for the scope of work are outlined in Englobe's Proposal 14/04/14083 Rev 2, dated August 14, 2015. The purpose of this investigation was to determine the subsurface conditions in the area of the existing culvert for the contract preparation of the Detailed Design package. Englobe investigated the foundation area by the drilling of boreholes, carrying out in-situ tests, and performing geotechnical laboratory testing on select samples.

2 SITE DESCRIPTION

A Corrugated Steel Pipe (CSP) culvert is located on Highway 60 at Station 11+698 in the Township of Chaffey. The topography in the area of this site is generally rolling. The existing highway embankment currently supports three undivided lanes of highway (two lanes with an eastbound passing lane), running in a west-east direction. The existing highway at the culvert location is constructed on a granular embankment, containing mixed rock pieces, that is approximately 6.3 m in height, with centreline Elevation of 329.6 m at the culvert location. The existing embankment slopes in the area of the culvert have been generally established at angles of approximately 1.9H:1V to 2.0H:1V. The culvert at this location is an 800 mm diameter Corrugated Steel Pipe (CSP) culvert, approximately 37.4 m in length. Flow through the culvert is from the south to the north (right to left). To the south of the embankment at the culvert location, a municipal road (Shay Road) runs parallel to the highway.

It is understood that there is no other infrastructure (below or above grade services) at the culvert location.

2.1 SITE PHYSIOGRAPHY AND SURFICIAL GEOLOGY

This project is located in the Geomorphic Sub-province known as the Muskoka Ridges and Pockets. The topography on this section of Highway 60 is generally rolling. Layers of earth overlie bedrock. Within the project area, native overburden consists primarily of sands overlying bedrock. Organic materials were also observed.

Bedrock in the area, based on Ontario Geologic Survey (OGS) Map MRD-126, consists of migmatitic rocks and gneisses of undetermined protolith.

3 INVESTIGATION PROCEDURES

The fieldwork for this investigation was carried out during the period of November 30th to December 18th, 2015, during which time five (5) sampled boreholes were advanced. Three (3) boreholes were advanced through the embankment. A single borehole was also advanced at both inlet (south) and outlet (north) ends of the culvert.

The field investigation was carried out using a truck and bombardier mounted CME drilling rigs equipped with hollow stem augers, standard augers, casing equipment, coring equipment 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. The number of blows per 300 mm penetration was recorded as the “N” value. If refusal to further advance of the augers was encountered within the proposed depth of borehole, the boring was advanced through diamond drilling, using H size coring equipment. All samples taken during this investigation were stored in labeled containers for transport to our North Bay laboratory for visual examination and select laboratory testing.

During the field investigation, three boreholes (Borehole No. 1, 2, and 3) were advanced through the existing embankment. Fragmented rock was encountered within the embankment at each of these boreholes. At Borehole No. 1, hollow stem augers were able to advance past the fragmented rock within the embankment. However, at Borehole Nos. 2 and 3, coring equipment was employed to penetrate through the fragmented rock. At these boreholes, hollow stem auger and split spoon sampling was limited to a 1.5 m depth in the embankment fills containing the fragmented rock, below which H casing was used to advance deeper. Sampling was undertaken by advancing the HQ core barrel to the sampling depth at which split spoon sampling was undertaken from the bottom of the HQ core barrel. Following sampling, the HQ core barrel was then advanced to the depth of the next sample. The rock (gravel, cobble, and boulder sizes) encountered during the coring was retrieved to provide estimates of the concentration of rock within the embankment fill. The percent recovery of the split spoon samples and retrieved rock has been provided on Tables Nos. R-1 and R-2, Appendix 2.

At Boreholes Nos. 1, 4, and 5, when auger refusal was encountered, NQ size diamond coring equipment was used to determine the nature of refusal (bedrock). At Borehole Nos. 2 and 3, HQ size diamond coring equipment was used to penetrate the embankment fills and bedrock.

Groundwater conditions in the open boreholes were observed during the advancement of and immediately following completion of the individual boreholes. A 25 mm diameter piezometer was installed in Borehole Nos. 1 and 5 prior to backfilling to allow for further monitoring of the shallow groundwater levels. 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 in accordance with requirements of 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.

The fieldwork for this investigation was under the full time direction of a senior member of the Englobe engineering staff (Jame Lavigne) 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 at the North Bay Englobe laboratory. Laboratory testing of select samples carried out at the North Bay Englobe laboratory 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). Unconfined compressive strength tests (UTC) were carried out by Golder Associates Limited on select rock samples recovered at Borehole Nos. 2 and 3. A summary of results presented on the laboratory sheets in Appendix 3 (Figures Nos. L-1 to L-8 and Table No. L-9).

The location of the individual boreholes was determined in the field using highway chainage (established by exp Services) and offsets relative to highway centreline. The MTO co-ordinates, northing and easting, were then established for the boring locations, using coordinates from MTM Zone 10, NAD 83 CSRS. The borehole elevations are based on coordinating the borehole locations with the highway survey carried out by exp. Services. Elevations contained in this report are referenced to geodetic datum.

4 SUBSURFACE CONDITIONS

Details of the subsurface conditions revealed by the investigation program are presented on the enclosed Records of Borehole Sheets (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 11+698, TWP OF CHAFFEY

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, five (5) sampled boreholes were put down at this site, with Borehole Nos. 1 to 3 advanced through the embankment, Borehole No. 4 advanced at the culvert outlet, and Borehole No. 5 advanced at the culvert inlet. At the time of the subsurface investigation, the ground surface elevations at Boreholes Nos. 1 to 5 were recorded at Elevations 329.6, 329.6, 329.4, 323.7, and 324.3 m, respectively.

4.1.1 Pavement Structure

Borehole Nos. 1, 2, and 3 were advanced through the embankment where a pavement structure consisting of 90 to 140 mm asphalt concrete was penetrated underlain by a base/subbase layer of crushed gravel approximately 260 to 360 mm thick.

4.1.2 Granular Fill

Underlying the pavement structure at Borehole Nos. 1, 2, and 3, a layer of granular fill consisting of brown sand, some gravel to gravelly, trace to some silt was penetrated. The natural moisture content measured on retrieved samples of this deposit was generally in the order of 2 to 7%. Gradation analyses were carried out on four (4) samples of this deposit, the results of which indicated 14 to 53% gravel size particles, 39 to 75% sand size particles, and 8 to 14% silt and clay size particles (Figure No. L-1, Appendix 3). This deposit was encountered to depths of 1.4, 0.9, and 1.1 m below grade at Borehole Nos. 1, 2, and 3, respectively (Elevations 328.2, 328.7, and 328.3 m, respectively).

4.1.3 Mixed Fill

Underlying the granular fill at Borehole Nos. 1, 2, and 3, a layer of mixed fill consisting of brown sandy gravel, trace to some silt was penetrated. Cobble to boulder sized rock pieces were encountered in the mixed fill layer.

As noted in Section 3, HQ coring was undertaken through the mixed embankment fills. Core recovery examination indicated that the approximate percentage of rock pieces within the mixed fill at Borehole Nos. 2 and 3 ranged from 4 to 76%. The percent recovery of rock pieces is included in Table No. R-2 (Appendix 2). The recovery of split spoon samples in the mixed fills was also recorded and ranged from 0 to 17%, see Table R-1, Appendix 2. Photos of the rock returned from the coring through the embankment are enclosed (Photo Nos. 1 and 2 (Appendix 2)). In general, the rock pieces returned were gravel to cobble size (<200 mm diameter), however occasional boulder sized rock pieces (between 200 and 400 mm diameter) were cored through at Borehole Nos. 2 and 3. One unconfined compressive strength test (UCT) was carried out on an intact rock sample recovered at Borehole 3, at a depth of 2.4 m, and indicated an unconfined compressive strength of 130.8 MPa (Appendix 3).

The natural moisture content measured on retrieved samples (i.e. sand and gravel portion) of the mixed fill layer deposit was generally in the order of 1 to 6%. Gradation analyses were carried out on two (2) samples of this deposit, the results of which indicated 54 to 75% gravel size particles, 19 to 37% sand size particles, and 6 to 9% silt and clay size particles (Figure No.L-2, Appendix 3). Based on SPT ‘N’ values of 10 to 28 blows per 300 mm penetration and 10 blows per 76 mm penetration, the compactness of this deposit was described as compact to very dense, and generally compact. This deposit was encountered to depths of 4.4, 4.6, and 4.3 m below grade at Borehole Nos. 1, 2, and 3, respectively (Elevations 325.2, 325.0, and 325.1 m, respectively).

4.1.4 Sand Fill

Underlying the mixed embankment fill at Borehole Nos. 1, 2, and 3, a layer of sand fill consisting of brown sand, trace gravel, trace to some silt, trace organics was penetrated. The natural moisture content measured on retrieved samples of this deposit was generally in the order of 20 to 25%. A gradation analysis was carried out on one (1) sample of this deposit, the results of which indicated 5% gravel size particles, 77% sand size particles, and 18% silt and clay size particles (Figure No. L-3, Appendix 3). Based on SPT 'N' values of 1 to 15 blows per 300 mm penetration, the relative density of this deposit was described as very loose to compact. This deposit was encountered to a depth of 6.1 m below grade at Borehole Nos. 1, 2, and 3 (Elevations 323.5, 323.5, and 323.3 m, respectively).

4.1.5 Organic Soils

At ground surface at Borehole Nos. 4 and 5, a layer of fine fibrous organics soil was penetrated. The natural moisture content of a sample of this organic layer was about 104%. This organic soil layer was encountered to approximate depths of 0.1 and 0.3 m below ground surface at Borehole Nos. 4 and 5, respectively (Elevations 323.6 and 324.0 m, respectively).

4.1.6 Sands and Silts to Sands

Underlying the sand fill at Borehole No. 3, and underlying the surficial organics at Borehole No. 4, a deposit of grey sand and silt to sand with to some silt, trace gravel, trace clay was penetrated. The natural moisture content measured on samples of this deposit ranged from 17 to 25%. Gradation (hydrometer) analyses were carried out on two (2) samples of this deposit, the results of which indicated 1 to 6% gravel size particles, 48 to 69% sand size particles, 23 to 42% silt size particles, and 2 to 9% and clay size particles (Figure No. L-4, Appendix 3). Based on SPT 'N' values of 3 to 37 blows per 300 mm penetration, this deposit was described as very loose to dense, generally compact. This deposit was encountered to depths of 7.3 and 2.1 m below grade at Borehole Nos. 3 and 4, respectively (Elevations 322.1 and 321.6 m, respectively).

4.1.7 Silts and Clayey Silts

Underlying the sand fills at Borehole Nos. 1 and 2, underlying the sands at Borehole No. 3, and underlying the surficial organics at Borehole No. 5, deposit of silt, some clay to clayey, trace gravel, trace to with sand, was penetrated. The natural moisture content measured on samples of this deposit ranged from 16 to 28%. Gradation (hydrometer) analyses were carried out on six (6) samples of this deposit, the results of which indicated 0 to 3% gravel size particles, 5 to 22% sand size particles, 56 to 83% silt size particles, and 11 to 25% clay size particles (Figure No. L-5, Appendix 3). Atterberg Limit Testing was carried out three (3) samples of this deposit from

Borehole nos. 2 to 5, the results of which indicated Plastic Limits of 15 to 19% and Liquid Limits of 17 to 22% (Figure No. L-7, Appendix 3). Atterberg Limit Testing was carried out on two (2) samples obtained from Borehole No. 1, the results of which indicated Plastic Limit of 17 to 18% and Liquid Limit of 23 to 25% (Figure No. L-7, Appendix 3).

Based on the results of the Atterberg Limits testing, this deposit was described as inorganic silts of slight plasticity (ML), however, samples of this deposit obtained from Borehole No. 1 indicated a slightly increased plasticity (i.e. clayey silts of low plasticity (CL-ML)).

Based on SPT ‘N’ values of 12 to 58 blows per 300 mm penetration, this deposit was described as compact to very dense. This deposit was encountered to depths of 9.1, 9.1, 8.4, and 2.9 m below ground surface at Borehole Nos. 1, 2, 3, and 5, respectively (Elevations 320.5, 320.5, 321.0, and 321.4 m).

4.1.8 Till

Underlying the silts and clayey silts at Borehole Nos. 1, 2, 3, and 5, a deposit of till described as silty sand, trace gravel to sand and gravel, some silt, was penetrated. The natural moisture content measured on samples of this deposit was in the order of 3 to 12%. Gradation (sieve) analyses were carried out on two (2) samples of this deposit, the results of which indicated 9 to 39% gravel size particles, 43 to 58% sand size particles, and 18 to 33% silt and clay size particles (Figure No. L-6, Appendix 3). Based on a SPT ‘N’ value of 19 to 90 blows per 300 mm penetration, this deposit was described as compact to very dense. This deposit was encountered to depths of 11.5, 11.7, 12.1, and 3.8 m below ground surface at Borehole Nos. 1, 2, 3, and 5, respectively (Elevations 318.1, 317.9, 317.3 and 320.5 m).

4.1.9 Bedrock

Underlying the sands at Borehole No. 4 and underlying the till at Borehole Nos. 1, 2, 3, and 5, bedrock was proven by diamond core drilling. The bedrock was described as black gneiss bedrock. Based on RQD values of 0 to 96%, the bedrock was described as very poor to excellent quality, generally good quality. Core photos are included in Appendix 2.

One unconfined compressive strength test (UCT) was carried out on an intact rock sample recovered at Borehole 2, at a depth of 12.4 m, and indicated an unconfined compressive strength of 60.7 MPa (see Appendix 3).

Sampling in the bedrock was terminated at depths of 14.6, 15.0, 12.5, 5.2, and 6.9 m below grade at Borehole Nos. 1 to 5, respectively (Elevations 315.0, 314.6, 316.9, 318.5, and 317.4 m, respectively). It should be noted that, when encountered, the underlying bedrock surfaces in this area can be very erratic in nature, varying substantially in Elevation over short horizontal distances.

4.2 GROUNDWATER DATA

At the time of this investigation period (November 30th to December 18th, 2015), a surface water level at Elevation 324.4 m was observed at the culvert inlet.

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 piezometer was installed in Borehole Nos. 1 and 5 to obtain post borehole completion water levels. These levels are recorded on the individual Record of Borehole Log Sheets (Appendix 2).

The water levels were measured at Elevations 324.6, 323.1, and 324.3 m at Borehole Nos. 1, 4, and 5, respectively.

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

5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

A foundation investigation was carried for the proposed replacement of a CSP culvert as identified by the MTO.

The existing culvert, located at Station 11+698, in the Township of Chaffey, is a 800 mm diameter CSP culvert approximately 37.4 m long. The existing culvert invert, at centreline, is estimated to be at a depth of approximately 6.3 m (Elevation 323.3 m). The culvert invert at the inlet and outlet are measured at Elevations 323.6 and 322.9 m, respectively, based on the survey produced by exp Services. The existing highway embankment currently supports two undivided lanes of highway plus an eastbound passing lane, running in a west-east direction. Flow through the culvert is from the right to the left (south to north). Based on data from this foundation investigation, the embankment supporting the existing pavement structure at this site has been constructed using a granular pavement structure overlying granular embankment fills mixed with rock pieces (gravel to boulder size) overlying sand fill. The native material underlying the embankment fill generally consisted of compact to very dense sands overlying shallow bedrock.

It is understood that culvert replacement using trenchless technologies is preferred at this site. As such, the type of culvert used to replace the existing will likely be a pipe culvert (i.e. CSP). It is further understood that the proposed replacement culvert could have a diameter of up to 1.5 m to allow personnel to access the culvert.

