



July 2014

REPORT ON

**Preliminary Foundation Investigation and Design
Irondale River Culvert Replacement
Site No. 40-063c
Highway 118, 1.1 km East of Regional Road 648
Monmouth Township, Ontario
W.P. 4128-10-01**

Submitted to:
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REPORT



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**PRELIMINARY FOUNDATION REPORT
IRONDALE RIVER CULVERT REPLACEMENT - HIGHWAY 118**

PART A

**PRELIMINARY FOUNDATION INVESTIGATION REPORT
IRONDALE RIVER CULVERT REPLACEMENT
SITE 40-063C
HIGHWAY 118, 1.1 KM EAST OF REGIONAL ROAD 648
W.P. 4128-10-01**



PRELIMINARY FOUNDATION REPORT IRONDALE RIVER CULVERT REPLACEMENT - HIGHWAY 118

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by MMM Group Ltd. (MMM) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations associated with the Design-Build of seven culvert replacements and two bridge replacements at various locations in the Eastern Region of Ontario as part of the 22 Structures MEGA 2 project. This report presents the results of the foundation investigation conducted for the replacement of Irondale River culvert, Site No. 40-063c (WP 4128-10-01) located on Highway 118 about 1.1 km east of Regional Road 648 in Monmouth Township, Ontario.

The purpose of the foundation investigation was to assess the subsurface conditions for the proposed culvert replacement by drilling four boreholes and carrying out in situ testing and laboratory testing on selected samples. The terms of reference for the original scope of work are outlined in the MTO's Request for Proposal (RFP) dated April 2012. The work was carried out in accordance with Golder's Quality Control Plan dated August 2012.



2.0 SITE DESCRIPTION

The Irondale River culvert is located on Highway 118 about 1.1 km east of Regional Road 648 in Monmouth Township, Ontario. The existing culvert (Site No. 40-063c) is located at Station 23+862.

The existing culvert is a 6.54 m wide by 2.44 m high, triple-span, non-rigid timber frame, open footing structure with transverse timber cribbing/struts across the bottom which are in-filled with large granular/river rock. The culvert is about 20.0 m in length. The date of construction of the culvert is unknown. It is understood that the culvert is in fair to poor condition. The existing culvert inverts are at about Elevations 369.2 and 368.9 m at the north and south ends, respectively, with flow in the culvert from north to south. The depth of water within the culvert was about 0.8 m at the time of the field investigation. The width of the water course is between about 7 and 8 m at both the inlet and outlet.

The existing pavement grade at the culvert location is at about Elevations 373 m. In this area, Highway 118 is typically one lane wide in each direction (i.e., a two-lane highway). The existing embankment slopes at the culvert locations are about 2 to 3 m in height and are sloped at about 2 horizontal to 1 vertical (2H:1V). Based on visual observations at the time of Golder's field investigation, the existing embankment and side slopes are in good condition, with no visual evidence of settlement or instability.



3.0 INVESTIGATION PROCEDURES

The subsurface investigation was carried out for the culvert replacement between May 8 and 15, 2013, at which time four boreholes (numbered 13-231 to 13-234, inclusive) were advanced at the locations shown on Drawing 1. The boreholes were advanced as follows:

- Boreholes 13-231 and 13-233 were advanced near the culvert ends at the toe of the Highway 118 embankment, using 108 mm inside diameter continuous-flight hollow-stem augers on a track-mounted drill rig, supplied and operated by Marathon Drilling Ltd. of Ottawa, Ontario. The boreholes were advanced to auger refusal at depths of about 7.7 and 10.4 m below the existing ground surface in Boreholes 13-231 and 13-233, respectively.
- Boreholes 13-232 and 13-234 were advanced through the existing Highway 118 embankment using 108 mm inside diameter continuous-flight hollow-stem augers on a truck-mounted drill rig, supplied and operated by Marathon Drilling Ltd. of Ottawa, Ontario. The boreholes were advanced to auger refusal at depths of about 12.3 and 9.8 m below the existing ground surface in Borehole 13-232 and 13-234, respectively.

Soil samples in the boreholes were obtained at vertical intervals of about 0.76 and 1.52 m, using a 50 mm outer diameter split-spoon sampler in accordance with Standard Penetration Test procedures.

The water levels in the open boreholes were observed throughout the drilling operations. A standpipe piezometer was installed in Borehole 13-233 to monitor the groundwater level at the site. The standpipe consists of a 32 mm diameter rigid PVC pipe with a 1.5 m long slotted screen section, installed within silica sand backfill and sealed by a section of bentonite pellet backfill.

The boreholes were backfilled with bentonite pellets, mixed with native soils in the overburden. The site conditions were restored following completion of work.

The field work was supervised by a member of Golder's technical staff, who located the boreholes, supervised the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled, and transported to Golder's laboratory in Ottawa for further examination. Index and classification tests consisting of grain size distribution and water content testing were carried out on selected soil samples. All of the laboratory tests were carried out to MTO and/or ASTM standards as appropriate.

The borehole locations were determined by Golder in relation to existing site features. The ground surface elevations were also surveyed by Golder to an established benchmark provided by MMM, consisting of a round iron bar on the northwest side of Highway 118, labelled HCP 324. The elevation of the benchmark is understood to be Elevation 372.19 m. The borehole locations, including MTM NAD83 northing and easting coordinates and ground surface elevations referenced to Geodetic datum, are summarized in the following table and are shown on Drawing 1.



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Borehole Number	Borehole Location	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)
13-231	South end of the culvert	4983410.8	405745.4	369.7
13-232	Highway 118 westbound lane on the east side of the culvert	4983426.6	405732.4	372.6
13-233	North end of the culvert	4983432.4	405723.1	371.4
13-234	Highway 118 eastbound lane on the west side of the culvert	4983417.9	405717.9	372.9



4.0 SITE GEOLOGY AND STRATIGRAPHY

4.1 Regional Geological Conditions

The site is located in the southern portion of the physiographic region known as the Algonquin Highlands, and just north of the Georgian Bay fringe, as delineated in *The Physiography of Southern Ontario*.¹

The Algonquin Highlands is gently sloping from a central high point at approximately Elevation 550 m, to about Elevation 275 m in the west and about Elevation 185 m in the east. It is characterized by relatively shallow deposits of outwash sand and gravel and/or glacial till overlying granite and other hard Precambrian bedrock.¹

4.2 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The results of geotechnical laboratory testing are also presented on Figures B1 and B2 contained in Appendix B.

A soil stratigraphy section projected along the centreline of the existing culvert area is shown on Drawing 1. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions at the location of the proposed culvert replacement consist of embankment fill overlying a layered deposit of sand to sand and gravel. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Pavement Structure and Embankment Fill

The pavement structure encountered within Boreholes 13-232 and 13-234 consists of about 0.1 m of asphaltic concrete overlying 0.3 m of grey crushed stone base. The pavement structure at these locations is underlain by embankment fill, which was fully penetrated to depths of between about 3.1 and 3.5 m (Elevations 369.5 and 369.4 m, respectively). The embankment fill is between about 2.7 and 3.1 m thick. About 0.8 m (Elevation 368.9 m) of embankment fill was encountered at ground surface at Borehole 13-233, which was drilled near the north toe of the Highway 118 embankment.

The embankment fill generally consists of gravelly sand to sand and gravel and contains cobbles and/or boulders.

Standard Penetration Test (SPT) N values for the embankment fill range from 8 to 76 blows per 0.3 m of penetration, indicating a loose to very dense state of packing.

The results of grain size distribution testing carried out on selected samples of the embankment fill are provided on Figure B1 in Appendix B. However, the results shown only reflect the portion of the sample with particle sizes less than about 50 mm due to the diameter of the SPT sampler. As noted above, the embankment fill also contains larger sized particles of gravel, cobbles, and boulders.

The measured water contents of tested samples of the embankment fill ranged from approximately 1 to 5 percent.

