Region of Peel

Addendum to Environmental Study Report

Improvements to Bovaird Drive, from Lake Louise Drive/Worthington Avenue to 1.45 km west of Heritage Road in the City of Brampton

May 2015

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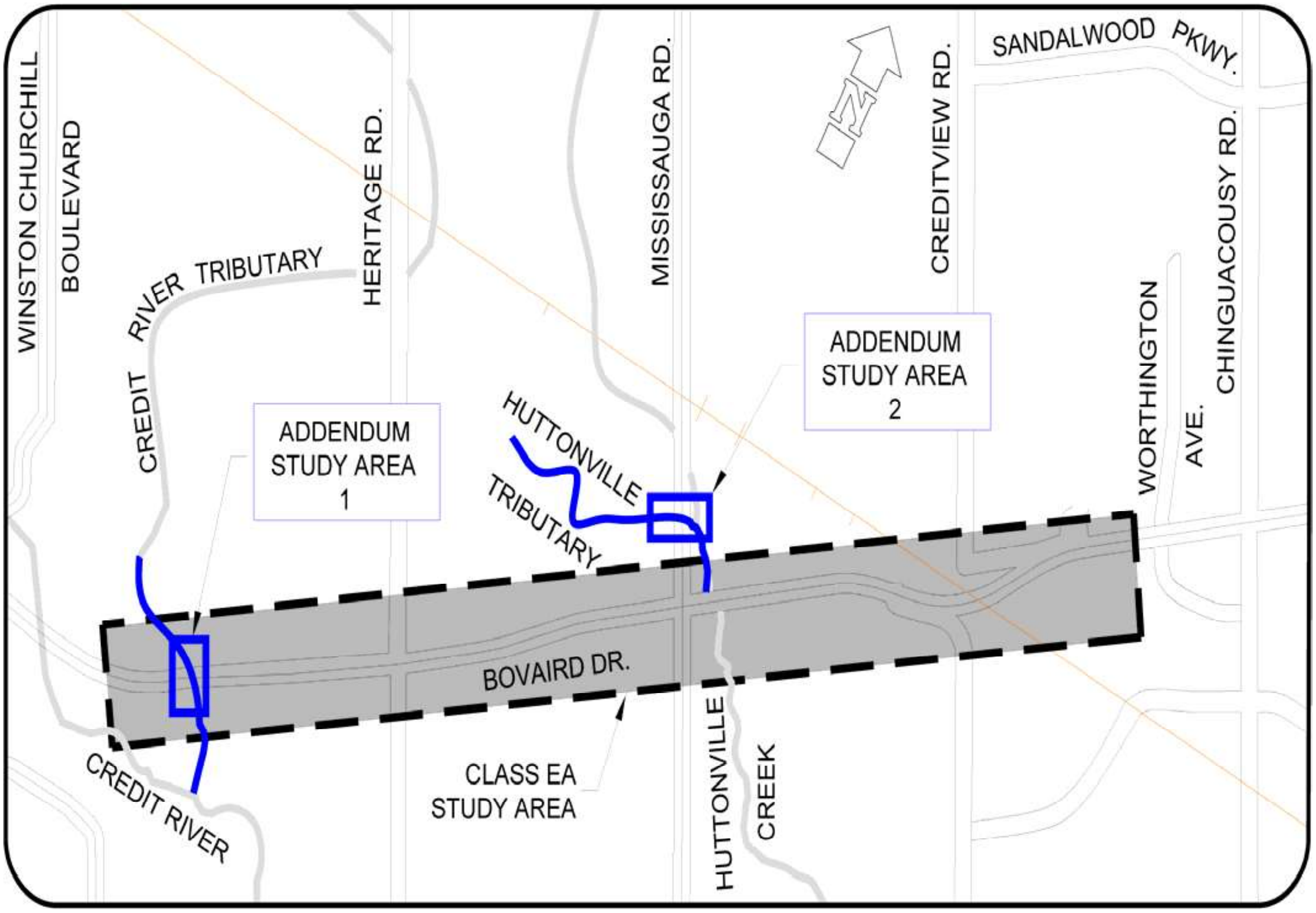


ENVIRONMENTAL STUDY REPORT ADDENDUM

1. Introduction

Since the completion of the Bovaird Drive Class Environmental Assessment (EA) in April 2013, implementation of the recommended improvements has commenced, through a variety of different projects. However, a number of site-specific issues at two culvert crossings have been identified which result in changes to the recommendations made in the Environmental Study Report. These recommended changes, and the assessment process leading to the recommended changes, will be addressed by this Addendum.

To differentiate between the two locations, the Credit River Tributary crossing of Bovaird Drive is designated as Study Area 1 and the Huttonville Creek Tributary crossing of Mississauga Road is designated at Study Area 2 (ref. Key Plan). This addendum outlines the background to each location as defined in the original ESR document, a summary of the investigations completed since the completion of the Class EA, an assessment of alternatives for each location, and the revised recommendations. This addendum has been completed in accordance with the requirements of the Municipal Class Environmental Assessment, Oct 2000, as amended 2007 & 2011.

2. Background

Bovaird Drive (Regional Road 107) is an important roadway link and a major east-west arterial roadway in the City of Brampton. The section of Bovaird Drive from Mississauga Road to the western limit of the study area is rural and the roadway currently has two core lanes, with an eastbound truck climbing lane leaving Norval.

Mississauga Road north of Bovaird Drive is a two lane north-south arterial roadway in the City of Brampton. The road is currently configured as a rural road, with open ditches on either side of the roadway. At this location, Mississauga Road is scheduled to be widened to 4-lanes in the near future, and ultimately widened to 6-lanes.

The Class EA examined the need and feasibility for widening and improvements on Bovaird Drive to address short term and long term issues related to planned future growth, operational, geometric, capacity and storm drainage deficiencies.

The preferred planning alternative developed for the Bovaird Drive corridor is Alternative 6: A combination of Alternatives 3 to 5:

3. Transit service improvements;
4. Travel Demand Management; and
5. Widen Bovaird Drive with intersection improvements to increase capacity.

3. Class EA Recommendations

Various design options were prepared and assessed by the Class EA study team. Based on input provided by stakeholders including representatives of the new developments, technical agencies, and public participants, as well as based on a formal assessment by the study team, a preliminary design was prepared to address the preferred planning alternative.

At the crossing of the Credit River Tributary of Bovaird Drive (Study Area 1), roadway improvements were not required to address the identified planning alternatives. However, the culvert was identified as a barrier to fish passage, a constraint for fluvial geomorphological variables, and insufficiently sized for the Regional Storm event. The inlet portion of the culvert was also identified to be structurally deficient. It was recommended that further study of the culvert be conducted by the Region of Peel through a separate project, due to the long time frames associated with development within the Heritage Heights Community, the pending recommendations of the Heritage Heights Subwatershed Study, and that the culvert had limited overtopping potential due to the deep valley system.

The crossing of the Huttonville Creek Tributary of Mississauga Road (Study Area 2) is situated within a section of the roadway that is to be widened. Widening will occur in two stages; first on an interim basis to four (4) lanes and again to six (6) lanes. As no environmental concerns were identified at this location during the Class EA, the existing culvert was recommended to be extended in either direction to accommodate the interim and ultimate conditions.

4. Progress Since Completion of Class EA

Since the filing of the Class EA for Bovaird Drive, a number of small projects have commenced to fulfill the recommendations made by the ESR. However, some concerns have been identified which were not fully addressed by the Class EA, as follows:

Study Area 1

The detailed design for the culvert commenced in October 2013, with a focus on repair and remediation of the existing culvert and improving fish passage through the drainage area.

Within the existing culvert, there are several gradient changes ranging from 0.1 % to 42%, where the downstream section of culvert has an average grade of 2.1 % and the upstream section of culvert has an average gradient of 7.3%. To maintain the elevation of the culvert inlet and to provide improved fish passage through the new culvert, a 4 m gradient drop would be required in the upstream section of channel. To create this gradient drop would require significant channel realignment upstream of the culvert to maintain a 2% slope in the system. This alternative would require riparian vegetation removal and access to private property for an extended duration.

Study Area 2

During the Class EA, the detailed design for the 4-lane widening of Mississauga Road had commenced. Widening for the 4-lane widening would require work within the Huttonville Creek floodplain along the east side of Mississauga Road. The Class EA recommended that the ultimate 6-lane widening be completed to the west of Mississauga Road, and no further widening be completed to the east.

There is an existing 1200mm diameter corrugated steel pipe culvert crossing under Mississauga Road which is located approximately 200m north of the intersection of Bovaird Drive and Mississauga Road. With both the interim and ultimate configuration, it was identified this culvert would require extensions to either side to provide for the widened road platform. Both the Class EA and interim 4-lane widening proceeded on this basis.

Subsequent to the completion of the Class EA for Bovaird Drive, the Ministry of Natural Resorces and Forestry (MNRF) identified that this Mississauga Road drainage feature provides contributing habitat for Redside Dace, which is listed as “Endangered” under Endangered Species Act. As a result, the crossing is subject to Endangered Species Act ESA 17(2)(c) permitting requirements. Other factors identified to require further study included hydraulic conveyance, fluvial geomorphology, and integration with future development.

As part of the Mississauga Road interim 4-lane widening project identified above, the culvert has been under review by the relevant regulatory agencies including MNRF and CVC. Regular correspondence has been completed from October 2014 to March 2015 to review specific details of the proposed culvert. The conclusions drawn from this addendum do not preclude the ongoing discussions with these agencies.

5. Addendum

Given the scale of the issues identified above, concern over the impact of the proposed work on both private lands and the natural environment was expressed by various parties. To address these concerns, it was determined that an addendum to the Class EA should be completed.

To confirm the need of an addendum, the Ministry of Environment and Climate Change (MOECC) was contacted on September 18, 2014. The need for an addendum document was confirmed by Amanda Graham, Environmental Assessment Coordinator for the MOECC on September 19, 2014.

6. Stakeholder and Agency Consultation

Notice of Addendum

A Notice of Addendum (ref. Appendix ‘A’), detailing the study areas and a brief description of the proposed work, was submitted to relevant stakeholders, property owners, and organizations by mail and e-mail in October 2014.

Region of Peel departmental staff, agency staff, and stakeholders who actively participated in consultation include the following individuals:

Dan Bennington	Region of Peel
David Melton	Region of Peel
Liam Marray	Credit Valley Conservation
Jakub Kilis	Credit Valley Conservation
Amanda Graham	Ministry of Environment and Climate Change
Mark Heaton	Ministry of Natural Resources and Forestry
Melinda Thompson	Ministry of Natural Resources and Forestry
Cindy Latendresse	Department of Fisheries and Oceans

Notice of Filing Addendum

All parties having expressed an interest in the project have been notified by letter regarding completion of the Addendum. Copies of the Addendum were made available at the following locations:

Region of Peel, Clerk's Department
10 Peel Centre Drive
5th Floor, Suite A
Brampton, ON L6T 4B9
Phone: 905.791.7800 ext. 4526

City of Brampton, Clerk's Department
2 Wellington Street West, 1st Floor
Brampton, ON L6Y 4R2
Phone: 905.874.2101

City of Brampton Public Library
Cyril Clark Branch
20 Loafers Lake Lane
Brampton, ON L6Z 1X9
Phone: 905.793.INFO(4636)
Mon. - Thurs. 10:00 a.m. – 9:00 p.m.
Fri. 10:00 a.m. – 6:00 p.m. Sat. 10:00 a.m. – 5:00 p.m.
Sun. 1:00 p.m. – 5:00 p.m.

A review period of not less than thirty (30) days will be provided, during which comments will be received from stakeholders and agencies. Should stakeholders raise issues that cannot be resolved through discussions with Region of Peel and Consultant staff, the stakeholder may request the Minister to require the Region of Peel to complete an individual EA in accordance with Part II of the EA Act. This is known as a "Part II Order" (formerly known as a 'Bump-up'). However, it is anticipated that all concerns will be resolved through discussion between the Region of Peel and the concerned party.

7. Site Investigations

As part of the Addendum study, a review of each study area was completed. The investigations were completed, as a supplement to previous studies completed for the Class EA, for the following factors relevant to the proposed undertaking:

Study Area 1

Fish and Fish Habitat

From anecdotal correspondence with local landowners and from video footage, large-bodied migratory fish were observed within the pool immediately downstream of the culvert. These fish were unsuccessful in passing through the culvert. Approximately 50 m downstream of the culvert, a remnant concrete structure is present within the watercourse which causes additional passage difficulty to small bodied fish. Large bodied fish are able to enter the culvert outlet, but not successfully pass through the culvert. Small bodied fish are likely present at the culvert outlet pool, however, a 0.6m drop at the culvert outlet prevents small bodied fish passage. MNRF have also electrofished downstream of the culvert, and have confirmed the presence of Rainbow Trout, Coho Salmon, and other salmon species within the tributary.

Fluvial Geomorphology

A geomorphic assessment and preliminary design was completed by Parish Geomorphic (ref. Appendix 'B'). From a geomorphic perspective, it is evident that the existing culvert is inadequately sized to effectively convey flows and permit efficient sediment transport leading to issues related to excessive scour and fish passage. Ideally, the proposed structure should be wider to enable more natural channel functions. The width of the structure would be at least 3x the channel width, which has been shown to reduce any long-term implications to the creek and structure. Based on the geomorphic assessment of the watercourse, an ultimate crossing structure size of 12m is recommended for the existing watercourse. The ultimate configuration would consist of a structure which would provide adequate space for natural channel processes to operate while also accommodating minor channel adjustments and improved fish passage.

The ultimate crossing structure would reduce channel design limitations allowing for the development of natural channel design that addresses flow conveyance issues and fish passage concerns, ultimately improving habitat availability and geomorphic stability within the watercourse. The complete removal of the existing culvert would provide adequate area to re-establish/maintain the existing grade and planform of the channel while also allowing for the incorporation of natural channel features. Since the complete removal of the existing culvert is currently not feasible, alternative options were determined and are discussed in subsequent sections of this report.

Geotechnical Engineering

A Foundation Investigation Report was completed (ref. Appendix ‘C’). The removal of the culvert is proposed to be carried out by open-cut excavation, along with the removal of the old highway 7 embankment. An open-channel with stable sideslopes (approximately perpendicular to Bovaird Drive) may be built within the length of the existing culvert to be removed. The road embankment (Bovaird Drive) over the new inlet, i.e., the north end of the existing culvert underneath Bovaird Drive, will be excavated and new stable sideslope constructed.

Based on the soil profile observed at the borehole locations and the rehabilitation works being considered, the founding strata for the headwalls/retaining walls/wingwalls will be hard silty clay/ clayey silt till and/or very dense weathered shale, which will provide adequate support for structures.

To replace the slope removed for construction of the culvert, a slope of 2H:1V on the north side of Bovaird Drive is required. The loose soil should be replaced and/or compacted properly during the construction of the slope, and a minimum 2 m wide bench should be provided as per OPSD 202.010.

Hydrogeological Study

A hydrogeological study was completed by Amec Foster Wheeler (ref. Appendix ‘D’). The hydrogeological information and investigation for the Site consisted of a desk-top study of available information from government records and geotechnical reports completed in the study area. Information was also gathered from drilling boreholes at 4 locations and installing monitors at two of these locations. Single well response tests were completed to estimate the hydraulic conductivity of the saturated materials in the immediate vicinity of the culvert. The data was incorporated into a generic conceptual model and analyzed using Visual Modflow. Using this conceptual model, it is predicted that the maximum rate of dewatering of groundwater that may be expected will be less than 50 m^3/d. Consequently, a Permit to Take Water (PTTW) is deemed to be unnecessary.

Stage II Archaeological Assessment

The Stage 1 assessment (AMEC 2012) indicated that the current study area had archaeological potential due to their proximity to: 1) 29 previously registered archaeological sites within a 2-km radius; 2) a tributary of the Credit River; 3) a historic transportation route (Bovaird Drive West); and 4) one historic structure as shown in the Tremaine’s Map of 1859 and the Illustrated Historical Atlas of 1877. As a result, a Stage 2 archaeological assessment was conducted of the study area (ref. Appendix ‘E’ Stage 2 Archaeological Assessment).

A comprehensive test pit survey was conducted at five-metre intervals, and nothing of cultural heritage value or interest was encountered. In light of these results, no further archaeological assessment is required for the study area.

The reporting and recommendations identified above were submitted to the Ministry of Tourism, Culture, and Sport (MTCS). The MTCS accepted the report and recommendations on August 8, 2014.

Stormwater Management

The existing 1.20m span x 2.8m high x 104.8m +/- long box culvert with an internal drop conveys flow from a 466 ha drainage area under Bovaird Drive. Due to structural deficiencies at the north end of the culvert, the Region of Peel has recommended removal of the culvert upstream of the internal drop. The Class EA recommended that this culvert be ultimately replaced with a 12 m span x 2 m span to convey the Regional Storm peak flow of 48.3 cubic metres per second (cms). The Class EA also recommended that the replacement culvert sizing and timing be determined within another study subsequent to the completion of the Heritage Heights Subwatershed Study. The Heritage Heights Subwatershed Study is not slated to be complete until at least late 2015, with development to commence in 2023. Based on the long time frame for development and immediate need to provide a structurally sound culvert, the Region of Peel is recommending removal of the north end of the culvert upstream of the internal drop and construction of an interim extension culvert and associated creek works. The interim culvert extension is being recommended as it would eliminate the need for an interim retaining wall on the north side of Bovaird Drive. The creek works are being recommended to address the lower upstream culvert invert after elimination of the internal drop.

The recommended interim culvert would continue to convey the 100 year peak flow of 16.40 cms with a freeboard of 6.95 m. During the Regional Storm spill to the west along the adjacent driveway and then to Bovaird Drive would occur with a peak flow of 17.49 cms, matching the existing Regional Storm spill to Bovaird Drive. Regional Storm flood elevations for recommended culvert and creek works would be the same as existing elevations.

Structural Engineering

The Structural Inspection Report completed for the Class EA noted that the north portion of the existing culvert under old Highway 7 is structurally deficient. The culvert has deteriorated further since the completion of the Class EA in 2010, and action is required to remediate the poor structural condition of the north barrel of the existing culvert.

Utilities

A subsurface utility engineering (SUE) report was completed by T2 Utility Engineers. A copy of the report is included in Appendix ‘F’. Utilities identified within the study area include Hydro One Brampton, Bell, Union Gas, and storm sewer. Of these, only Hydro One Brampton was found to be in conflict with the proposed culvert work. Relocation of the poles in conflict has been completed.

Study Area 2

Fish and Fish Habitat

During site visits, a number of small fish were observed in and around the culvert. It is anticipated that the expansion of the culvert to a larger span will improve fish habitat, and will better support the Redside Dace found within the larger Huttonville Creek watershed system immediately downstream. A fish community is not present upstream of the Mississauga Road crossing.

Fluvial Geomorphology

The existing 1200mm dia. corrugated steel pipe currently drains to a parallel channel immediately west of Huttonville Creek. With the construction of the proposed road widening, including a retaining wall along the east side of Mississauga Road, the parallel channel will be eliminated. Through discussions with MNRF and CVC, the loss of the parallel channel will be compensated for with a short channel (including a pool and riffle sequence) from the location of the outlet of the culvert to a point a short distance downstream.

Geotechnical Engineering

A geotechnical engineering study has been completed for the study area. The soil profile for the study area generally consists of topsoil, fill soils (silty sand, sand and gravel, silty clay and/or clayey silt), very stiff to hard native silty clay / clayey silt till, followed by weathered shale. Based on the soil profiles observed at the borehole locations, shallow foundations (i.e., spread/strip footings or mat foundations) are feasible to support the structures being considered (i.e., precast concrete arch structures). Shallow foundations should be founded on the very stiff to hard silty clay / clayey silt till or weathered shale.

Hydrogeological Study

Groundwater elevation data indicates that the static groundwater level is 1.5 to 2.3 m below ground surface at an elevation of about 233.0 to 233.8 m. The underside of the proposed footings are designed to be completed in the clayey silt till at an elevation of 233.9 m, or just above the water table. In addition, the hydraulic conductivity of the clayey silt till into which the excavation is proposed is estimated to be less than 1 x 10-7 m/s. Consequently no groundwater dewatering is expected to be necessary for the replacement of the culvert across Mississauga Road. Should the static water level in the silty clay till be above the base of the footings excavations, the low hydraulic conductivity of the saturated soil supports the conclusion that no PTTW would be required for dewatering.

Stage II Archaeological Assessment

The Stage 1 assessment (AMEC 2012) indicated that there is no archaeological potential at study area 2. As a result, a Stage II Archaeological Assessment is not required.

Stormwater Management

The culvert has been recommended to be increased in size from a 1200mm diameter corrugated steel pipe to a 3.2m span x 1.5m high precast arch culvert to meet the requirements of the fluvial geomorphology. This culvert will convey the Regional Storm event, with no overtopping.

Structural Engineering

The existing structure has some corrosion along the invert of the culvert. Replacement of the structure is recommended.

Utilities

A subsurface utility engineering (SUE) report will be completed by T2 Utility Engineers. Utilities identified within the study area include Enbridge Gas and a number of sanitary and watermains (both existing and planned for future). The recommendations made by the SUE investigation will be implemented in the detailed design phase.

8. Assessment of Alternatives

Based on the information collected for both the Class EA and the subsequent studies, an assessment of alternatives for each study area was completed using the following categories:

- Natural Environment – including vegetation, wildlife habitat, surface water, fisheries, and fluvial geomorphology
- Social, Cultural, and Economic Impact – including archaeology and cultural heritage resources, access considerations, utilities, construction disruptions, safety, and travel delay/traffic capacity
- Planning – including incremental capital cost and compatibility with Regional and City plans and policies

A copy of the assessment table for each study area is included in Appendix ‘G’. A summary of each assessment is provided below.

Study Area 1

Do Nothing – Maintain Existing Culvert with Existing Roadway Width
Option 1 – Remove a Portion of the Existing Culvert (north barrel) and Partially Replace with a Cast-in-Place Structure with the same Cross-Section as the Remaining Portion of the Culvert
Option 2 – Implement Option 1, With a Maximum 4% Slope from the Culvert Extension to the Existing Creek
Option 3 – Remove North Portion of the Culvert and Install Permanent Retaining Wall

Based on the review of the various categories, Option 1 – Remove a Portion of the Existing Culvert (north barrel) and Partially Replace with a Cast-in-Place Structure with the same Cross-Section as the Remaining Portion of the Culvert was selected as the preferred alternative.

Study Area 2

Do Nothing – Maintain Existing Culvert with Existing Road Width
Option 1 – Extend Existing 1200mm dia. Corrugated Steel Pipe to Accommodate the Proposed Road Widening
Option 2 – Replace Existing 1200mm dia. Corrugated Steel Pipe with a 3.2m span x 1.5m high Precast Arch Culvert

Based on the review of the various categories, Option 2 - Replace Existing 1200mm dia. corrugated steel pipe with a 3.2m span x 1.5m high Precast Arch Culvert was selected as the preferred alternative.

9. Description of Recommended Design

Based on the site investigation, assessment of alternatives, and design completed to date, the recommendations made by the Bovaird Drive Class EA are revised as follows:

Study Area 1

- Removal of 39m of the existing culvert (north barrel)
- Extend south barrel 20m north (without grade drop)
- Installation of fish baffles within the culvert to improve passage for local large-bodied fish
- Installation of temporary shoring
- Reconstruction of the upstream portion of the creek for approximately 65m
- Relocation of one (1) hydro pole
- Temporary staging of Bovaird Drive (reduce to one lane in each direction)
- Construction of temporary access roads into the valley
- Construction from July 1st to March 31st (warm water in-stream work window)
- Monitoring program for 5 years post-construction

Study Area 2

- Replace the existing culvert with a 1.2m x 3.2m precast open-footing culvert
- Provide a connection to the existing channel to meet the requirements for Redside Dace Habitat
- In-Water construction from July 1st to September 15th (Redside Dace window)

A plan view depicting the preliminary recommendation for each study area is attached.