5.2 FOUNDATION CONSIDERATIONS

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

Based on the characteristics of the native subgrade present below the culverts, the response of the existing embankment, and maintaining a founding elevation similar to that of the existing culvert, a factored bearing resistance at ULS of 250 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 125 kPa can be used for design, in consideration of 25 mm total settlement and 19 mm of differential settlement, depending on structure rigidity.

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 150 kPa, and a geotechnical reaction at SLS of 75 kPa would apply for design, in consideration of 25 mm total settlement and 19 mm of differential settlement, depending on structure rigidity, and taking into consideration the limited depth of overburden and smaller footing width (i.e. open culvert supported on footings 0.5 m in width and established at a depth of 1.5 m below creek bed, founded on the compact to very dense native soils).

5.3 CULVERT DESIGN, BEDDING, AND EMBEDMENT

The embankment consists of granular fills mixed with cobble/boulder sized rock pieces. The results of this investigation indicate that, below the culvert invert, the native soils were compact to very dense silts to very stiff clayey silts, underlain by compact to very dense tills. A review of the condition of the pavement surface, at the culvert locations, revealed some 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.

A precast concrete rigid frame box culvert can also be considered for culvert replacement at this site. Bedding for a rigid frame box culvert shall consist of Granular A with a thickness of 300 mm. The bedding under the middle third of the box unit base should be loosely placed and uncompacted to prevent overstressing the middle third (bottom span) as the box sides settle, in accordance with OPSS 422.07.07. The upper 75 mm portion of the Granular A bedding should be uncompacted throughout the length/width of the box and incorporated as the top levelling course. Alternatively, specifically if construction is carried out under wet conditions, a 19 mm clear stone bedding and levelling coarse should be used, which would aid in dewatering applications. During backfilling the embankment fill should be placed in a balanced manner on the outer sides of the box unit. The elevation difference of the backfill on either side of the box unit must be limited to a maximum of 400 mm. Backfilling and construction of pre-cast concrete box culverts shall be in accordance with OPSS 422. Cover material for concrete box culverts can consist of Granular A, placed to the dimensions as shown on MTOD-803.021.

The joints between precast box units should be covered with a strip of Non-Woven Class II Geotextile 600 mm in width, centered over the joint, covering the top of the culvert and extending down the sides of the culvert to prevent the infiltration of fines.

Apron (cut-off) walls, 1.2 m deep, must be added to the ends of the rigid frame box culvert in accordance with the MTO Concrete Culvert Design Manual.

The inlet and outlet stream bed shall be protected with a 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 head difference between the inlet and outlet, it is recommended that clay seals be used at this culvert location.

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 CONSIDERATIONS

The invert elevation of the existing culvert at centreline is at 323.3 m, with the top of the embankment at Elevation 329.6 m at the centreline of highway. The culvert inverts at the inlet and outlet are at Elevations 323.6 and 322.9 m, respectively. As such, the embankment at this location is approximately 6.3 m in height above the culvert invert at the centreline of highway. Considering the height of the embankment open cut excavations are not considered feasible unless local lowering of the grade is undertaken or a protection system (temporary vertical wall) is used.

In general, an open cut excavation can be considered if the platform is temporarily lowered by approximately 1.9 m. If this lowering cannot be accommodated then consideration can be given to a combination of lowering and widening or to constructing a temporary vertical wall for use as a protection system.

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 culvert to an Elevation of approximately 327.7 m.
- Limit traffic to a single lane on the left, with a minimum platform width of 6 m, under 24/7 traffic control.
- Open cut excavate, to the right, and install approximately 17.5 m of new culvert.
- Reconstruct the embankment on the right, with a minimum platform width of 6 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.

It should be noted that additional subsurface information will be required if widening beyond the existing embankment toe is required.

5.4.2 Temporary Protection System

As noted above, consideration could be given to constructing a vertical wall, along centreline, for use as a temporary protection system.

The installation of a protection system for use in the culvert replacement operation will require penetration through approximately 6.3 m of granular fills mixed with rock fill at the centreline of highway. The embankment fill is generally underlain by compact to very dense silts and very stiff clayey silts, underlain by very dense tills. As noted, the mixed rock fill was encountered in the embankment. Considering the presence of mixed rock fill in the embankment, advancing a temporary retaining system (i.e. driven sheet piles) through the mixed rock fill may be problematic. A notice to Contractor indicating the presence of the cobble/boulder sized rock fragments in the embankment has been included in Appendix 5. Several approaches to constructing a protection system are described below. See Table A, Appendix 5, for advantages and disadvantages for the different type of protection system considered for this site. Conceptual shoring locations are illustrated on Figure No. SK-4, Appendix 5.

One method to construct a protection system would be to penetrate the mixed rock fill in the embankment with H piles (soldier piles) extending into the underlying native soils and/or into bedrock and install lagging. Pre-drilling may likely be required to advance the H piles through the rock fill and into the underlying native soils. 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 Section 26.12.4.1 of the Canadian Foundation Manual (4th Edition):

$R = \sigma'_z * A_s * L_s * \alpha_g$ 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.

Alternatively, a caisson wall or 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 to dense silts and very stiff clayey silt or probably into bedrock, depending upon the size and capacity of the micropiles. Over the actual culvert location, the piles would be carried down to top of culvert grade followed by bracing, with a suitably sized waler and anchorage system, tied into the full depth piling at the culvert sides, in order to provide support at the top of the piling over the culvert barrel. Depending on the section properties of the retaining structure, walers and bracing struts or ground anchor support systems will probably be required. As the excavation progresses downward in 1 to 1.2 m lifts, a reinforced shotcrete, tied into the piles, is applied. Once one half of the 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. However these shoring system are generally more costly, as such are not recommended at this site.

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 locations are illustrated on Figure No. SK-4, Appendix 5.

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

Considering the cohesionless nature of the embankment fills (granular pavement structure overlying a granular fill and rock fill mix) a rectangular apparent pressure distribution over the height of the cut would be appropriate for design of the temporary shoring. The width of the apparent rectangular pressure distribution, over the height of excavation, can be considered equal to $0.65*K_a*\gamma*H$, where:

K_a = active earth pressure,

γ = unit weight, and

H = height of wall above the base of excavation.

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

5.4.3 Trenchless/Tunnelling Techniques

The boreholes through the embankment indicate that cobble to boulder sized rock pieces are present within the existing embankment at this location. The embankment is approximately 6.3 m in height at the centreline of highway. As such, a trenchless approach to culvert replacement would eliminate the need for open cuts, roadway protection systems, and associated traffic delays. Several trenchless technologies are available, as outlined in the following table. However, the cobble/boulder size rock encountered in the embankment may limit the type of trenchless method that can be used at this site. While it appears that the existing culvert has been established within the sand fill deposit (i.e. below the mixed fills with cobble and boulder), the horizontal extent of the sand fill is not known. As such, considering the size of the proposed replacement culvert, the Contractor must be prepared to advance through cobble and boulder size obstructions within the embankment.

The following table contains the advantages and disadvantages of the different trenchless techniques.

METHOD	ADVANTAGES	DISADVANTAGES
Horizontal Directional Drilling	• Can be used in most ground condition • Generally does **not** require staging pits therefore minimal ground water control required • Alignment can be adjusted to avoid obstructions	• Site grades may require longer bore or staging pits • Larger drilling equipment may be required • Requires drilling fluid to maintain the bore, which could result in heave • Size of pipe limited to 140 to 1200 mm
Symmetrix Drilling	• Can be advanced through bedrock, and most overburden types • has been used to advance casings through many rock fills in Scandinavian countries	• Size limited to 140 to 1220 mm • May require staging pits for horizontal drilling
Jack and Bore	• Good contractor availability • Good for shorter tunnel length (<100 m) • Good gradient control	• Requires entrance and exit pits/shafts • Groundwater control is required for the bore and shafts • Elevated potential for ground subsidence • Boring diameter 1 m plus required to allow removal occasional cobbles/boulders • Diameter range generally 200 to 1500 mm • Not suited to rock fills or high concentrations of large obstructions
Pipe Ramming	• Minimal groundwater control required along the installation route (unless required to remove obstruction/old pipe) • Can penetrate soils containing cobbles/boulders if obstruction less than casing diameter. • Has been used successfully in the USA to penetrate a railway rock fill embankment	• Installation problems can occur in soft soils with cobble/boulders • Requires staging pits/shafts • Groundwater control is required for staging pits • Possible ground subsidence in very loose soils • Size of pipe is generally limited to less than 2.0 m diameter, although Contractors are developing methods to increase up to 3.0 m plus

To date, there are no known projects in Ontario where trenchless methods have been used to install casing through rock fills. However, the Symmetrix System, as described above, is a proven technology and has been used recently in Ontario and for over 8 years in Scandinavian countries for advancing horizontal holes up to 1200 mm diameter through rock fill, and as such could be considered for use at this site.

Pipe Ramming could also be considered, for advancing a heavily reinforced casing through fills including rock fills. However, to Pipe Ram, the casing must be large enough to allow hand mining operations to address large pieces of rock that could not be swallowed into the advancing casing. Generally, a minimum 1.2 m diameter is required to have sufficient room to hand mine rock pieces.

Jack and Bore is a common method of advancing a culvert using trenchless methods. However, considering the cobble and boulder size obstructions and requirements for dewatering of the loose sand fills along the alignment, Jack and Bore is not considered to be a suitable method for culvert installation at this site. As such, Jack and Bore will not be discussed further.

The following is a brief discussion of the Symmetrix and Pipe Ramming methods.

5.4.3.1 *Symmetrix*

The Symmetrix system has been used in Ontario for advancing vertical holes, some 1 m diameter, through solid rock and rock fills. However, to date, it has not been used in a horizontal direction. An advantage of the Symmetrix system is that it can accommodate uneven bit pressures, which frequently develop when advancing through materials containing soils and rock. The Symmetrix system has been proven, outside Canada, for casings up to 1200 mm diameter in granite type rock fills and therefore warrants consideration for further testing in Ontario.

5.4.3.2 *Pipe Ramming*

The other trenchless technology that has been considered for advancing a casing through an embankment containing cobble/boulder size rock pieces would be to employ pipe ramming techniques. Pipe ramming has been carried out through granular materials containing cobbles and boulders for projects in Ontario. If undertaken, the size of the casing would have to be large larger than the largest anticipated size of rock fill and large enough to allow a person to enter to hand mine obstruction (i.e. pieces of rock fill). During the foundation investigation, the largest piece of rock fill encountered in the embankment boreholes was in the order of 395 mm, however, larger pieces of rock (slope protection), up to some 1 m, were observed on the embankment slopes. As such, it is recommended that pipe ramming use a larger diameter casing (i.e. 1.2 to 1.5 m diameter).

In addition, staging (driving/receiving) pits are required to allow pipe ramming. Considering the proximity of Shay Road to the south of the highway embankment, the size of the staging pits would be limited. As such, the pipe would likely need to be advanced from the north side of the highway. Groundwater was encountered at Elevations 324.3 and 323.1 m in the boreholes put down at the inlet and outlet, respectively. Groundwater control will be required for the staging pits, see Section 5.4.

The high compressive strength of granitic rock would also require a robust, heavily reinforced casing shoe.

Based on the above, pipe ramming could be considered.

5.4.3.3 *Trenchless Technique Recommendations*

As noted above, the existing CSP culvert has a 760 m diameter. However, a culvert of up to 1.5 m diameter is being considered for culvert replacement. Two of the trenchless technologies that are able to penetrate an embankment with a high percentage of rock pieces of cobble to boulder size include Symmetrix drilling and pipe ramming. Both systems appear to be feasible at this site, however, neither has been previously used by the MTO. Considering the subsurface conditions and anticipated Contractor availability, Pipe Ramming would be the preferred trenchless construction method for consideration for replacing the culvert at this site.

5.5 LATERAL EARTH PRESSURES

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

PARAMETER	GRANULAR A	GRANULAR B TYPE I	EXISTING GRANULAR FILL	EXSISTING MIXED FILLL
Unit Weight (kN/m^3)	22.8	21.2	19.0	21.0
Angle of Internal Friction	35°	33°	32°	34°
Coefficient of Active Earth Pressure (Ka)	0.28	0.32	0.31	0.28
Coefficient of Passive Earth Pressure (Kp)	3.54	3.12	3.23	3.54
Coefficient of Earth Pressure at Rest (Ko)	0.44	0.48	0.47	0.44
PARAMETER	**EXISTING SAND FILL**	**NATIVE SANDS**	**NATIVE SILTS**	**NATIVE TILLS**
Unit Weight (kN/m^3)	19.0	19.0	18.5	19.0
Angle of Internal Friction	30°	32°	32°	34°
Coefficient of Active Earth Pressure (Ka)	0.33	0.31	0.31	0.28
Coefficient of Passive Earth Pressure (Kp)	3.00	3.23	3.23	3.54
Coefficient of Earth Pressure at Rest (Ko)	0.50	0.47	0.47	0.44

For rigid structures, such as a precast concrete culvert, deflection cannot occur, as such the “at-rest” condition (K_o) applies. For flexible structures, such as CSP/HDPE culverts, deflection can occur, as such the “active” condition (K_a) applies. The “passive” condition (K_p) applies when the wall is in compression (in a direction opposite to the wall loading).

5.6 EXCAVATION AND DEWATERING

As noted, culvert installation using pipe ramming will require excavation and dewatering for the staging pits.

All temporary 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 native material at the culvert ends, when wet, is considered a Type 4 soil as defined in the Occupational Health and Safety Act and Regulations for Construction Projects. Temporary open excavations below the groundwater table in fill and/or native materials may slough to angles as flat as 3H:1V or possibly shallower, dependent upon the Contractors' chosen method of controlling the groundwater.

Bedrock was not encountered at the borehole locations within the anticipated depth of trenchless boring and/or excavations for staging pits, therefore bedrock excavation and/or blasting operations are not anticipated.

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

At the time of investigation, the groundwater was encountered at Elevations of 323.1 to 324.6 m. As such, dewatering will be required for the staging pits required for 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 pipe ramming operations. The effectiveness of this method of groundwater control would be limited to conditions where the prevailing groundwater table is less than some 1 m above the final excavation depth. If the excavation must penetrate to a greater depth below the prevailing groundwater table a more effective groundwater control method, such as a vacuum well point system, or enclosed sheet pile excavation, should be considered by the contractor to maintain a stable excavation base.

Consideration should be given to installing the new culvert parallel to the existing culvert, either up or down chainage. This will allow stream flow/diversion through the existing culvert during installation.

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 construction operations cannot be stressed enough.

5.7 CONSTRUCTION CONCERNS

Considering the nature of the embankment fill through which the new culvert will be installed, namely granular mixed with rock pieces of cobble and boulder sizes, potential difficulties may arise during trenchless culvert installation. The Contractor must be prepared to advance the proposed culvert through the mixed fills including cobble and boulder sized rock fragments.

As noted in Section 5.6 the culvert subgrade must be adequately dewatered to maintain the bearing resistance of the foundation subgrade. The Contractor must also be prepared to deal with seasonal and yearly fluctuations of ground/surface water. A Notice to Contractor is included in Appendix 5.

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 Englobe 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 Englobe not be involved during the full construction phase, our liability is strictly limited to the factual information contained herein only.

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

Section 5 of this reported is intended for the use of the client and the design team only and is not intended to be included in the tender documents. Inclusion of the factual information (Sections 1 to 5 inclusive) in the tender documents is furnished merely for the general information of bidders and is not in any way warranted or guaranteed by or on behalf of the owner or the owner's consultants and its subconsultants or the consultants' or subconsultants' employees, and neither the owner nor its consultants or its employees shall be liable for any representations negligent or otherwise contained in the documents.