¹ Chapman, L.J. and D.F. Putnam. *The Physiography of Southern Ontario*. Ontario Geological Survey Special Volume 2, Third Edition, 1984. Accompanied by Map P.2715, Scale 1:600,000.



4.2.2 Layered Sand to Sand and Gravel

A layered deposit of sand, sand and gravel and sandy gravel was encountered below the embankment fill at Boreholes 13-232, 13-233 and 13-234 and at ground surface at Borehole 13-231. This deposit was proven to depths ranging from 7.7 to 12.3 m or Elevations 360.3 to 363.2 m.

This layered deposit also contains cobbles and/or boulders. Organic matter was also encountered within a silty sand layer at Borehole 13-234.

SPT N values for the layered material range from 2 to 61 blows per 0.3 m of penetration indicating a very loose to very dense state of packing. However, the blow counts for the deposit are typically in the compact range.

The results of grain size distribution testing on several samples of the deposit are shown on Figure B2 in Appendix B. The measured natural water content of the deposit ranges from about 9 to 23 percent.

4.2.3 Auger Refusal

Auger refusal was encountered at Elevations 362.0, 360.3, and 361.0 m at Boreholes 13-231, 13-232, and 13-233, respectively. These instances of refusal likely indicate the bedrock surface but could also represent cobbles or boulders in the deposit.

The following table summarizes the auger refusal depths and elevations as encountered at the three borehole locations.

Borehole Number	Existing Ground Surface Elevation (m)	Depth to Refusal (m)	Auger Refusal Elevation (m)
13-231	369.7	7.7	362.0
13-232	372.6	12.3	360.3
13-233	371.4	10.4	361.0

4.2.4 Groundwater Conditions

The groundwater level observed upon completion of drilling at Borehole 13-231 was at about Elevation 368.9 m. The groundwater levels were not established at Boreholes 13-232 and 13-234.

The groundwater level in the piezometer in Borehole 13-233 was measured on June 3, 2013, approximately three weeks following completion of drilling, as summarized in the table below:

Borehole Number	Ground Surface Elevation (m)	Water Level Depth (m)	Water Level Elevation (m)	Date
13-233	371.4	1.8	369.6	June 3, 2013

It is understood that the water level in the river was at about Elevation 369.4 m as measured by MMM in October 2012.

It should be noted that groundwater levels in the area are subject to fluctuations both seasonally and with precipitation events.



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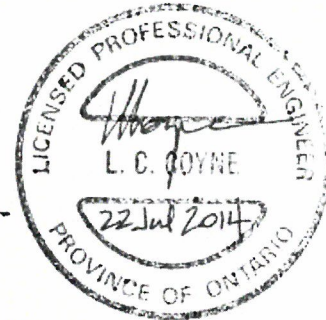
5.0 CLOSURE

This Preliminary Foundation Investigation Report was prepared by Ms. Susan Trickey, P.Eng. and Mr. Matt Kennedy, P.Eng., and was reviewed by Ms. Lisa Coyne, P.Eng., a Principal and senior geotechnical engineer with Golder. Mr. Fin Heffernan, P.Eng., Golder's Designated MTO Foundations Contact for this project, conducted an independent quality review of the report.

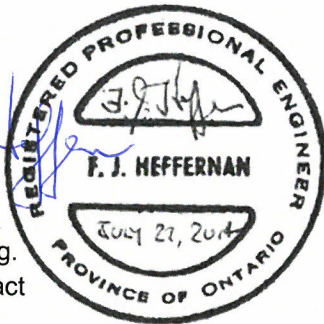
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**PRELIMINARY FOUNDATION REPORT
IRONDALE RIVER CULVERT REPLACEMENT - HIGHWAY 118**

PART B

PRELIMINARY FOUNDATION DESIGN REPORT

IRONDALE RIVER CULVERT REPLACEMENT

SITE 40-063C

HIGHWAY 118, 1.1 KM EAST OF REGIONAL ROAD 648

W.P. 4128-10-01



6.0 DISCUSSION AND PRELIMINARY ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides preliminary foundation design recommendations for the proposed replacement of the existing Irondale River culvert on Highway 118. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this preliminary subsurface investigation. The discussion and preliminary recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to carry out the preliminary design of the foundations for the replacement structure. Further investigation and analysis will be required during detail design.

Where comments are made on construction, they are provided to highlight those aspects that could affect the preliminary design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

The replacement of the culvert will be along the existing highway and culvert alignment as shown on Drawing 1. The invert levels of the existing culvert will be maintained for the replacement. It is also understood that the existing Highway 118 grade will be maintained (i.e., there will be no grade raise of the highway) and only minor embankment widenings are currently planned. The construction staging will require the use of a temporary modular bridge on the south side of the highway.

6.2 Foundation Options

The existing culvert is a 6.54 m wide by 2.44 m high, triple-span, non-rigid timber frame, open footing structure with transverse timber cribbing/struts across the bottom which are in-filled with large granular/river rock. The culvert is about 20.0 m in length. The date of construction of the culvert is unknown. It is understood that culvert it is in fair to poor condition. The existing culvert inverts are at about Elevations 369.2 and 368.9 m at the north and south ends, respectively, with flow in the culvert from north to south. The depth of water within the culvert was about 0.8 m at the time of the field investigation. The width of the water course is between about 7 and 8 m at both the inlet and outlet.

The existing pavement grade at the culvert location is at about Elevation 373 m. In this area, Highway 118 is typically one lane wide in each direction (i.e., a two-lane highway). The existing embankment slopes at the culvert locations are about 2 to 3 m in height and are sloped at about 2H:1V. Based on visual observations at the time of Golder's field investigation, the existing embankment and side slopes are in good condition, with no visual evidence of settlement or instability.

Based on the subsurface conditions, only shallow foundation options have been considered for preliminary design for the replacement of the existing Irondale River culvert. It is not considered to be a practical or economical option to support the culvert on deep foundations because the shallow subsoils will provide adequate bearing resistance and settlement performance given that essentially no grade raise is proposed for Highway 118 and only minor widenings of the highway embankment will be required.



PRELIMINARY FOUNDATION REPORT IRONDALE RIVER CULVERT REPLACEMENT - HIGHWAY 118

A summary of the advantages and disadvantages associated with each shallow foundation option is provided below, and a comparison of the alternative foundation options based on advantages, disadvantages, constructability and relative costs is provided in Table 1 following the text of this report.

- **Concrete box culvert founded on the native layered sand to sand and gravel:** A box culvert could be considered for the culvert replacement provided it is founded on or within the compact layered sand to sand and gravel, below the native soils that contain organic matter (i.e., below Elevation 369.0 m). Minimal settlement of the foundations (i.e., less than about 25 mm) is anticipated. The soils at the site are water-bearing, and active dewatering would be required to control the ground and groundwater during excavation and construction of the culvert replacement. It is expected that temporary protection systems and/or cofferdams would be required during excavation and construction.
- **Rigid frame open footing culvert founded on native layered sand to sand and gravel:** A rigid frame open footing culvert could also be considered for the culvert replacement, provided it is founded on the compact native layered sand to sand and gravel. As above, the footings should be founded below the native soils containing organic matter (i.e., below Elevation 369.0 m). Minimal settlement of the foundations (i.e., less than about 25 mm) is anticipated. As noted above, the soils are water-bearing, and active dewatering would be required to control the ground and groundwater during excavation and construction. A temporary protection system and/or cofferdams would be required during excavation and construction.

Based on the above considerations, the preferred option from a geotechnical/foundations perspective is to replace the culvert with a rigid frame open footing culvert founded on the native layered sand to sand and gravel. Several methods of construction were considered as part of the structural assessment, including a precast culvert (open or closed), a precast bebo arch system, and a cast-in-place culvert. Due to the large culvert size required, durability considerations, and associated construction costs, the preferred structural alternative is understood to be a cast-in-place, rigid frame culvert. Alternatively, a combination of cast-in-place footings and a precast culvert section could be considered, as this could expedite the foundation construction and minimize the duration of dewatering operations.