APPENDIX ‘A’

NOTICE OF STUDY COMMENCEMENT

Region of Peel
Working for you

Public Notice

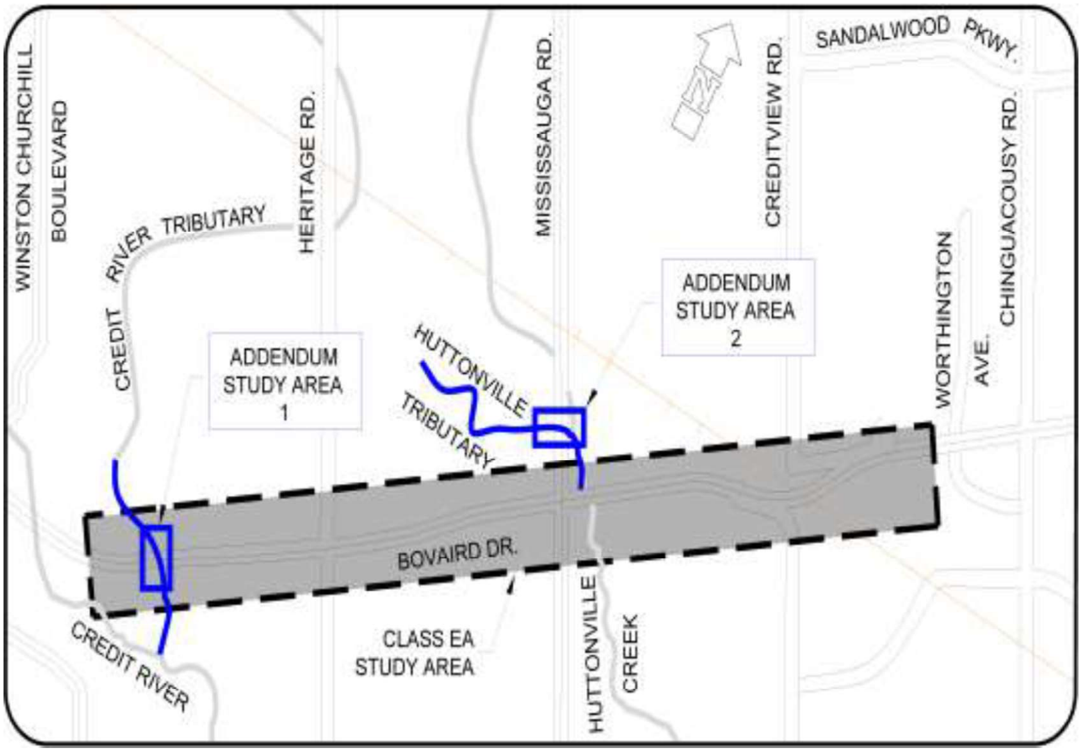
Notice of Addendum

BOVAIRD DRIVE (R.R. 107) FROM LAKE LOUISE DRIVE/WORTHINGTON AVENUE TO 1.45 KM WEST OF HERITAGE ROAD

In 2013 the Region of Peel completed a Municipal Class Environmental Assessment (Class EA) study for Improvements to Bovaird Drive, from Lake Louise Drive/Worthington Avenue to 1.45 km west of Heritage Road in the City of Brampton (study area is shown on the map). Among other objectives, the Class EA identified the need to improve short and long term issues related to planned future growth, operational, geometric, capacity and storm drainage deficiencies.

The Project

AMEC Environment & Infrastructure has been retained by the Region of Peel to undertake an Addendum to revise the recommendations made in the Environmental Study Report (ESR) for the crossing of the Credit River Tributary of Bovaird Drive (Study Area 1) and the crossing of a Huttonville Creek Tributary of Mississauga Road (Study Area 2). It is anticipated that the proposed work will include rehabilitation / replacement of the crossings, including channel work on the upstream and downstream sides of the culverts.



The Process

This study will be undertaken as an addendum to the 2013 ESR. The Study will follow the approved process of the MEA Municipal Class Environmental Assessment, October 2000, as amended in 2007 & 2011. The addendum will document the need and justification for the culvert remediations and channel work, and detail the changes to the 2013 ESR. A Notice of Filing Addendum will be provided upon completion of the study, and the Addendum will be placed on public record for a review period of 30 days. Subject to comments received, the Region of Peel intends to proceed with the construction phase of this project.

If you have any comments or questions regarding the study, please contact either of the following:

Mr. Dan Bennington, C.E.T.
Project Manager, Roads – Design and Construction
Transportation, Public Works, Region of Peel
10 Peel Centre Drive, Suite B, 4th Floor
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Phone: 905.791.7800 ext 7811; Fax: 905.791.1442
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David Sinke, P. Eng.
Consultant Project Manager
AMEC Environment & Infrastructure
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Peel	10 Peel Centre Drive, Suite B, 4th Floor	Brampton, ON L6T 4B9			david.melton@peelregion.ca
nd nada	3027 Harvester Road, Unit 304	Burlington, ON L7R 4K3	Cindy will direct the notice to the appropriate person.	905-639-8687	cindy.latendresse@dfo-mpo.gc.ca
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APPENDIX ‘B’

GEOMORPHIC ASSESSMENT

DRAFT REPORT

Credit River Tributary at Bovaird Drive:
Geomorphic Assessment and Preliminary Design

February 20, 2015

Ref: 01-13-74

PARISH geomorphic

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Document Title:	Credit River Tributary at Bovaird Drive: Geomorphic Assessment and Preliminary Design
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Version:	05
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Project name:	Credit Tributary at Bovaird
Project number:	01-13-74
Client:	AMEC Environment & Infrastructure
Reference:	01-13-74 DRAFT

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1. Introduction

The deteriorating conditions of an existing culvert located along Bovaird Drive in the Municipality of Brampton, has raised concerns over its performance and safety. The existing culvert was constructed in two phases with the original being constructed of brick and currently in poor condition requiring removal or replacement. Parish Geomorphic Ltd. (PGL) was retained by AMEC Environment and Infrastructure to conduct a geomorphic assessment of the watercourse which is being conveyed through this culvert, an unnamed tributary to the Credit River. The assessment was completed in order to provide fluvial geomorphological input on the tributary's condition to assist with the development of design options for the rehabilitation of the existing culvert.

1.1 Study Area

The culvert being examined resides along one of the many tributaries of the Credit River. The culvert is located along Bovaird Drive, between Winston Churchill Boulevard to the west and Heritage Road to the east (**Figure 1.1**). The unnamed tributary drains into the Credit River approximately 320m downstream of the Bovaird Drive culvert. The surrounding area consists primarily of low lying agricultural land with a small urban area, Norval, located to the west. According to subwatersheds defined by the Credit Valley Conservation authority, the tributary flows within the Norval to Port Credit subwatershed of the Credit River which drains into Lake Ontario at Port Credit.

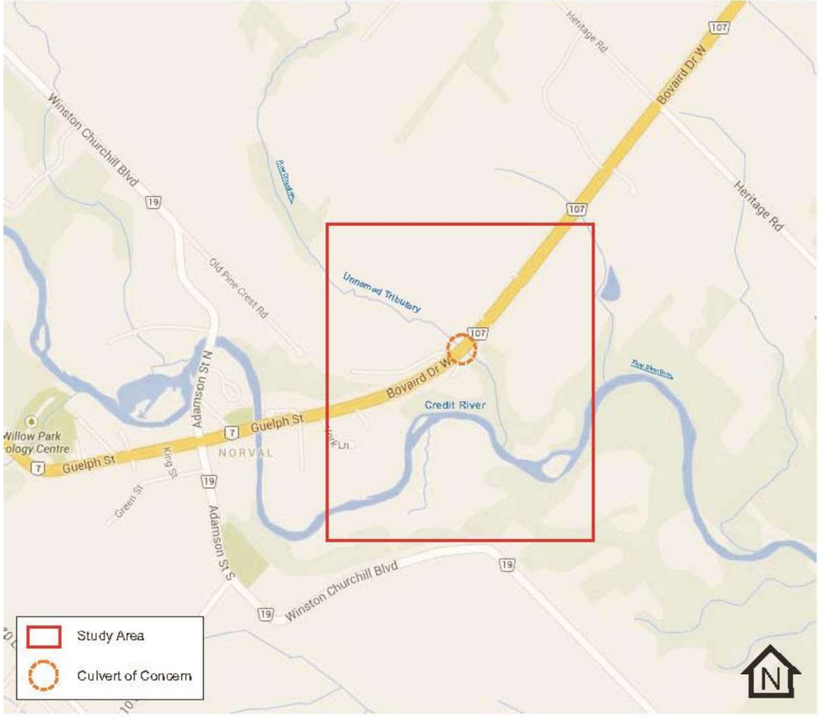

Figure 1.1: Location of study area and culvert of concern.

1.2 Aims and Objectives

The purpose of this geomorphic investigation is to assess the existing conditions of the unnamed tributary upstream and downstream of the culvert. Based on the desktop analysis and detailed field investigations, an understanding of the geomorphic condition and dominant physical processes operating within the watercourse will be determined. With an understanding of the existing issues within the channel and factors influencing the channel form and function, a channel design that will enhance the geomorphic condition of the watercourse will be developed. In order to achieve this objective, the following work plan was undertaken:

- Collect and review any pertinent background information, such as topographic mapping, historical aerial photographs and any previous reports that would pertain to this watercourse;
- Using available mapping and digital ortho imagery, confirm channel reach boundaries;
- Based on historical aerial photographs and digital ortho imagery, delineate an appropriate meander belt width on a reach basis;
- Complete rapid field reconnaissance to assess the existing geomorphic condition, document any existing issues within the watercourse and confirm desktop results;
- Conduct detailed field survey to determine the existing bankfull dimensions, planform and profile;
- Analyze field data to investigate the hydraulic condition of the channel and to determine the appropriate design dimensions;
- Based on the data collected, a channel design that addresses the issues identified and enhances the geomorphic condition in the vicinity of the culvert is developed.

2. Desktop Analysis

2.1 Background Review

A brief data review has been undertaken to provide background information on the unnamed tributary and the condition of the existing culvert. The review of previous studies provides baseline data on which the current study can build upon ensuring the proper understanding of the geomorphic processes operating within the channel. The background review will also provide insight on the issues surrounding the existing culvert.

Bovaird Drive Class EA: Stream Crossing Geomorphological Assessment – Parish Geomorphic Ltd. 2012

A fluvial geomorphological assessment of the Unnamed Tributary and the existing culvert was conducted by PGL (2012) as part of a larger scale Environmental Assessment which characterized the streams and crossings along Bovaird drive. The study included a historical assessment (using historical mapping and aerial photographs from 1974, 1989 and 2009), reach delineation, meander belt width assessment, rapid field reconnaissance and a risk-based assessment of the watercourse crossing to highlight key management considerations (**Table 2.1**).

The study delineated two reaches along the unnamed tributary, one extending upstream of Bovaird Drive (BV-A1) and the other downstream (BV-A2). Reach BV-A1 was determined to be stable or 'In Regime' with evidence of planform adjustment being noted. A bankfull width of 6m was measured and a final meander belt width of 48m was determined. Reach BV-A2 was determined to be in a state of transition with widening as the most prominent form of adjustment. A bankfull width of 8.5m was recorded and a final meander belt width of 16m was delineated. Available historic aerial photography was not extensive enough to provide an accurate measure of the 100-year migration rates.

The existing crossing structure was determined to be a 1.20m (w) x 2.80m (h) closed bottom, pre-cast concrete box culvert described as being intact but experiencing heavy erosion at the downstream end resulting in the formation of a scour pool (approximately 0.6m deep). The culvert does not take into account the channel width or the meander belt width leading to flow conveyance issues upstream and scouring downstream. The scouring downstream has left culvert perched and has brought forth concerns regarding the culverts suitability for fish passage.

Using a risk-based approach, a recommended structure size for the culvert of concern was determined from a geomorphic perspective (**Table 2.2**). Based on the meander amplitude measured upstream of the crossing, a preliminary structure size of 10 m was identified. An examination of the channel size and rapid assessment results, in particular the RGA scores which identified widening and planform adjustment as the dominant modes of adjustment, a 2 m factor of safety was applied. The result is a recommended span of 12 m, which is sufficient to support the long-term form and function of the channel and minimize risk to the crossing structure from fluvial processes.

Table 2.1: Summarizes conditions recorded in the Geomorphic Crossing Assessment conducted by PGL (2012).

Crossing and Photograph	Description	RGA / RSAT	Management Considerations
	**Structure** • Pre-cast concrete box culvert, closed bottom, • Dimensions: 1.20m (w) x 2.80m (h) x 65m (l) • Condition : Culvert intact but heavily eroded around the structure downstream where a scour pool has developed (0.6m deep). **Overall stream character** : • US – defined channel in ravine setting with evidence of widening and good pool-riffle sequencing. • DS – geomorphologically active, widening, channel degrading into bedrock. Valley wall contact in ravine setting • Riparian zone 100m, deciduous forest. **Issues / Disturbance:** • Channel width > Opening • Major pooling and erosion downstream • Culvert perched • Concerns regarding fish passage	**BV-A1** **RGA:** In regime **RSAT:** Moderate habitat quality **BV-A2** **RGA:** Transitional **RSAT:** Moderate habitat quality	• Culvert currently does not take into account channel width or the meander belt width and is causing major pooling and erosion downstream. • Key opportunity for improvement through culvert widening and regrading. Some rehabilitation work likely to be required. • Improvement of fish passage.

Table 2.2: Previously determined geomorphic parameters and recommended structure size for the culvert crossing of concern (Parish, 2012).

Reach	Preliminary Meander Belt Width (m)	100-Year Migration Rates (Risk)	Meander Amplitude (m)	Bankfull Width (m)	Valley Setting	RGA Score (Risk)	Recommended Structure Size (m)
BV-A1 Upstream	40	N/A	10*	6.0 At crossing	Unconfined	0.19 In Regime (low)	12.0 m
BV-A2 Downstream	14	N/A	--	8.5 At crossing	Partially Confined	0.36 Transitional/Stresses (moderate)	

* Governing meander amplitude in vicinity of the crossing

2.2 Geology

Based on geological maps made available by the Ontario Geologic Survey (OGS), a description of the geology encompassing the study area was conducted. The headwaters of the Unnamed Tributary to the Credit River begin within the South Slope Physiographic Region located north of the study area. The majority of the watercourse flows within the Peel Plain Physiographic Region which is characterized by till comprised of silt to clayey silt materials. The underlying bedrock consists of red shale of the Queenston Formation. The surficial geology, like most of the Peel Plain, is comprised of primarily of glacial till. The presence of a coarse textured glaciolacustrine deposit has been noted near the downstream end of the Unnamed Tributary, near its confluence with the Credit River.

2.3 Historical Assessment

Building on the investigations completed in previous studies (Parish, 2012), a historical assessment of the study area was undertaken using available historic mapping of Brampton (1942, 1960, 1976 and 1980), aerial photographs (1974, 1989 and 2002) and a 2009 orthophoto encompassing the study area. Although historical aerial photos were examined, few included the desired watercourse. The resolution of historical airphotos and presence of dense vegetation within the valley further restricted investigation into natural channel planform adjustments and 100-year migration rates could not be accurately assessed.

Landuse within the study area has remained predominantly rural with scattered dwellings being present since 1942. Few residential dwellings were present in Norval to the west of the study area in 1942 and increased in number by 1960. The dominant landuse surrounding the study area continues to be rural. Examination of historical maps displays varying channel alignments which were determined to be a result of the accuracy of mapping surveys. Historical channel modifications tend to be common in rural areas, but based on the current and previous historical assessment of the existing watercourse, no evidence of channelization or realignment was detected.

2.4 Reach Delineation

Reaches are defined as lengths of channel that display similar physical characteristics and have a setting that remains nearly constant along their length. Thus, in a reach, the controlling and modifying influences on the channel are similar, and are reflected in similar geomorphological form, function and processes within the reach. Reaches delineated in the Bovaird Geomorphic Crossing Assessment (Parish, 2012) were defined based on a desk top assessment of characteristics including sinuosity, valley setting, gradient, and tributary confluence locations identified using aerial photography, topographic mapping and drainage network maps. Two reaches were previously delineated (BV-A1 and BV-A2) within the current study area (**Figure 2.4**). The previously delineated reaches were deemed to be appropriate and were therefore used for this study.

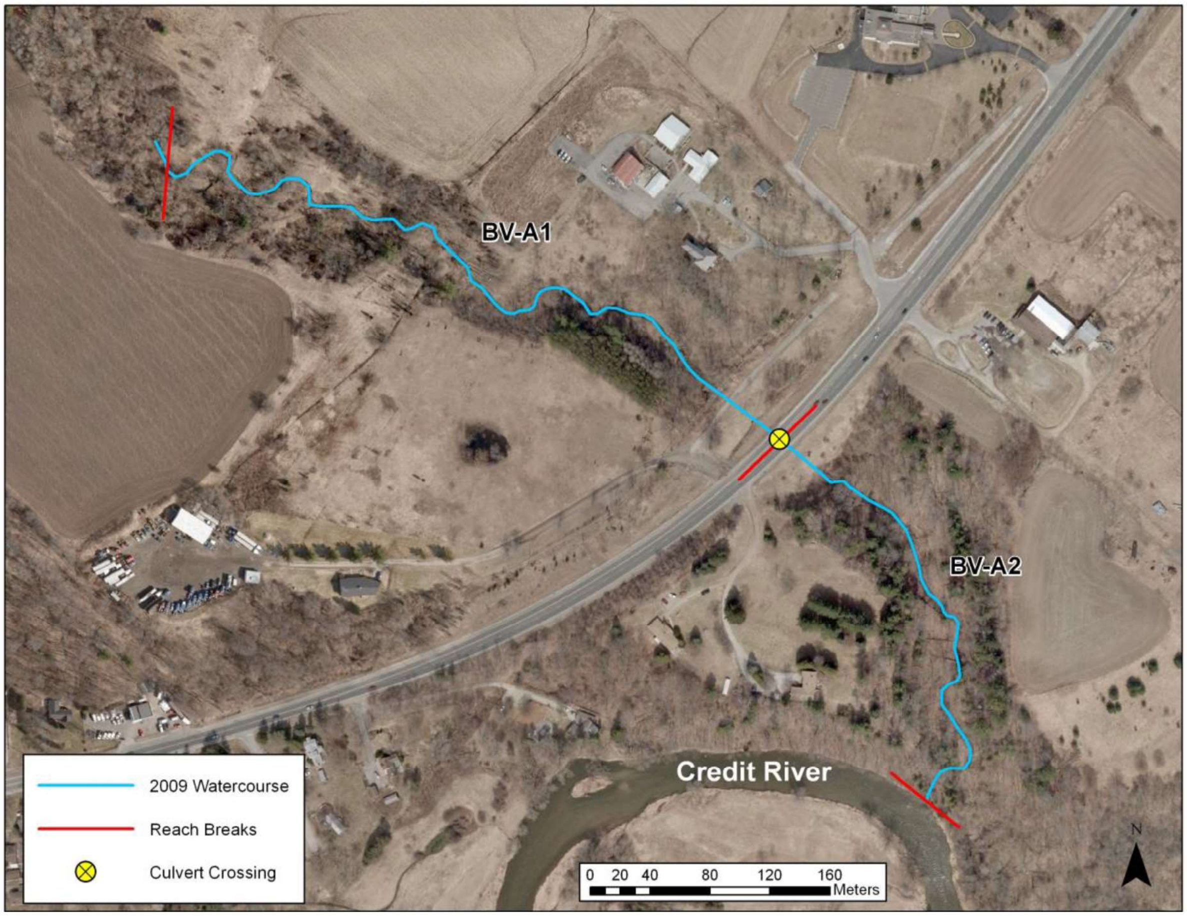

Figure 2.4: Delineated reaches within the study area.

2.5 Meander Belt Width

Streams and rivers are dynamic features that change their configuration and position within a floodplain by means of meander evolution, development and migration processes. When meanders change shape and position, the associated erosion and deposition that enables these changes to occur can cause loss or damage to private property and infrastructure. For this reason, when development or other activities are contemplated near a watercourse, it is desirable to designate a corridor that is intended to contain all of the natural meander and migration tendencies of the channel. Outside of this corridor, it is assumed that private property and structures will be safe from the erosion potential of the watercourse. The space that a meandering watercourse occupies on its floodplain, within which all associated natural channel processes occur, is commonly referred to as the meander belt.

The previous geomorphic crossing assessment (Parish, 2012) determined a meander belt width for both Reaches BV-A1 and BV-A2. For the purpose of this study, a desktop analysis was completed to reconfirm the

meander belt width that was previously determined for each. For this analysis, process-based methodology for determining the meander belt width was undertaken based on background information, historic data, degree of valley confinement and channel planform (Parish, 2004).

Reach BV-A1's previously delineated meander belt width was determined to be appropriate for this particular reach. The preliminary meander belt width for BV-A1 measured 40m. For Reach BV-A2, the previously delineated meander belt width of 14m was determined to be inadequate. An updated meander belt width was designated based on the governing meander amplitude. The updated meander belt width for BV-A2 extended 20m (a 6m extension from the previously delineated belt width). The downstream reach, BV-A2, has a narrower meander belt width than BV-A1 as it is straighter and more confined than the upstream reach. Since no migration rate analysis could be conducted for either reach, a 20% factor of safety was added to each preliminary meander belt width in order to define the final meander belt width. Reach BV-A1 and BV-A2 had a final meander belt width of 48m and 24m, respectively (**Figure 2.5**).