Appendix 1 Key Plan

Drawing No. 1	Key Plan

KEY PLAN **Drawing No. 1**

NOT TO SCALE

FOUNDATION INVESTIGATION
AND DESIGN REPORT
GWP 5005-05-00
Highway 60

Culvert 11+698, Twp of Chaffey

Reference No: 14/07/13083-F10 June 2016

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Appendix 2 Subsurface Data

Enclosure No. 1	List of Abbreviations and Symbols
Enclosure Nos. 2 to 6	Record of Borehole Sheet
Table Nos. R-1 and R-2:	Recovery Table
Enclosure No. 7:	Core Photos

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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
WH Sampler advanced by static weight of hammer and/or rods
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) *Bedrock:*

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

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

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

D - Laboratory Vane Test

¨ - Compression test in laboratory

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

e) *Soil Moisture:*

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

4. TERMINOLOGY

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

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

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

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

SAMPLE DESCRIPTION NOTES:

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

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

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

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

METRIC

RECORD OF BOREHOLE NO. 1

Englobe

REFERENCE 14/07/14083-F10 DATUM Geodetic LOCATION N 5022099.7 E 327285.7 - Chaffey Twp., Station 11+695 ORIGINATED BY ELS

PROJECT GWP 5005-05-00, Highway 60 BOREHOLE TYPE Truck Mounted CME 55 - Hollow Stem Augers COMPILED BY DM

CLIENT AECOM DATE (Started) 30 November 2015 DATE (Completed) 1 December 2015 TIME (Completed) CHECKED BY MAM

ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
329.6	Ground Surface						
0.0	140 mm Asphalt 360 mm Crushed Gravel GRANULAR FILL - sand, some to with gravel, trace silt brown, moist (very dense)	1	AS			o	
		2	AS			o	
		3	SS	74/254 mm		o	
328.2 1.4	MIXED FILL - sandy gravel, trace silt mixed with cobble/boulder sized rock pieces brown, moisture (compact)	4	SS	14		o	54 37 (9)
		5	SS	20			
		6	SS	23			
325.2 4.4	SAND FILL - sand, trace gravel, some silt brown, wet (very loose)	7	SS	2	water levels	o	5 77 (18)
323.5 6.1	existing culvert invert at approximately 323.4 m SILT and - clayey, trace to some sand brownish grey to grey, moist (compact)	8	SS	17		o (with limits)	0 19 56 25
		9	SS	22		o (with limits)	0 5 75 20
320.5 9.1	TILL - sand and gravel, some silt, trace clay wet	10	SS	22			

Continued Next Page

Plot headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; ELEVATION SCALE 329 328 327 326 325 324 323 322 321 320; STRATA PLOT

COMMENTS
Borehole advanced through full depth of embankment fill with hollow stem augers. NQ size coring equipment used to sample bedrock.

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) 1/12/15 7:55:00 AM	6.7	-
2) 2/12/15 3:10:00 PM	4.8	-
3) 3/12/15 3:35:00 PM	5	-

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

METRIC

RECORD OF BOREHOLE NO. 1

Englobe

REFERENCE 14/07/14083-F10 DATUM Geodetic LOCATION N 5022099.7 E 327285.7 - Chaffey Twp., Station 11+695 ORIGINATED BY ELS

PROJECT GWP 5005-05-00, Highway 60 BOREHOLE TYPE Truck Mounted CME 55 - Hollow Stem Augers COMPILED BY DM

CLIENT AECOM DATE (Started) 30 November 2015 DATE (Completed) 1 December 2015 TIME (Completed) CHECKED BY MAM

ELEV DEPTH	DESCRIPTION (see Enclosure No. 1) Continued from Previous Page	STRATA PLOT	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)
	(very dense) 100 mm to 200 mm cobble to boulder size rock pieces encountered from depth 9.6 m to 10.3 m		11	RC							
			12	SS	55		319		○		
318.1 / 11.5	Auger Refusal Start Rock Coring BEDROCK - black gneiss (poor to good quality)		13	RC	REC= 95% RQD= 45%		318				
			14	RC	REC= 100% RQD= 24%		317				
			15	RC	REC= 97% RQD= 79%		316				
315.0 / 14.6	End of Sampling End of Borehole						315				

MEL-GEO 14083 - BOREHOLE LOGS - F10.GPJ MEL-GEO.GDT 4/7/16

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ENCLOSURE NO.:3 (Pg. 1 of 2)

METRIC

RECORD OF BOREHOLE NO. 2

Englobe

REFERENCE	14/07/14083-F10	DATUM	Geodetic
LOCATION	N 5022103.3 E 327288.5 - Chaffey Twp., Station 11+695	ORIGINATED BY	ELS
PROJECT	GWP 5005-05-00, Highway 60	BOREHOLE TYPE	Truck Mounted CME 55 - Hollow Stem Augers and HQ Coring
COMPILED BY	DM	CLIENT	AECOM
DATE (Started)	2 December 2015	DATE (Completed)	2 December 2015
TIME (Completed)		CHECKED BY	MAM

ELEV DEPTH	SOIL PROFILE – DESCRIPTION (see Enclosure No. 1)	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
329.6	Ground Surface				
0.0	120 mm Asphalt 280 mm Crushed Gravel GRANULAR FILL - sand, some gravel to gravelly, trace to some silt brown, moist	1	AS		27 60 (13)
		2	AS		
328.7		3	SS	58/178 mm	39 47 (14)
0.9	MIXED FILL - sandy gravel, trace to some silt, cobble/boulder sized rock brown, moist (compact)	4	SS	13	
		5	SS	28	
		6	SS	29/150 mm	
	250 mm boulder encountered at depth of 3.5 m	7	SS	27	75 19 (6)
325.0 4.6	SAND FILL - sand, trace gravel, some silt, trace clay, trace grass rootlets brown, wet (compact)	8	SS	15	
323.5 6.1	existing culvert invert at approximately 323.3 m SILT - trace sand, some gravel, some clay seams of clay greyish brown, wet (compact/dense)	9	SS	38	
		10	SS	12	3 6 77 14
320.5 9.1	TILL - silty sand, trace gravel brown, wet (dense) 150 mm cobbble encountered at 9.6 m depth	11	SS	19	9 58 (33)

Continued Next Page

Plot headings: GROUND WATER CONDITIONS; ELEVATION SCALE (329, 328, 327, 326, 325, 324, 323, 322, 321, 320); 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
Advanced borehole with hollow stem augers to 1.5 m depth. Advanced HQ size casing beyond 1.5 m, retrieving split spoon samples before advancing casing.

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 14083 - BOREHOLE LOGS - F10.GPJ MEL-GEO.GDT 4/7/16

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

METRIC

RECORD OF BOREHOLE NO. 2

Englobe

REFERENCE 14/07/14083-F10 DATUM Geodetic LOCATION N 5022103.3 E 327288.5 - Chaffey Twp., Station 11+695 ORIGINATED BY ELS

PROJECT GWP 5005-05-00, Highway 60 BOREHOLE TYPE Truck Mounted CME 55 - Hollow Stem Augers and HQ Coring COMPILED BY DM

CLIENT AECOM DATE (Started) 2 December 2015 DATE (Completed) 2 December 2015 TIME (Completed) CHECKED BY MAM

ELEV DEPTH	SOIL PROFILE: DESCRIPTION (see Enclosure No. 1)	STRATA PLOT	SAMPLES: 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)
	Continued from Previous Page						319				
317.9			12	SS	45				○		
11.7	Auger Refusal Start Rock Coring BEDROCK - black gneiss (very poor to excellent quality)		13	RC	REC=100% RQD=72%		318				
			14	RC	REC=100% RQD=0%		317				
			15	RC	REC=100% RQD=26%		316				
314.6			16	RC	REC=97% RQD=96%		315				
15.0	End of Sampling End of Borehole										

Legend: UNCONFINED ○; FIELD VANE +; QUICK TRIAXIAL ●; LAB VANE ×. Plastic limit w_P, natural moisture content w, liquid limit w_L.

MEL-GEO 14083 - BOREHOLE LOGS - F10.GPJ MEL-GEO.GDT 4/7/16

ENCLOSURE NO.:4 (Pg. 1 of 2)

METRIC

RECORD OF BOREHOLE NO. 3

Englobe

REFERENCE 14/07/14083-F10 DATUM Geodetic LOCATION N 5022104.7 E 327296.1 - Chaffey Twp., Station 11+700.5 ORIGINATED BY ELS

PROJECT GWP 5005-05-00, Highway 60 BOREHOLE TYPE Truck Mounted CME 55 - Hollow Stem Augers and HQ Coring COMPILED BY DM

CLIENT AECOM DATE (Started) 3 December 2015 DATE (Completed) 3 December 2015 TIME (Completed) CHECKED BY MAM

ELEV / DEPTH (m)	DESCRIPTION (see Enclosure No. 1)	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
329.4	Ground Surface				
0.0	90 mm Asphalt 260 mm Crushed Gravel	1	AS		
	GRANULAR FILL - sand, some gravel, trace silt	2	AS		14 75 (11)
	brownish grey to brown, moist				
328.3 / 1.1	(compact)	3	SS	20	53 39 (8)
	MIXED FILL - sandy gravel, trace silt cobble to boulder sized rock pieces brown, moist	4	SS	10	
		5	SS	10/76mm	
	boulder from 2.6 to 3.0 m depth				
		6	SS	50/0mm	
	boulder from 3.7 to 3.9 m depth				
325.1 / 4.3	SAND FILL - sand, trace gravel, trace to some silt brown to dark grey, wet (very loose)	7	SS	1	
	existing culvert invert at approxiamtely 323.3 m				
323.3 / 6.1	SAND AND SILT - trace gravel	8	SS	12	1 48 42 9
322.1 / 7.3	SILT - some clay, trace gravel, trace sand grey, wet (dense)				
321.0 / 8.4	TILL - sand, trace to and gravel, some silt cobble to boulder sizes rock pieces grey, wet (dense)	9	SS	40	1 7 81 11
	Continued Next Page	10	SS	28	

Chart headings: GROUND WATER CONDITIONS; ELEVATION SCALE (329 to 320); 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
Advanced and sampled with hollow stem augers to 1.5 m depth. Advanced HQ size casing beyond 1.5 m, retrieving split spoon samples before advancing casing.

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 14083 - BOREHOLE LOGS - F10.GPJ MEL-GEO.GDT 4/7/16

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ENCLOSURE NO.:4 (Pg. 2 of 2)

METRIC

RECORD OF BOREHOLE NO. 3

Englobe

REFERENCE 14/07/14083-F10 DATUM Geodetic LOCATION N 5022104.7 E 327296.1 - Chaffey Twp., Station 11+700.5 ORIGINATED BY ELS

PROJECT GWP 5005-05-00, Highway 60 BOREHOLE TYPE Truck Mounted CME 55 - Hollow Stem Augers and HQ Coring COMPILED BY DM

CLIENT AECOM DATE (Started) 3 December 2015 DATE (Completed) 3 December 2015 TIME (Completed) CHECKED BY MAM

ELEV DEPTH	DESCRIPTION (see Enclosure No. 1) Continued from Previous Page	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)
							319				
			11	SS	40/0mm						
							318				
			12	RC							
317.3 12.1	Auger Refusal Start Rock Coring										
			13	RC	REC= 93% RQD= 87%		317				
316.9 12.5	BEDROCK - black gneiss End of Sampling End of Borehole										

Legend: 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)

MEL-GEO 14083 - BOREHOLE LOGS - F10.GPJ MEL-GEO.GDT 4/7/16

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

METRIC

RECORD OF BOREHOLE NO. 4

Englobe

REFERENCE 14/07/14083-F10	DATUM Geodetic	LOCATION N 5022119.8 E 327303.0 - Chaffey Twp., Station 11+696.5	ORIGINATED BY JL
PROJECT GWP 5005-05-00, Highway 60		BOREHOLE TYPE Truck Mounted CME 45 - Hollow Stem Augers and NQ Coring	COMPILED BY DM
CLIENT AECOM		DATE (Started) 14 December 2015 / DATE (Completed) 14 December 2015 / TIME (Completed)	CHECKED BY MAM

ELEV DEPTH	DESCRIPTION (see Enclosure No. 1)	STRATA PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	NATURAL MOISTURE CONTENT w (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
323.7	Ground Surface													
323.6 / 0.1	100 mm organic soil													
	SAND - trace gravel, some to some silt; some grass rootlets; grey to brown, wet; (very loose/dense)		1	SS	3				~20					
						▽ ▼	323							
			2	SS	18	Cave-in			~21		6	69	23	2
			3	SS	37	Cave-in	322		~17					
321.6 / 2.1	Auger Refusal; Start Rock Coring; BEDROCK - black gneiss; (poor to good quality)		4	RC	REC= 97% RQD= 84%		321							
			5	RC	REC= 100% RQD= 49%		320 / 319							
318.5 / 5.2	End of Sampling; End of Borehole													

Plot scales: 20 40 60 80 100; Water content: 20 40 60. Legend: PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 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 (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1) 15/12/15 10:30:00 AM	0.6 ▽	1
2) 15/12/15 12:00:00 PM	0.6 ▼	1.9
3)	-	-

MEL-GEO 14083 - BOREHOLE LOGS - F10.GPJ MEL-GEO.GDT 4/7/16

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

METRIC

RECORD OF BOREHOLE NO. 5

Englobe

REFERENCE 14/07/14083-F10 DATUM Geodetic LOCATION N 5022086.9 E 327281.7 - Chaffey Twp., Station 11+700 ORIGINATED BY JL

PROJECT GWP 5005-05-00, Highway 60 BOREHOLE TYPE Truck Mounted CME 45 - Hollow Stem Augers and NQ Coring COMPILED BY DM

CLIENT AECOM DATE (Started) 15 December 2015 DATE (Completed) 15 December 2015 TIME (Completed) CHECKED BY MAM

ELEV / DEPTH (m)	DESCRIPTION (see Enclosure No. 1)	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
324.3	Ground Surface					
0.0 / 324.0	fine fibrous organic soil, black, wet	1	SS	26/150 mm	104	
0.3	SILT - trace to with sand, some clay, grey, moist (compact/very dense)	2	SS	17		0 12 66 12
		3	SS	17		
		4	SS	58		0 6 83 11
321.4 / 2.9	TILL - sand and gravel, some silt, brown to grey, wet (very dense)	5	SS	90		39 43 (18)
320.5 / 3.8	Auger Refusal. Start Rock Coring. BEDROCK - black gneiss (fair to excellent quality)	6	RC	REC= 98% RQD= 69%		
		7	RC	REC= 98% RQD= 92%		
317.4 / 6.9	End of Sampling. End of Borehole					

Chart headings: SOIL PROFILE; SAMPLES; STRATA PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (324, 323, 322, 321, 320, 319, 318); 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) 16/12/15 9:00:00 AM	0	3.3
2) 16/12/15 9:05:00 AM	0	4.9
3) 18/12/15 12:35:00 PM	0	4.9

MEL-GEO 14083 - BOREHOLE LOGS - F10.GPJ MEL-GEO.GDT 4/7/16

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Percent Recovery in Split Spoons and Driven Through Embankment Fills

GWP 5505-05-00

Table R-1: Embankment Core Recovery

BOREHOLE	CORE	DEPTH (m)	% RECOVERY
2*	A	1.52 – 2.29	25
	B	2.29 – 3.05	4
	C	3.05 – 3.51	64
	D	3.51 – 4.57	26
3**	A	1.52 – 2.29	25
	B	2.29 – 3.12	76
	C	3.12 – 4.27	56

*see Photo No. 1, Appendix 2
**see Photo No. 2, Appendix 2

Table R-2: Split Spoon Recovery

BOREHOLE	SAMPLE	TYPE OF SAMPLE	DEPTH (m)	% RECOVERY
1	1	AS	0.15 – 0.41	-
	2	AS	0.41 – 0.76	-
	3	SS	0.76 – 1.22	57
	4	SS	1.52 – 2.12	17
	5	SS	2.29 – 2.89	0
	6	SS	3.05 – 3.65	0
	7	SS	4.57 – 4.17	42
	8	SS	6.10 – 6.70	50
	9	SS	7.62 – 8.22	63
	10	SS	9.14 – 9.60	100
	11	SS	10.36 – 10.96	54
2	1	AS	0.15 – 0.35	-
	2	AS	0.35 – 0.76	-
	3	SS	0.76 – 0.91	57
	4	SS	1.52 – 2.12	13
	5	SS	2.29 – 2.89	8
	6	SS	3.05 – 3.35	0
	7	SS	3.51 – 4.11	8
	8	SS	5.03 – 5.63	42
	9	SS	6.55 – 7.31	42
	10	SS	7.92 – 8.52	75
	11	SS	9.60 – 10.20	58
	12	SS	11.13 – 11.73	55
3	1	AS	0.15 – 0.30	-
	2	AS	0.30 – 0.45	-
	3	SS	0.76 – 0.36	17
	4	SS	1.52 – 2.12	17
	5	SS	2.29 – 2.39	0
	6	SS	3.20 – 3.30	0
	7	SS	4.57 – 5.10	33
	8	SS	6.55 – 7.15	63
	9	SS	8.07 – 8.67	75
	10	SS	9.45 – 10.36	0
	11	SS	10.97 – 11.07	100

Embankment Fill Coring at Borehole No. 2	Photo: 1

Photo 1a (BH No 2, core)
Notes: Recovered samples have been spread over full length of core run, except where cobble/boulder size rock was cored.