6.3 Culvert Foundation Options

6.3.1 Concrete Box Culvert

6.3.1.1 *Founding Level and Bedding*

It is not necessary to found a box culvert at the standard depth for frost protection purposes as box structures are tolerant of small magnitude movements related to freeze-thaw cycles should these occur. The box culvert should, however, be founded below any existing fill and surficial soils containing organic matter.

The bedding and/or leveling pad requirements for a box culvert replacement should be in accordance with Ontario Provincial Standard Specification (OPSS) 422 (*Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut*) for concrete box culverts. It is recommended that the box culvert segments be placed on a minimum thickness of 300 mm of granular bedding material meeting OPSS 1010 Granular A or Granular B Type II.

The table below summarizes the recommended preliminary founding level for the culvert, assuming a substrate thickness of 400 mm, a bottom slab thickness of 300 mm and bedding thickness as described above. Based on these elevations, the box culvert replacement will be typically founded on the layered sand to sand and gravel.



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Invert Location	Proposed Invert Elevation (m)	Box Culvert Founding Elevation (m)	Subgrade Level (m)
North End	369.2	368.5	368.2
South End	368.9	368.2	367.9

The footing subgrade should be inspected in accordance with OPSS 902 (*Construction Specification for Excavating and Backfilling – Structures*) to check that all existing fill, loose or surficial soils, or other unsuitable materials have been removed. The founding soils will be susceptible to disturbance and should be protected with a concrete working slab (100 mm thick concrete slab with a compressive strength of 20 MPa) if the concrete for the footing is not placed within four hours of the inspection and approval of the subgrade. Further discussion regarding subgrade preparation and protection is provided in Section 6.7.3.

6.3.1.2 Geotechnical Resistances

For a box culvert founded at the elevations provided in Section 6.3.1.1, a factored geotechnical resistance at Ultimate Limit States (ULS) of 300 kPa and a geotechnical resistance at Serviceability Limit States (SLS) for 25 mm of settlement of 200 kPa may be used for preliminary design purposes.

These preliminary geotechnical resistances are provided for loads applied perpendicular to the surface of the footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.7.4 of the *Canadian Highway Bridge Design Code (CHBDC 2006)* and its *Commentary*.

The preliminary geotechnical resistance values provided above will have to be re-evaluated and modified as necessary during detail design.

6.3.2 Rigid Frame Open Footing Culvert

6.3.2.1 Founding Level and Frost Protection Requirements

Strip footings for an open footing culvert replacement, and for any associated concrete wing walls/retaining walls, should be founded on the layered sand to sand and gravel, below any existing fill and surficial soils containing organic matter.

As per Ontario Provincial Standard Drawing (OPSD) 3090.101 (*Foundation Frost Depths for Southern Ontario*), the frost penetration depth in the area is 1.8 m. Therefore, the footings should be provided with a minimum of 1.8 m of earth cover below the lowest surrounding grade to provide adequate protection against frost penetration. The table below summarizes the recommended preliminary founding levels for the culvert.

Invert Location	Proposed Invert Elevation (m)	Open Footing Culvert Founding Elevation (m)
North End	369.2	367.4
South End	368.9	367.1



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The footing subgrade should be inspected in accordance with OPSS 902 (*Construction Specification for Excavating and Backfilling – Structures*) to check that all existing fill, loose or surficial soils, or other unsuitable materials have been removed. The founding soils will be susceptible to disturbance and should be protected with a concrete working slab (100 mm thick concrete slab with a compressive strength of 20 MPa) if the concrete for the footing is not placed within four hours of the inspection and approval of the subgrade. Further discussion regarding subgrade preparation and protection is provided in Section 6.7.3.

6.3.2.2 Geotechnical Resistance

Strip footings placed on the properly prepared subgrade, at the founding elevations identified above, should be designed based on the following preliminary factored geotechnical resistances at ULS and geotechnical resistances at SLS.

Footing Width	Factored Geotechnical Resistance at ULS	Geotechnical Resistance at SLS*
Up to 3.0 m	300 kPa	200 kPa

Note: * For 25 mm of total settlement for the given footing width.

The structural engineer must verify that the selected footing width is sufficient to resist overturning for the design of any retaining walls associated with the culvert replacement. The ULS resistance and settlement are dependent on the footing size, configuration and applied loads; the preliminary geotechnical resistances should, therefore, be reviewed if the selected footing width is greater than 3.0 m or the founding elevation differs significantly from those provided in Section 6.3.2.1.

These preliminary geotechnical resistances are provided for loads applied perpendicular to the surface of the footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.7.4 of the *Canadian Highway Bridge Design Code (CHBDC 2006)* and its *Commentary*.

The preliminary geotechnical resistance values provided above will have to be re-evaluated and modified as necessary during detail design.

6.4 Settlement

It is understood that a minor grade raise (estimated to be up to approximately 0.5 m) is currently proposed for Highway 118 as part of the culvert replacement. In addition, minor widenings less than 2 m wide at the shoulders of both the east and west embankment slopes are proposed temporarily to help facilitate construction staging and to a lesser extent for the final embankment geometry. However, provided the SLS geotechnical resistances for the culvert are limited to the values provided in Section 6.3, the total and differential culvert settlements should be less than about 25 and 15 mm, respectively.

6.5 Culvert Backfill and Erosion Protection

Backfill, cover and construction of the frost taper (backfill transition) for concrete culverts should be completed in accordance with OPSS 422 (*Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut*) or OPSS 902 (*Construction Specification for Excavating and Backfilling – Structures*) as well as OPSD 803.010 (*Backfill and Cover for Concrete Culverts*), as appropriate.



Backfill to culvert walls should consist of granular fill meeting the requirements of OPSS 1010 Granular A or Granular B Type II, but with less than 5 percent passing the No. 200 sieve. The backfill should be placed and compacted in accordance with MTO's Special Provision SP105S21 (*Amendment to OPSS 501*). The fill depth during placement should be maintained equal on both sides of the culvert walls, with one side not exceeding the other by more than 500 mm. The culvert should be designed for the full overburden pressure and live load assuming that the embankment fill has a unit weight of 22 kN/m³ for Granular A and 21 kN/m³ for Granular B Type II or select earth fill above and/or surrounding the culvert.

For a box culvert, to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall should be provided at the upstream and downstream ends of the box culvert replacement.

If the flow velocities are sufficiently high, provision should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert inlet and outlet. The requirements for and design of erosion protection measures for the culvert inlet should be assessed by the hydraulic design engineer. As a minimum, rip-rap treatment for the culvert outlet should be consistent with the standard Treatment Type A presented in OPSD 810.010 (*Rip-Rap Treatment for Sewer and Culvert Outlets*), with the rip-rap placed up to the toe of slope level, in combination with the cut-off measures noted above.

6.6 Embankment Construction and Stability

As mentioned previously, a minor grade raise on the order of 0.5 m may be required at the culvert site. It is also understood that minor widenings of less than 2 m in width at the shoulders of both the east and west embankment slopes are proposed temporarily to help facilitate construction staging and to a lesser extent for the final embankment geometry. In addition, a temporary modular bridge is proposed on the south side of the highway during the staged construction, and embankments up to approximately 2 to 3.5 m in height are anticipated adjacent to the modular bridge.

The subsurface conditions at the location of the proposed culvert replacement consist of embankment fill overlying a layered deposit of compact sand to sand and gravel.

If encountered in the excavation area adjacent to the culvert replacement, any topsoil, organic matter or softened/loosened soils should be stripped from below the approach embankment widenings and reconstruction areas. Such soils should also be stripped from below the footprint of approach embankments for the temporary modular bridge.