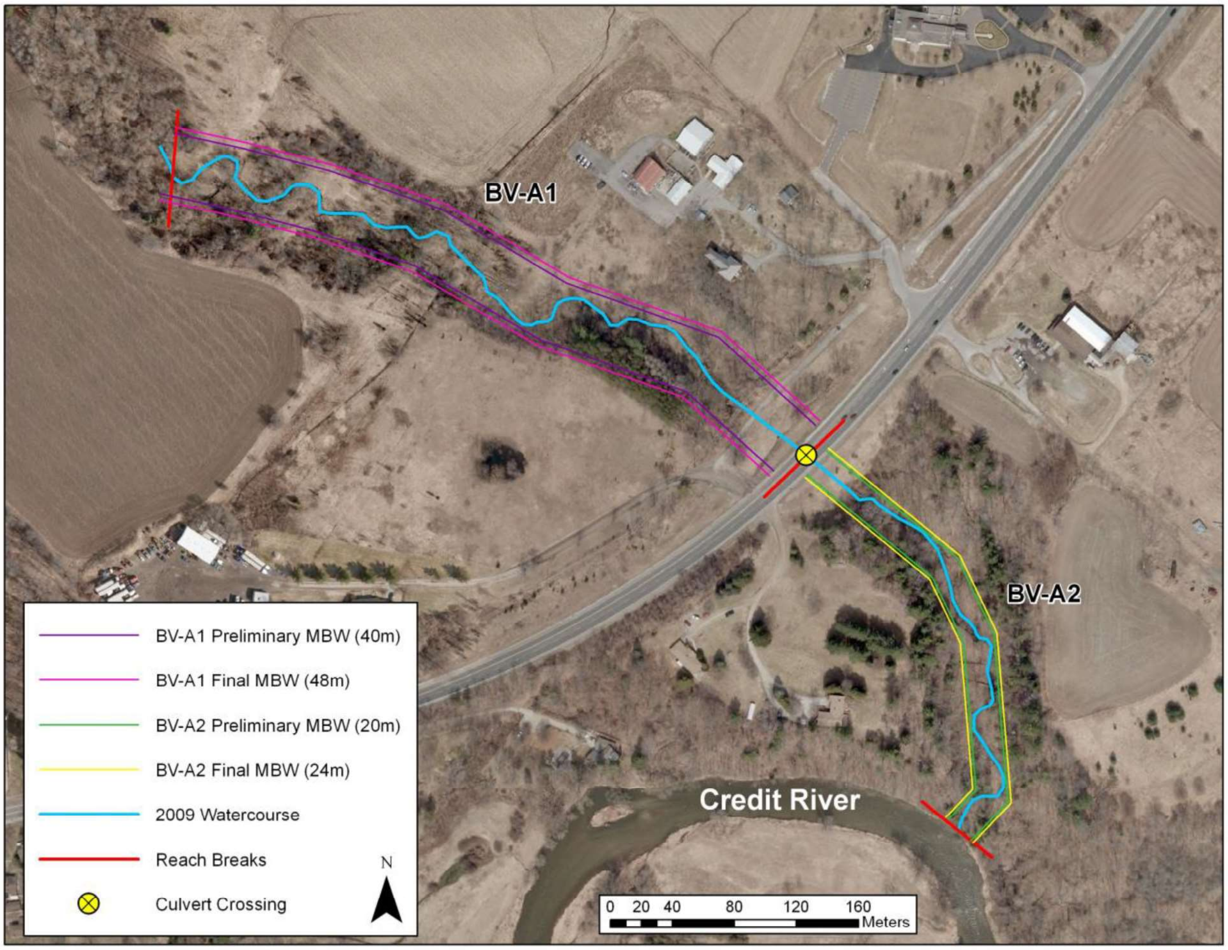

Figure 2.5: Delineated meander belt width for reaches BV-A1 and BV-A2.

3. Field Investigations

3.1 Rapid Field Assessment

In order to assess existing geomorphic conditions and document any evidence of channel instability, a field reconnaissance survey was conducted along both delineated reaches according to two rapid assessment protocols – Rapid Geomorphic Assessment and Rapid Stream Assessment Technique. A Rapid Geomorphic Assessment (RGA) documents observed indicators of channel instability (MOE, 1999). Observations are quantified using an index that identifies channel sensitivity based on evidence of aggradation, degradation, channel widening and planimetric adjustment. The index produces values that indicate whether the channel is stable/in regime (score <0.20), stressed/transitional (score 0.21-0.40) or adjusting (score >0.41). A summary of the 2013 RGA results for each reach is provided in **Table 4.1**.

The Rapid Stream Assessment Technique (RSAT) provides a broader view of the system by also considering the ecological functioning of the stream (Galli, 1996). Observations include instream habitat, water quality, riparian conditions, and biological indicators. Additionally, the RSAT approach includes semi-quantitative measures of bankfull channel dimensions, type of substrate, vegetative cover, and channel disturbance. RSAT scores rank the channel as maintaining a low (<20), moderate (20-35) or high (>35) degree of stream health. A summary of the 2013 RSAT results for each reach is provided in **Table 4.1**.

3.2 Detailed Field Survey

As part of the detailed field assessments, standard protocols and known field indicators were used to quantify the bankfull cross-sectional dimensions of the reaches (e.g. bankfull depth and width). A modified Wolman pebble count was used to characterize the channel bed substrate materials. In addition to noting bank characteristics (e.g. height and composition), an *in situ* shear stress test was performed on bank materials. These measurements were completed at five cross-sections within the each delineated reach. A total station was used to survey each reach to obtain a longitudinal profile and provide a measure of the local energy gradient. A summary of the existing channel conditions is provided in **Table 4.1** and a detailed account of the results can be found in **Appendix A**.

4. Existing Conditions

This section summarizes the channel characteristics observed and recorded during field visits conducted on December 6th and December 12th for BV-A1 and BV-A2, respectively. A summary of bankfull dimensions, substrate characteristics and rapid field assessment results for Reach BV-A1 and BV-A2 are provided in **Table 4.1**. The combined longitudinal profile of both reaches, indicating the location of the Bovaird Drive culvert, is presented in **Figure 4.2**.

Table 4.1: Summary of reach characteristics.

	BV-A1	BV-A2
RGA Score	0.36 (Transitional)	0.36 (Transitional)
RSAT Score	24 (Moderate)	24 (Moderate)
Average Bankfull Width (m)	4.22	6.31
Average Bankfull Depth (m)	0.37	0.30
Average Maximum Bankfull Depth (m)	0.56	0.49
Average Cross-sectional Area (m^2)	1.54	1.98
Bankfull Gradient (%)	1.56	2.58
Bed Material D_{50} (mm)	12.18	10.73
Sinuosity	1.23	1.26
Bed Material D_{84} (mm)	75.87	49.40
Bank Materials	si/cl/fs	si/cl/fs
Average Bankfull Discharge (m^3/s)	3.16	5.14

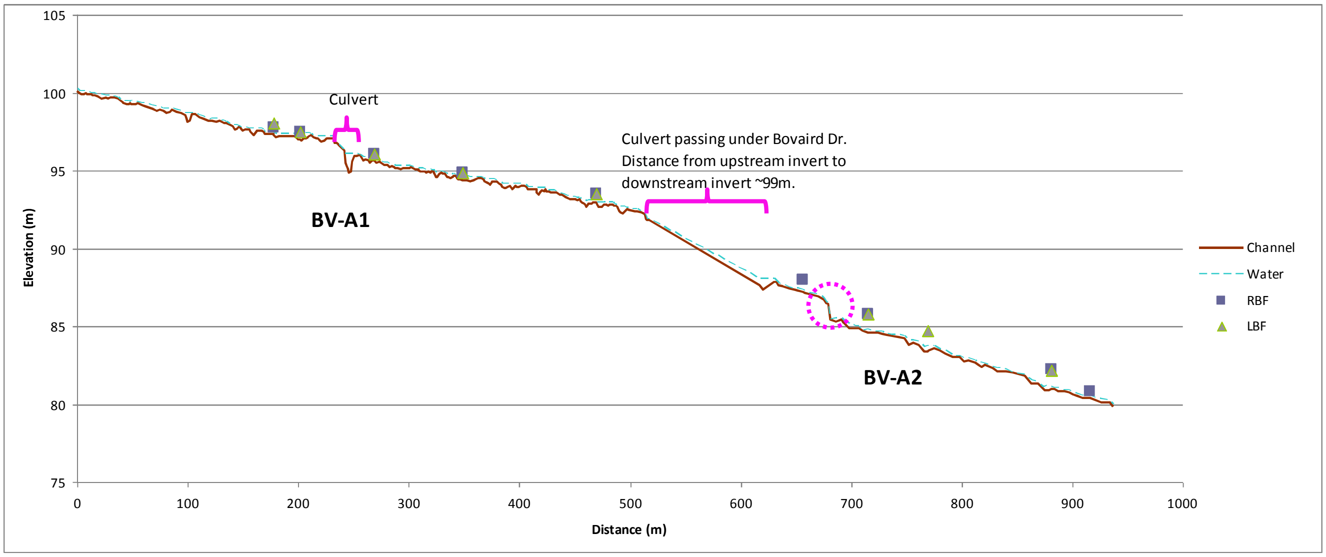

Figure 4.2: Combined longitudinal profile of both Reach BV-A1 (US of Bovaird Dr culvert) and BV-A2 (DS of Bovaird Dr culvert). The location of the Bovaird Dr culvert is identified within the profile along with the small culvert in BV-A1 and remnants of a relic weir in BV-A2.

4.1 Reach BV-A1: Upstream of Bovaird Drive

BV-A1 encompasses a 516m section of channel immediately upstream of the Bovaird Drive culvert. This section of channel flows through an unconfined channel setting surrounded by mixed forest and agricultural land. The reach scored a 0.36 RGA score indicating that the channel is considered to be stressed or in transition. Widening was determined to be the most prominent form of geomorphic adjustment observed within the reach with some evidence of degradation and planimetric adjustment noted. The channel consisted of low banks with erosion occurring along outside meander bends and at valley wall contacts. Some instances of leaning trees, exposed roots, and steeply eroded banks were observed within the reach.

The average bankfull width of the channel is 4.22m (3.0-5.28m) with an average bankfull depth of 0.37m (0.30-0.45m). Channel substrate consists mainly of gravel, sand and clay with inclusion of cobbles (D_{50} of 12.18mm). The energy gradient was determined to be 1.56% for this reach and the calculated average bankfull discharge is 3.16m^3/s.

Two culverts were identified within the reach and both were determined to be attributing to instability within the watercourse (**Figure 4.3**). The small culvert located near the upstream end of the reach (250m upstream of Bovaird Drive) is undersized and set at a steeper slope than the natural channel. This has led to the development of a deep scour pool immediately downstream of the outlet and backwatering at the upstream end resulting in aggradation. The second culvert, which conveys flows under Bovaird Drive, has also been identified as a major source of channel disturbance. Based on existing channel dimensions and flows, the culvert is considered to be undersized. The undersized culvert restricts effective conveyance of flows leading

to issues with flow constriction causing channel widening and degradation. Immediately upstream of the culvert, the channel consists of steeply eroding banks which increase in height towards the culvert, evidence of channel widening and degradation. The culvert drains into Reach BV-A2 located south of Bovaird Drive.

Figure 4.3: Photographs of existing culverts within Reach BV-A1, the small culvert approximately 250m US of Bovaird Drive (top) and the US (North) portion of the Bovaird Drive culvert (bottom).

4.2 BV-A2: Downstream of Bovaird Drive

BV-A2 spans the 320m channel downstream of the Bovaird Drive culvert until it flows into the Credit River at the downstream extent of the reach. This section of channel flows through a partially confined setting with multiple valley wall contacts observed within the reach. An RGA score of 0.36 was determined indicating that the reach is stressed and in a state of transition. Widening was identified as the most prominent form of adjustment with signs of degradation also being observed. Fallen and leaning trees, presence of large organic debris and extensive basal scouring were typical signs of widening noted within the reach. Signs of degradation included channel incision into the undisturbed bedrock, headcutting due to knickpoint migration, elevated tree roots and a suspended armour layer visible in the bank. Evidence of planimetric form change was noted at the downstream extent of the reach as the formation of chutes and the presence of cut off channels were noted just before the channel drains into the Credit River.

The average bankfull width of the channel is 6.31m (4.50-8.32m) with an average bankfull depth of 0.30m (0.16-0.40m). Channel substrate consists mainly of gravel and sand with inclusion of cobble sized shale particles (D_{50}=10.73mm). The energy gradient for BV-A2 was determined to be 2.58%, greater than that of the upstream (as evidenced by **Figure 4.2**). The average bankfull discharge was calculated to be 5.14m^3/s.

The most significant channel disturbance within the reach is the undersized culvert which conveys flows under Bovaird Drive (**Figure 4.4**). Immediately downstream of the Bovaird Drive culvert, a large scour pool has formed leaving the culvert invert perched creating a barrier for fish passage. Bed and bank scour, resulting from elevated flow velocities released from the culvert during high flows, have caused increases in channel width and depth immediately downstream of the culvert. Approximately 60m downstream of the Bovaird Drive culvert the remnants of a relic weir structure was observed (**Figure 4.4**). At this location, a sudden drop in elevation of approximately 1.2m was recorded with large pieces of concrete present creating a small cascade-like feature. This features impedes fish migration to upstream areas potentially reducing available habitat for fish species. Additional channel disturbances noted include, valley wall contacts which confine the channel and restrict lateral migration at various locations, and accumulations of large woody debris which were a common occurrence within the reach.

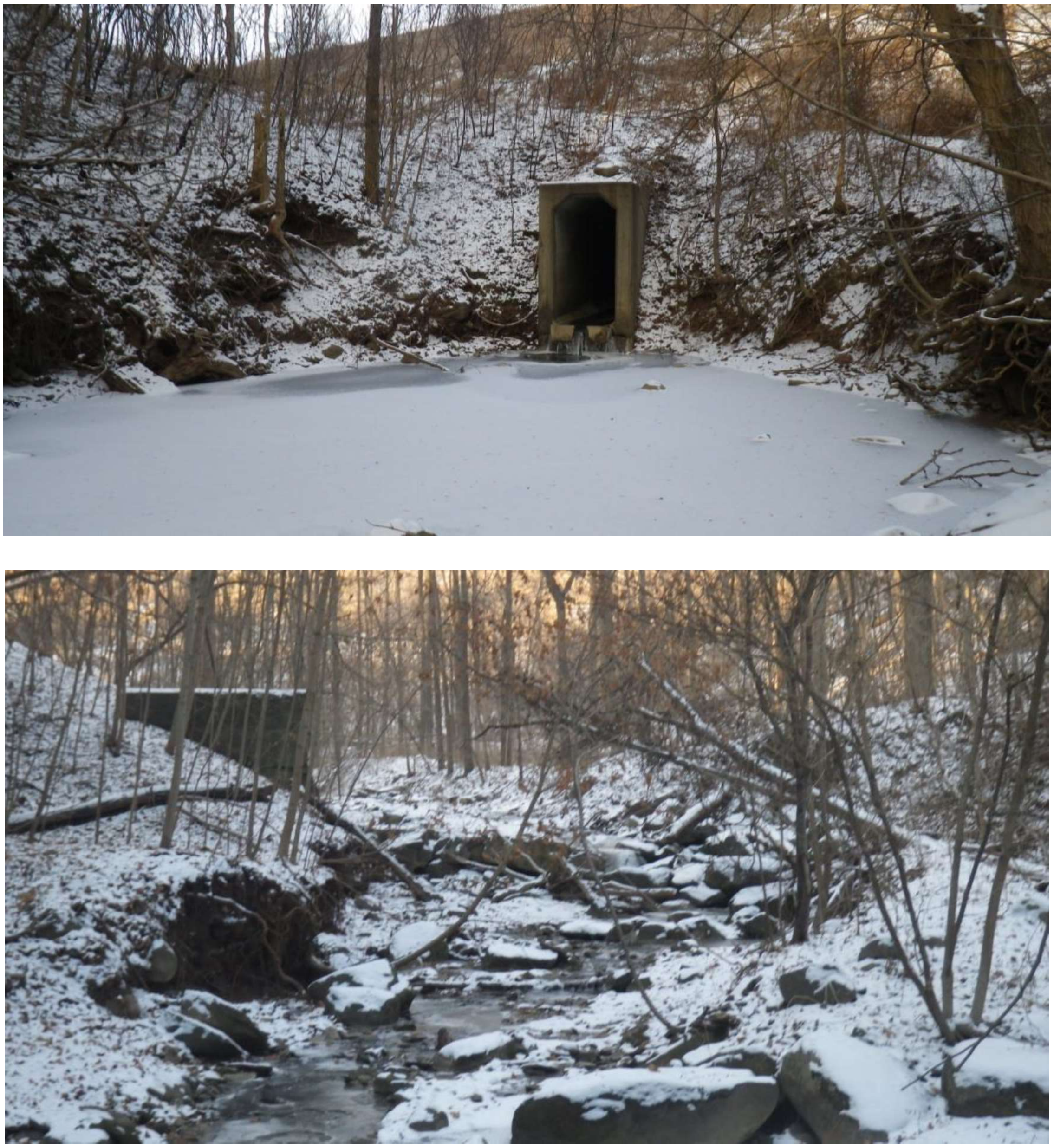

Figure 4.4: Photographs of existing fish barriers within Reach BV-A2, the perched culvert immediately DS of Bovaird Drive (top) and the relic weir approximately 60m DS of Bovaird Drive (bottom).

5. Geomorphic Summary

The geomorphic assessment examined two reaches along the conveyed watercourse, an Unnamed Tributary to the Credit River, both of which were subject to a detailed survey. Reach BV-A1 represented the watercourse immediately upstream of the existing culvert, while Reach BV-A2 constituted the watercourse immediately downstream of the culvert. Reach BV-A1 was determined to be stressed/in transition showing signs of channel widening, degradation and planform change. The reach was characterized as having a bankfull gradient of 1.56%, average bankfull width of 4.22m, depth of 0.37m and substrate consisting of gravel, sand and clay with inclusions of cobbles. Reach BV-A2 was determined to be stressed with widening as the predominant geomorphic process. The reach was characterized as having a bankfull gradient of 2.58%, average bankfull width of 6.31m, depth of 0.30m and substrate consisting of gravel and sand with inclusions of cobble sized shale particles. The average bankfull discharge conveyed by reach BV-A1 and BV-A2 was determined to be 3.16m^2/s and 5.14m^2/s, respectively.

Due to the dynamic nature of rivers, the designation of a corridor intended to contain all of the natural channel functions is desirable. The final meander belt width delineated provides an adequate estimate of the lateral area required for natural channel meander and migration to take place. Based on the existing valley conditions and channel planform, a meander belt width of 48m and 24m was designated for reaches BV-A1 and BV-A2, respectively. These defined corridors will serve as a recommended valley floor width for areas immediately upstream and downstream of the existing culvert.

From a geomorphic perspective, it is evident that the existing culvert is inadequately sized to effectively convey flows and permit efficient sediment transport leading to issues related to excessive scour and fish passage. Ideally, the proposed structure should span the meander belt width, although in most cases this is cost-prohibitive. Based on the geomorphic assessment of the watercourse, an ultimate crossing structure size of 14m is recommended for the existing watercourse. The ultimate crossing structure would consist of a free spanning bridge providing adequate space for natural channel processes to operate while also accommodating minor channel adjustments and improving fish passage.

The ultimate crossing structure would reduce channel design limitations allowing for the development of natural channel design that addresses flow conveyance issues and fish passage concerns, ultimately improving habitat availability and geomorphic stability within the watercourse. The complete removal of the existing culvert would provide adequate area to re-establish/maintain the existing grade and planform of the channel while also allowing for the incorporation of natural channel features. Since the complete removal of the existing culvert is currently not feasible, alternative options were determined and channel designs to accommodate these options have been developed.

6. Alternative Channel Design

6.1 Design Approach

Due to the deteriorating condition of the north portion of the existing culvert, two rehabilitation options were developed to temporarily improve conditions until a proper ‘ultimate’ structure crossing can be constructed. Option 1 proposes the removal of the north portion of the culvert, installation of temporary shoring and regrading of the road embankment on the north side of Bovaird Drive with a 2:1 slope. This option would require a 20m upstream extension to the north portion of the culvert to compensate for the regarding of the road embankment. Option 2 proposes the removal of the north portion of the existing culvert and installation of a permanent retaining wall to reinforce the excavated bank.

Based on the cost-benefit assessment of both alternatives, Option 1 was selected by the design team as the preferred solution. With the intent on minimizing environmental disturbance along the watercourse, the proposed design directed at reconstructing the channel immediately upstream of the new culvert inlet is the implementation of a step-pool system. Although this channel form is unnatural to the existing system, the proposed design reduces the extent of upstream disturbance while continuing to provide adequate fish passage for large bodied species.

6.2 Preliminary Channel Design

As the temporary solution to improving the condition of the existing culvert requires daylighting its north portion, the channel (BV-A1) will need to tie into the proposed elevation of the newly established culvert invert (205.8m). The tie-in elevations create vertical constraints which dictate the channel profile. Due to the significant base level change resulting from the removal of the north portion of the Bovaird Drive culvert, a true natural channel design would require extensive reconstruction work and would result in substantial environmental disturbance in order to re-establish an appropriate slope similar to that of the existing channel.

The tributary provides habitat and serves as a migratory corridor for fish species. The existing obstruction in BV-A2 inhibits the upstream migration of small bodied fish, but larger bodied fish have been identified upstream of this feature, their presence extending to the Bovaird Drive culvert crossing. Maintaining fish habitat and migratory corridors is a secondary objective to current project and therefore the proposed design should minimize disturbance to existing habitats while also providing passage for large bodied fish species. The proposed design will stabilize the channel immediately upstream of the culvert inlet by installing a series of steps and pools to make up grade while limiting the extent of disturbance to the channel. The step-pool geometry proposed is intended to meet necessary height and run-up requirements for large bodied fish species maintaining the tributaries role as a potential migratory corridor.

The planform was designed to add length to the channel and provide variability while also limiting extent of disturbance to the existing watercourse. The proposed planform intends on partially overlapping the existing channel for a short distance to train flows towards the new planform centered within valley. The planform demonstrates a slight meander to increase channel length and accommodate the design features. The proposed planform has an estimated length of 60m. Installation of large armour stone blocks crossing the channel will form the basis of the step-pool design. All pools will be 6m long with the exception of one longer and deeper pool located at the apex of the meander to serve as a resting pool for migrating fish.

The upstream invert of the proposed Bovaird Drive culvert extension determined the downstream tie-in elevation for the channel design within BV-A1 (205.8m). The suggested upstream tie-in location was selected as it is centered within the valley limiting potential valley wall contact issues and provides sufficient area to implement the appropriate design dimensions. The proposed upstream tie-in elevation is 209.5m, a bed elevation difference of 3.7m with respect to the culvert invert, and coupled with an approximate 60m channel length gives the reconstructed channel section a slope of 5.7%.

The constructed channel is intended to provide stable channel conditions under steepened longitudinal conditions by constructing a step-pool morphology. The bankfull discharge calculated based on measurements from the detailed field survey was used as the design discharge. The proposed design presents nine 6m long pools with a maximum depth of 0.5m and includes one longer 10m long pool with a maximum depth of 0.7m. Detailed pool dimensions for the proposed design are provided in **Table 6.1**. The pools will be separated by a series of large 1m x 1m x 0.5m armour stone blocks (L x H x W) with top of stone elevations offset by 0.4m to create the step-pool system. The maximum pool depths will be located immediately downstream of the step to providing a plunge pool area.

Table 6.1: Summary of proposed pool dimensions.

Parameter	Typical Pool	Larger Resting Pool
Top Width (m)	4.5	4.5
Bed Width (m)	3.0	2.5
Bank Slope (H:V)	1.5:1	2:1
Max Depth (m)	0.5	0.7
Length (m)	6	10

To reach the desired step height and ensure stone stability, the armour stone blocks should be embedded into the channel bed. The channel bed and armour stone blocks should not be constructed as flat surfaces, but in fact should contain a slight decline towards the center of the channel to concentrate low flows. It is important that the armour stone blocks extend well into the bank to prevent the channel from outflanking the steps. The steps should also display a curved stone orientation with the apex of the curve pointing in the upstream direction to direct flows toward the center of channel and away from the banks. Placement of coarse material along pool boundaries, particularly the banks and upstream end of steps, should be included to ensure stability of pool features and minimize incision. A stone size distribution capable of remaining stable under bankfull

flow conditions was determined and presented in **Table 6.2**. The coarser fraction of the distribution should be concentrated along the banks and upstream ends of steps while the finer fraction should be concentrated along the bed of the pools downstream of the steps.

Table 6.2: Summary of substrate distribution for coarse boundary material.

Percentile	Grain Size (mm)
D_{95}	600
D_{90}	500
D_{84}	450
D_{50}	300
D_{16}	200
D_{10}	100

When constructing the pools, it is essential that fine native materials be included into the prescribed distribution to enhance the finer fraction and minimize the amount of void space between individual particles. As the underlying geology of the area consists of shale bedrock, the inclusion of excavated coarser platy-shale material may also be desired along bed and banks. Apart from limiting the amount of void spaces, the inclusion of native material can help maintain some of the ecological integrity of the watercourse by providing material that is readily mobilized resembling natural channel conditions.