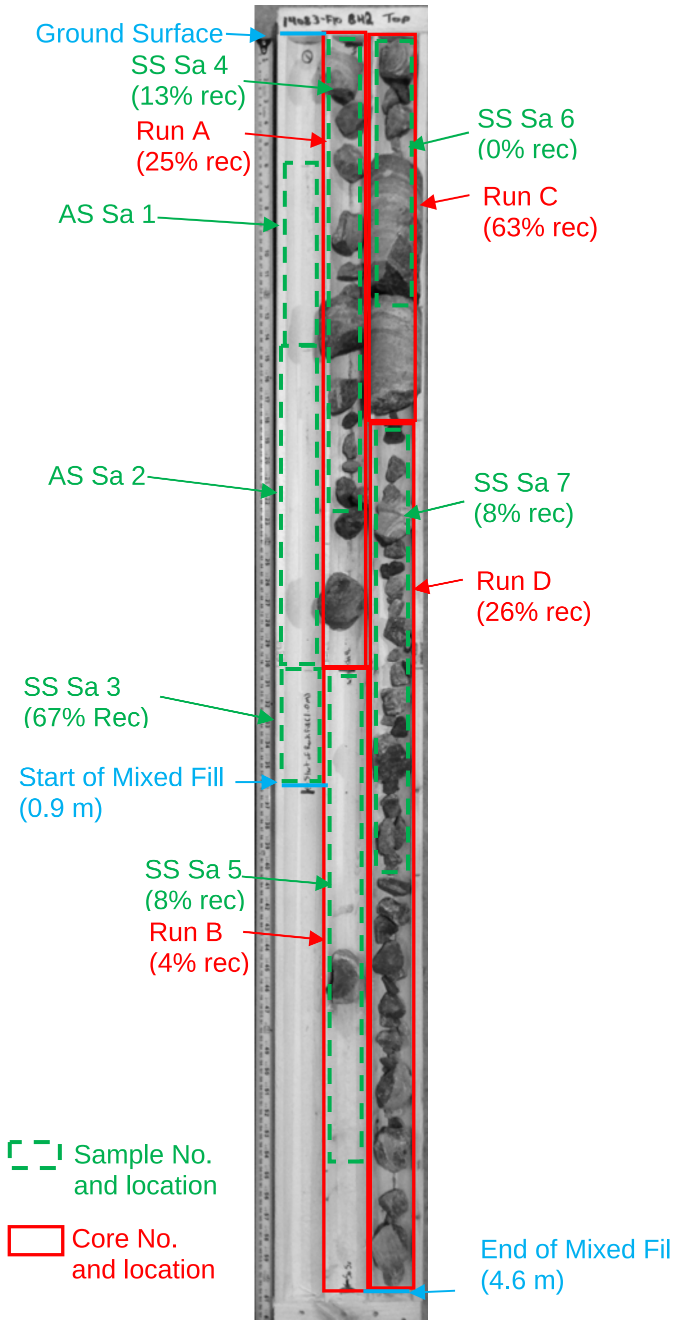


Photo 1b (BH No. 2, core with description)
Notes: Material from AS and SS samples not included in core photos. Location of AS and SS samples shown for reference. See logs for description of samples.

Project: GWP 5005-05-00 – Hwy 60, Station 11+698, Chaffey Township	Photos By: Englobe Date: January 2016

Embankment Fill Coring at Borehole No. 3	Photo: 2

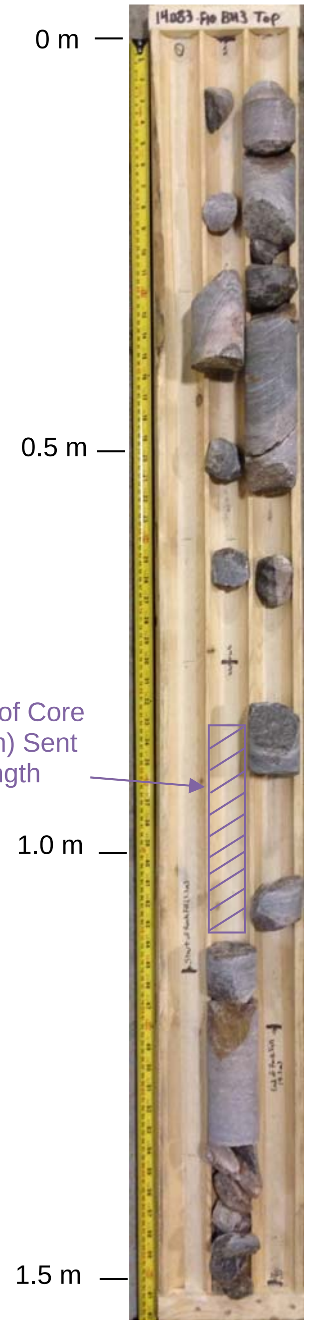


Photo 2a (BH No 3, core)
Notes: Recovered samples have been spread over full length of core run, except where cobble/boulder size rock was cored.

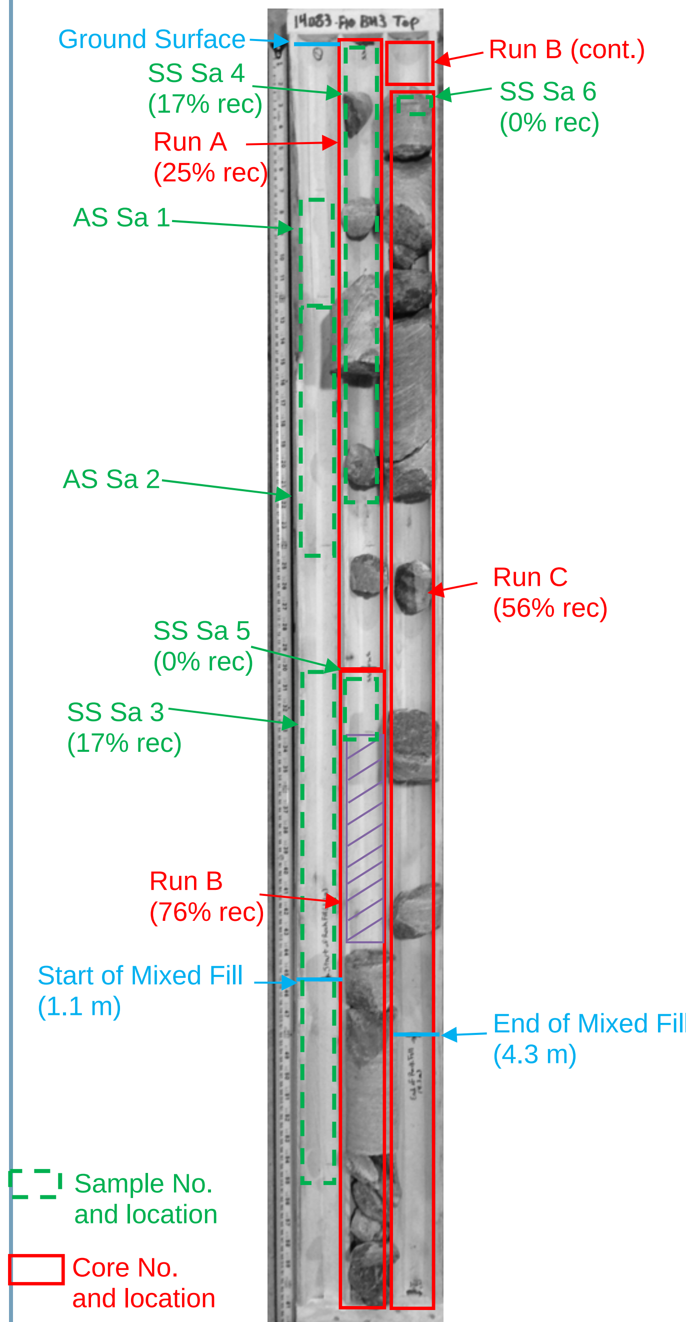
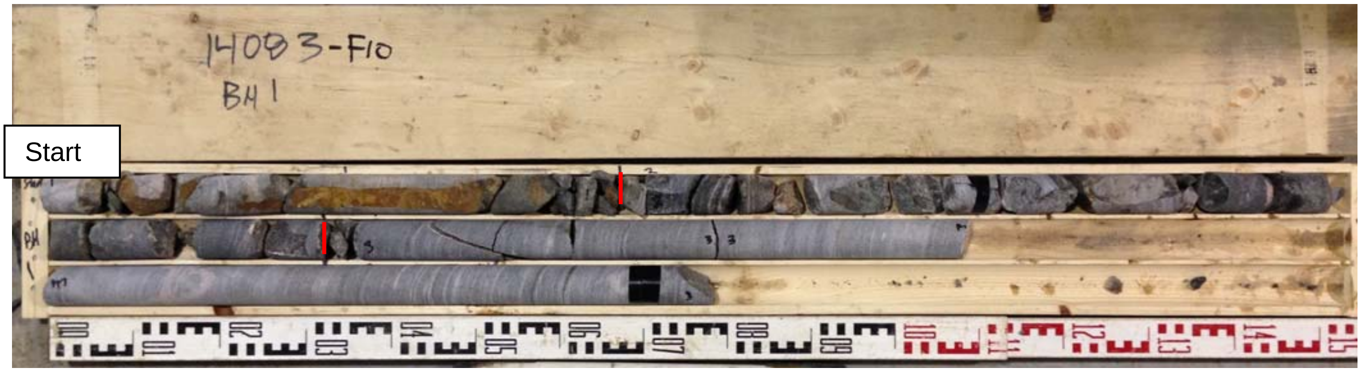


Photo 2b (BH No. 3, core with description)
Notes: Material from AS and SS samples not included in core photos. Location of AS and SS samples shown for reference. See logs for description of samples.

Project: GWP 5005-05-00 – Hwy 60, Station 11+698, Chaffey Township	Photos By: Englobe Date: January 2016

Bedrock Core Photos – Borehole No. 1	Photo: 3



Bedrock Core Photos – Borehole Nos. 2 and 3	Photo: 4

Project: GWP 5005-05-00 - Hwy 60 – Culvert, Station 11+698, Township of Chaffey	Photos Provided By: Englobe Date: December 2015

Bedrock Core Photos – Borehole 4 (left) and 5 (right)	Photo: 5 and 6

Start BH 4

Start BH 5

Project: GWP 5005-05-00 – Hwy 60, Station 11+698, Chaffey Township	Photos By: Englobe Date: January 2016

Appendix 3 Borehole Plan and Lab Data

Drawing No. 2:	Borehole Location and Soil Strata
Figure Nos. L-1 to L-6:	Grain Size Distribution Curves
Figure No. L-7:	Atterberg Limits
Figure No. L-8:	Rock Compressive Strength Results
Table No. L-9:	Lab Test Summary Sheet