Any new embankment fill should be placed and compacted in accordance with MTO's Special Provisions 206S03 (*Earth Excavation, Grading*) and 105S21 (*Amendment to OPSS 501*). Benching of the existing embankment side slopes should be carried out to "key in" the new fill materials for the widening, in accordance with OPSD 208.010. Commonly in embankment widening construction, the fill material cut from the existing embankment side slope for creation of these benches is re-used for the embankment widening below/adjacent to each bench area. Any additional embankment fill needed for construction could consist of clean earth fill, granular fill or rock fill.

If earth fill or granular fill is used, placement of topsoil and seeding or pegged sod is recommended to reduce surface water erosion on the embankment side slopes.



For the soil conditions at the culvert and the existing/proposed embankment heights (up to about 3.0 to 3.5 m), the embankment will have an adequate factor of safety against both static and seismic slope instability (i.e., at or greater than 1.3 and 1.1 under static and seismic conditions, respectively). The side slopes of the embankment should be sloped no steeper than 2H:1V. If rock fill is used the side slopes should be sloped no steeper than 1.25H:1V.

Settlement of the embankment will occur as a result of compression of the new embankment fill placed in the immediate vicinity of the culvert replacement for the temporary widening and minor grade raise, or for the approaches to the temporary modular bridge. Provided that the embankment material consists of Select Subgrade Material or clean earth fill, the settlement of the embankment fill itself is expected to be less than 25 mm. The use of granular fill for the new embankment construction would reduce this magnitude of post-construction settlement (likely to less than half that value) since the majority of settlement of these fills will occur during construction.

If rock fill is used, settlement of the rock fill itself will depend on the type of rock and on the method and sequence of placement and compaction of the fill. Assuming that the rock fill is placed in accordance with the requirements outlined in SP206S03, the settlement of the rock fill in embankments is estimated to be about 1 percent of the embankment height and it is anticipated that the majority of this settlement will occur during the first year following construction.

6.7 Construction Considerations

The following sections identify future construction issues that should be considered during the functional design stage as they may impact the planning and preliminary design.

6.7.1 Excavation and Temporary Protection Systems

Temporary excavations for the culvert replacement are expected to extend to a depth between about 1.5 and 2.5 m below the groundwater/river level (i.e., up to about 5 to 6 m below the existing Highway 118 grade), into the water-bearing, loose to dense layered sand to sand and gravel deposit. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. The existing fill above the water table would be classified as Type 3 soil based on the OHSA. According to OHSA, excavations that extend to, or into, Type 3 soils should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V). The layered sand to sand and gravel below the water table would be classified as Type 4 soil based on OSHA, and excavations in these materials should be sloped no steeper than 3H:1V. However, if active dewatering is used for the sand to sand and gravel soils (i.e., assuming that the groundwater level in the soils is lowered to about 0.5 m below the maximum depth of excavation) these soils may be classified as Type 3, according to OHSA and temporary excavation side slopes could be made at 1H:1V.

If the above open cut excavation side slopes cannot be accommodated, then a temporary protection system (i.e., temporary excavation shoring) will be required. Where shoring is required, the protection system should be designed and constructed in accordance with OPSS 539 (*Temporary Protection Systems*). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS 539.



It is considered that soldier pile and lagging or an interlocking sheetpile system would be feasible at this site. The use of an interlocking sheetpile system has an advantage over soldier pile and lagging in that it would aid in groundwater control at this site, although the presence of cobbles or boulders may impact the depth that sheetpiling can be driven and the effectiveness of the system. The soldier pile and lagging or sheetpiling would be supported against lateral movement using walers, tie backs (into the bedrock) and/or internal struts/braces or socketing into the bedrock.

6.7.2 Groundwater and Surface Water Control

Control of the surface water and groundwater will be necessary for the construction of the replacement culvert, to allow excavation and foundation construction to be carried out in dry conditions.

Depending on the river flow at the time of construction, the surface water flow could be passed through the site by means of a temporary pipe, or diverted by pumping from behind a temporary cofferdam. Surface water should be directed away from the excavation areas, to prevent ponding of water that could result in disturbance and weakening of the subgrade.

The excavation for the culvert replacement will extend into the water-bearing layered sand to sand and gravel deposit. Based on the grading of the deposit as shown on Figure B2 in Appendix B, a well point system could be employed to lower the groundwater level to about 0.5 to 1 m below foundation level. It is anticipated that the use of interlocking sheetpile walls (cofferdams), with dewatering from wells or wellpoints within or outside the cofferdams, will also be appropriate to control the excavation sides and groundwater for foundation excavations. Based on the subsurface soil and groundwater conditions, it is anticipated that the dewatering rate will exceed 50 m³/day, and therefore a Permit to Take Water (PTTW) will be required for this site.

6.7.3 Subgrade Protection

All embankment fill, topsoil, organics, and soft or loose soils should be removed from below the proposed founding elevations and wasted or reused as landscaping fill, as required. Subgrade preparation should be performed and monitored in accordance with OPSS 902 (*Construction Specification for Excavating and Backfilling – Structures*). The cleaned excavation base should be inspected prior to pouring/placement of the footings for the rigid frame open footing culvert or placing granular bedding for the box culvert.

The layered sand to sand and gravel soils that will be exposed at the foundation subgrade level will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that a concrete working slab be placed on the subgrade within four hours after preparation, inspection and approval of the footing subgrade.

6.7.4 Obstructions

The layered sand to sand and gravel contains cobbles and boulders, which could affect the installation of the protection systems. Further observation is recommended in the next stage of investigation in support of the Design-Build.

6.7.5 Temporary Modular Bridge

It is understood that a temporary modular bridge is proposed on the south side of the existing highway embankment as part of the construction staging.



Based on the borehole information from the current foundation investigation, the foundations for the temporary modular bridge should be founded on the native compact layered sand to sand and gravel, below any existing fill and surficial soils containing organic matter. For preliminary design, the foundations on the layered sand to sand and gravel can be designed for a factored geotechnical resistance at ULS of 300 kPa and a geotechnical resistance at SLS (for 25 mm of settlement) of 200 kPa.

However, the preliminary geotechnical resistance values provided above will have to be re-evaluated and modified as necessary during detail design and confirmed with additional boreholes at the location of the temporary modular bridge abutments.

6.8 Recommendations for Further Work in Detail Design

Additional boreholes will be required during the future detail design stage of investigation, to further assess and/or confirm the subsurface conditions and the preliminary recommendations provided in this report, as follows:

- Assessment of the variability of any existing fill and surficial soils to confirm the founding elevations within the culvert replacement area.
- Further assessment of the groundwater level and permeability of the site soils to refine dewatering estimates.
- Observation of the presence of cobbles and/or boulders within the soil deposits, to assess the presence of such obstructions as they may affect excavations and the installation of elements of temporary protection systems.
- Assessment of the existing soil and groundwater conditions at the proposed foundation locations for the temporary modular bridge (i.e., a minimum of one borehole at each abutment location).



PRELIMINARY FOUNDATION REPORT IRONDALE RIVER CULVERT REPLACEMENT - HIGHWAY 118

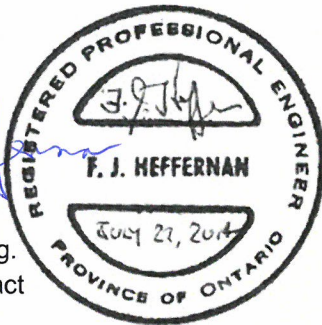
7.0 CLOSURE

This Preliminary Foundation Design Report was prepared by Ms. Susan Trickey, P.Eng. and Mr. Matt Kennedy, P.Eng., and was reviewed by Ms. Lisa Coyne, P.Eng., a Principal and senior geotechnical engineer with Golder. Mr. Fin Heffernan, P.Eng., Golder's Designated MTO Foundations Contact for this project, conducted an independent quality review of the report.

GOLDER ASSOCIATES LTD.