Above bankfull elevations, a floodplain area should be included to avoid channel confinement and help dissipate overbank flows resulting from significant rainfall events. The floodplain should be gradually sloped (2%) and blend with the existing valley wall with a 2:1 slope. The floodplain area should be vegetated with native grasses, shrubs and sparsely placed deciduous trees – similar to natural conditions observed upstream – to stabilize the floodplain and provide habitat for terrestrial species. Vegetation can be planted using seed or live transplant. Planting in the mid to late spring is ideal because it gives the plants a long growing season and provides a sufficient time for both root and shoot growth.

7. Design Considerations and Recommendations

7.1 Design Expectations

Although steps have been taken to maintain a certain degree of channel stability, natural channel designs are, by definition, intended to be dynamic. Therefore, it is expected that the channel will undergo adjustments upon experiencing a range of flows. Specific adjustments include the following:

- *Siltation in Pools* **–** During base flow conditions, pools behave as areas of backwater and, therefore, tend to accumulate fine sediments along their bed. These fine sediments area subsequently ‘flushed’ from the system during bankfull flow conditions.
- *Planform Adjustment* – In the absence of bioengineering bank stabilization or any hard stabilization techniques, slight changes to the channel planform may occur. Specifically, slight alterations in the sinuosity, meander wavelength and meander amplitude are expected.
- *Bar Formation* **–** In many cases, sediment will accumulate along the inner bank of well-defined river bends due to their hydraulic properties, which will ultimately form a point bar. Again, this mimics sediment storage processes seen in a natural channels.
- *Cross-section Sculpting* **–** As adjustment occurs in the channel planform, there will be associated changes in the thalweg location. This will alter the areas of erosion and deposition within a transect, which serves to sculpt the cross-section shape.

7.2 Implementation Recommendations

Recommendations regarding implementation and monitoring of the channel design are provided below. These recommendations are meant to ensure that the benefits of the natural channel design are realized and to avoid potential erosion concerns. They also allow for the identification of potential opportunities for future enhancement.

- *Construction Supervision* **–** A fluvial geomorphologist should be part of construction supervision to ensure proper function of the constructed channel. This supervision will enable timely and appropriate response to construction issues and ensure implementation of important design details.
- *Construction Phasing* **–** Implementation of channel construction should be based on the detailed layout in the design plans, followed by systematic excavation, grading, and stone placement from downstream to upstream, as the preferred direction. Construction should proceed in dry, dewatered conditions with additional sediment controls as necessary for site and watercourse protection.

- *Erosion Control* – During, and immediately after construction, soil and bank material fill be especially susceptible to erosion, as vegetation will not have established. Stabilization and seeding of all disturbed areas along with installation, where necessary, of bank erosion control (i.e., coir cloth, Geojute or similar biodegradable fibre mat) should occur immediately after sections of channel construction are completed, to minimize the risk of sediment-related impacts to the downstream watercourse.

- *Vegetation* – Rapid establishment of vegetation on the channel banks and adjacent floodplain will minimize potential erosion. Vegetation also provides cover, which improve aquatic habitat and water-quality.

- *Post-Construction Monitoring* – Channels designed to mimic naturally occurring systems generally allow for some channel adjustment to occur in response to annual and decadal changes in flow. Most adjustments to channel form will occur during the first year and then again during large flow events. For this reason, a general field reconnaissance along the entire length of the constructed channel should be completed immediately after construction and again after the first large flood event to identify any potential areas of concern. Any detailed monitoring (e.g. total station survey) of the constructed design elements should commence immediately after construction to obtain reference data for comparison to subsequent monitoring efforts.

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APPENDIX A

Detailed Field Survey Summary

DETAILED GEOMORPHOLOGICAL FIELD DATA SUMMARY

Credit River Tributary US of Bovaird Culvert

Project: **01-13-74**

Site Location:	Credit River Tributary US of Bovaird Culvert
Length surveyed:	516m
Number of cross-sections:	5
Date of Survey:	06-Dec-13

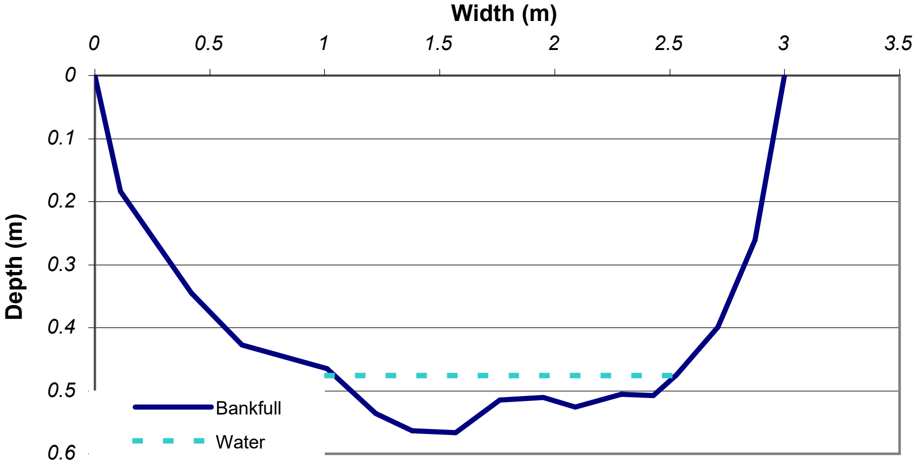
Modifying Factors

Surrounding Land Use:	Farm land, Mixed forest, residential
General Riparian Vegetation:	grasses, shrubs, trees
Existing Channel Disturbances:	culvert 200m US of bovaird drive, and bovaird drive culvert
Woody Debris:	Minor

Cross-Sectional Characteristics

	Range	**Average**
Bankfull Width (m)	3.00 - 5.28	4.22
Bankfull Depth (m)	0.30 - 0.45	0.37
Width / Depth	7.07 - 16.34	11.76
Wetted Width (m)	0.89 - 3.35	2.30
Water Depth (m)	0.05 - 0.24	0.11
Manning's n		0.035

Bankfull Cross-section - Site 6



DETAILED GEOMORPHOLOGICAL FIELD DATA SUMMARY

Credit River Tributary US of Bovaird Culvert

Project: 01-13-74

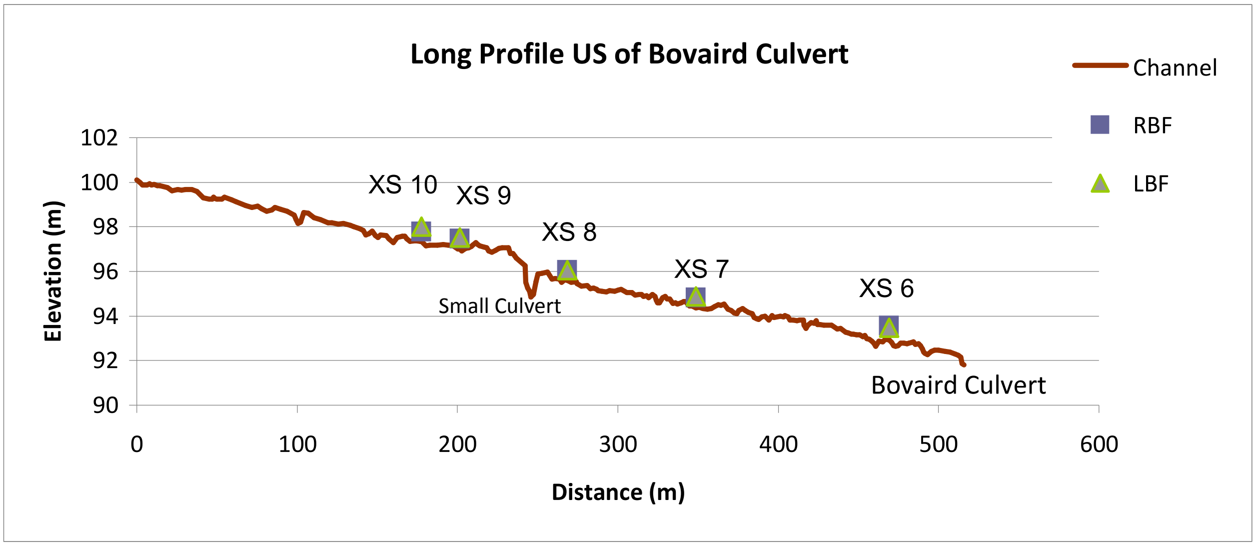
Bank Characteristics

	Range	Average
Bank Height (m)	0.25 - 1.2	0.69
Bank Angle (degrees)	30 - 90	62.5
Root Depth (cm)	8.0 - 94	27.5
Root Density ***(1=Low - 5=High)***	1 - 2	1.6
Protected by vegetation (%)	40 - 75	60.0
Amount of undercut (cm)	12.0 - 28	21.67
Banks with undercuts (%)	3 / 10	30%

Planform Characteristics

Long Profile (avg)

Bankfull Gradient: 1.56 %



DETAILED GEOMORPHOLOGICAL FIELD DATA SUMMARY

Credit River Tributary US of Bovaird Culvert

Project: 01-13-74

Substrate Characteristics

Particle Shape (cm):

	Range	Average
X	1 - 15	7.3
Y	3 - 23	11.7
Z	0.25 - 5	1.6

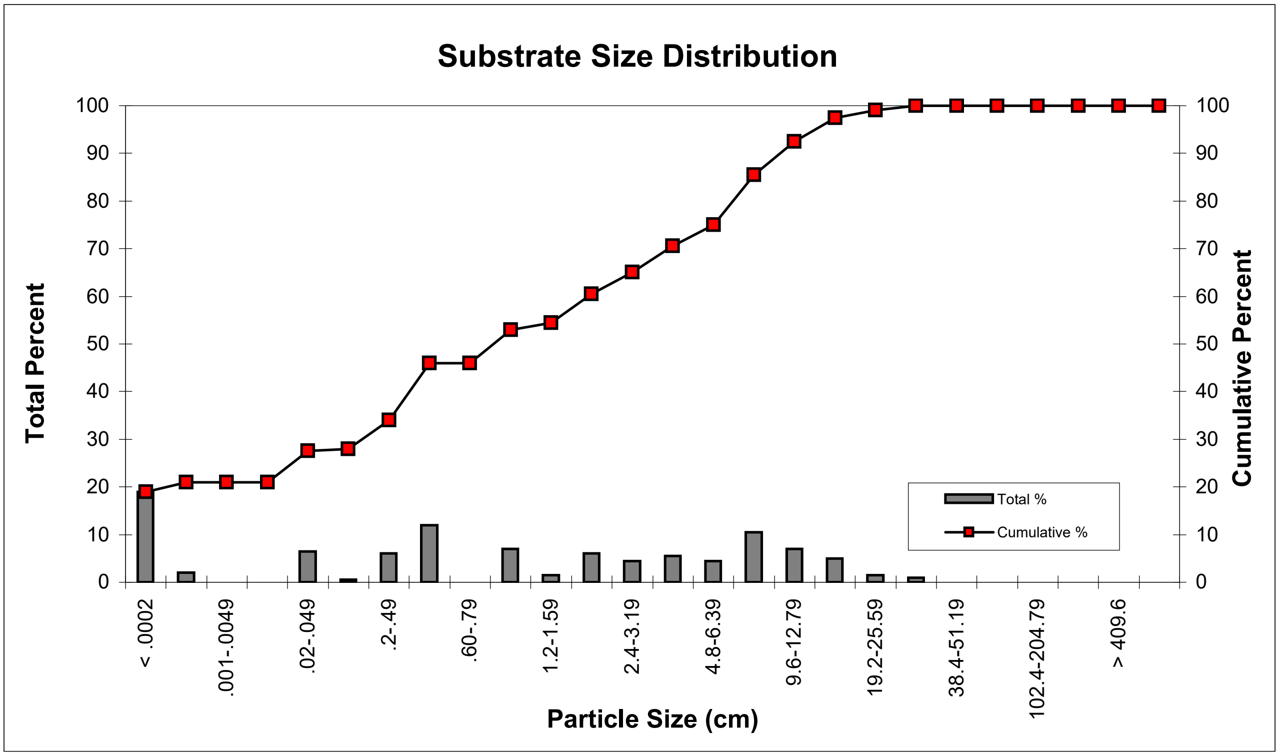
Hydraulic Roughness (cm):

	Range	Average
Maximum	5 - 10	8.0
Median	0.5 - 1	0.9
Minimum	0.0025 - 0.05	0.0

Embeddedness (%): 5 - 40 25.0

Particle Sizes (cm):

	Pebble Counts	
D10	0.0001053	cm
D50	1.22	cm
D90	9.60	cm



DETAILED GEOMORPHOLOGICAL FIELD DATA SUMMARY

Credit River Tributary US of Bovaird Culvert

Project: **01-13-74**

Field Observations

XS10
RB is simple and is vegetated by trees, shrubs, and short herbs/grasses
LB is vertical and is vegetated byshrubs, and short herbs/grasses
TOLB is 3m from toe of valley
LB is eroded and slumping with vertical bank
RB has a vegetated bar with low grade slope
LB has small vegetated island 3m us of XS

XS9
RB is simple and is vegetated by trees, shrubs, and short herbs/grasses
RB is simple and is vegetated by short herbs/grasses
RB has exposed clay at toe of bank and side of bank and has exposed trees roots and leaning trees
LB has a build up of detritus at toe of bank/ bank has a low grade/ xs is in a pool

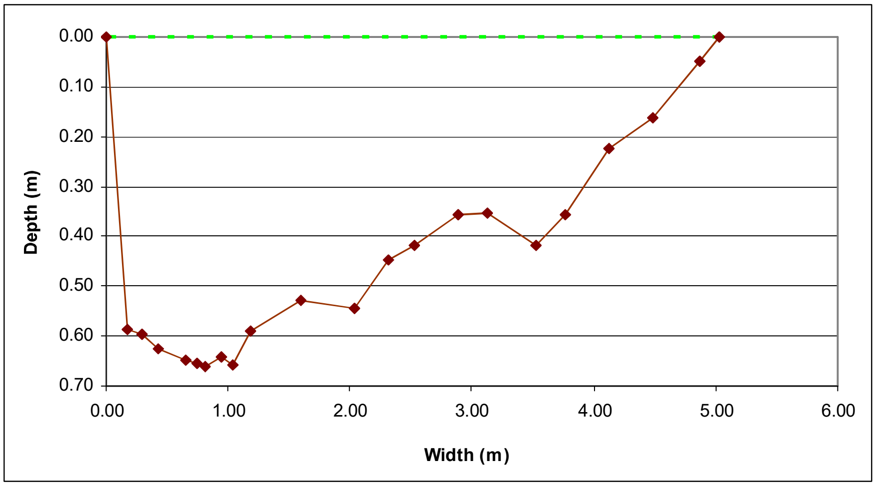
XS8
RB is simple and is vegetated by trees, shrubs, and short herbs/grasses
LB is vertical and is vegetated by trees, shrubs, and short herbs/grasses
RB has a low grade
LB is eroding with vertical banks and leaning trees/ exposed roots
XS is 7m D/S of large culvert in a riffle

XS7
RB is vegetated by trees, shrubs, and short herbs/grasses
RB is eroded with vertical banks and exposed roots/ exposed clay on right side of channel
LB is simple and is vegetated by tall and short herbs/grasses
LB has low grade bank with gradual slope
XS is at the start of a bend in a transition

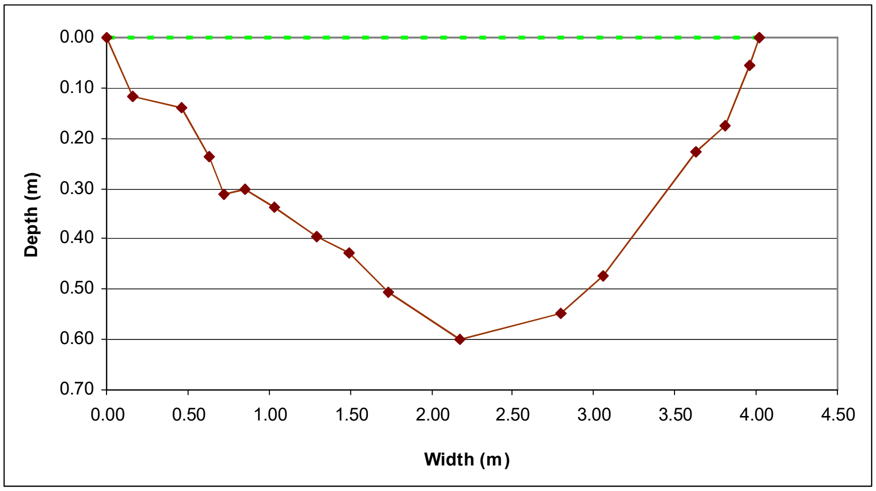
XS6
RB is vertical and is vegetated short herbs/grasses
LB is simple and is vegetated by tall and short herbs/grasses
RB is eroded with vertical bank
LB small vegetated bar due to previous bank failure
XS is 20m US of road culvert/ hobo is 3m U/S of xs/ xs is in a riffle

Reach BV-A1 (Upstream of Bovaird Drive Culvert)

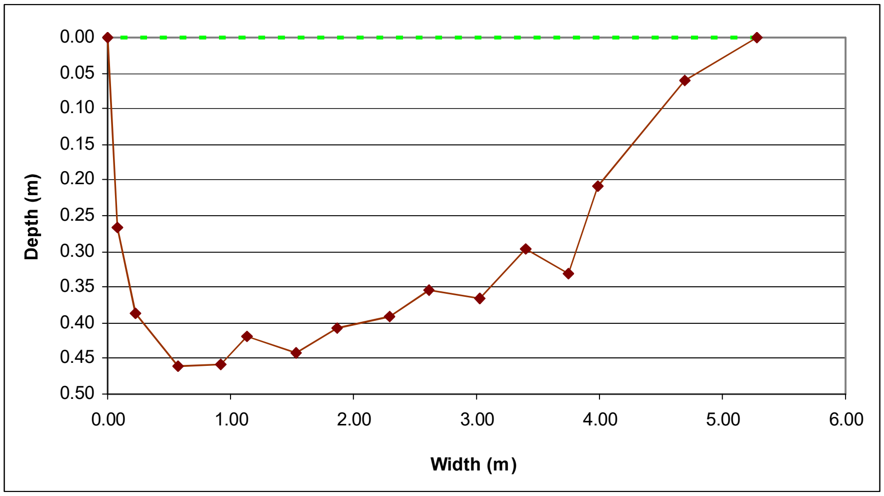
Bankfull Cross-section 10 (Upstream end of Reach)



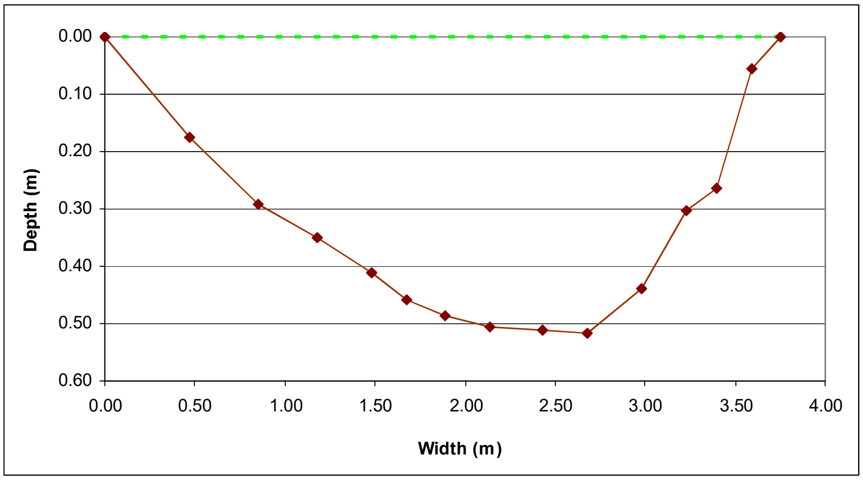
Bankfull Cross-section 9



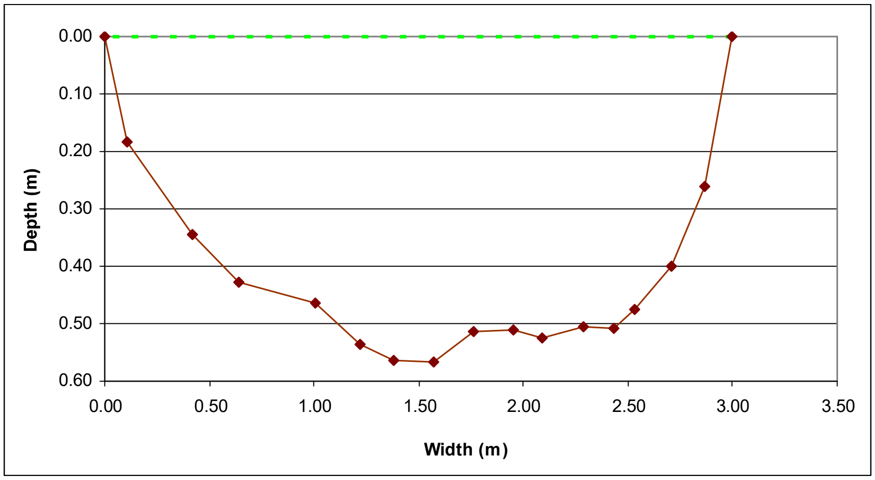
Bankfull Cross-section 8



Bankfull Cross-section 7



Bankfull Cross-section 6 (Downstream end of Reach)



DETAILED GEOMORPHOLOGICAL FIELD DATA SUMMARY

Credit River Tributary DS of Bovaird Culvert

Project: 01-13-74

Site Location:	Tributary to the Credit River at Bovaird
Length surveyed:	319.5m
Number of cross-sections:	5
Date of Survey:	12-Dec-13

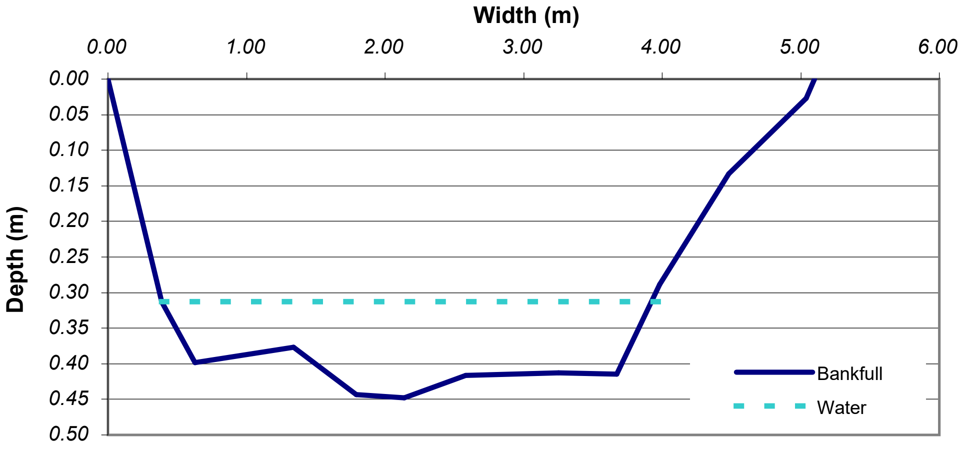
Modifying Factors

Surrounding Land Use:	Farm land, Mixed forest, residential
General Riparian Vegetation:	grasses, shrubs, trees
Existing Channel Disturbances:	bovaird drive culvert, old weir approx 60m DS of culvert
Woody Debris:	Major