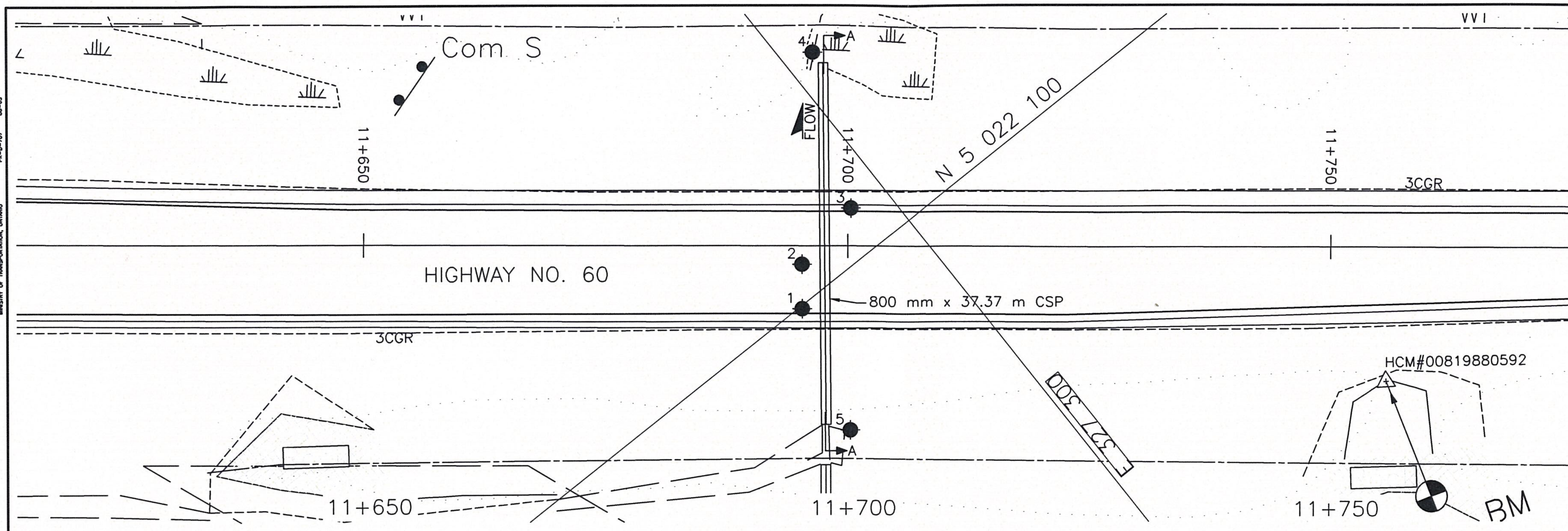
Englobe

DISTRICT
CONT. No.
GWP No. 5005-05-00

HWY 60 CULVERT
STA. 11+698
TOWNSHIP OF CHAFFEY
BOREHOLE LOCATIONS
AND SOIL STRATIGRAPHY

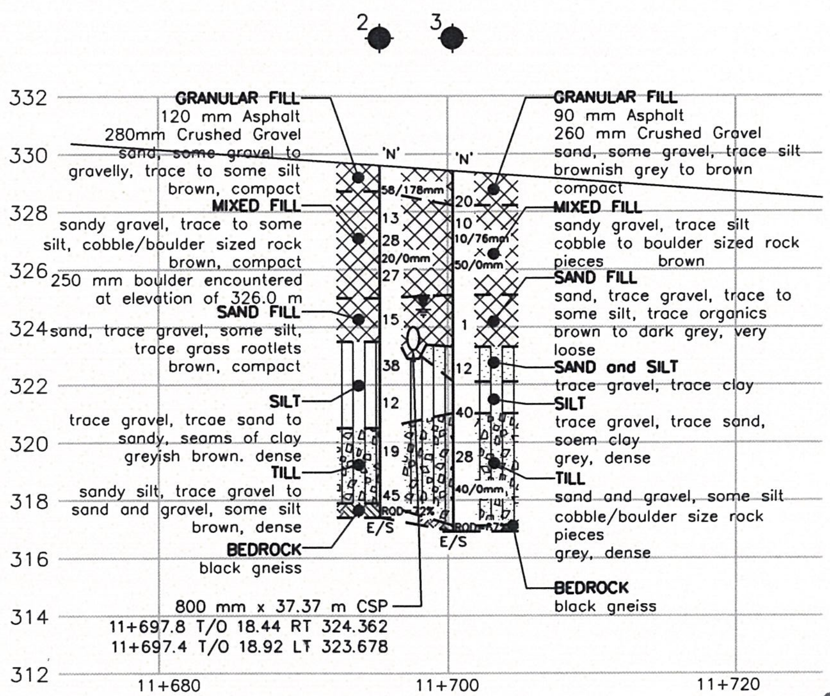
DRAWING 2

Englobe



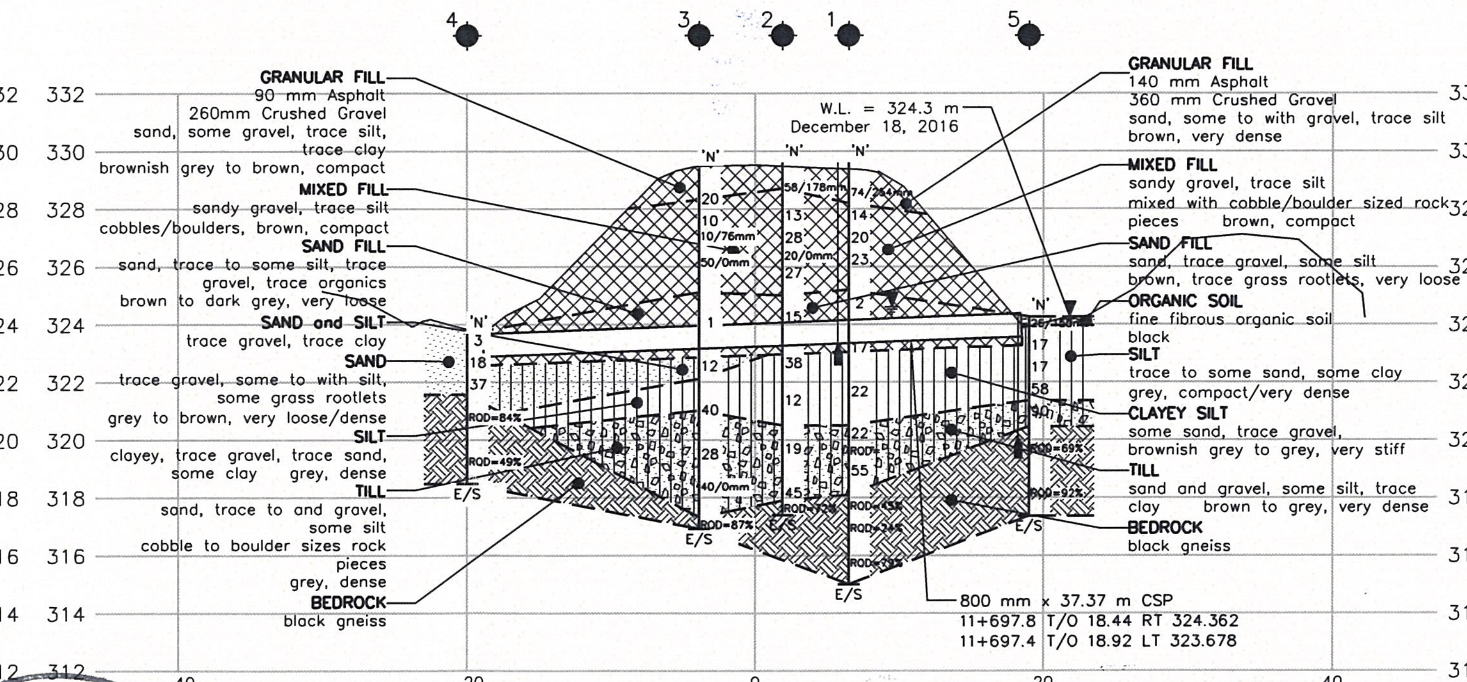
PLAN

SCALE 10m 10m



HWY 60 PROFILE

SCALE
HOR 10 5 0 10 20m
VERT 5 2.5 0 5 10m



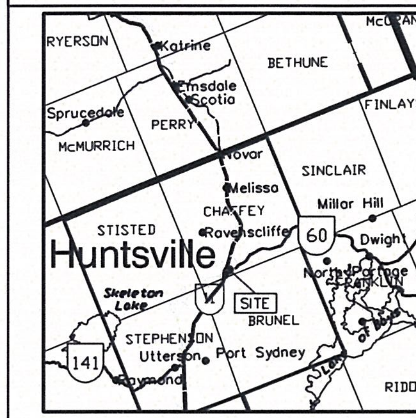
CROSS SECTION A-A

SCALE
HOR 10 5 0 10 20m
VERT 5 2.5 0 5 10m

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.

LICENSED PROFESSIONAL ENGINEER
16/07/15
S. HU
90524232
PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER
16/07/15
M. H. MacKAY
PROVINCE OF ONTARIO



KEY PLAN
N.T.S.

LEGEND

- ● Borehole
- N Blows/0.3 m (Std Pen Test, 475 J/blow)
- Water Level at Time of Investigation
- E/S End of Sampling
- Piezometer

BOREHOLE No.	ELEVATION	O/S	NORTHING	EASTING
1	329.6	6.5m Rt	5022099.7	327285.7
2	329.6	1.9m Rt	5022103.3	327288.5
3	329.4	3.9m Lt	5022104.7	327296.1
4	323.7	20m Lt	5022119.8	327303.0
5	324.3	19m Rt	5022086.9	327281.7

NOTES:

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.

Base plan and alignment based on a survey carried out by Exp.

Coordinates based on MTM Zone 10 NAD83 CSRS

GEOCRES No. 31E-363

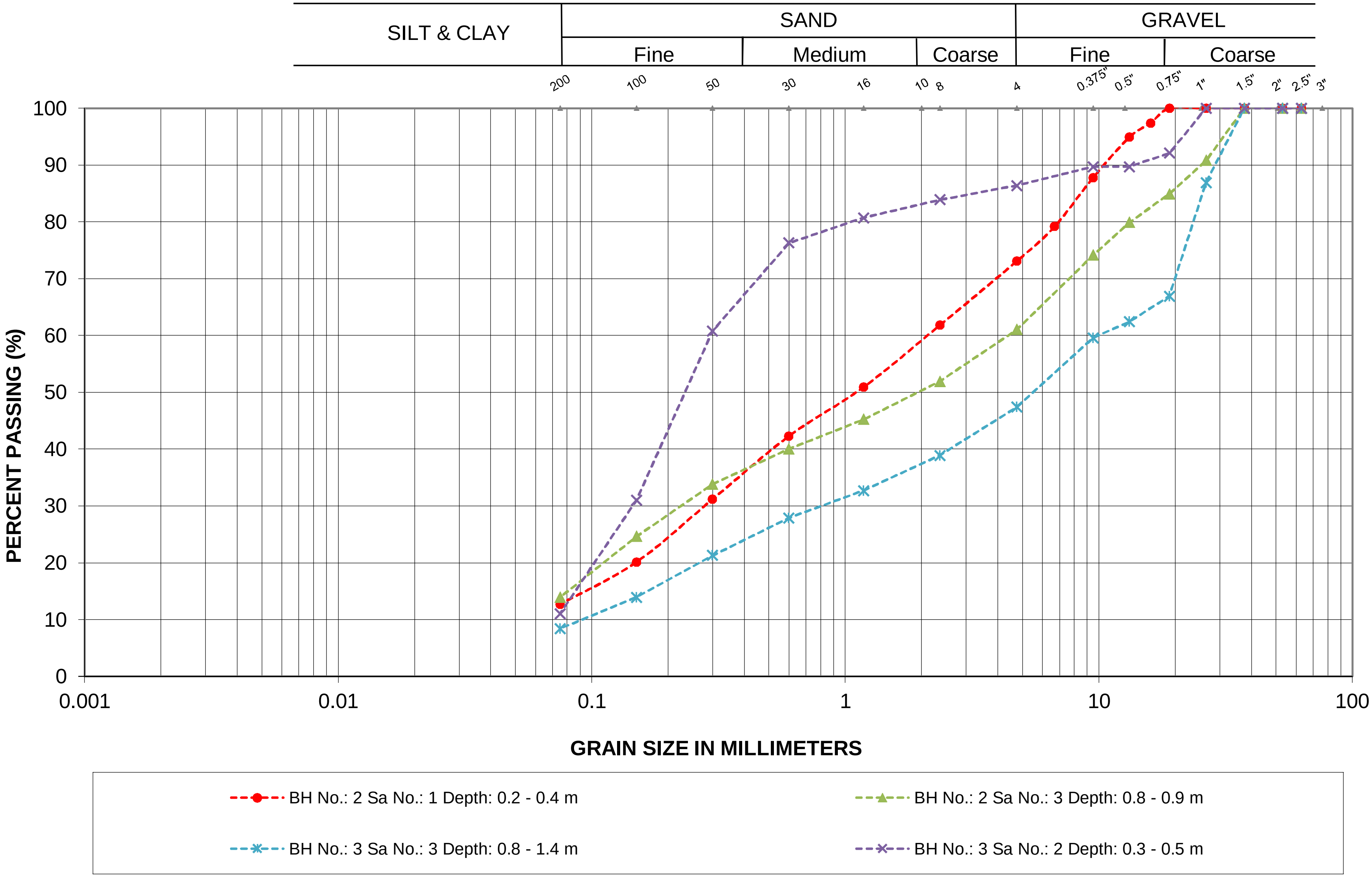
REVISIONS		
FEB/16	DM	DRAFT
JUN/16	DM	FINAL
		DESCRIPTION

DESIGN | CHK | CODE | LOAD | DATE JUL/16
DRAWN DM | CHK SH | SITE | STRUCT | SCHEME | DWG 2

CAD FILE LOCATION AND NAME: \2014\14083 - PAV & FDN, Hwy 60, Huntsville (AECOM)\FOUNDATIONS\Drawings\F014083 F10 - 11+698 (16-02-17).dwg
MODIFIED: 7/4/2016 4:31:45 PM BY: MITCDU
DATE PLOTTED: 7/5/2016 8:13:38 AM BY: DUNCAN MITCHELL

Reference No.: 14/07/14083-F10
Date: January, 2016

GRAIN SIZE ANALYSIS



GRANULAR FILL

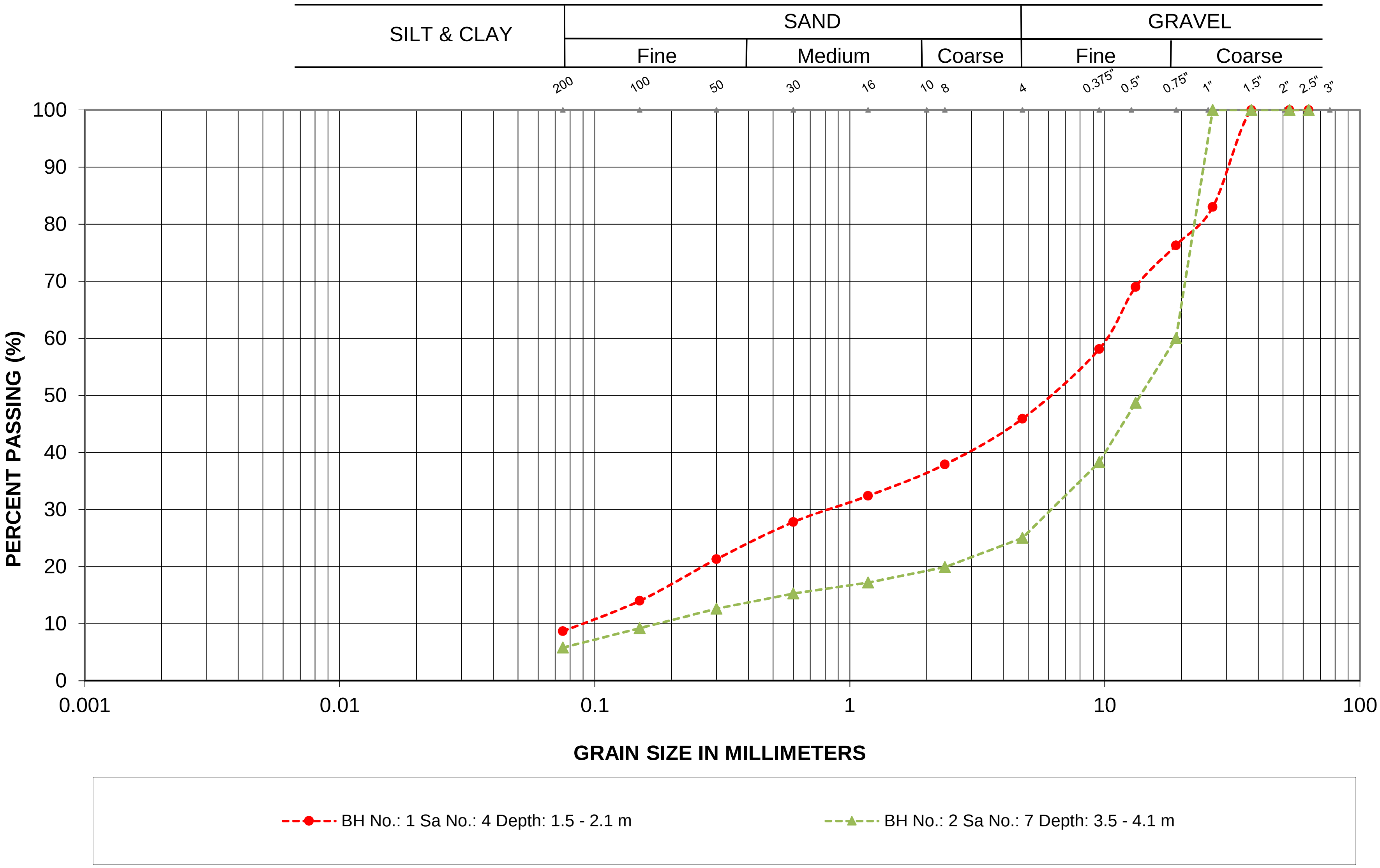
LOCATION: Hwy 60, Culvert Station 11+698
TWP of Chaffey

Englobe Corp.