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Lisa Coyne, P.Eng.
Senior Geotechnical Engineer, Principal



WAM/SAT/MJK/LCC/FJH/bg

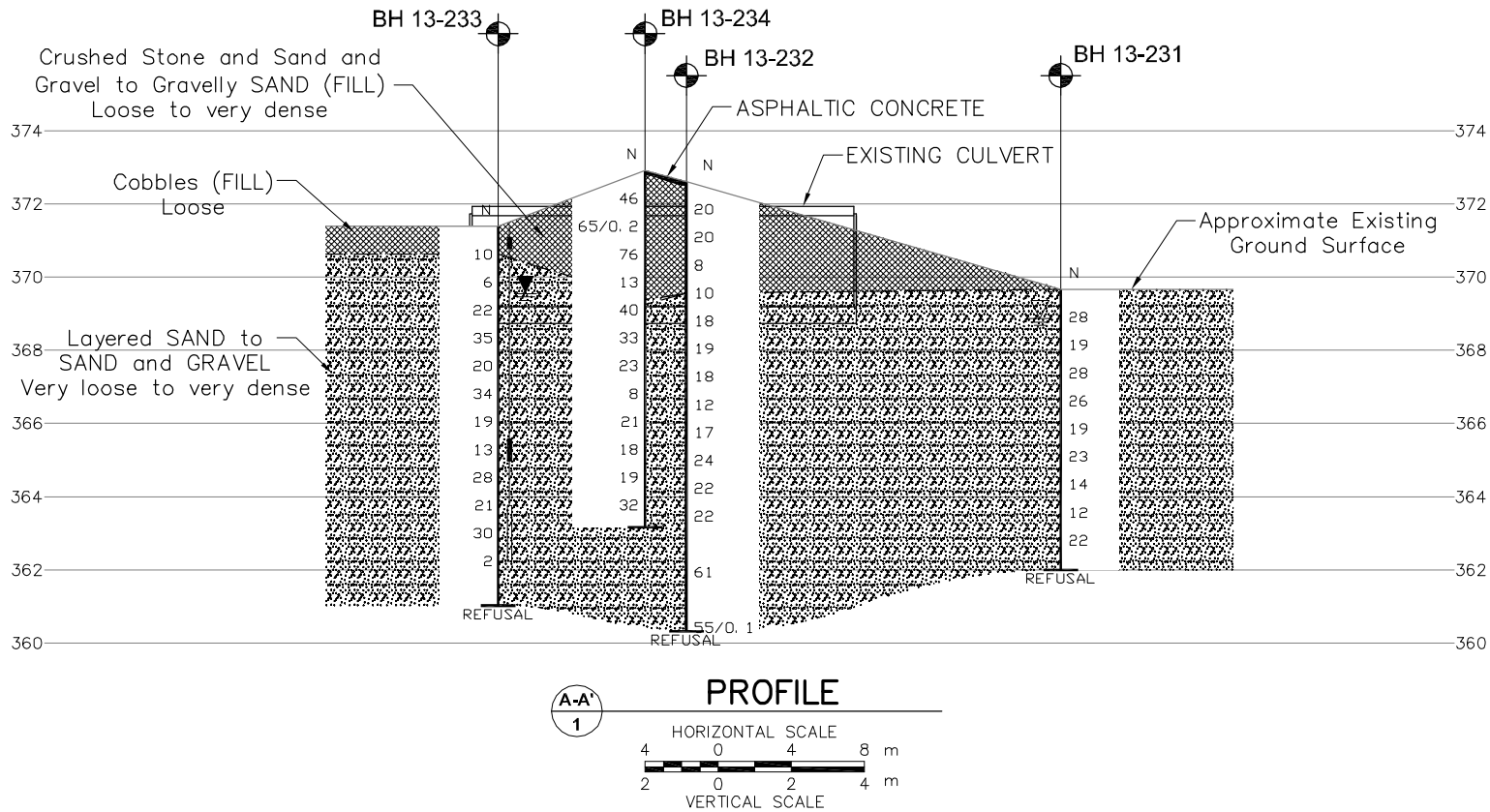
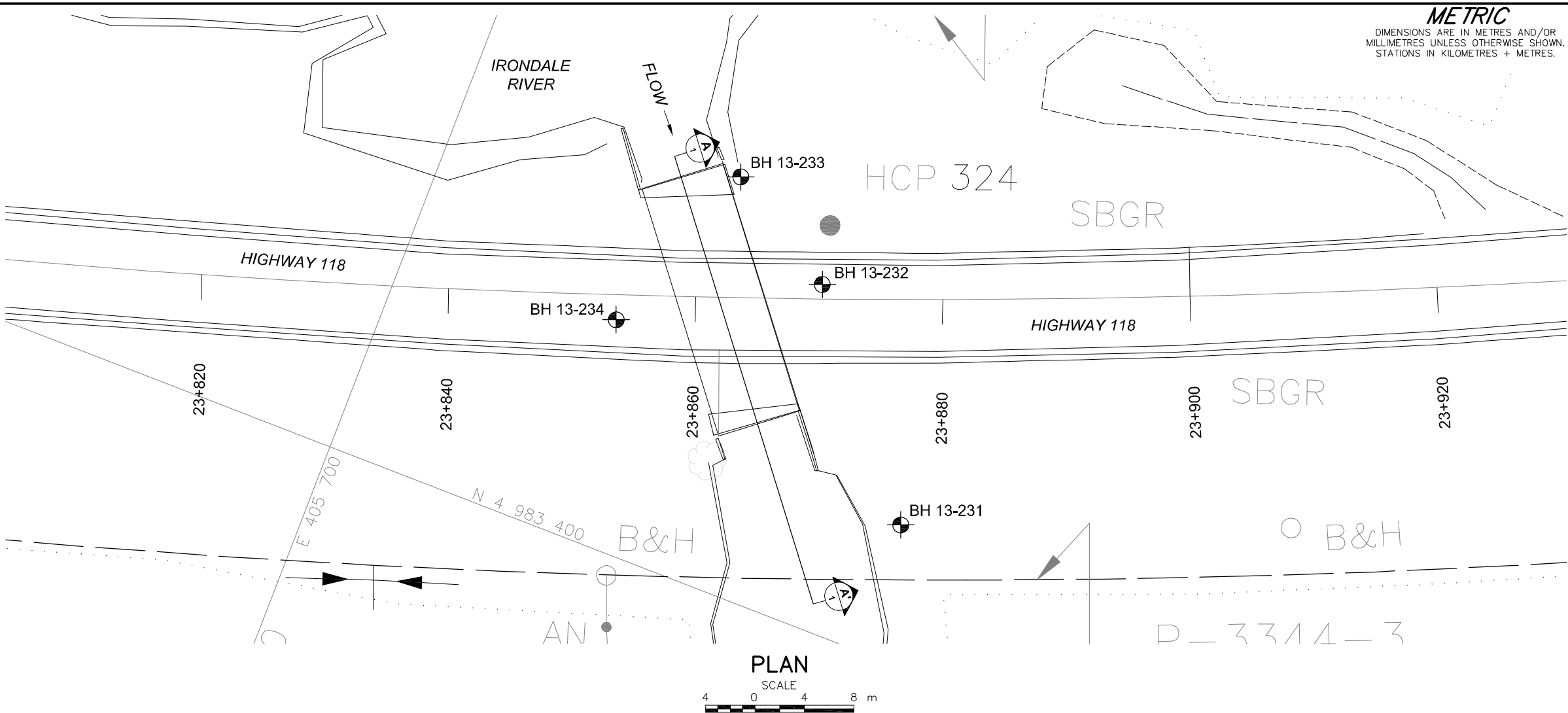
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july 2014.docx