Cross-Sectional Characteristics

	Range	**Average**
Bankfull Width (m)	4.50 - 8.32	6.31
Bankfull Depth (m)	0.16 - 0.40	0.30
Width / Depth	15.07 - 35.23	22.30
Wetted Width (m)	2.06 - 3.66	3.11
Water Depth (m)	0.08 - 0.27	0.14
Manning's n		0.035

Bankfull Cross-section - Site 4



DETAILED GEOMORPHOLOGICAL FIELD DATA SUMMARY

Credit River Tributary DS of Bovaird Culvert

Project: **01-13-74**

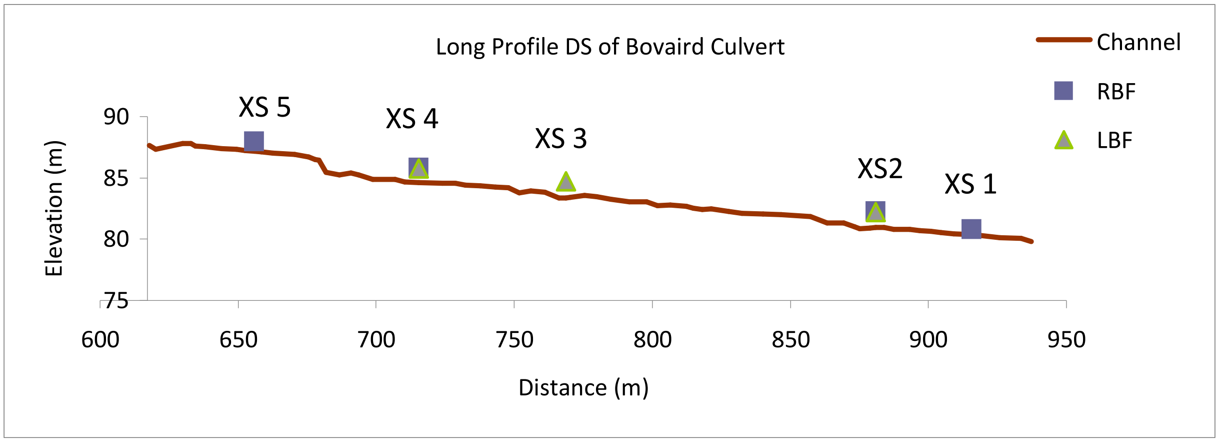
Bank Characteristics

	Range	Average
Bank Height (m)	0.5 - 20	5.76
Bank Angle (degrees)	18 - 90	56.56
Root Depth (cm)	30.0 - 100	65.0
Root Density ***(1=Low - 5=High)***	2 - 4	3.1
Protected by vegetation (%)	5 - 50	37.8

Planform Characteristics

Long Profile (avg)

Bankfull Gradient: 2.58 %



DETAILED GEOMORPHOLOGICAL FIELD DATA SUMMARY

Credit River Tributary DS of Bovaird Culvert

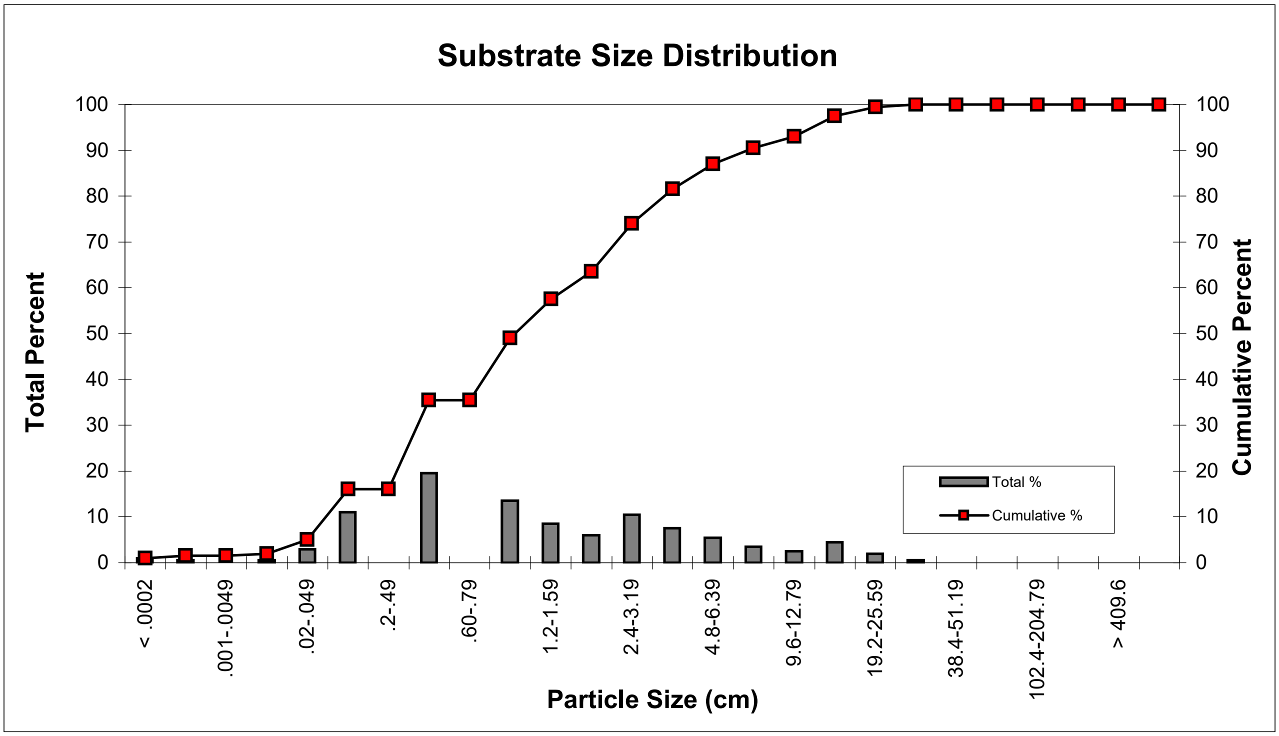
Project: **01-13-74**

Substrate Characteristics

Particle Shape (cm):		Range	Average
	X	2 - 21.5	10.5
	Y	2.5 - 43	14.1
	Z	0.5 - 4	2.0
Embeddedness (%):		30 - 40	32.5

Particle Sizes (cm):

	Pebble Counts	
D10	0.11	cm
D50	1.07	cm
D90	9.13	cm



DETAILED GEOMORPHOLOGICAL FIELD DATA SUMMARY

Credit River Tributary DS of Bovaird Culvert

Project: **01-13-74**

Field Observations

XS 5
RB is vertical and is vegetated by trees, shrubs, and short herbs/grasses
LB is complex and is vegetated by trees, shrubs, and short herbs/grasses
xs is 20m US of old weir

XS4
RB is a valley wall and is vegetated by trees, shrubs, and short herbs/grasses
LB is complex and is vegetated by trees, shrubs, and short herbs/grasses
Plate like substrate
30m Ds of old weir/ XS is in a riffle

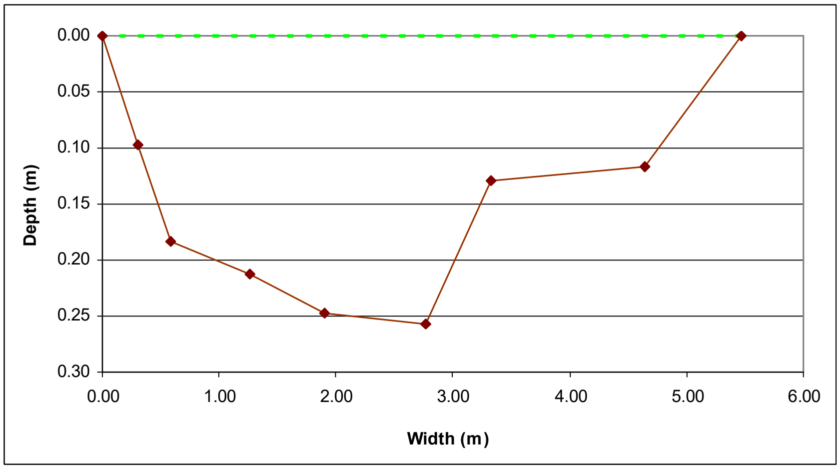
XS3
RB is complex and is vegetated by trees, shrubs, and short herbs/grasses
LB is a valley wall and is vegetated by trees, shrubs, and short herbs/grasses
There is a debris jam DS of Xs and Xs is in a pool

XS2
RB is a valley wall and is vegetated by trees, shrubs, and short herbs/grasses
LB is complex and is vegetated by trees, shrubs, and short herbs.grasses
Xs is in a riffle

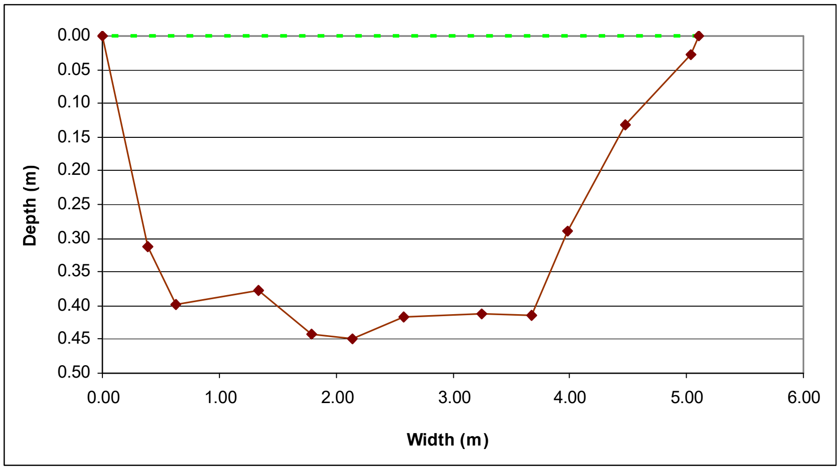
XS1
RB is complex and vegetated with trees and shrubs
and short herbs/grasses
LB is complex and is vegetated by trees, shrubs, and short herbs/grasses

Reach BV-A2 (Downstream of Bovaird Drive Culvert)

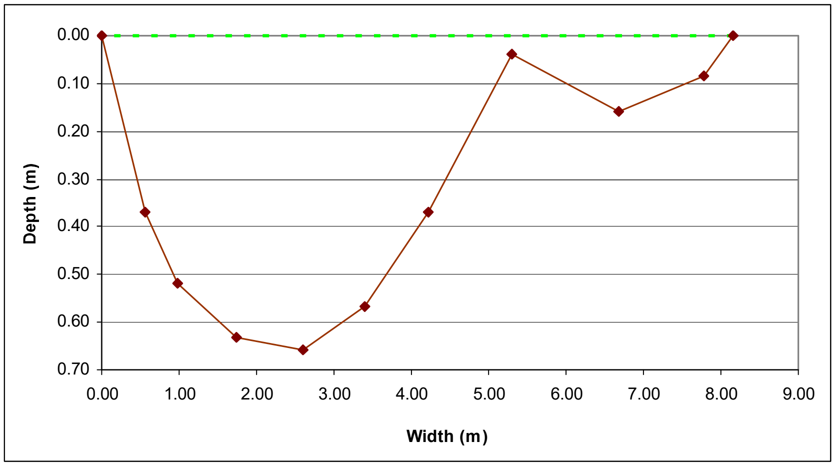
Bankfull Cross-section 5 (Upstream end of Reach)



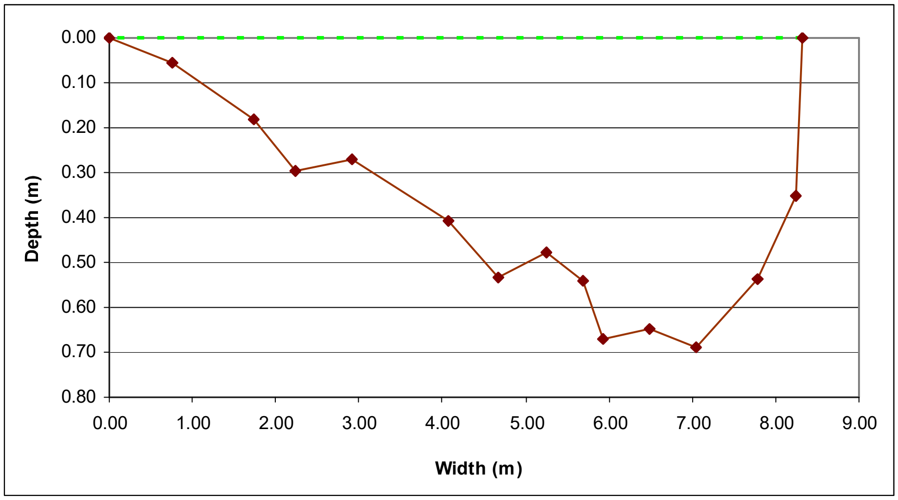
Bankfull Cross-section 4



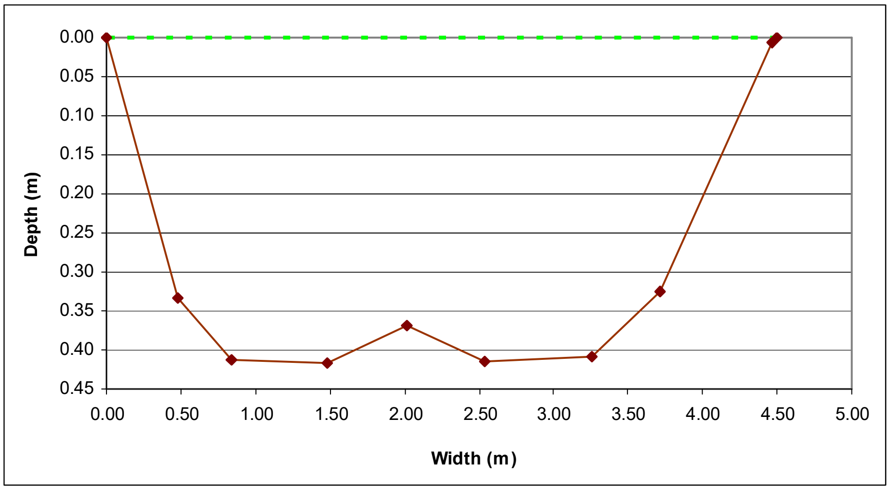
Bankfull Cross-section 3



Bankfull Cross-section 2



Bankfull Cross-section 1 (Downstream end of Reach)



APPENDIX B

Photo Summary

BV- A1 Upstream of Bovaird Drive Culvert

XS 10: View facing upstream.

XS 10: View facing downstream. Note bank erosion along outside meander bend (left bank). Right bank has gradual slope.

XS 9: View facing upstream. Slopes are gradual, some leaning trees can be observed on the bank (left bank).

XS 9: View facing downstream.

XS 8: View facing upstream. XS located downstream of culvert, approximately 200m from downstream extent of reach (Bovaird Drive)

XS 8: View facing downstream. Minor woody debris accumulating around tree on left bank. Left bank also experiencing erosion.

XS 7: View facing upstream.

XS 7: View facing downstream. Bank erosion present along outside meander bends.

XS 6: View facing upstream. Bank erosion can be seen along both banks.

XS 6: View facing downstream. Slightly more substantial bank erosion along right bank. Valley constraints appearing at the downstream extent of the reach.

BV-A2 Downstream of Bovaird Drive Culvert

XS 5: View facing upstream. Located at the upstream extent of reach BV-A2. Bovaird Drive culvert outlet seen in the distance.

XS 5: View facing downstream. Channel slightly wider than downstream XS's. Scour along right bank resulting in leaning trees and exposure of roots.

XS 4: View facing upstream. Exposed roots present along banks with overhanging vegetation observed on right bank (valley wall contact).

XS 4: View facing downstream. Valley wall contact on right bank.

XS 3: View facing upstream.

XS 3: View facing downstream. Valley wall contact on left bank. Exposed roots and J-shaped trees located on banks, indicative of widening.

XS 2: View facing upstream. Valley wall contact on right bank with a near vertical bank. Left bank has a gradual slope.

XS 2: View facing downstream. Note the valley wall contact on the right bank. Valley wall contact consists of shale material.

XS 1: View facing upstream. Located approx. 15m from Credit River confluence. Banks are much lower with some scouring occurring along outside meander bend (left bank).

XS 1: View facing downstream.

View facing upstream at the Bovaird Drive culvert outlet. It is evident that the culvert is undersized in relation to the existing watercourse. Scour along bed and banks of channel have resulted.

View facing upstream at remnants of an old weir located approximately 60m from the upstream reach extent. A sudden drop in bed elevation was observed at this location along with the inclusion of large boulders within the channel.

APPENDIX ‘C’

FOUNDATION INVESTIGATION REPORT

FOUNDATION INVESTIGATION REPORT

CREDIT RIVER TRIBUTARY CULVERT REHABILITATION ON BOVAIRD DRIVE CITY OF BRAMPTON, ONTARIO

REGION OF PEEL
PROJECT 13-4890

Submitted to:

The Regional Municipality of Peel
Works Department
Suite A, Room 101
10 Peel Centre Drive
City of Brampton, Ontario L6T 4B9
Canada

Submitted by:

AMEC Environment & Infrastructure,
a Division of AMEC Americas Limited
104 Crockford Boulevard
Scarborough, Ontario, M1R 3C3
Canada

22 May 2014

TP113114

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RECORD OF BOREHOLES

APPENDICES

1.0 INTRODUCTION

AMEC Environment & Infrastructure, a Division of AMEC Americas Limited (“AMEC”), was retained by The Regional Municipality of Peel ("Region"), to provide services for Detail Design and Contract Administration for Credit River Tributary Culvert Rehabilitation on Bovaird Drive in the City of Brampton. The project site plan is shown in Figure No. 1.

AMEC-Scarborough carried out a foundation investigation to support the detail design of the proposed rehabilitation undertaken by AMEC-Burlington. The investigation was carried out in accordance with the Region’s Request for Proposal (RFP No. 2013-508P, Region’s Project 13-4890) requirements. The scope of work of the foundation investigation included fieldwork and preparation of a Foundation Investigation Report.

This report contains the results of the geotechnical investigation, together with AMEC’s recommendations and comments. The recommendations and comments provided herein are based on factual information and are intended only for Design Engineers’ use. The number of boreholes may not be sufficient to determine all the factors that may affect construction methods and costs. Sub-surface soil and groundwater conditions between and beyond the boreholes may differ from those encountered at the borehole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation.

The anticipated construction conditions are also discussed, but only to the extent that they will likely influence design decisions. Construction methods discussed, however, express AMEC’s opinion only and are not intended to direct Contractors on how to carry out the construction. Contractors should be aware that the data and their interpretation presented in this report may not be sufficient to assess all the factors that may have an effect upon the construction.

Once the details of the proposed works are finalized, there should be on-going liaison with AMEC during both the design and construction phases of the project to confirm that the recommendations in this report are applicable and/or correctly interpreted and implemented. Also, any queries concerning the geotechnical aspects of the proposed project should be directed to AMEC-Scarborough for further elaboration and/or clarification.

The report is prepared with the condition that the design and construction will be in accordance with all applicable standards, codes, regulations of authorities having jurisdiction, and carried out using good engineering practices. Further, the recommendations and opinions in this report are applicable only to the proposed project as described above.

This report should be read in conjunction with the enclosed Report Limitations.

2.0 SITE AND PROJECT DESCRIPTION

The culvert to be rehabilitated is located under the embankments for the old Highway 7 and the existing Bovaird Drive West in the City of Brampton, Ontario, where a tributary of Credit River crosses the road from north to south. The old Highway 7 is no longer in use. The culvert is located about 1.1 km west of Heritage Road. The invert of the existing culvert is about 15 m below the existing ground surface of Bovaird Drive West. The existing culvert is about 98 m in total length and consists of the following three distinct barrels, as described in the RFP, located under Bovaird Drive West and the old Highway 7:

- *Under Bovaird Drive West:* Approximately 65 m long "south barrel", which has been constructed with 1.2 m wide x 2.8 m high pre-cast concrete boxes.
- *Under the old Highway 7:* Approximately 33 m long culvert, which consists of:
  - "Centre barrel", constructed with cast-in-place concrete.
  - "North barrel", constructed with masonry.

The entire length of the culvert under the old Highway 7 (centre and north barrels) is showing signs of deterioration and is proposed to be removed, together with the old Highway 7 embankment, and replaced by an open channel with stable sideslopes. The existing south barrel of the culvert under Bovaird Drive West is in fairly good condition and will remain in place.

In addition, the proposed culvert rehabilitation may consist of one or more of the following works:

- Construction of a headwall/retaining wall at the north end (and possibly south end) of the remaining south section of the existing culvert under Bovaird Drive West, and associated embankment slope(s); and/or
- Extension of the existing culvert under Bovaird Drive West (i.e. south barrel) to the north, after removal of the culvert underneath the old Highway 7; and/or
- Construction of a new supplementary culvert under Bovaird Drive West, adjacent to the existing culvert, to augment hydraulics, which will possibly be constructed using trenchless technique.

Currently, a ditch with catch basins to collect stormwater is located between the embankments of Bovaird Drive and the old Highway 7. The sideslopes of the existing embankments, approximately 15 m high, are covered with grass and/or trees.

3.0 INVESTIGATION PROCEDURES

The fieldwork was carried out between 9 and 11 December 2013 and consisted of advancing and sampling four (4) boreholes (BH 1 to BH 4) along the culvert alignment, as shown in Figure No. 2. Boreholes BH 1 and BH 2 were drilled on the south and north shoulder areas of Bovaird Drive West, while BH 3 and BH 4 were located on the old Highway 7. The boreholes were located on the two sides (east and west) of the existing culvert and drilled to an approximate depth of 20 m below the existing grade. Monitoring wells (50 mm diameter) were installed in Boreholes BH 1 and BH 3, for groundwater lever monitoring and slug testing for hydrogeological study. The slug test and hydrogeological finding are presented in a separate report prepared by AMEC. The details of boreholes are listed in Table 3.1.

Table 3.1 – Borehole Details

Borehole No.	Location	GPS Coordinates (UTM - NAD 83, Zone 17)		Borehole Depth (m)	Top of Borehole Elevation (m)	Monitoring Well Installation
		Northing	Easting			
BH 1	South shoulder of Bovaird Drive West, east of culvert	4833594	592931	19.9	221.2	Installed, well screen at 16.5 m to 19.5 m depth
BH 2	North shoulder of Bovaird Drive West, west of culvert	4833590	592905	19.8	219.8	*Not installed*
BH 3	Old Highway 7, west of culvert	4833609	592883	19.9	219.8	Installed well screen at 16.5 m to 19.5 m depth
BH 4	Old Highway 7, east of culvert	4833625	592893	19.8	220.4	*Not installed*

A monitoring well (BC 35) had been installed on the west side of the culvert (as shown in Figure No. 2) during a Class Environmental Assessment Study carried out by AMEC for Bovaird Drive West between 2009 and 2011. This monitoring well was still in workable condition at the time of this investigation.

The borehole locations were marked in the field relative to existing on-site features by AMEC and their surface elevations were subsequently surveyed relative to a geodetic benchmark in the vicinity of the project site. The benchmark consisted of a metal post located near the toe of the slope on the south side of Bovaird Drive West, east of the culvert. Details of the benchmark (BM) used are shown in Table 3.2 and the location is shown on Figure No. 2.