FIGURE L-1

Reference No.: 14/07/14083-F10
Date: January, 2016

GRAIN SIZE ANALYSIS



MIXED FILL

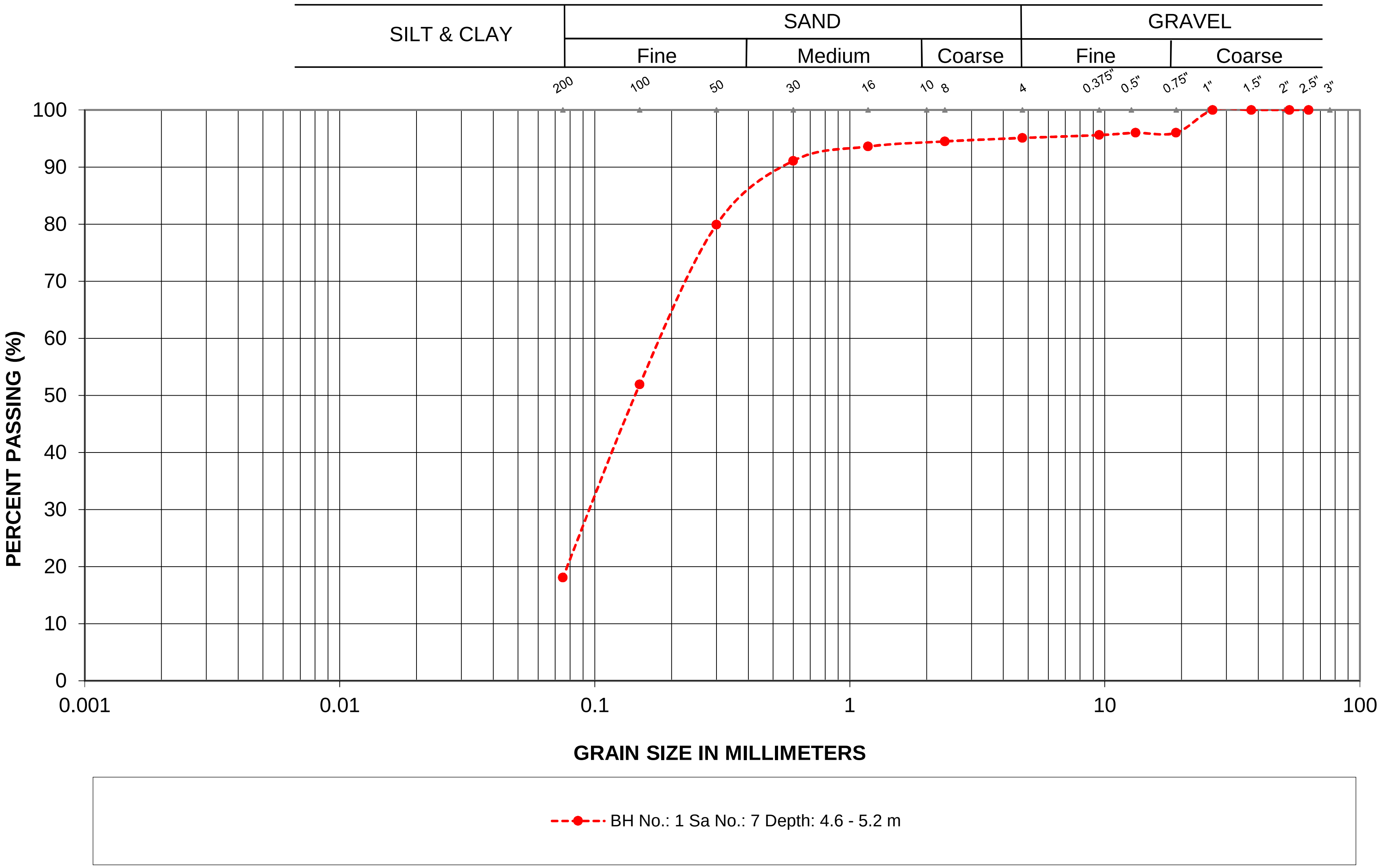
LOCATION: Hwy 60, Culvert Station 11+698
TWP of Chaffey

Englobe Corp.

FIGURE L-2

Reference No.: 14/07/14083-F10
Date: January, 2016

GRAIN SIZE ANALYSIS



SAND FILL

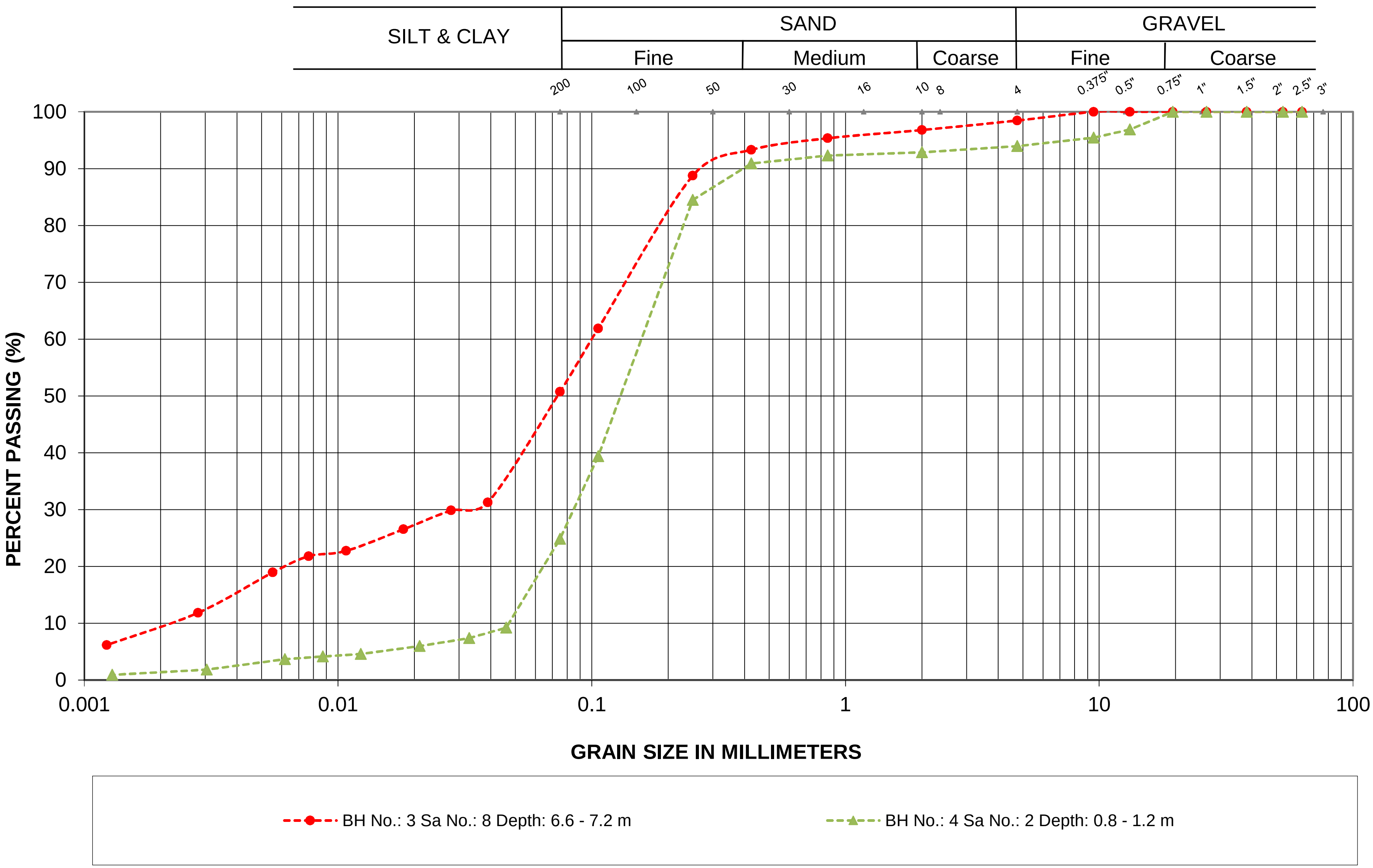
LOCATION: Hwy 60, Culvert Station 11+698
TWP of Chaffey

Englobe Corp.

FIGURE L-3

Reference No.: 14/07/14083-F10
Date: January, 2016

GRAIN SIZE ANALYSIS



SAND AND SILT to SAND

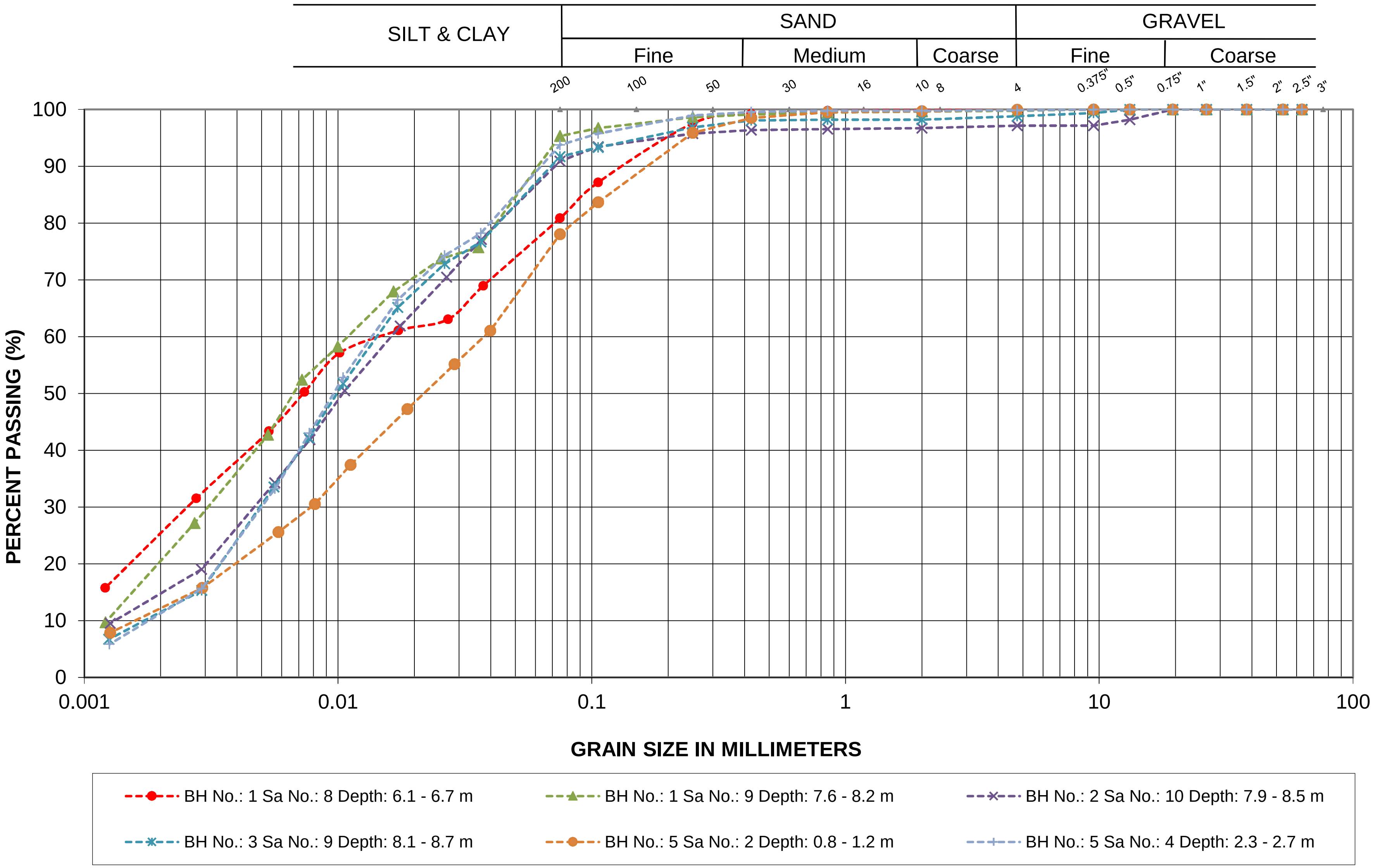
LOCATION: Hwy 60, Culvert Station 11+698
TWP of Chaffey

Englobe Corp.

FIGURE L-4

Reference No.: 14/07/14083-F10
Date: January, 2016

GRAIN SIZE ANALYSIS



SILT and CLAYEY SILT

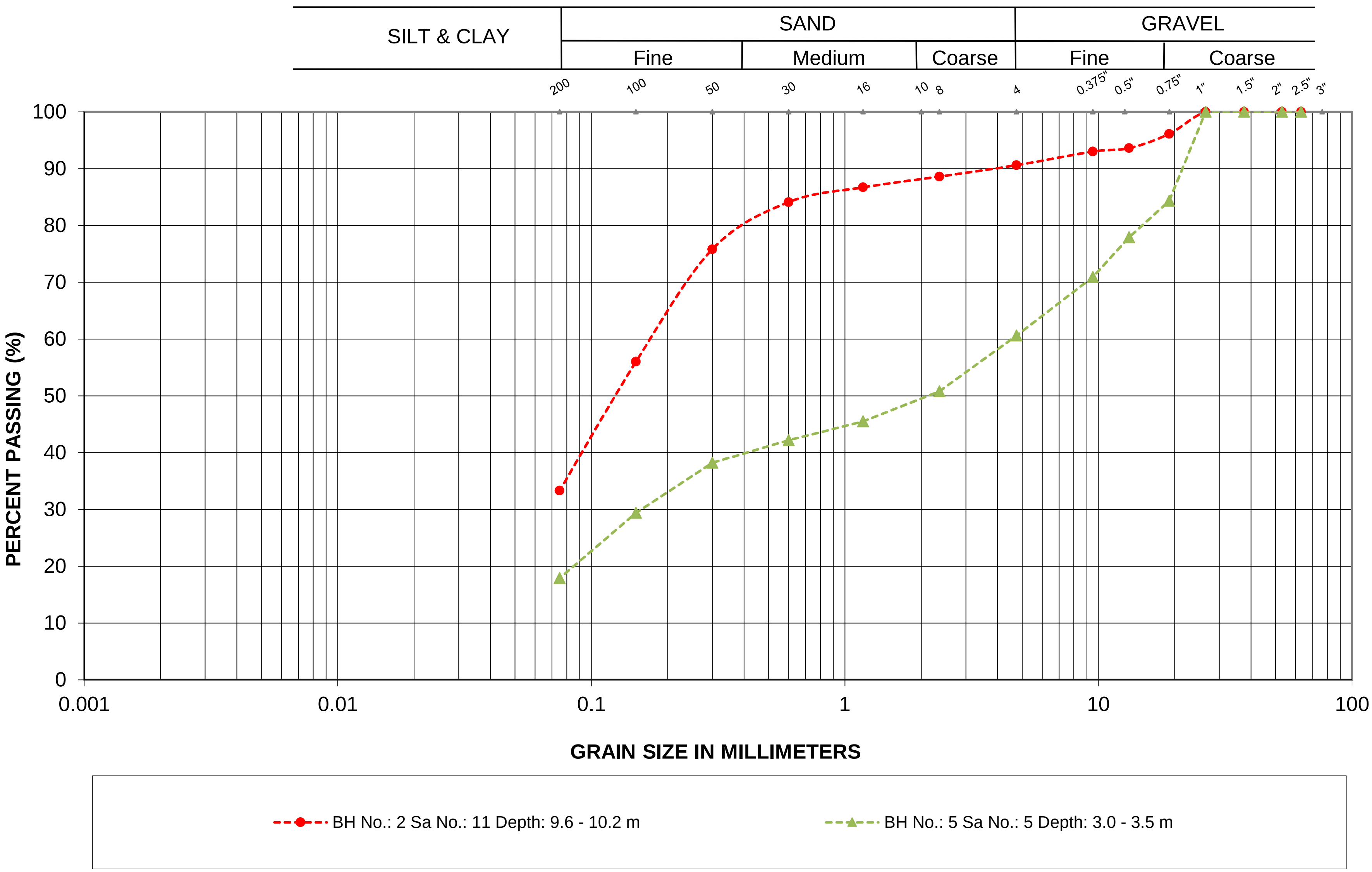
LOCATION: Hwy 60, Culvert Station 11+698
TWP of Chaffey

Englobe Corp.