PRELIMINARY FOUNDATION REPORT IRONDALE RIVER CULVERT REPLACEMENT - HIGHWAY 118

Table 1 – Comparison of Foundation Alternatives

Foundation Option	Feasibility	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Box Culvert founded on the layered sand to sand and gravel	<ul style="list-style-type: none">■ Feasible	<ul style="list-style-type: none">■ Shallower excavation depths■ Minimal settlement	<ul style="list-style-type: none">■ Groundwater control/dewatering and a temporary protection system are required	<ul style="list-style-type: none">■ Moderate cost	<ul style="list-style-type: none">■ Moderate risk of instability to existing embankments without appropriate temporary protection and dewatering; provided protection systems and dewatering are in place and meet performance requirements, this becomes a low risk
Rigid Frame Open Footing Culvert founded on the sand to sand and gravel	<ul style="list-style-type: none">■ Feasible, preferred option	<ul style="list-style-type: none">■ Minimal settlement	<ul style="list-style-type: none">■ Deeper excavation depth■ Groundwater control/dewatering and a temporary protection system are required	<ul style="list-style-type: none">■ Moderate cost	<ul style="list-style-type: none">■ Greater risk of instability to existing embankments without appropriate temporary protection and dewatering due to deeper excavation below water table; provided protection systems and dewatering are in place and meet performance requirements, this becomes a low risk



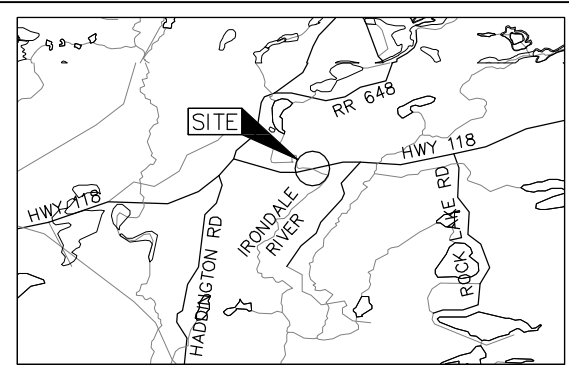
CONT No.
GWP No. 4128-10-01

HIGHWAY 118-CULVERT REPLACEMENT
IRONDALE RIVER
SITE 40-063C
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



Golder Associates Ltd.
OTTAWA, ONTARIO, CANADA



LEGEND

- Borehole - Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation
- WL in piezometer
- WL upon completion of or during drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
12-231	369.7	4983410.8	405745.4
12-232	372.6	4983426.6	405732.4
12-233	371.4	4983432.4	405723.1
12-234	372.9	4983417.9	405717.9

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the design configuration as shown elsewhere in the Preliminary Design Report.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete Preliminary Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by MMM Group Limited, drawing file no. B-PLAN 40-063.dwg, received March 27, 2013.

NO.	DATE	BY	REVISION
Geocres No. 31D-565			
HWY. 118	PROJECT NO. 12-1121-0099-1230		
SUBM'D. SAT	CHKD. FJH	DATE: JUL. 2014	SITE: 40-063C
DRAWN: JM	CHKD. SAT	APPD. FJH	DWG.1





APPENDIX A

Borehole Records

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures, and in the text of the report are as follows:

I. SAMPLE TYPE		III. SOIL DESCRIPTION			
AS	Auger sample	(a) Cohesionless Soils			
BS	Block sample	Density Index (Relative Density)	N		
CS	Chunk sample		Blows/300 mm		
DO or DP	Seamless open-ended, driven or pushed tube samplers		Or Blows/ft.		
DS	Denison type sample		0 to 4		
FS	Foil sample		4 to 10		
RC	Rock core		10 to 30		
SC	Soil core		30 to 50		
SS	Split spoon sampler		over 50		
ST	Slotted tube				
TO	Thin-walled, open				
TP	Thin-walled, piston	(b) Cohesive Soils			
WS	Wash sample	C _u or S _u			
DT	Dual tube sample	Consistency			
DD	Diamond drilling				
II. PENETRATION RESISTANCE			kPa	Psf	
			0 to 12	0 to 250	
			12 to 25	250 to 500	
			25 to 50	500 to 1,000	
			50 to 100	1,000 to 2,000	
			100 to 200	2,000 to 4,000	
Standard Penetration Resistance (SPT), N:		Hard	Over 200	Over 4,000	
The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split spoon sampler for a distance of 300 mm (12 in.).		IV. SOIL TESTS			
Dynamic Cone Penetration Resistance (DCPT); N _d :		w	Water content		
The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive an uncased 50 mm (2 in.) diameter, 60 ⁰ cone attached to “A” size drill rods for a distance of 300 mm (12 in.).		w _p or PL	Plastic limited		
PH:	Sampler advanced by hydraulic pressure	w _l or LL	Liquid limit		
PM:	Sampler advanced by manual pressure	C	Consolidaiton (oedometer) test		
WH:	Sampler advanced by static weight of hammer	CHEM	Chemical analysis (refer to text)		
WR:	Sampler advanced by weight of sampler and rod	CID	Consolidated isotropically drained triaxial test ¹		
Cone Penetration Test (CPT):		CIU	Consolidated isotropically undrained triaxial test with porewater pressure measurement ¹		
An electronic cone penetrometer with a 60 ⁰ conical tip and a projected end area of 10 cm ² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q _t), porewater pressure (u) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.		D _R	Relative density		
		DS	Direct shear test		
		G _s	Specific gravity		
		M	Sieve analysis for particle size		
		MH	Combined sieve and hydrometer (H) analysis		
		MPC	Modified Proctor compaction test		
		SPC	Standard Proctor compaction test		
		OC	Organic content test		
		SO ₄	Concentration of water-soluble sulphates		
		UC	Unconfined compression test		
		UU	Unconsolidated undrained triaxial test		
		V	Field vane test (LV-laboratory vane test)		
		γ	Unit weight		

Note: ¹ Tests which are anisotropically consolidated prior shear are shown as CAD, CAU.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
$\ln x$	natural logarithm of x
$\log_{10} x$ or $\log x$	logarithm of x to base 10
g	acceleration due to gravity
t	time
FOS	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma'$
ϵ	linear strain
ϵ_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial vertical effective overburden stress
$\sigma_1 \sigma_2 \sigma_3$	principal stresses (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3) / 3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) formerly (G_s)
e	void ratio
n	porosity
S	degree of saturation
*	Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_L or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity Index $= (w_L - w_p)$
w_s	shrinkage limit
I_L	liquidity index $= (w - w_p) / I_p$
I_c	consistency index $= (w_L - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (overconsolidated range)
C_s	swelling index
C_α	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	overconsolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

τ_p or τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction $= \tan \delta$
c'	effective cohesion
c_u or s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3) / 2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3) / 2$
q	$(\sigma_1 - \sigma_3) / 2$ or $(\sigma'_1 - \sigma'_3) / 2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes:

$$^1 \tau = c' + \sigma' \tan \phi'$$

$$^2 \text{ shear strength} = (\text{compressive strength}) / 2$$

PROJECT		12-1121-0099-1230		RECORD OF BOREHOLE No 13-231		SHEET 1 OF 1		METRIC																
G.W.P.		4128-10-01		LOCATION		N 4983410.8 ; E 405745.4		ORIGINATED BY																
DIST		Eastern HWY 118		BOREHOLE TYPE		Power Auger 200 mm Diam. (Hollow Stem)		COMPILED BY																
DATUM		Geodetic		DATE		May 14-15, 2013		CHECKED BY																
SAT																								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			ELEVATION SCALE			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES																			
369.7 0.0	GROUND SURFACE SAND, trace gravel Compact Brown to grey																							
368.9 0.8	SAND, some gravel, trace silt, with cobbles Compact Grey Moist to wet		1	SS	28																			
			2	SS	19																			
			3	SS	28																			
			4	SS	26																			
			5	SS	19																			
			6	SS	23																			
			7	SS	14																			
			8	SS	12																			
			9	SS	22																			
362.0 7.7	END OF BOREHOLE AUGER REFUSAL NOTES: 1. Water level in open borehole at a depth of 0.8 m below ground surface (Elev. 368.9 m), measured during drilling.																							