Table 3.2 – Benchmark Details*

GPS Coordinates (UTM - NAD 83, Zone 17)		Elevation (m)
Northing	Easting	
4833635	592991	220.241

* As povided by AMEC-Burlington

All borehole locations were cleared of underground utilities and all mandatory permits were obtained prior to commencement of drilling. The boreholes were advanced using solid-stem and/or hollow-stem augers, with a truck-mounted power-auger drilling rig, under the full-time oversight of experienced geotechnical personnel from AMEC.

Soil samples were taken at 0.76 m (2.5 ft.) intervals up to a depth of 3.0 m, and at 1.5 m (5 ft.) intervals thereafter, while performing the Standard Penetration Test (SPT) in accordance with ASTM D1586. The SPT sampling consisted of freely dropping a 63.5 kg (140 lb) hammer for a vertical distance of 0.76 m (30 inches) to drive a 51 mm (2 inch) diameter O.D. split-barrel (split spoon) sampler into the ground. The number of blows of the hammer required to drive the sampler into the relatively undisturbed ground by a vertical distance of 0.30 m (12 inches) was recorded as SPT ‘N’ value of the soil, which indicated the consistency of cohesive soils or compactness of non-cohesive soils. The results of SPT are shown on the Record of Boreholes.

The groundwater conditions in the open boreholes were observed throughout the drilling operation and upon completion of drilling. Monitoring wells (50 mm diameter PVC pipes) were installed in two (2) boreholes (BH 1 and BH 3) for groundwater level monitoring and slug testing. Upon completion of drilling, the boreholes without monitoring wells were backfilled with bentonite in accordance with the general requirements of Ministry of the Environment (MOE) Regulation 903. Prior to backfilling or well installation, free standing groundwater levels were measured, if present, in all boreholes. The measured groundwater levels are shown on the Record of Boreholes.

The soil samples were transported to AMEC’s Laboratory for further review and laboratory testing, which included natural water content determination of all soil samples, grain size analyses and Atterberg Limit tests on selected soil samples. The results of the laboratory tests are presented on the corresponding Record of Boreholes and in Appendix A.

Selected soil samples were transported to AGAT Laboratories in Mississauga, Ontario, for soil chemical analysis. The Certificates of Analyses are included in Appendix B.

One selected soil sample was selected and submitted to AGAT Laboratories in Mississauga for corrosivity testing (pH, Chloride, Sulphate, Resistivity and Conductivity). The Certificates of Analyses are included in Appendix B.

4.0 REGIONAL GEOLOGY

Based on Quaternary Geology of Brampton Area, Western Toronto (Map P.3072, Geological Series – Preliminary Map, 1987, published by the Ministry of Northern Development and Mines), the geology in the project area consists of Halton Till, red to brown gritty silt to clayey silt till. The area close to the creek (tributary to Credit River) comprises modern alluvium (gravel, sand, clay, muck) and/or bedrock (exposed or thin drift covered shale and dolostone). Based on Map 2544 (Bedrock Geology of Ontario, Southern Sheet), published by the Ministry of Northern Development and Mines, the bedrock in the project area consists of shale of Queenston formation.

5.0 SUB-SURFACE CONDITIONS

Based on the soil conditions encountered at the borehole locations which were drilled in unpaved areas, the soil profile comprised surficial topsoil or sand and gravel underlain by fill soils (sandy silt / silty sand, silty sand and gravel, silty clay / clayey silt) overlying silty clay / clayey silt till and/or weathered shale.

The stratigraphic units and groundwater conditions are discussed in the following sections and are intended to provide the designers with an understanding of the anticipated soil conditions across the site. Additional information is provided in the Record of Boreholes. It should be noted that the soil and groundwater conditions can vary between and beyond the borehole locations.

5.1 Topsoil

Surficial topsoil, approximately 150 mm to 350 mm in thickness, was encountered at Boreholes BH 2 to BH 4. The topsoil consisted primarily of brown / dark-brown sandy silt / silty sand and/or silty clay / clayey silt mixed with organic matter and rootlets.

5.2 Fill Soils

5.2.1 Sandy Silt / Silty Sand / Silty Sand and Gravel Fill

Sandy silt / silty sand / silty sand and gravel fill soils were encountered at the ground surface in Borehole BH 1 and immediately below the topsoil in Boreholes BH 2 to BH 4, and extended to depths of about 8.7 m to 12.0 m (Elevation 207.0 m to 212.5 m) below the existing ground surface. In Borehole BH 4, interbedding of silty clay / clayey silt fill (Section 5.2.2) was observed within this fill. The sandy silt / silty sand / silty sand and gravel fill soils were typically brown, dark brown or grey, and contained trace to some clay, organic matter, rootlets and cobbles.

Measured SPT ‘N’-values of the fill soils typically ranged from 3 to 50 blows per 0.3 m. Measured water contents varied from about 5 % to 21 %.

The results of grain size analysis completed on two samples of the fill soils are presented in Table 5.1.

Table 5.1 - Results of Grain Size Analyses and Atterberg Limit Tests
(Sandy Silt / Silty Sand / Silty Sand and Gravel Fill)

Borehole No.	Sample No.	Depth (m)	Grain Size Distribution				Atterberg Limit			USCS Modified Group Symbol
			Gravel (%)	Sand (%)	Fines		Liquid Limit	Plastic Limit	Plasticity Index	
					Silt (%)	Clay (%)				
BH 1	SS 8	7.6 – 8.2	18	33	34	15	25	14	11	SC
BH 3	SS 6	4.6 – 5.2	12	55	33		*Not tested*			SM

The relevant Plasticity Chart is presented in Figure No. A1, and the grain size distribution curves are presented in Figure No. A2 in Appendix A.

5.2.2 Silty Clay / Clayey Silt Fill

Silty clay / clayey silt fill soils were encountered underlying and/or interbedded within the sandy silt / silty sand / silty sand and gravel fill in Boreholes BH 1, BH 3 and BH 4, and extended to depths of about 11.0 m to 14.9 m (Elevations 206.3 m to 209.4 m) below the existing ground surface. The silty clay / clayey silt fill was typically brown, grey or dark grey, and contained some sand, trace to some gravel, organic matter, rootlets, wood pieces and trace cobbles.

Measured SPT 'N'-values of the silty clay / clayey silt fill ranged from 6 to 27 blows per 0.3 m. Measured water contents varied from about 11 % to 26 %.

5.3 Silty Clay / Clayey Silt Till

Native silty clay / clayey silt till was encountered underlying the fill soils and overlying weathered shale (Section 5.4) in Boreholes BH 3 and BH 4, and extended to depths of 13.2 m at Borehole BH 3 and 14.5 m below the existing grade at BH 4. The silty clay / clayey silt till were reddish brown or grey in colour and contained shale and limestone fragments.

Measured SPT 'N'-values of the silty clay / clayey silt till ranged from 50 blows per 0.1 m to 90 blows per about 0.3 m, indicating hard consistency. Measured water contents of the silty clay / clayey silt till ranged from 6 % to 13 %.

The results of grain size analysis completed on a sample of the silty clay / clayey silt till are presented in Table 5.2.

Table 5.2 - Results of Grain Size Analyses and Atterberg Limit Tests
(Silty Clay / Clayey Silt Till)

Borehole No.	Sample No.	Depth (m)	Grain Size Distribution				Atterberg Limit			USCS Modified Group Symbol
			Gravel (%)	Sand (%)	Fines		Liquid Limit	Plastic Limit	Plasticity Index	
					Silt (%)	Clay (%)				
BH 4	SS 11	12.2 – 12.6	2	3	75	20	28	18	10	CL

The relevant Plasticity Chart is presented in Figure No. A1, and the grain size distribution curve is presented in Figure No. A3 in Appendix A.

5.4 Weathered Shale

Weathered shale (Queenston) was encountered underlying the fill soils in Boreholes BH 1 and BH 2, and the silty clay / clayey silt till in Boreholes BH 3 and BH 4, and extended to termination depths of the boreholes, varying from 19.8 m to 19.9 m (Elevations 200.0 m to 201.3 m). The weathered shale was reddish brown in colour and contained some clayey silt seams and limestone.

The weathered shale could be augered through (within the borehole depths, although with some difficulty), from which the measured SPT 'N'-values were more than 50 blows per 0.3 m at all locations. Measured water content in the weathered shale varied from about 5 % to 18 %. The higher water content could possibly be due to groundwater seepage into the bottom of the boreholes during drilling.

5.5 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling in the open boreholes. The groundwater levels were also measured after drilling in the monitoring wells installed in Boreholes BH 1 and BH 3, together with BC 35. The installation detail of the existing monitoring well (BC 35) from AMEC's previous investigation (in AMEC Report No. TT93042 dated 30 June 2011) is included in Appendix C. The results of groundwater depth measurements are shown on the Record of Boreholes and summarized in Table 5.3.

Table 5.3 – Results of Groundwater Measurements

Borehole No.	Upon Completion of Drilling			In Monitoring Well		
	Date	Depth (m)	Elevation (m)	Date	Depth (m)	Elevation (m)
BH 1	11 Dec 2013	Dry	-	4 Feb 2014	14.6	206.6
BH 2	10 Dec 2013	17.7	202.1	*No monitoring well*		
BH 3	9 Dec 2013	13.7	206.1	4 Feb 2014	11.1	208.7
BH 4	9 Dec 2013	11.0	209.4	*No monitoring well*		
BC 35 (1)	27 Oct 2009	Dry	-	17 Mar 2010 4 Feb 2014	10.5 10.9	207.6 207.2

(1) Ground elevation at Borehole BC 35 = 218.1 m.

It should be noted that the groundwater at the site would fluctuate seasonally and can be expected to be somewhat higher during the spring months and in response to precipitation events and water level in the tributary.

6.0 DISCUSSIONS AND RECOMMENDATIONS

The purpose of the geotechnical investigation was to obtain subsurface information and to provide geotechnical recommendations with respect to the removal of the approximately 33 m long section (north and centre barrels) of the existing Credit River Tributary culvert, which is underneath the old Highway 7 embankment and has deteriorated significantly, and the replacement by a new open channel with associated structures. Based on the Preliminary Grading Plan (Appendix D) prepared by the designers (AMEC-Burlington) and the RFP requirements, discussions and recommendations, with respect to the geotechnical aspects of the culvert rehabilitation project, are required. In addition to the removal of the culvert and embankment of the old Highway 7, other associated works considered for the rehabilitation are:

- Construction of headwall/retaining wall/wing walls at the north end (and possibly south end) of the remaining south barrel under Bovaird Drive West, and associated embankment slope(s); and/or,
- Extension at the north end of the remaining culvert under Bovaird Drive West, after removal of the culvert under the old Highway 7; and/or,
- Construction of a new supplementary culvert under Bovaird Drive West, adjacent to the existing culvert, to augment hydraulics, which will possibly be constructed using trenchless technique.

Based on the results of the field investigation, the soil profile at the site comprised surficial topsoil and/or fill soils (sand and gravel, silty sand / sandy silt, silty sand and gravel, silty clay / clayey silt) overlying native silty clay / clayey silt till and/or weathered shale. At the borehole locations, the fill depths varied from 12.8 m to 14.9 m. In two of the boreholes located on Bovaird Drive West (BH 1 and BH 2), the fill soils were directly underlain by weathered shale. In the boreholes located on the old Highway 7 (BH 3 and BH 4), thin deposits (1.5 m and 3.5 m thick) of silty clay / clayey silt till were encountered underlying the fill soils and overlying the weathered shale.

Groundwater levels measured in the monitoring wells varied from 10.5 m to 14.6 m below the existing ground surface (Elevations 206.6 m to 208.7 m).

As per the Preliminary Grading Plan (Appendix D), the invert level of the culvert is about 12 m to 16 m below the existing ground surface. At the old Highway 7 area, the invert level is about 15 m below ground surface. The excavation work for the removal of the north section of the culvert and construction of an open channel will be predominantly within the fill soils and open cut excavation is feasible.

The foundations for head walls/retaining walls/wingwalls at both the north end and south end of the culvert under Bovaird Drive West, if constructed, and the culvert extension can be founded either on the silty clay / clayey silt till or the weathered shale.

A new supplementary culvert may be required under Bovaird Drive West to augment hydraulics of the tributary. The additional culvert will possibly be constructed by trenchless techniques. No information was available for the additional culvert, in terms of size and location, at the time of preparation of this report. If constructed, the alignment of the culvert will possibly pass through the bottom portion of the existing fill soils and/or through the native soil/weathered shale. One of the trenchless methods normally used in similar site conditions, i.e., Jacking and Boring, is feasible. Possible presence of cobbles in the fills soils may present some difficulty. Depending on the size of the culvert to be installed, a different trenchless method (e.g., horizontal directional drilling, pipe ramming, microtunneling, etc.) may be feasible.

For new slopes, general recommendations are provided hereinafter. However, slope stability analysis should be carried out for all the design road embankment slopes and channel sideslopes, both temporary and permanent, during the detail design.

The following sections discuss the geotechnical aspects of the works being considered for the rehabilitation. It should be noted that the recommendations herein are based on the preliminary information available and may need to be revised and/or supplemented, when design details are finalized.

6.1 Removal of Culvert under Old Highway 7 and Construction of Open Channel

The existing culvert under the old Highway 7, which is proposed to be removed, is about 33 m long, with the invert about 15 m below the top of the embankment. As per the RFP, the removal of culvert is proposed to be carried out by open-cut excavation, along with the removal of the old highway 7 embankment. An open-channel with stable sideslopes (approximately perpendicular to Bovaird Drive West) may be built within the length of the existing culvert to be removed. The road embankment (Bovaird Drive West) over the new inlet, i.e., the north end of the existing culvert underneath Bovaird Drive West, will be excavated and a new sideslope will have to be stable.

For stable permanent slopes, a minimum of 3 Horizontal to 1 Vertical (3H:1V) slope or flatter should be provided for fill slopes, as per Ontario Provincial Standard Drawing (OPSD 200.010) – "*Earth/Shale Grading, Undivided Rural*". For embankment heights greater than 8 m, a minimum 2 m wide bench should be provided, as per OPSD 202.010 – "*Slope Flattening using surplus excavated Material on Earth or Rock Embankment*".

Notwithstanding the above statements, slope stability analysis should be carried out to confirm long term stability of the slope, during the detail design.

All topsoil, organic matters, soft / loose and unsuitable soils should be removed from excavated slope and backfilled with compacted approved fill.

Proper erosion control measures of the new embankment surfaces should be implemented, both during construction and on a permanent basis. This can be achieved by immediate seeding or sodding or other slope stabilization measures.

Excavation and dewatering are discussed in Section 6.4.1.

6.2 Headwalls / Retaining Walls / Wingwalls and Culvert Extension

After removal of the old Highway 7 embankment and the culvert under it, headwalls and/or retaining walls and/or wingwalls may be required at the north end of the remaining culvert under Bovaird Drive West. Alternatively, as shown in the Preliminary Design Grade (Appendix D), the culvert (under Bovaird Drive West) may be extended, in which case the need for headwalls and retaining walls may not be required, although wingwalls may still be required. Similarly, headwalls and/or retaining walls and/or wingwalls may also be constructed at the south end of the existing culvert.

6.2.1 Foundations

Based on the soil profile observed at the borehole locations and the rehabilitation works being considered, the founding strata for the headwalls/retaining walls/wingwalls will be the hard silty clay/ clayey silt till and/or very dense weathered shale, which would provide adequate support for structures.

Details regarding the structures were not available at the time of preparing this report. Based on the soil encountered in the boreholes, geotechnical reaction at Serviceability Limit States (SLS) and geotechnical resistance at Ultimate Limit States (ULS) provided in Table 6.1 may be used for preliminary design purpose. Higher values may be possible based on final design and detail foundation analysis, if required.

Table 6.1 - RECOMMENDED ULS/SLS BEARING VALUES AT BOREHOLE LOCATIONS

Borehole No.	Founding Stratum	Depth Below Existing Grade (m)	Approximate Elevation (m)	Geotechnical Pressure Reaction at SLS (kPa)	Factored Geotechnical Pressure Resistance at ULS(1) (kPa)
BH 1	Fill Very dense weathered shale	Above 14.9 (±) Below 14.9 (±)	Above 206.3 (±) Below 206.3 (±)	Not recommended 400	Not recommended 600
BH 2	Fill Very dense weathered shale	Above 12.8 (±) Below 12.8 (±)	Above 207.0 (±) Below 207.0 (±)	Not recommended 400	Not recommended 600
BH 3	Fill Hard silty clay/clayey silt till Very dense weathered shale	Above 11.7 (±) 11.7 - 13.2 (±) Below 13.2 (±)	Above 208.1 (±) 208.1 - 206.7 (±) Below 206.7 (±)	Not recommended 250 400	Not recommended 375 600
BH 4	Fill Hard silty clay/clayey silt till Very dense weathered shale	Above 11.0 (±) 11.0 - 14.5 (±) Below 14.5 (±)	Above 209.4 (±) 209.4 - 205.9 (±) Below 205.9 (±)	Not recommended 250 400	Not recommended 375 600

(1) A resistance factor of Φ = 0.5 has been applied to the ULS values provided.

For foundations designed and constructed as recommended in this report and in accordance with good construction practice, the SLS soil bearing values provided would correspond to total and differential settlements of up to 25 mm and 20 mm, respectively. In order to achieve the SLS/ULS soil bearing pressures as indicated in Table 6.1, the exposed subgrade should be free of loose/soft, disturbed wet or otherwise deleterious materials.

6.2.2 Design Soil Parameters

The unfactored soil parameters listed in Table 6.2 may be used for design. It should be noted that these parameters are based on published information and/or semi-empirical/theoretical relationships. The parameters provided are conservative and should be verified by field/laboratory testing, if more accurate parameters are required.

Table 6.2 - Unfactored Static Soil Parameters for Design

Material	Total Stress Analysis		Effective Stress Analysis		Earth Pressure Coefficients(1)			Bulk Unit Weight (kN/m^3)	Coefficient of Friction between Concrete and Soil
	C (kPa)	Φ (deg)	c' (kPa)	Φ' (deg)	Active K_a	At-Rest K_o	Passive K_p		
Undisturbed Native Soils									
Hard silty clay/clayey silt till	100	0	0	28(2)	0.36	0.53	2.8	20	0.4
Very dense weathered shale	100	0	0	30	0.36	1.0(3)	2.8	22	0.4
Engineered Fill (4)									
Granular A (OPSS 1010)	0	35	0	35	0.27	0.43	3.7	24(5)	0.4
Granular B Type I (OPSS 1010)	0	32	0	32	0.31	0.47	3.3	23(5)	

(1) Values based on semi-empirical relationships. For SLS, K_p values should be reduced to 1/3 of indicated value to limit lateral movement.
(2) Normally-consolidated range.
(3) Due to potential swelling of shale
(4) All engineered fill should be compacted to at least 100 % SPMDD for supporting foundations.
(5) Bulk unit weight values for engineered fill compacted to 100 % SPMDD. For backfill of retaining walls, unit weights for Granular A and Granular B compacted to 95 % SPMDD may be taken as 22 kN/m^3, and 21 kN/m^3, respectively.

6.2.3 Design Frost Depth

The design frost penetration depth for the project area is 1.2 m. Therefore, a permanent soil cover of 1.2 m or its thermal equivalent is required for frost protection of foundations.

6.3 Supplementary Culvert by Trenchless Technique

A supplementary culvert to augment the hydraulics of the Tributary may be required. The supplementary culvert, if constructed would likely be installed by trenchless technique and would possibly be located parallel to, and at an elevation the same as or slightly higher than the existing culvert invert. No other details (size, location, etc.) were known at the time of preparation of this report.

Trenchless technique (i.e., tunneling) depends upon a number of factors, of which the important ones are the groundwater conditions and the soil types through which the tunnel must pass. The following geotechnical factors should be considered for the selection of tunneling method:

a. The proposed tunneling method should cause minimal disturbance to the existing road and its usage.
b. The proposed tunneling method would not cause instability of the existing road embankments.
c. The proposed tunneling method should consider suitable means of groundwater/surface water dewatering during the tunneling work, if it is encountered.

The tunnel for this project would likely be through the existing embankment. Based on the information available and the site/soil conditions, installation by jacking and boring would be feasible. A general description of the jacking and boring method is presented in the following section. Other tunneling methods (such as horizontal directional drilling, pipe ramming, microtunneling, etc.) may also be considered, if necessary, once the details of the culvert are known.

6.3.1 Jacking and Boring

The construction of the tunnel by this method should conform to Ontario Provincial Standard Specification (OPSS) **–** "*Construction Specification for Pipeline and Utility Installation by Jacking and Boring*" (OPSS 416).

This technique forms a horizontal borehole from a drive shaft to a reception shaft by means of a rotating cutting head. Spoil is transported back to the drive shaft by helical auger flights rotating inside a steel casing. The casing is jacked in place simultaneously with the augering operation. After the installation of the steel casing, the culvert pipe is installed inside the casing and the gap between the casing and the pipe is grouted. Steel casing is typically used due to its high strength, good flexibility and good workability. Other casing material (e.g., concrete) may be used, depending on the design against surrounding pressure, workability, cost, etc. It should be noted that this method of tunneling does not allow significant change in direction between the drive shaft and the reception shaft.

The fill soils (sandy silt / silty sand, silty sand and gravel, silty clay / clayey silt) expected to be encountered during tunneling may not be stable at the tunnel face, particularly if groundwater seepage occurs. Provisions for handling groundwater seepage (possibly perched) during tunneling should be considered and a contingency plan should be in place prior to start of tunneling. The tunnel alignment should be provided with a gentle gradient so that water seepage into the opening can be directed away from the tunnel face. If there is a possibility of loss of soils into the tunnel, proper measure(s) should be implemented (e.g., installing a shield at the tunnel face, grouting the soils around the tunnel prior to excavation, etc.). As a minimum and as a preventative measure against development of potential flowing or running condition and to maintain stability of the tunnel face, a plug of soil should be left inside the front end of the tunnel casing at all times. The size of the plug depends on the soil and groundwater conditions encountered at the time of the tunneling. If unexpected high groundwater flow is encountered and/or loss of soil through the tunnel is excessive, the tunneling operation should be stopped immediately and remedial measures should be taken to stabilize the tunnel face. Potential gap between the tunnel casing and the soil, after the completion of tunneling, should be grouted to reduce settlements.

The Contractor should be made aware of the possibility of encountering cobbles/boulders.

For general design purposes, the following parameters (and the values provided in Table 6.2, as required) may be used:

- The Unfactored coefficient of friction between the steel casing and the sandy/silty soils should be calculated by using a friction angle of 32^o.
- The bulk unit weight of the overburden above the tunnel crown should be considered as at least 20 kN/m^3.
- For the soils surrounding the tunnel, the estimated Soil Modulus of Elasticity, E, should be in the range of 15 MPa for overburden fill soils), 80 MPa (hard/very dense soils) and 100 MPa for very dense weathered shale.
- The coefficient of lateral earth pressure at rest, K_o, shown in Table 6.2 should be used for the tunnel liner design.

6.3.2 Settlement Monitoring during Tunneling

During tunneling, the ground over and in the vicinity of the tunnel alignment may experience settlement. Good workmanship and site control is the most effective way to reduce settlements to practical minimum. Ground movement during tunneling should be monitored together with the monitoring of tunnel activity. This is to confirm that the tunnelling process does not cause any significant impact on the road embankment and the steel pipe casing/pipe is properly installed. If any adverse effect of tunneling is identified by the monitoring program, the tunneling process can be modified accordingly.