FIGURE L-5

Reference No.: 14/07/14083-F10
Date: January, 2016

GRAIN SIZE ANALYSIS



TILL

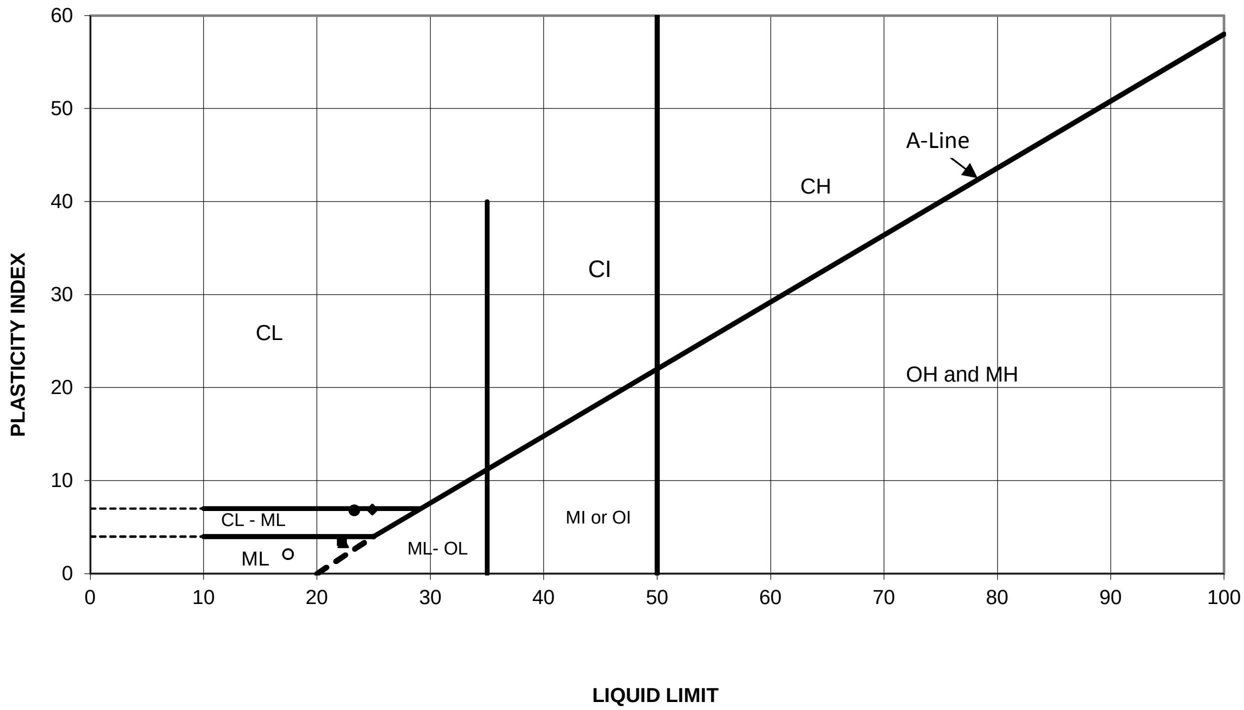
LOCATION: Hwy 60, Culvert Station 11+698
TWP of Chaffey

Englobe Corp.

FIGURE L-6

ATTERBERG LIMITS TEST RESULTS	FIGURE L-7

ATTERBERG INDICES



SYMBOL	BH	Sa. No.	Depth(m)	Elev.(m)	Liquid Limit	Plastic Limit	Plasticity Index	NMC %
●	1	8	6.4	323.2	23.3	16.5	6.8	16.8
◆	1	9	7.9	321.7	24.9	18.0	6.9	26.5
■	2	10	8.2	321.2	22.2	18.8	3.4	27.5
▲	3	9	8.4	321.0	22.3	18.9	3.4	26.4
○	5	2	1.0	323.4	17.4	15.4	2.1	15.5

Date: Feb-16
Project: Hwy 60
Location: Sta. 11+698, Twp. of Chaffey

Prep'd: AT
Chkd: MAM
Ref. No.: 14/07/14083-F10

Englobe Corp.

UNCONFINED COMPRESSION TEST (UC) OF INTACT ROCK CORE SPECIMENS

ASTM D7012

SAMPLE IDENTIFICATION

PROJECT NUMBER	14/07/14083-F10	SAMPLE NUMBER	Run 4
PROJECT NAME	-	SAMPLE DEPTH, m	0.67-0.94(from top)
BOREHOLE NUMBER	2	DATE:	2015-12-16

TEST CONDITIONS

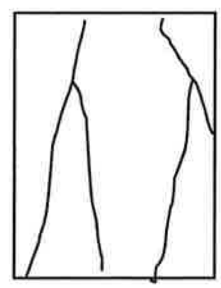
MACHINE SPEED, mm/min	N/A	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.17

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	13.77	WATER CONTENT, (specimen) %	0.06
SAMPLE DIAMETER, cm	6.34	UNIT WEIGHT, kN/m^3	26.53
SAMPLE AREA, cm^2	31.53	DRY UNIT WT., kN/m^3	26.52
SAMPLE VOLUME, cm^3	434.23	SPECIFIC GRAVITY	-
WET WEIGHT, g	1175.20	VOID RATIO	-
DRY WEIGHT, g	1174.50		

VISUAL INSPECTION

FAILURE SKETCH



TEST RESULTS

STRAIN AT FAILURE, %	N/A	COMPRESSIVE STRENGTH, MPa	60.7

REMARKS:

Checked By: [signature]

Golder Associates

UNCONFINED COMPRESSION TEST (UC) OF INTACT ROCK CORE SPECIMENS
ASTM D7012

FIGURE L-8

BEFORE COMPRESSION

AFTER COMPRESSION

Date Dec. 18, 2015
Project 14/07/14083-F10

Golder Associates

Drawn Frank
Chkd. [signature]

UNCONFINED COMPRESSION TEST (UC) OF INTACT ROCK CORE SPECIMENS

ASTM D7012

SAMPLE IDENTIFICATION

PROJECT NUMBER	14/07/14083-F10	SAMPLE NUMBER	Run 5C
PROJECT NAME	-	SAMPLE DEPTH, m	Boulder
BOREHOLE NUMBER	3	DATE:	2015-12-16

TEST CONDITIONS

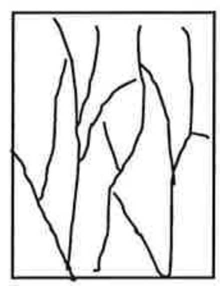
MACHINE SPEED, mm/min	N/A	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.27

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	14.00	WATER CONTENT, (specimen) %	0.10
SAMPLE DIAMETER, cm	6.17	UNIT WEIGHT, kN/m^3	25.82
SAMPLE AREA, cm^2	29.93	DRY UNIT WT., kN/m^3	25.80
SAMPLE VOLUME, cm^3	418.85	SPECIFIC GRAVITY	-
WET WEIGHT, g	1103.30	VOID RATIO	-
DRY WEIGHT, g	1102.20		

VISUAL INSPECTION

FAILURE SKETCH



TEST RESULTS

STRAIN AT FAILURE, %	N/A	COMPRESSIVE STRENGTH, MPa	130.8

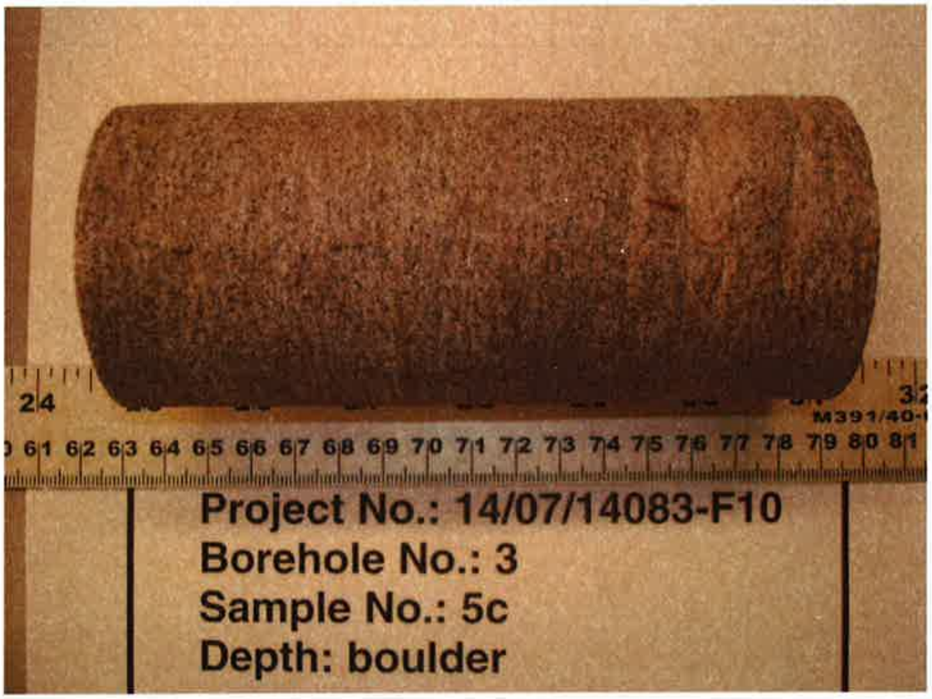
REMARKS:

Checked By:

Golder Associates

UNCONFINED COMPRESSION TEST (UC) OF INTACT ROCK CORE SPECIMENS
ASTM D7012

FIGURE L-8



BEFORE COMPRESSION

AFTER COMPRESSION

Date Dec. 18, 2015
Project 14/07/14083-F10

Golder Associates

Drawn Frank
Chkd.

Reference No.: 14/07/14083-F10
Date: January 2016

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
1	1	0.2					2.3							
	2	0.4					3.2							
	3	0.8					3.8				74/254 mm			
	4	1.5	54	37	9		1.7				14			
	5	2.3									20			
	6	3.1									23			
	7	4.6	5	77	18		20.1				2			
	8	6.1	0	19	56	25	16.8	23.3	16.5	6.8	17			
	9	7.6	0	5	75	20	26.5	24.9	18.0	6.9	22			
	10	9.1									22			
	11	9.6												
	12	10.4					3.0				55			
	13	11.5												Rec= 95%, RQD= 45%
	14	12.0												Rec= 100%, RQD= 24%
	15	13.1												Rec= 97%, RQD= 79%
2	1	0.2	27	60	13		3.2							
	2	0.4					5.0							
	3	0.8	39	47	14		4.6				58/178 mm			
	4	1.5					1.0				13			
	5	2.3					0.1				28			
	6	3.05					1.2				29/150mm			
	7	3.51	75	19	6		6.4				27			
	8	5.03					24.9				15			
	9	6.55					16.3				38			
	10	7.92	3	6	77	14	27.5	22.2	18.77	3.4	12			
	11	9.6	9	58	33		11.4				19			
	12	11.13					12.4				45			
	13	11.73												Rec= 100%, RQD= 72%
	14	12.2												Rec= 100%, RQD= 0%

Laboratory Tests - Summary Sheet

Englobe

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 (%)				
2	15	12.5												Rec= 100%, RQD= 26%
	16	13.3												Rec= 97%, RQD= 96%
3	1	0.2					2.6							
	2	0.3	14	75	11		6.8							
	3	0.8	53	39	8		1.9				20			
	4	1.5					2.7				10			
	5	2.3									10/76mm			
	6	3.2									50/0mm			
	7	4.6					21.0				1			
	8	6.6	1	48	42	9	16.8				12			
	9	8.1	1	7	81	11	26.4	22.3	18.9	3.4	40			
	10	9.5									28			
	11	11.0									40/0mm			
	12	11.6												
	13	12.2												Rec= 93%, RQD= 87%
4	1	0.0					23.1				3			
	2	0.8	6	69	23	2	24.6				18			
	3	1.52					17.3				37			
	4	2.13												Rec= 97%, RQD= 84%
	5	3.65												Rec= 100%, RQD= 49%

Laboratory Tests - Summary Sheet

Englobe

Borehole No.	Sample No.	Depth	Grain Size Analysis				NMC	Atterberg Limits			SPT 'N'	USCS	Unit Weight (kN/m3)	Remarks
			Gravel Size (%)	Sand Size (%)	Silt Size (%)	Clay Size (%)		LL (%)	PL (%)	IP (%)				
5	1	0.0					104.3				26/150mm			
	2	0.8	0	22	65	13	15.5	17.4	15.4	2.1	17			
	3	1.5					22.4				17			
	4	2.3	0	6	83	11	25.7				58			Non-Plastic (NP)
	5	3.1	39	43	18		9.7				90			
	6	3.8												Rec= 98%, RQD= 69%
	7	5.3												Rec= 98%, RQD= 92%

Appendix 4 Photo Essay

Enclosure No. 8: Photo Essay

Embankment at Culvert Location – Looking East	Photo: 7

Embankment at Culvert Location – Looking West	Photo: 8

Project: GWP 5005-05-00 - Hwy 60 – Culvert, Station 11+698, Township of Chaffey	Photos Provided By: Englobe Date: December 2015

Culvert Inlet – Looking North	Photo: 9
	
View of Culvert Outlet – Looking North	Photo: 10
	
Project: GWP 5005-05-00 - Hwy 60 – Culvert, Station 11+698, Township of Chaffey	Photos Provided By: Englobe Date: December 2015

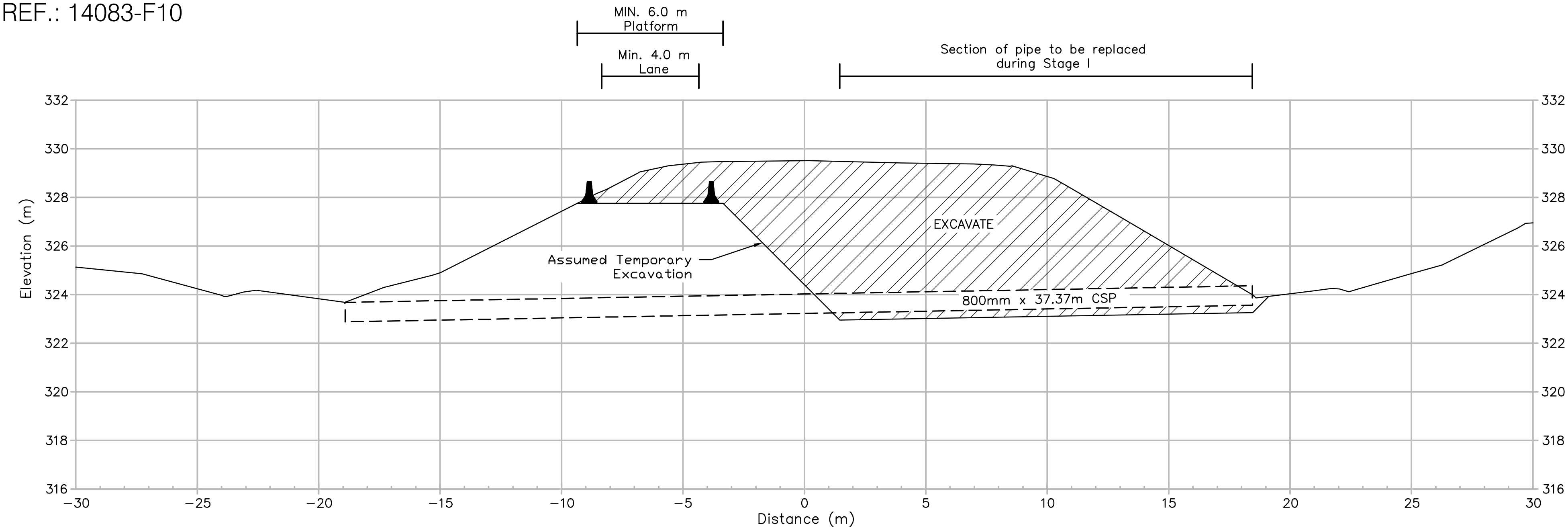
Appendix 5 Design Data

Table A:	Comparison of Shoring Alternatives
Figure No. SK-3:	Conceptual Staging Plan
Figure No. SK-4:	Conceptual Shoring Locations
Figure No. SK-5	Conceptual Shoring Sections
	Notice to Contractor: Obstruction