PROJECT 12-1121-0099-1230		RECORD OF BOREHOLE No 13-232		SHEET 1 OF 2		METRIC	
G.W.P. 4128-10-01		LOCATION N 4983426.6 ; E 405732.4		ORIGINATED BY HEC			
DIST Eastern HWY 118		BOREHOLE TYPE Power Auger 200 mm Diam. (Hollow Stem)		COMPILED BY JM			
DATUM Geodetic		DATE May 8, 2013		CHECKED BY SAT			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL LIMIT MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL			
								○ UNCONFINED + FIELD VANE					○								w _p	w	w _L
								● QUICK TRIAXIAL × REMOULDED															
372.6	GROUND SURFACE																						
0.0	ASPHALTIC CONCRETE																						
372.2	Crushed stone (FILL) Grey																						
0.4	Gravelly sand, with cobbles (FILL) Compact to loose Brown Moist																						
			1	SS	20												35	56	8	1			
			2	SS	20																		
			3	SS	8																		
369.5																							
3.1	SAND and GRAVEL, with cobbles Compact Brown, grey and grey-brown Moist to wet		4	SS	10																		
			5	SS	18													46	49	5	0		
			6	SS	19																		
			7	SS	18														48	48	4	0	
			8	SS	12														54	41	5	0	
			9	SS	17																		
			10	SS	24																		
			11	SS	22														40	55	5	0	
			12	SS	22																		

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

GTA-MTO 001 1211210099.GPJ GAL-GTA.GDT 01/07/14 JM

PROJECT		RECORD OF BOREHOLE No 13-232				SHEET 2 OF 2		METRIC									
12-1121-0099-1230																	
G.W.P. 4128-10-01		LOCATION N 4983426.6 ;E 405732.4				ORIGINATED BY HEC											
DIST Eastern HWY 118		BOREHOLE TYPE Power Auger 200 mm Diam. (Hollow Stem)				COMPILED BY JM											
DATUM Geodetic		DATE May 8, 2013				CHECKED BY SAT											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100					
361.9	SAND and GRAVEL, with cobbles Compact Brown, grey and grey-brown Moist to wet						362										
10.7	SAND, some gravel, trace silt, with cobbles and boulders Compact to very dense Grey-brown Wet		13	SS	61												24 71 5 0
							361										
360.3			14	SS	55/0.1												
12.3	END OF BOREHOLE AUGER REFUSAL																

GTA-MTO 001 1211210099.GPJ GAL-GTA.GDT 01/07/14 JM

PROJECT <u>12-1121-0099-1230</u>		RECORD OF BOREHOLE No 13-233		SHEET 1 OF 2		METRIC	
G.W.P. <u>4128-10-01</u>		LOCATION <u>N 4983432.4 ; E 405723.1</u>		ORIGINATED BY <u>HEC</u>			
DIST <u>Eastern</u> HWY <u>118</u>		BOREHOLE TYPE <u>Power Auger 200 mm Diam. (Hollow Stem)</u>		COMPILED BY <u>JM</u>			
DATUM <u>Geodetic</u>		DATE <u>May 13-14, 2013</u>		CHECKED BY <u>SAT</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W _p	W	W _L		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× REMOULDED						
371.4	GROUND SURFACE						20	40	60	80	100						
0.0	Cobbles, some sand (FILL) Loose Brown Moist																
370.6																	
0.8	SAND and GRAVEL, trace silt Loose to compact Brown Moist to wet		1	SS	10												
			2	SS	6												
			3	SS	22												
			4	SS	35												
367.9																	
3.5	SAND, trace to some gravel, trace silt, with cobbles Compact to dense Brown to grey-brown Wet		5	SS	20												
			6	SS	34												
			7	SS	19												
			8	SS	13												
			9	SS	28												
364.1																	
7.3	SAND and GRAVEL, trace silt, with cobbles Compact Brown Wet		10	SS	21												
363.2																	
8.2	SAND, trace gravel and silt, with cobbles and boulders Compact Brown Wet		11	SS	30												
362.3																	
9.1	SAND, trace silt Very loose Brown Wet		12	SS	2												

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

GTA-MTO 001 1211210099.GPJ GAL-GTA.GDT 01/07/14 JM

PROJECT		RECORD OF BOREHOLE No 13-233				SHEET 2 OF 2		METRIC								
G.W.P. 12-1121-0099-1230		LOCATION N 4983432.4 ; E 405723.1				ORIGINATED BY HEC										
DIST Eastern HWY 118		BOREHOLE TYPE Power Auger 200 mm Diam. (Hollow Stem)				COMPILED BY JM										
DATUM Geodetic		DATE May 13-14, 2013				CHECKED BY SAT										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
	--- CONTINUED FROM PREVIOUS PAGE ---						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100					WATER CONTENT (%) 25 50 75				
361.0	END OF BOREHOLE AUGER REFUSAL															
10.4	NOTES: 1. Water level in well screen at a depth of 1.8 m below ground surface (Elev. 369.6 m), measured on June 3, 2013.															

PROJECT 12-1121-0099-1230		RECORD OF BOREHOLE No 13-234		SHEET 1 OF 1		METRIC	
G.W.P. 4128-10-01		LOCATION N 4983417.9 ; E 405717.9		ORIGINATED BY HEC			
DIST Eastern HWY 118		BOREHOLE TYPE Power Auger 200 mm Diam. (Hollow Stem)		COMPILED BY JM			
DATUM Geodetic		DATE May 9, 2013		CHECKED BY SAT			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL LIMIT MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								20 40 60 80 100					w _p w w _L				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED									
372.9	GROUND SURFACE																
0.0	ASPHALTIC CONCRETE																
0.1	Crushed stone (FILL)																
372.5	Grey																
0.4	Sand and gravel, trace silt, with cobbles and boulders (FILL) Compact to very dense Brown Moist to wet																
			1	SS	46											43 51 5 1	
			2	SS	65/0.2												
			3	SS	76											49 43 7 1	
			4	SS	13												
369.4																	
3.7	Silty SAND, trace gravel, with organic matter Compact Brown Moist to wet																
			5	SS	40											55 37 7 1	
368.6	Sandy GRAVEL, trace silt, with organic matter and silty sand seams Dense Grey Wet																
4.3			6	SS	33											43 49 7 1	
	SAND and GRAVEL, trace silt, with cobbles Dense Brown to grey Wet																
367.6			7	SS	23												
5.3	SAND, some gravel, trace silt Compact to loose Grey Wet																
			8	SS	8											18 77 4 1	
			9	SS	21												
365.7	SAND, trace to some gravel, trace silt, with cobbles and boulders Compact Brown Wet																
7.2			10	SS	18												
			11	SS	19												
			12	SS	32											11 84 4 1	
363.2	END OF BOREHOLE																
9.8																	