A settlement monitoring plan should be designed, when the proposed construction method is available and prior to tunneling. The proposed method should be reviewed by the foundation/tunnel engineer. It is recommended that a qualified geotechnical consultant supervise the installation and monitoring of surface settlements.

6.4 Construction Considerations

6.4.1 Excavation and Dewatering

All excavation should be carried out in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects. Based on the soil conditions encountered in the boreholes, the soils to be excavated can be classified as follows:

All fill soils	Type 3

Silty clay / clayey silt till	Type 2
Weathered shale	Type 1 / Type 2

Accordingly, a bank slope of 1H:1V is required for excavations in accordance with the Ontario Health and Safety Regulations. For Type 1 and Type 2 soils, a 1.2 m high vertical cut at the bottom of excavation may generally be constructed. However, under groundwater table, a 1.2 m high vertical cut may not be stable and flatter slopes may be required. Near the ground surface, occasional 3H:1V slopes may be required due to loose / soft surficial soils. If open cut cannot be carried out, a shoring system may be used to limit the extent of excavation, subject to engineering design and approval.

For temporary cut slopes (e.g., removal of the existing old Highway 7 embankment), stability of cut slopes will have to be frequently monitored by the geotechnical engineer. If the cut slopes are subject to erosion (e.g., due to rainfall, high groundwater flow, etc.), slope stabilization measures (e.g., covering the slope faces with plastic sheets, excavating flatter slope, etc.) will have to be implemented.

Stockpiles of excavated materials should be kept at a distance equal to the height of the cut from the edge of the excavation to prevent slope instability, subject to confirmation by the geotechnical engineer. Care should also be taken to avoid overloading of any underground services / structures by stockpiles.

No major excavation difficulties are foreseen in the existing soils, but allowance should be made for removing boulders and cobbles that may possibly be present in the fill, till and weathered shale with limestone. The terms describing the compactness (loose, compact, dense, and very dense) or consistency (stiff, very stiff and hard) of soil strata give an indication of the effort needed for excavation. For weathered shale, and possibly for hard/very dense soils, additional efforts in excavation will likely be required, including the use of hydraulic impact hammers or similar equipment.

Based on the soil and groundwater conditions at the borehole locations, dewatering within the excavated area should not be significant and could be carried out by a system of sumps and pumps. High water flow rates, e.g., from perched water in the silty/sand fill soils, may be encountered during the course of the construction and the dewatering effort could require an increased number of sumps and pumps or a well point system. This should be further evaluated prior to construction via test pit excavation in order to select that the most effective dewatering method.

All surface water, particularly from the Credit River Tributary, should be directed away from any open excavations. A cofferdam and/or diversion of the Tributary flow may be required for such purpose. During the construction, temporary runoff controls such as sediment trap, interceptor drain, dyke and / or silt fence should be provided and installed to prevent uncontrolled water / sediment flow into existing water courses. The effluent from dewatering operations should also be filtered or passed through sediment traps to prevent turbidity.

The founding subgrade for structures (walls/culvert) will possibly consist of either till or weathered shale. The use of protective skim coat of lean concrete may be warranted where founding surfaces are to be exposed for extended period, especially if the founding subgrade is weathered shale and/or if the work is carried out during wet weather. Under inclement weather conditions, an adequate granular working surface or lean concrete mud mat would be required to minimize disturbance and protect the integrity of the subgrade soils. Care should also be exercised to minimize disturbance to the final subgrade during excavation.

It is recommended that qualified geotechnical personnel be present during the foundation excavation to review the conditions of the excavation.

6.4.2 Backfill and Soil Reuse

Based on the visual and tactile examination of the soil samples, the on-site excavated fill soils (sandy silt / silty sand, silty sand and gravel, silty clay / clayey silt) and the native silty clay / clayey silt till may be re-used as backfill soils, where required (e.g., backfilling behind headwall/retaining walls/wing walls), provided that all organic matter and deleterious materials, if any, are removed. Some processing of the soils, e.g., drying, may be required, if the soils are very wet and cannot be compacted properly. Soil chemical tests were carried out on selected soil samples to evaluate soil reuse and disposal suitability. The results and finding of the limited soil chemical analysis are discussed in Section 7.0

Excavated chunks or blocks of cohesive (clayey) soils should be reduced to less than 100 mm in size for use as backfill. Unless the clayey soils are properly reduced in size and compacted in sufficiently thin lifts, post-construction settlement could occur. It is therefore recommended that, in settlement-sensitive areas, granular materials be used as backfill to minimize subsequent settlement. It is recommended that all backfilling be tested and approved by a Geotechnical Engineer.

6.4.3 Swelling of Shale

Shale has a tendency to swell upon release of in-situ stress and/or in contact with water, which would “squeeze” into the excavation, and thereby, exert pressure onto any structure constructed against it. The “squeeze” can be both horizontal (e.g., side squeezing) and/or vertical (e.g., bottom heaving), and generate high pressures on any structure built against it. Therefore, it is imperative to include this behaviour in design and construction of any structure in shale. Two swelling parameters should be considered, i.e., "free swell potential" and "swell suppression pressure". "Free swell potential" is the tendency to swell without any external constraint. Free swell potential for typical Ontario shale ranges from less than 0.5 % for highly durable shale to 20 % for low durability shale, with durability related to resistance to weathering (*Reference: “Evaluation of Shales for Construction Projects – An Ontario Shale Rating System”, prepared by Ministry of Transportation and Communications, March 1983*). Various tests conducted on shale have shown that the application of stress (“swell suppression pressure”) can suppress swelling. Table 6.3 provides a general guideline for swelling parameters for shale to be considered in design, if structures are to be built on or within the weathered shale.

Table 6.3 –Swell Parameters for Shale(1)

Shale Type	Free Swell Potential(2) (%)	Swell Suppression Pressure(3) (MPa)
Weathered	0.5 to 20	0.3 to 0.7

(1) Based on published empirical values ("*Evaluation of Shales for Construction Projects*", *MTO*). It is to be noted that the swell suppression pressure increases with depth.
(2) Shale is allowed to swell freely without any restriction.
(3) Shale is not allowed to swell freely by applying pressure against it.

The swelling potential of shale is a time dependent property which will decrease with time. Therefore, a commonly-used method of mitigating the effects of rock squeeze is to allow sufficient time for free swell, after the shale is excavated, prior to construction of any permanent structure against it. This can be done by incorporating the time required for shale swell into the construction schedule. However, such delay in construction cannot be accepted in some projects (e.g., temporary open cut in existing road embankment). In such cases, crushable material (e.g., preformed or sprayed foam can be installed, where practical, between the excavated rock and structure interface to allow rock deformation (swelling) into the crushable material, which will prevent/minimize the build-up of pressure against the structure.

In order to reasonably estimate the swell potential, a detail investigation, including specialized laboratory tests, will be necessary to establish the time-deformation relationship of the shale in the project area.

Shale can become soft or degraded after excavation and being exposed to the weather, especially if it comes in contact with surface water or there is groundwater seepage through the shale bedrock, which can affect the stability of the excavated area. To minimize this effect during construction, the exposure time of the shale has to be minimized. Therefore, it is necessary to inspect the exposed shale at the time of excavation and to monitor the exposed shale conditions during construction. If unfavourable weathering is anticipated, it is recommended that the exposed shale surface be protected by, as a minimum, a temporary protective measure (e.g., a thin layer of lean concrete, shotcrete, etc.).

6.4.4 Temporary Shoring

Vertical excavation may be required for construction of the structures (e.g., culvert extension, retaining/wingwalls), which may, in turn, require temporary shoring. This can be accomplished by sheeting and bracing system (e.g. soldier piles with lagging or similar) or by using a trench box, in order to support the sides of the excavation.

The temporary shoring system should be designed to resist the lateral earth, surcharge and hydrostatic pressures which could occur during construction. Bracing should be installed within the shoring system to minimize movement of the soils. The temporary shoring system should be designed in accordance with the Canadian Foundation Engineering Manual's latest Edition and the requirements of the Ontario Health and Safety Regulations. The soil parameters provided in Table 6.2 may be used for the design of temporary shoring.

6.5 Slope Stability Analysis

Slope stability analysis should be carried out for all new slopes and headwalls/retaining walls/wingwalls that are higher than 2 m during the detail design, once the details have been finalized.

7.0 LIMITED SOIL CHEMICAL ANALYSIS

7.1 Environmental Sample Collection and Analysis

The environmental components of the subsurface investigation included the following activities:

- Conducting the soil sampling activities in accordance with Ontario Ministry of Environment (MOE) document entitled "*Guidance on Sampling and Analytical Methods for Use at Contaminated Sites in Ontario",* dated December 1996 and Ontario Regulation 153/04;
- Submission of two (2) soil samples from two (2) selected boreholes for laboratory analysis of metals and inorganic parameters to assist in determining appropriate soil disposal options, if required, during construction;
- Submission of one (1) soil sample per project area for Ontario Regulation 347 as amended by Ontario Regulation 558/00 (O. Reg. 347) Toxicity Characteristic Leaching Procedure (TCLP) for metals and inorganics, benzo(a)pyrene [B(a)P], polychlorinated biphenyls (PCBs) and volatile organic compounds (VOCs), to determine landfill acceptability of soil originating from the Site;
- Comparison of the laboratory analytical results to soil standards presented in the MOE document entitled "*Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act*," dated April 15, 2011 and O. Reg 347, as amended by O. Reg. 558/00, Schedule 4 Leachate Quality Criteria provided in the MOE document entitled "*Registration Guidance Manual For Generators of Liquid Industrial and Hazardous Waste*," October 2000 (the "Schedule 4 Criteria").

7.2 Site Condition Standards

Soil results are compared to the MOE Table 1 soil standards for Residential/ Parkland/ Institutional/ Industrial/ Commercial/Community Property Use presented in the MOE document "*Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act*", dated April 15, 2011 (Table 1 SCS) and Table 3 - soil standards for Industrial / Commercial / Community Property Use presented in the MOE document "*Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act*", dated April 15, 2011 (Table 3 SCS).

It should be noted that environmental exemptions for roads may apply under O.Reg 153/04 as amended by O.Reg. 511/09. If, having regard to any phase one and phase two environmental site assessments for a property, a qualified person determines that an applicable site condition standard is exceeded at the property solely because a substance has been used on a highway for the purpose of keeping the highway safe for traffic under conditions of snow or ice or both, as provided for under section 2 of Regulation 339 of the Revised Regulations of Ontario, 1990 (Classes of Contaminants – Exemptions), the applicable site condition standard is deemed not to be exceeded for the purpose of Part XV.1 of the Act. O. Reg. 153/04, s. 48 (3) ["road" means the part of a common or public highway, street, avenue, parkway, square, place, bridge, viaduct or trestle that is improved, designed or ordinarily used for regular traffic and includes the shoulder].

Due to the application of road salts for control of snow and ice on Brampton roads, it is common to find elevated concentrations of electrical conductivity (EC) and sodium adsorption ratio (SAR) and therefore these parameters would be exempt under O. Reg.153/04 (for re-use of soils on-site).

As noted in Section 7.1, soil results were also classified in accordance to O. Reg. 347 for landfill disposal options.

7.3 Soil Sampling, Inspection and Preservation Procedures

Soil samples were obtained for laboratory analysis and field screening, where applicable, using a drill rig equipped with split spoon sampling capabilities. The procedures are consistent with generally accepted professional practices and with the Ontario Ministry of the Environment Guidance on Sampling and Analytical Methods for Use at Contaminated Sites in Ontario, dated December 1996 and O.Reg. 153/04 as amended. The sampling procedure is described below.

The soil samples retrieved during the borehole investigation were examined, classified, and logged according to soil type, moisture content, colour, consistency, and presence of visual and/or olfactory indicators of negative impact. Soil samples were split into duplicate fractions upon recovery at the surface. The primary sample fractions were placed in 250 millilitre (mL) sample jars with Teflon-lined lids and subsequently stored in coolers on ice for future potential laboratory analysis. The duplicate sample fractions were placed in Ziploc™ sample bags and stored at ambient temperature. The duplicate soil sample fractions were screened for total organic vapour (TOV) and combustible organic vapour (COV) concentrations using the sample headspace method.

The TOV/COV screening measures the cumulative organic/combustible vapour present within sample headspace. TOV/COV results are semi-quantitative at best and are generally only used for relative sample comparison purposes when selecting samples from individual boreholes for laboratory analysis. A RKI Eagle 2, equipped with dual sensors, was used to measure TOV and COV concentrations; the sensors were calibrated to a known isobutylene standard (for TOV sensor) and to a known hexane standard (for COV sensor).

All soil samples were collected in accordance with strict environmental sampling protocols to minimize loss of volatile organics and to ensure reliable and representative results. Disposable nitrile gloves were used and replaced between the handling of successive samples. All soil sampling equipment (open tube samplers, stainless steel trowels, shovels, spatulas, etc.) was thoroughly decontaminated between soil sample locations to prevent potential cross contamination. Decontamination activities included:

- Physical removal of any adhered debris;
- Wash/scrub in Alconox™ soap solution;
- Distilled water rinse;
- Methanol rinse; and
- Air dry.

Representative soil samples collected during the investigation were submitted for laboratory analysis of suspected parameters of concern. The analytical laboratory employed to perform the laboratory analysis, AGAT Laboratories of Mississauga, Ontario (AGAT), is accredited by the Canadian Association for Laboratory Accreditation (CALA) in accordance with ISO/IEC 17025:2005 – *"General Requirements for the Competence of Testing and Calibration Laboratories"* for the tested parameters and has met the standards for proficiency testing developed by the Standards Council of Canada (SCC) for parameters set out in the Soil, Ground Water and Sediment Standards.

7.4 Environmental Test Results and Considerations

No evidence (i.e., visual/olfactory) of environmental impacts were observed in any of the soil samples collected from the Site. Field screening measurements of total/combustible gas vapours undertaken with the RKI Eagle 2 are provided on the Record of Boreholes. The highest TOV reading was 60 part per million (ppm) and the highest COV reading was 2 ppm.

Two (2) soil samples were submitted for laboratory analysis of metals and inorganics.

The soil samples collected as part of this assessment that exceeded the Table 1 SCS are as follows:

- BH1 / SS4: sodium adsorption ratio ("SAR") and electrical conductivity ("EC"); and
- BH3 SS3: SAR.

The remaining laboratory analyses were below the Table 1 SCS for metals and inorganics. All soil samples were below the Table 3 SCS for metals and inorganics.

Refer to Table 7.1 for comparison of analytical results to the Table 1 SCS and Table 3 SCS.

Table 7.1 - Soil Chemical Analysis Metals and Inorganics

Location					Borehole 1	Borehole 3
Sample ID					BH1 / SS4	BH3 / SS3
Depth (metres below ground level)					2.3 - 2.9	1.5 - 2.1
Soil Vapour COV					0 ppm	0 ppm
Soil Vapour TOV					0 ppm	0 ppm
Laboratory ID Number					5055108	5055109
	Units	RDL	Table 1^{A}	Table 3^{B}		
Calculated Parameters						
Sodium Adsorption Ratio	N/A	N/A	2.4	12	**4.94**	**2.64**
Inorganics						
Chromium (VI)	µg/g	0.2	0.66	(10) 8	<	<
Conductivity	mS/cm	0.005	0.57	1.4	**1.17**	0.167
Free Cyanide	µg/g	0.040	0.051	0.051	<	<
Available (CaCl2) pH	pH	N/A	*	*	7.82	7.77
Metals						
Antimony	µg/g	0.8	1.3	(50) 40	<	<
Arsenic	µg/g	1	18	18	5	4
Barium	µg/g	2	220	670	70	62
Beryllium	µg/g	0.5	2.5	(10) 8	<	<
Boron	µg/g	5	36	120	<	6
Boron (Hot Water Soluble)	µg/g	0.10	N/A	2	0.21	0.13
Cadmium	µg/g	0.5	1.2	1.9	<	<
Chromium	µg/g	2	70	160	17	15
Cobalt	µg/g	0.5	21	(100) 80	7.1	8.8
Copper	µg/g	1	92	(300) 230	37	28
Lead	µg/g	1	120	120	14	9
Mercury	µg/g	0.10	0.27	(20) 3.9	<	<
Molybdenum	µg/g	0.5	2	40	<	<
Nickel	µg/g	1	82	(340) 270	13	15
Selenium	µg/g	0.4	1.5	5.5	<	<
Silver	µg/g	0.2	0.5	(50) 40	<	<
Thallium	µg/g	0.4	1	3.3	<	<
Uranium	µg/g	0.5	2.5	33	<	<
Vanadium	µg/g	1	86	86	20	22
Zinc	µg/g	5	290	340	46	46

Notes: (A) "Ontario Regulation 153/04-Records of Site Condition" Table 1 Full Depth Background Site Condition Standards for Residential / Parkland / Institutional / Industrial / Commercial / Community Property Use. Table 1 exceedences if any, indicated by **bold**. (B) "Ontario Regulation 153/04-Records of Site Condition" Table 3 Full Depth Generic Site Condition Standards in a Non-Potable Ground Water Condition for Industrial / Commercial / Community Property Use. ( ) Standards in brackets apply to medium and fine textured soils. Table 3 exceedences, if any, indicated by **bold**. "RDL" means reportable detection limit. "<" indicates not detected above the reportable detection limit. "N/A" means not applicable. "*" As per Ontario Regulation 153/04, in order to apply the generic Site Condition Standards, pH for surface soil (<1.5 metres) should be between 5 and 9 and for soil (>1.5 metres), pH should be between 5 and 11."µg/g" means micrograms per gram. "mS/cm" means millisiemens per centimetre. "ppm" means parts per million. "COV" means combustible organic vapour. "TOV" means total organic vapour.

The reported leachate concentrations from BH1 / SS5 were compared to the Schedule 4 Criteria. The reported concentrations of metals and inorganics, VOCs, PCBs and B(a)P were below the Schedule 4 Leachate Quality Criteria. Therefore, the soil would be considered as acceptable non-hazardous soil for disposal at most MOE approved landfills.

The laboratory certificates of analysis are presented in Appendix B. The results of the O. Reg. 347 TCLP analysis are summarized in Tables 7.2 and 7.3.

It should be noted that EC and SAR are commonly associated with de-icing activities (i.e. road salt) for roadways and parking lots. EC and SAR in soil do not cause any human health effects, however, may affect plant growth (only a concern within the upper 1.5 metres of soil).

Table 7.2 – O.Reg. 347 TCLP Inorganic parameters

Location				Borehole 1
Sample ID				BH1 / SS5
Depth (metres below ground level)				3.0 - 3.6
Soil Vapour COV				0 ppm
Soil Vapour TOV				0 ppm
Laboratory ID Number				5055110
	Units	RDL	Schedule 4^{A}	
Arsenic Leachate	mg/L	0.010	2.5	<
Barium Leachate	mg/L	0.100	100	0.948
Boron Leachate	mg/L	0.050	500	<
Cadmium Leachate	mg/L	0.010	0.5	<
Chromium Leachate	mg/L	0.010	5.0	<
Lead Leachate	mg/L	0.010	5.0	<
Mercury Leachate	mg/L	0.01	0.1	<
Selenium Leachate	mg/L	0.010	1.0	<
Silver Leachate	mg/L	0.010	5.0	<
Uranium Leachate	mg/L	0.050	10.0	<
Fluoride Leachate	mg/L	0.05	150	0.24
Cyanide Leachate	mg/L	0.05	20.0	<
(Nitrate + Nitrite) as N Leachate	mg/L	0.70	1000	<

Notes: (A) Ontario Ministry of the Environment (MOE) "Registration Guidance Manual for Generators of Liquid Industrial and Hazardous Waste" (October 2000) Schedule 4 Leachate Quality Criteria. Schedule 4 exceedences if any, indicated by **bold**. "RDL" means reportable detection limit. "<" indicates not detected above the reportable detection limit. "mg/L" means milligrams per litre. "ppm" means parts per million. "COV" means combustible organic vapour. "TOV" means total organic vapour.

Table 7.3 – O.Reg. 347 TCLP VOCs, PCBs and B(a)P

Location	Borehole 1
Sample ID	BH1 / SS5
Depth (metres below ground level)	3.0 - 3.6
Soil Vapour COV	0 ppm
Soil Vapour TOV	0 ppm
Laboratory ID Number	5055110

	Units	RDL	Schedule 4[A]	
Vinyl Chloride	mg/L	0.030	0.2	<
1,1 Dichloroethene	mg/L	0.020	1.4	<
Dichloromethane	mg/L	0.030	5.0	<
Methyl Ethyl Ketone	mg/L	0.090	200	<
Chloroform	mg/L	0.020	10.0	<
1,2-Dichloroethane	mg/L	0.020	0.5	<
Carbon Tetrachloride	mg/L	0.020	0.5	<
Benzene	mg/L	0.020	0.5	<
Trichloroethene	mg/L	0.020	5.0	<
Tetrachloroethene	mg/L	0.050	3.0	<
Chlorobenzene	mg/L	0.010	8.0	<
1,2-Dichlorobenzene	mg/L	0.010	20.0	<
1,4-Dichlorobenzene	mg/L	0.010	0.5	<
Polychlorinated Biphenyls	mg/L	0.005	0.3	<
Benzo(a)pyrene	mg/L	0.001	0.001	<

Notes: (A) Ontario Ministry of the Environment (MOE) "Registration Guidance Manual for Generators of Liquid Industrial and Hazardous Waste" (October 2000) Schedule 4 Leachate Quality Criteria. Schedule 4 exceedences if any, indicated by **bold**. "RDL" means reportable detection limit. "<" indicates not detected above the reportable detection limit. "mg/L" means milligrams per litre. "ppm" means parts per million. "COV" means combustible organic vapour. "TOV" means total organic vapour.

7.5 Quality Assurance / Quality Control

Field duplicate samples were not collected as part of this investigation, however, laboratory QA/QC procedures were followed.

The "*Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act*", 01 July 2011 (the "2011 Analytical Protocol") provides requirements for sample handling and storage requirements, reporting requirements, analytical methods and QA/QC procedures for analytical parameters.

As per the 2011 Analytical Protocol, all samples/sample extracts were analyzed within their applicable hold times using approved analytical methods. The report limits were met for all samples and tested parameters. No tested parameter was present in a detectable concentration in any laboratory Method Blank and all laboratory surrogates, reference materials and replicate samples are considered acceptable.

8.0 SOIL CORROSIVITY ANALYSIS

To assess the soil aggressiveness to concrete and embedded metal features, one (1) soil sample was submitted to AGAT Laboratories and subject to determination of pH, soluble Chloride, soluble Sulphate, Electrical Conductivity and Resistivity.

The corrosivity test results are summarized in Table 8.1. The complete laboratory test results and the Certificates of Analyses are included in Appendix B.

Table 8.1 – Summarized Soil Corrosivity Test Results

Sample ID	Resistivity (ohm-cm)	Chloride (µg/g)	Electrical Conductivity (mS/cm)	pH	Sulphate (µg/g)
BH 2 – SS 10	4480	63	0.223	8.20	27

Compared to the values in the available literature (i.e., J.D. Palmer, Soil Resistivity Measurement and Analysis, Materials Performance, Volume 13, 1974), the above-mentioned values of the soil resistivity should be considered as “moderate” for exposed metallic structures.

The measured water soluble sulphate in soil was about 27 µg/g. In accordance with Table 3 of the Canadian Standards Association (CSA) Series CSA A23.1-09, soil with the sulphate content ratio less than 0.1% (i.e. 1,000 ppm or µg/g) is not considered aggressive to concrete. Therefore, in accordance with Table 6 of the CSA Series A23.1-09, Type GU Portland cement may be used for concrete.