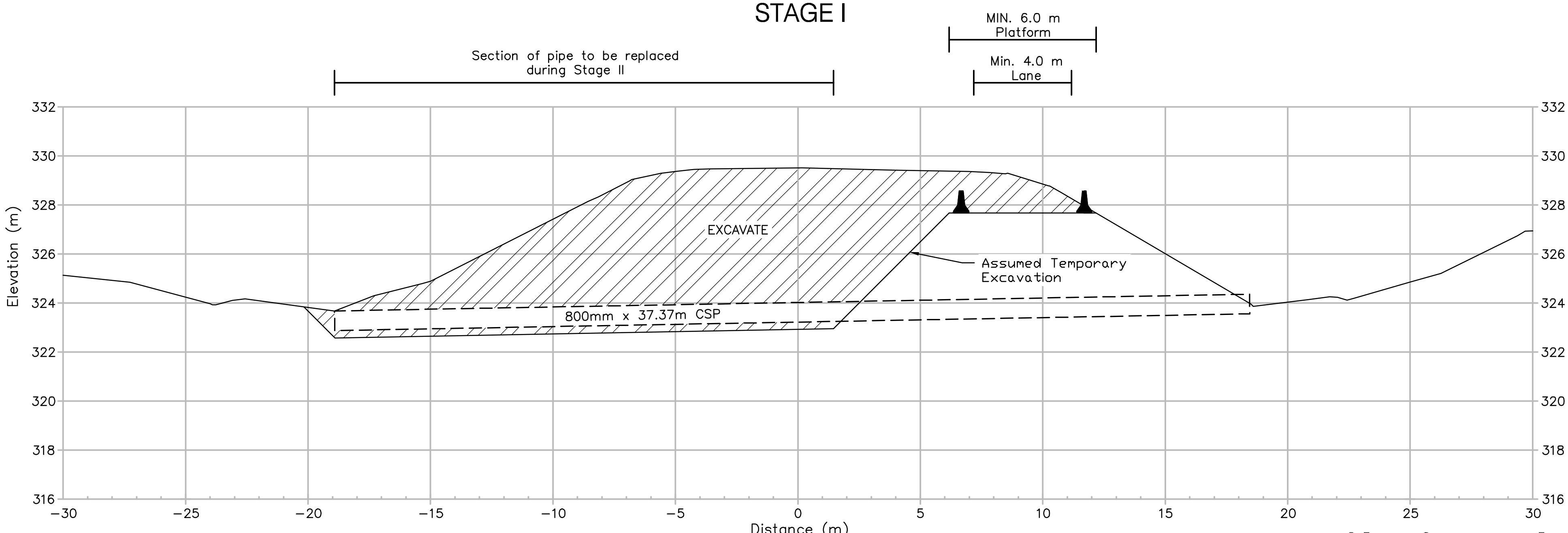
Table A – Comparison of Shoring Alternatives

Method	Depth Range (m)	Advantages	Disadvantages	Remarks	Estimated Costs
Wood Sheeting	1.5 – 5	-Low cost, -Easily installed in good ground conditions	-Limited by soil conditions, -Limited depth of installation, -Low strength, -discontinuous	Not recommended due to rock pieces encountered in embankment fill and native soils	$ 650/m^2
Steel Sheet Piles	5 – 21	-High strength, continuous, -Readily available	-Limited by soil conditions (i.e. obstructions)	Not recommended due to rock pieces in embankment	$ 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	Recommended provided sufficiently predrilled through cobbles/boulders encountered in embankment fills and dewatering during excavation	$ 725/m^2 Predrilling 1500/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	Feasible using special equipment drilled through cobbles/boulders encountered in embankment fills	
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	Considered as alternative for protection system, however, higher cost	$ 1200 to 1500/m^2

REF.: 14083-F10



STAGE I



STAGE II

METRIC

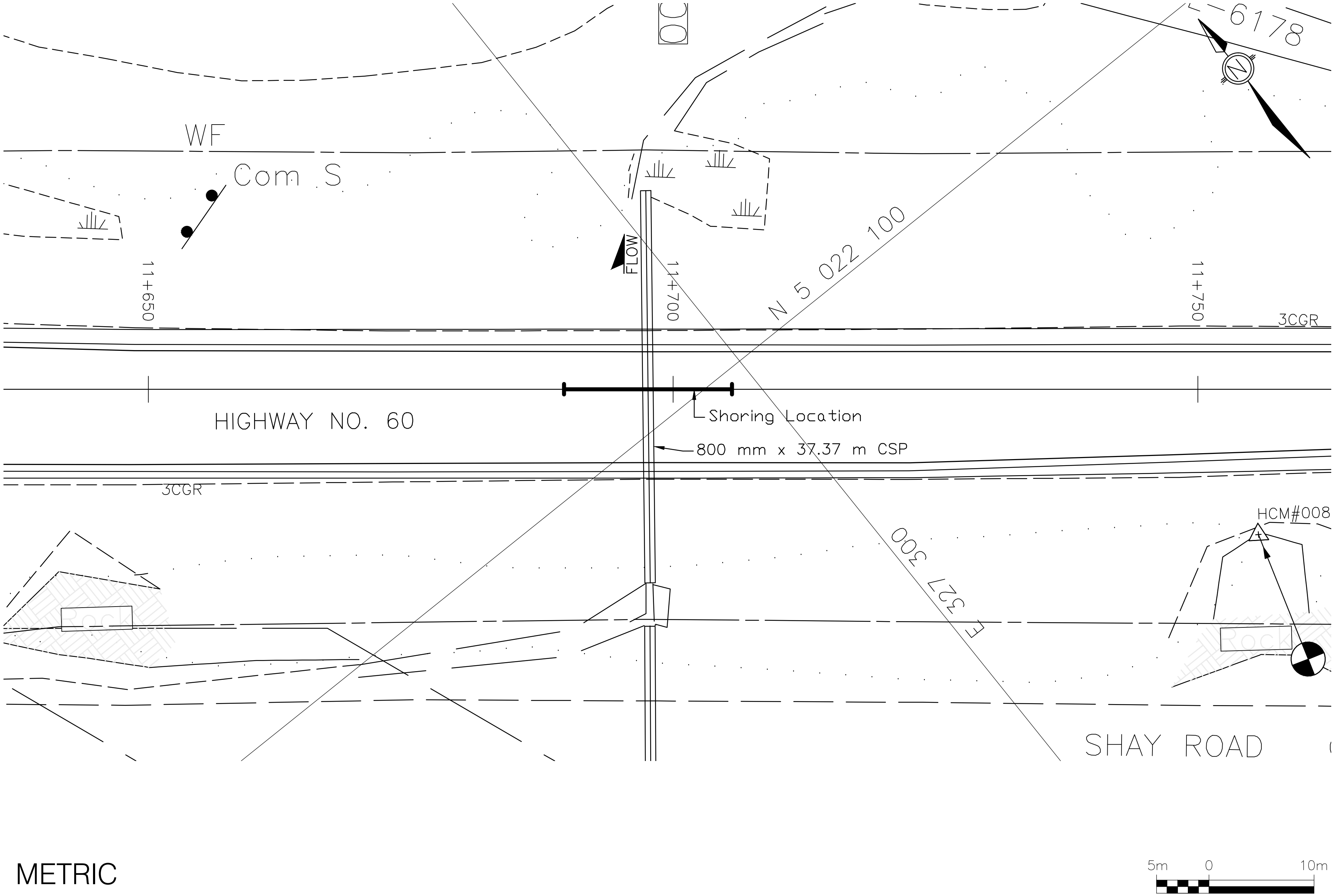
Dimensions are in meters and/or millimeters unless otherwise shown. Stations are in kilometers + meters.

2.5m 0 5m

Highway 60, Township of Chaffey - Culvert at Station 11+698
Conceptual Shoring Location Plan

FIGURE SK-3

REF.: 14083-F10

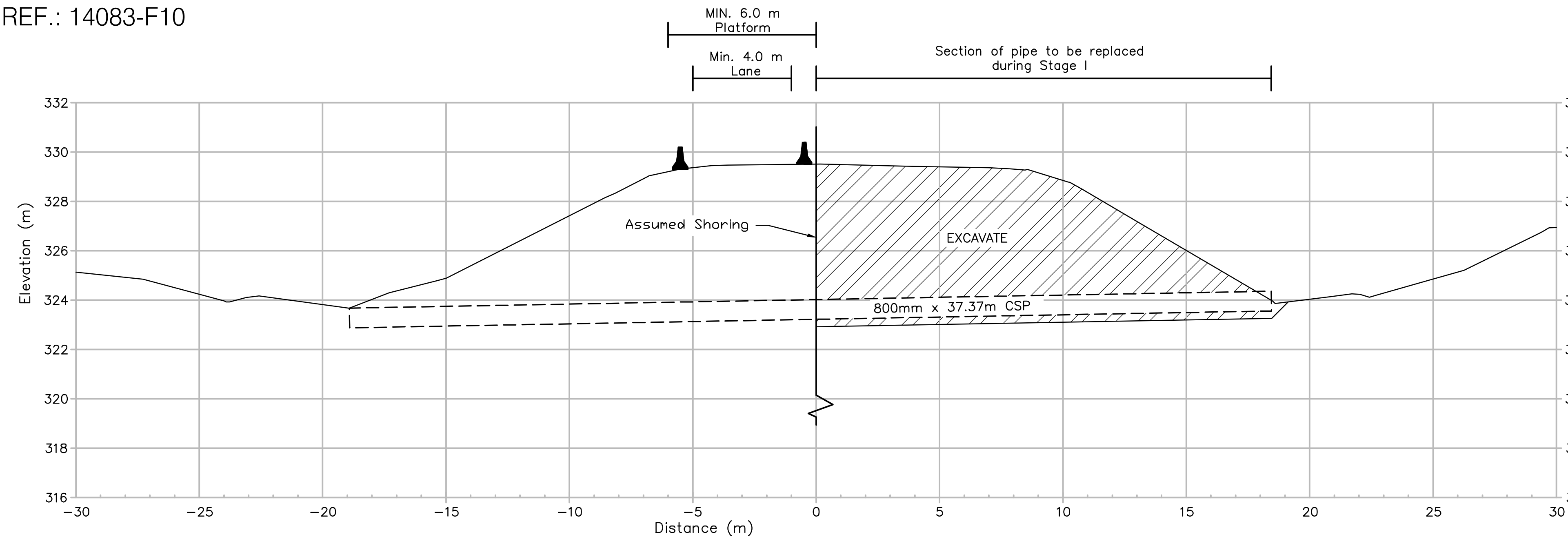


METRIC

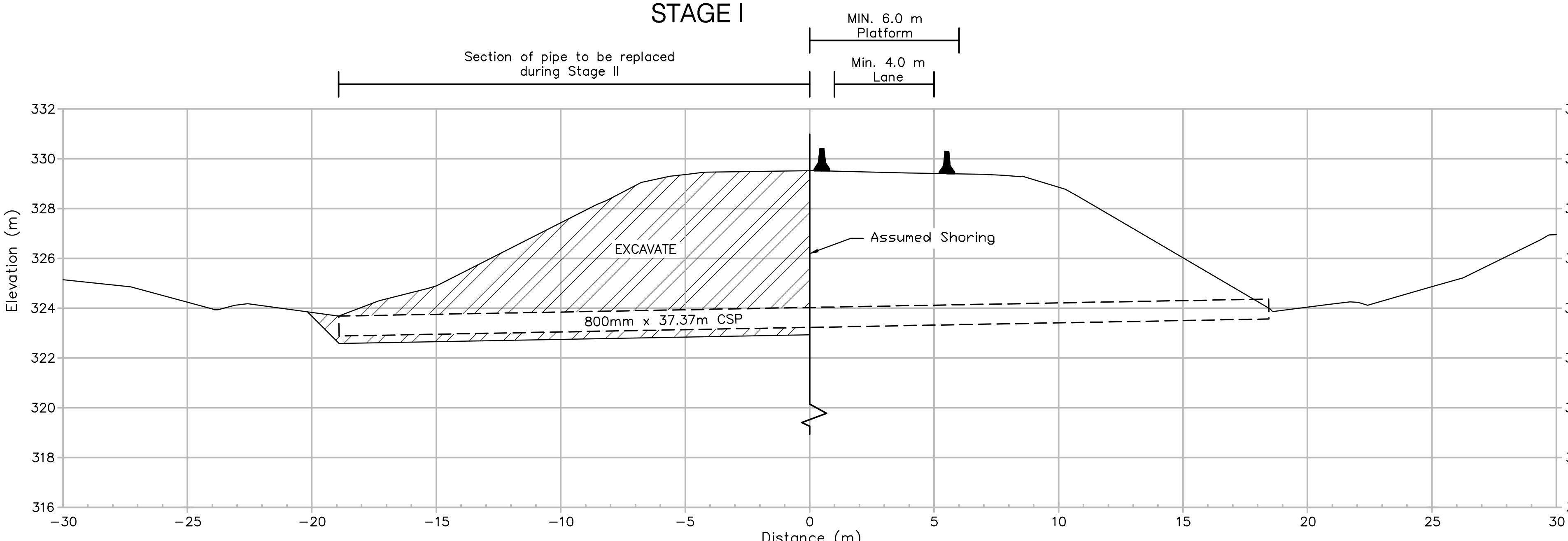
Dimensions are in meters and/or millimeters unless otherwise shown. Stations are in kilometers + meters.

Highway 60, Township of Chaffey - Culvert at Station 11+698 Conceptual Shoring Location Plan	FIGURE SK-4

REF.: 14083-F10



STAGE I



STAGE II

METRIC

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

2.5m 0 5m

Highway 60, Township of Chaffey - Culvert at Station 11+698
Conceptual Shoring Location Plan

FIGURE SK-5

NOTICE TO CONTRACTOR – Obstructions in Fill and Native Glacial Tills

Special Provision

The Contractor is advised that, at the borehole locations, mixed cobble/boulder sized rock fragments were encountered in the embankment fills and native glacial tills overlying bedrock. The contractor should be prepared to deal with these materials for dewatering, temporary protection system and other construction activities. The Contractor must also be prepared to deal with seasonal and yearly fluctuations of ground/surface water.