GTA-MTO 001 1211210099.GPJ GAL-GTA.GDT 01/07/14 JM

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE



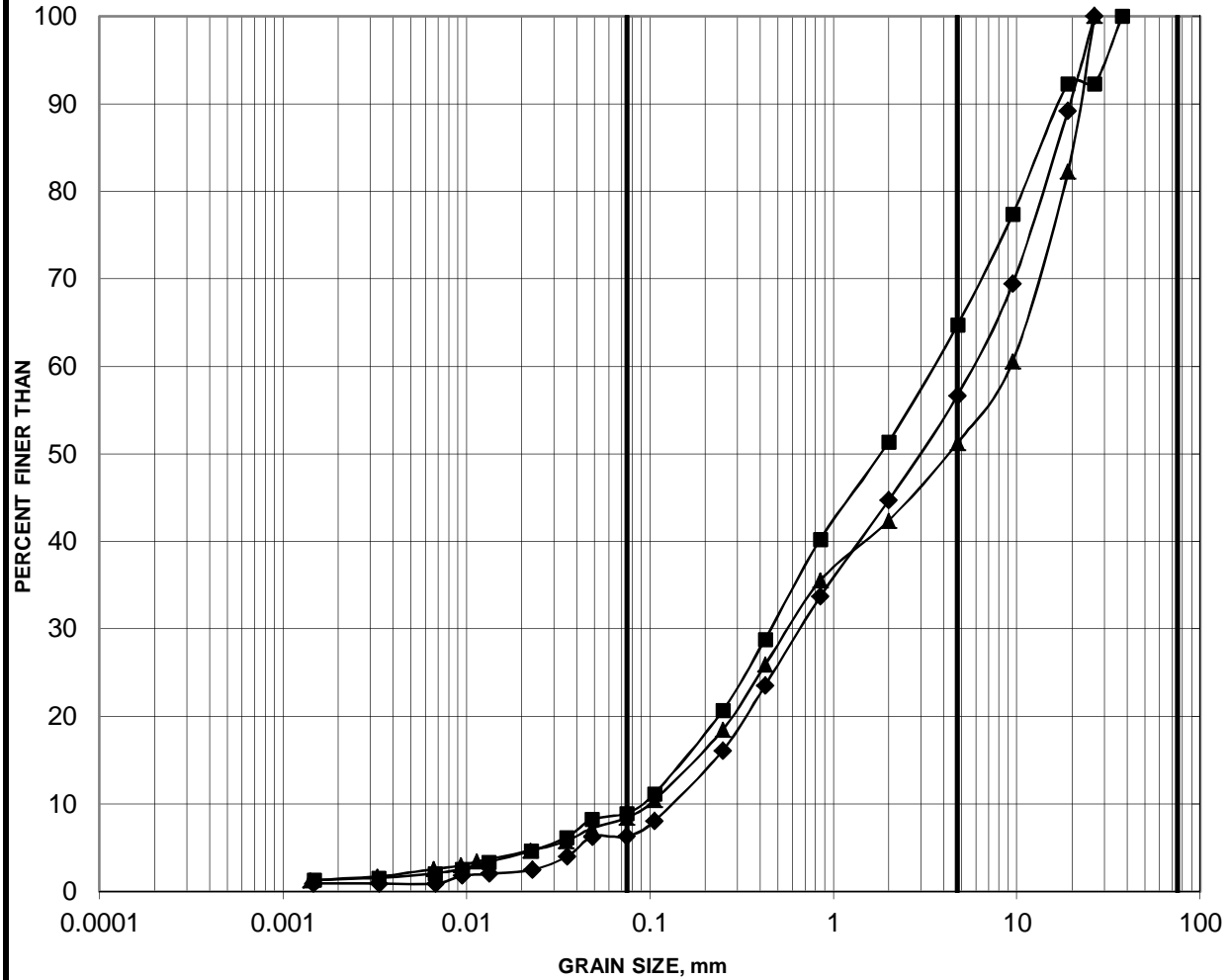
APPENDIX B

Laboratory Test Results

GRAIN SIZE DISTRIBUTION

FIGURE B1

EMBANKMENT FILL



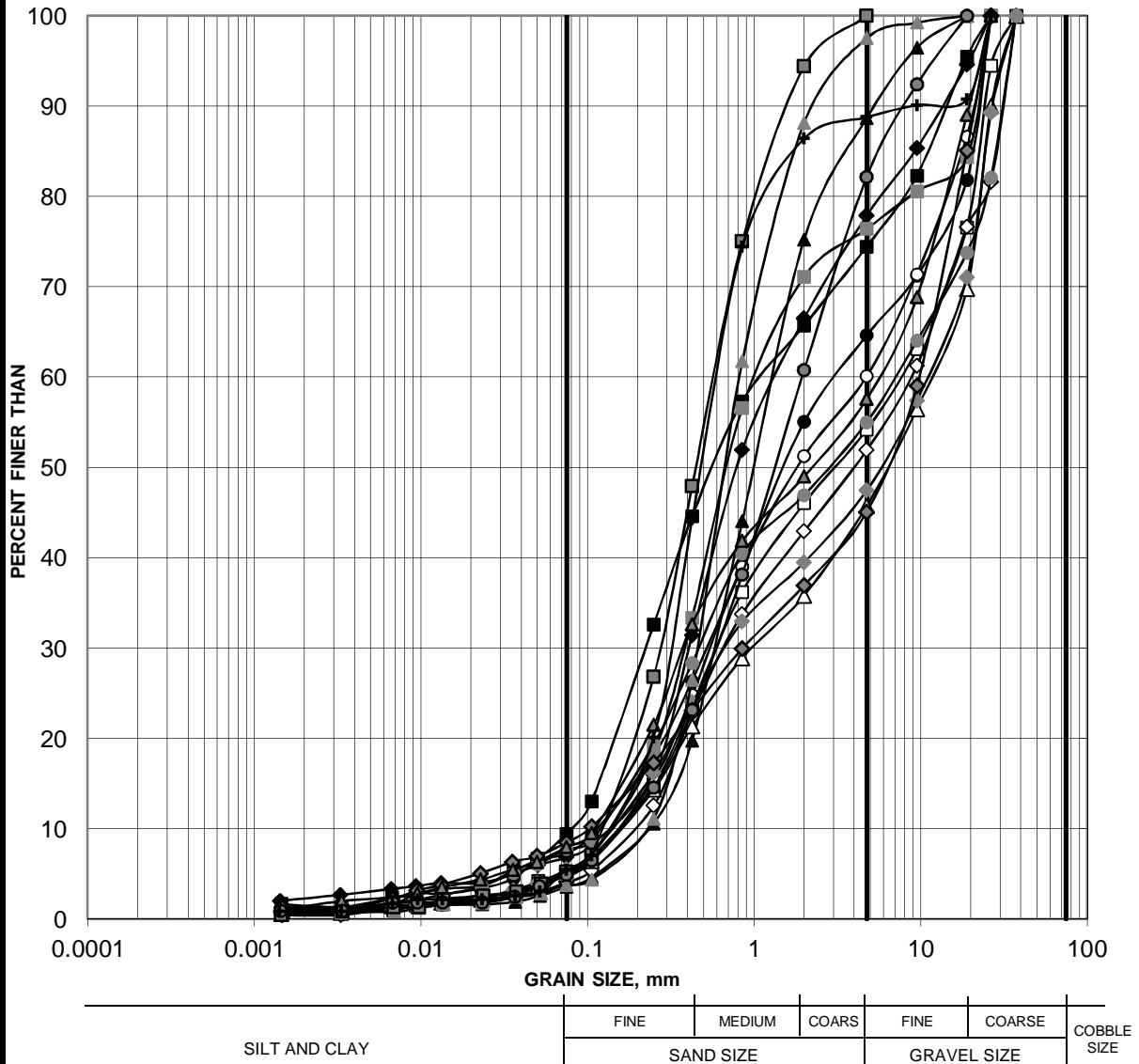
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
13-232	1	0.76-1.37
13-234	1	0.76-1.37
13-234	3	2.29-2.90

GRAIN SIZE DISTRIBUTION

FIGURE B2

Layered SAND to SAND and GRAVEL



Borehole	Sample	Depth (m)
13-231	1	1.52-2.13
13-231	3	2.29-2.90
13-231	5	3.81-4.42
13-231	9	6.86-7.47
13-232	5	3.81-4.42
13-232	7	5.34-5.95
13-232	8	6.10-6.71
13-232	11	8.38-8.99
13-232	13	10.67-11.11
13-233	3	2.29-2.90
13-233	5	3.81-4.42
13-233	10	7.62-8.23
13-233	12	9.15-9.76
13-234	5	3.81-4.42
13-234	6	4.57-5.18
13-234	8	6.10-6.71
13-234	12	9.15-9.76

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