Soil corrosivity should be assessed by a corrosivity expert, if necessary.

9.0 EARTHQUAKE CONSIDERATIONS

Based on the depth of soil to bedrock and the soil type (native) encountered in the boreholes and in conformance with Section 4.4.6 of the Canadian Highway Bridge Design Code (CHBDC, CAN/CSA-S6-06), the project site conditions may be classified as “Soil Profile Type I”. Site Coefficient should be considered as per Table 4.4, Section 4.4.6 of CHBDC.

10.0 CLOSURE

The sub-soil information and recommendations contained in this report should be used solely for the purpose of geotechnical investigation of this project.

AMEC should be retained to review the recommendations for this specific applicability, once the details of the proposed works are finalized and prior to the final design stage of the project. Additional investigation may be required to provide geotechnical information for the final design.

The geotechnical aspects of the report have been prepared by Shami Malla, M.Eng., P.Eng., and reviewed by Prapote Boonsinsuk, Ph.D., P.Eng. The limited soil chemical analysis has been prepared by Jonathan Wakani, P.Geo., Geoscientist, and reviewed by Jeff Carson, P.Eng., Associate Environmental Engineer.

The Report Limitations is an integral part of this report.

Sincerely,

AMEC Environment & Infrastructure,
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REPORT LIMITATIONS

The conclusions and recommendations given in this report are based on information determined at the borehole locations. The information contained herein in no way reflects on the environmental aspects of the project, unless otherwise stated. Subsurface and groundwater conditions between and beyond the boreholes may differ from those encountered at the borehole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation. It is recommended practice that a Geotechnical Engineer be retained during construction to confirm that the subsurface conditions across the site do not deviate materially from those encountered in the boreholes.

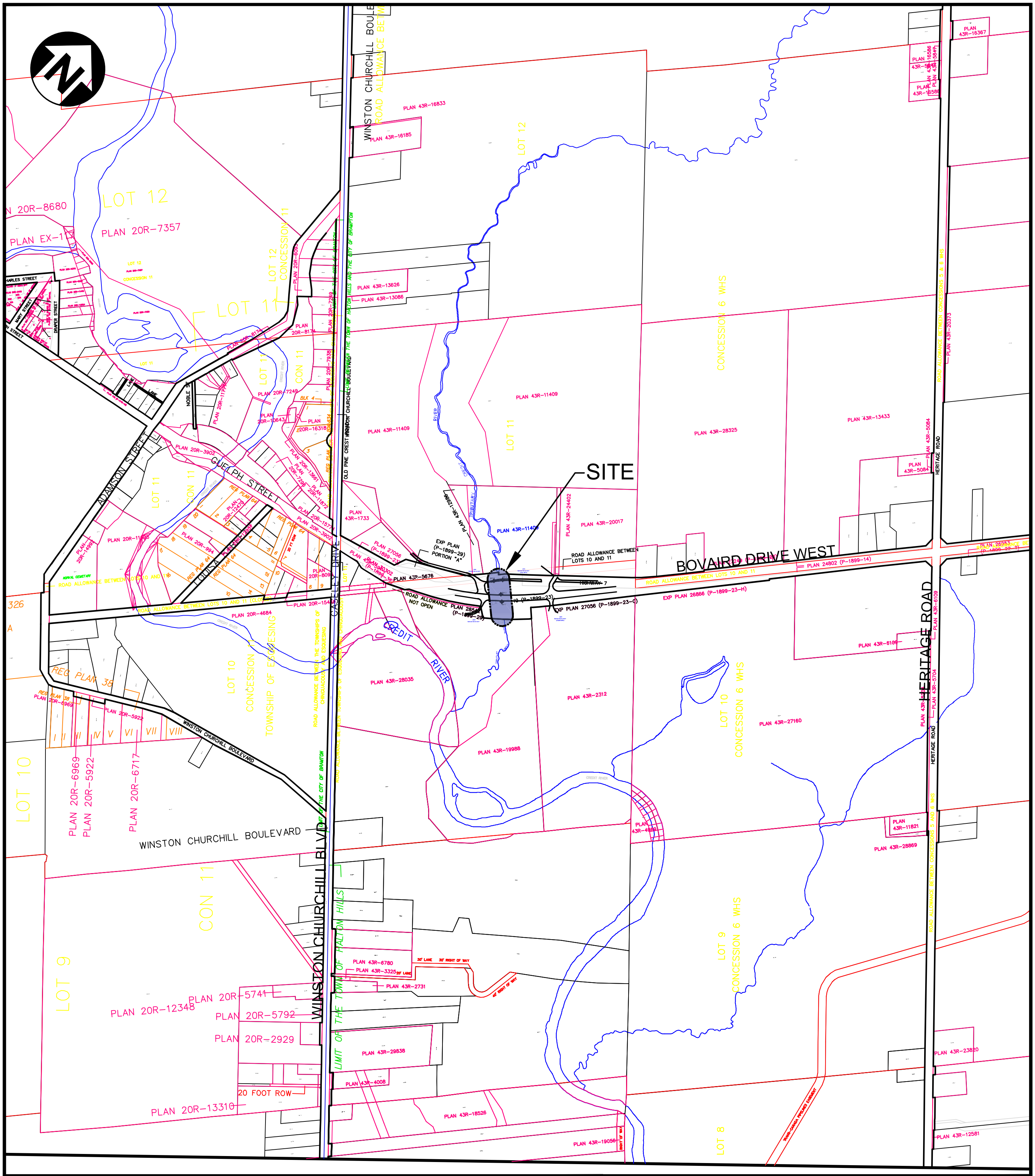
The design recommendations given in this report are applicable only to the project described in the text, and then only if constructed substantially in accordance with the details stated in this report. Since all details of the design may not be known, it is recommended that AMEC be retained during the final design stage to verify that the design is consistent with AMEC recommendations, and that assumptions made in AMEC analysis are valid.

The comments made in this report relating to potential construction problems and possible methods of construction are intended only for the guidance of the designer. The number of boreholes may not be sufficient to determine all the factors that may affect construction methods and costs. For example, the thickness of fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusions as to how the subsurface conditions may affect their work. This work has been undertaken in accordance with normally accepted geotechnical engineering practices. No other warranty is expressed or implied.

The benchmark and elevations mentioned in this report were obtained strictly for use by this office in the geotechnical design of the project. They should not be used by any other party for any other purpose.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. AMEC Environment & Infrastructure accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

FIGURES



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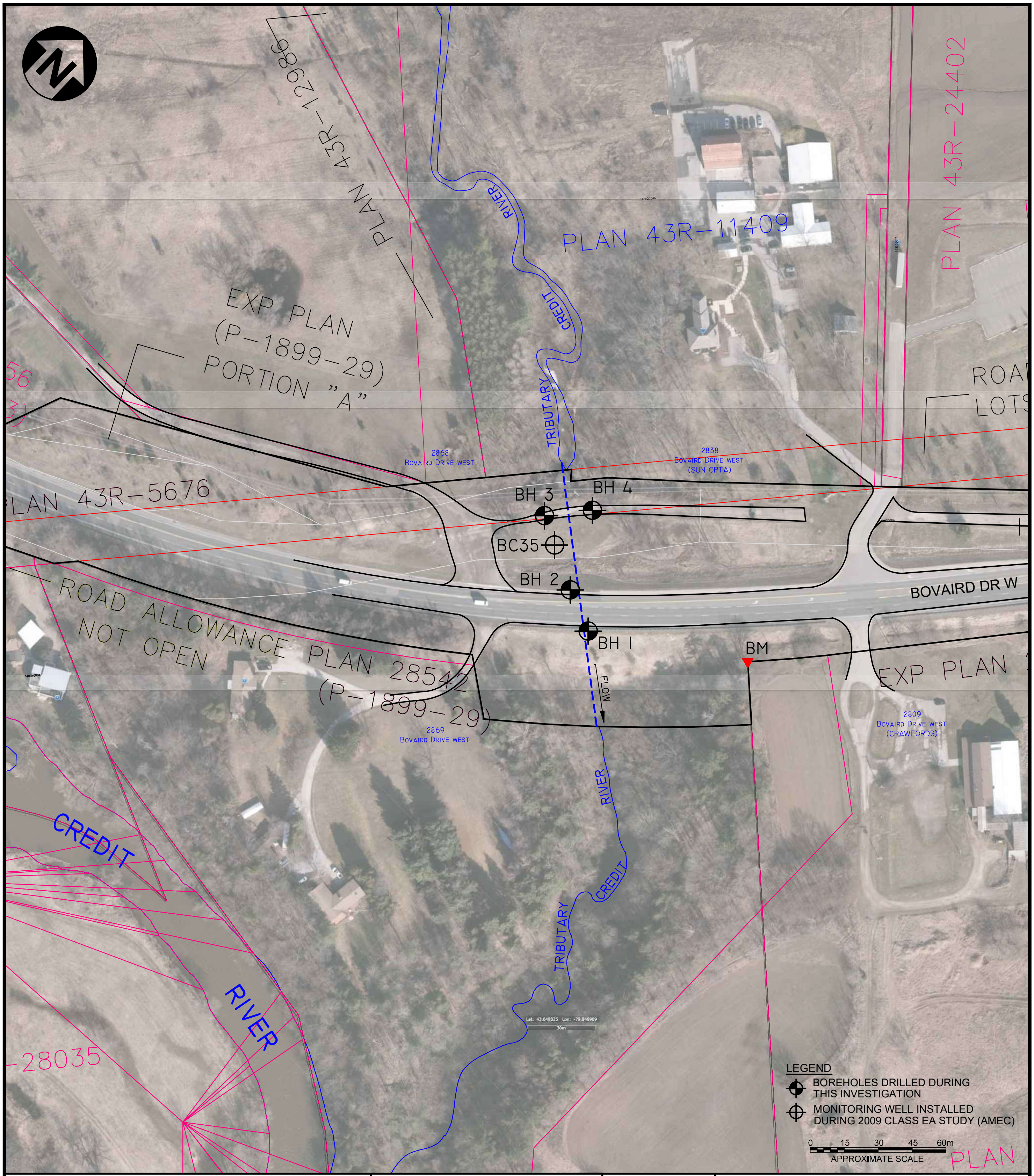
TITLE SITE LOCATION PLAN	DWN BY: KW	DATUM: -	DATE: DECEMBER 2013
PROJECT FOUNDATION INVESTIGATION REPORT CREDIT RIVER TRIBUTARY CULVERT REHABILITATION BOVAIRD DRIVE, CITY OF BRAMPTON, ON	CHK'D BY: SM	REV. NO.: -	PROJECT NO: TP113114.60.02
	PROJECTION: -	SCALE: N.T.S.	FIGURE No. 1

Z:\Projects\2013\TP - Burlington\TP113114.60 - Credit River Tributary\Locates\TP113114.60 - SitePlan - Borehole Location Plan_Fig2.dwg - SitePlan - Mar. 14, 2014 11:48am - kent.wong



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TITLE
BOREHOLE LOCATION PLAN

PROJECT
FOUNDATION INVESTIGATION REPORT
CREDIT RIVER TRIBUTARY CULVERT REHABILITATION
BOVAIRD DRIVE, CITY OF BRAMPTON, ON

DWN BY: KW	DATUM: -	DATE: JANUARY 2014
CHK'D BY: SM	REV. NO.: -	PROJECT NO: TP113114.60.02
PROJECTION: -	SCALE: AS SHOWN	FIGURE No. 2

Z:\Projects\2013\TP – Burlington\TP113114.60 – Credit River Tributary\Locates\TP113114.60 – Borehole Location Plan_Fig2.dwg – BHPlan – Mar. 18, 2014 1:31pm – kent.wong

RECORD OF BOREHOLES

Explanation of Borehole Logs
Record of Borehole (BH 1 to BH 4)

EXPLANATION OF BOREHOLE LOG

This form describes some of the information provided on the borehole logs, which is based primarily on examination of the recovered samples, and the results of the field and laboratory tests. Additional description of the soil/rock encountered is given in the accompanying geotechnical report.

GENERAL INFORMATION

Project details, borehole number, location coordinates and type of drilling equipment used are given at the top of the borehole log.

SOIL LITHOLOGY

Elevation and Depth

This column gives the elevation and depth of inferred geologic layers. The elevation is referred to the datum shown in the Description column.

Lithology Plot

This column presents a graphic depiction of the soil and rock stratigraphy encountered within the borehole.

Description

This column gives a description of the soil stratums, based on visual and tactile examination of the samples augmented with field and laboratory test results. Each stratum is described according to the *Modified Unified Soil Classification System*.

The compactness condition of cohesionless soils (SPT) and the consistency of cohesive soils (undrained shear strength) are defined as follows *(Ref. Canadian Foundation Engineering Manual)*:

Compactness of Cohesionless Soils	SPT N-Value*
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

Consistency of Cohesive Soils	Undrained Shear Strength kPa
Very soft	0 to 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very stiff	100 to 200
Hard	Over 200

* For penetration of less than 0.3 m, N-values are indicated as the number of blows for the penetration achieved (e.g. 50/25: 50 blows for 25 centimeter penetration).

Soil Sampling

Sample types are abbreviated as follows:

SS	Split Spoon	TW	Thin Wall Open (Pushed)	RC	Rock Core	GS	Grab Sample
AS	Auger Sample	TP	Thin Wall Piston (Pushed)	WS	Washed Sample	AR	Air Return Sample

Additional information provided in this section includes sample numbering, sample recovery and numerical testing results.

Field and Laboratory Testing

Results of field testing (e.g., SPT, pocket penetrometer, and vane testing) and laboratory testing (e.g., natural moisture content, and limits) executed on the recovered samples are plotted in this section.

Instrumentation Installation

Instrumentation installations (monitoring wells, piezometers, inclinometers, etc.) are plotted in this section. Water levels, if measured during fieldwork, are also plotted. These water levels may or may not be representative of the static groundwater level depending on the nature of soil stratum where the piezometer tips are located, the time elapsed from installation to reading and other applicable factors.

Comments

This column is used to describe non-standard situations or notes of interest.

MODIFIED * UNIFIED CLASSIFICATION SYSTEM FOR SOILS

*The soil of each stratum is described using the Unified Soil Classification System (Technical Memorandum 36-357 prepared by Waterways Experiment Station, Vicksburg, Mississippi, Corps of Engineers, U.S Army. Vol. 1 March 1953.) modified slightly so that an inorganic clay of "medium plasticity" is recognized.

MAJOR DIVISION			GROUP SYMBOL	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA
COARSE GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 75µm)	GRAVELS MORE THAN HALF THE COARSE FRACTION LARGER THAN 4.75mm	CLEAN GRAVELS (TRACE OR NO FINES)	GW	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	$C_u = \frac{D_{60}}{D_{10}} > 4;\ C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$
			GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS
		DIRTY GRAVELS (WITH SOME OR MORE FINES)	GM	SILTY GRAVELS, GRAVEL-SAND- SILT MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR P.I MORE THAN 4
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR P.I MORE THAN 7
	SANDS MORE THAN HALF THE COARSE FRACTION SMALLER THAN 4.75mm	CLEAN SANDS (TRACE OR NO FINES)	SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_u = \frac{D_{60}}{D_{10}} > 6;\ C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$
			SP	POORLY GRADED GRAVELS, GRAVEL- SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS
		DIRTY SANDS (WITH SOME OR MORE FINES)	SM	SILTY SANDS, SAND-SILT MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR P.I MORE THAN 4
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR P.I MORE THAN 7
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75µm)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	$W_L < 50\%$	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (SEE BELOW)
		$W_L > 50\%$	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS	
	CLAYS ABOVE "A" LINE NEGLIGIBLE ORGANIC CONTENT	$W_L < 30\%$	CL	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY OR SILTY CLAYS, LEAN CLAYS	
		$30\% < W_L < 50\%$	CI	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS	
		$W_L > 50\%$	CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS	
	ORGANIC SILTS & CLAYS BELOW "A" LINE	$W_L < 50\%$	OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	WHENEVER THE NATURE OF THE FINES CONTENT HAS NOT BEEN DETERMINED, IT IS DESIGNATED BY THE LETTER "F", E.G SF IS A MIXTURE OF SAND WITH SILT OR CLAY
		$W_L > 50\%$	OH	ORGANIC CLAYS OF HIGH PLASTICITY	
HIGH ORGANIC SOILS			Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOUR OR ODOUR, AND OFTEN FIBROUS TEXTURE

SOIL COMPONENTS

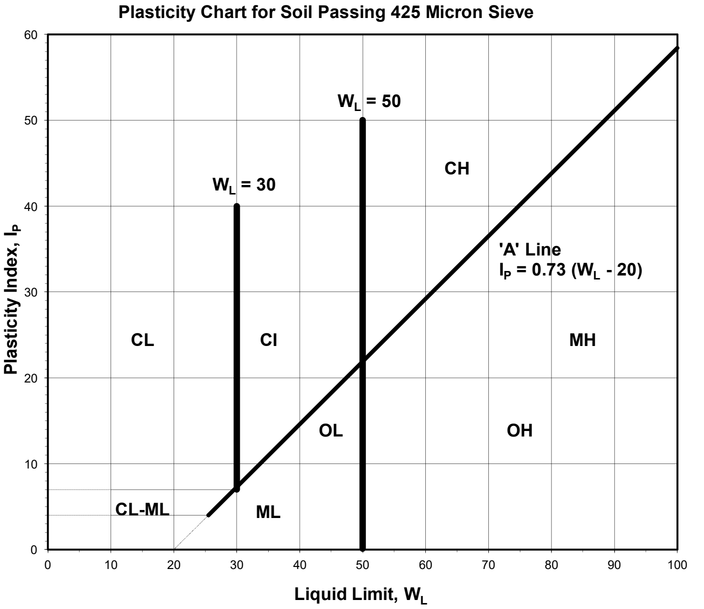
FRACTION	U.S STANDARD SIEVE SIZE		
		PASSING	RETAINED
GRAVEL	COARSE	76 mm	19 mm
	FINE	19 mm	4.75 mm
SAND	COARSE	4.75 mm	2.00 mm
	MEDIUM	2.00 mm	425 µm
	FINE	425 µm	75 µm
FINES (SILT OR CLAY BASED ON PLASTICITY)		75 µm	

DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS

PERCENT	DESCRIPTOR
35-50	AND
20-35	Y/EY
10-20	SOME
1-10	TRACE

OVERSIZED MATERIAL

ROUNDED OR SUBROUNDED: COBBLES 76 mm TO 200 mm BOULDERS > 200 mm	NOT ROUNDED: ROCK FRAGMENTS > 76 mm ROCKS > 0.76 CUBIC METRE IN VOLUME


Plasticity Chart for Soil Passing 425 Micron Sieve

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Note 1: Soils are classified and described according to their engineering properties and behaviour.

Note 2: The modifying adjectives used to define the actual or estimated percentage range by weight of minor components are consistent with the Canadian Foundation Engineering Manual.

RECORD OF BOREHOLE No. BH 1

Project Number: **TP113114**
Project Client: **Regional Municipality of Peel**
Project Name: **Credit River Tributary Culvert Rehabilitation on Bovaird Drive**
Project Location: **Bovaird Drive West, Brampton, Region of Peel, Ontario**
Drilling Location: **South shoulder, Bovaird Dr. West, east of culvert, E:592931, N:4833594**
Drilling Method: **150 mm Solid Stem Augers / 200 mm Hollow Stem Augers**
Drilling Machine: **Truck Mounted Drill**
Date Started: **Dec 11, 13** Date Completed: **Dec 11, 13**
Logged by: **JF**
Compiled by: **SC**
Reviewed by: **SM**
Revision No.: **0, 3/14/14**

LITHOLOGY PROFILE

DESCRIPTION

Geodetic Ground Surface Elevation: 221.2 m

brown
Sand and Gravel FILL
moist

220.8
0.4

brown
Sandy Silt/Silty Sand FILL
trace to some gravel, trace cobbles

------
trace to some clay

------
grey

----
wet

212.5
8.7

dark grey/brown
Silty Clay/Clayey Silt FILL
some sand to sandy, some gravel, trace cobbles

SOIL SAMPLING

Sample Type	Sample Number	Recovery (%)	SPT 'N' Value	GR	SA	SI	CL
SS	1	83	18				
SS	2	92	17				
SS	3	83	19				
SS	4	92	18				
SS	5	92	34				
SS	6	92	35				
SS	7	96	15				
SS	8	92	20	18	33	34	15
SS	9	75	27				

FIELD TESTING

Penetration Testing
○ SPT ☐ PPT ● DCPT
MTO Vane* Nilcon Vane*
△ Intact ◇ Intact
▲ Remould ◆ Remould
* Undrained Shear Strength (kPa)
20 40 60 80

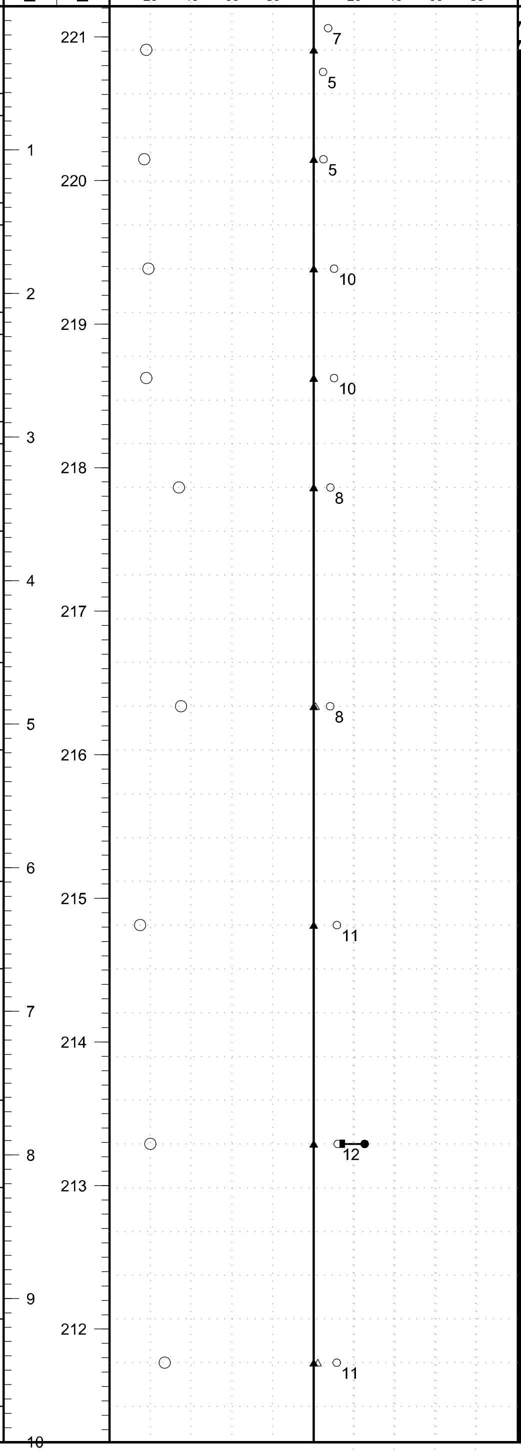
LAB TESTING

Soil Vapour Reading
☐ COV (LEL) ■ TOV (LEL)
2 4 6 8
△ COV (ppm) ▲ TOV (ppm)
100 200 300 400
W_P W W_L
Plastic Liquid
20 40 60 80

INSTRUMENTATION INSTALLATION

COMMENTS & GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

Used hollow stem augers.



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▽ No freestanding groundwater measured in open borehole on completion of drilling.

▼ Groundwater depth observed on 2/4/2014 at a depth of: 14.6 m.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 53

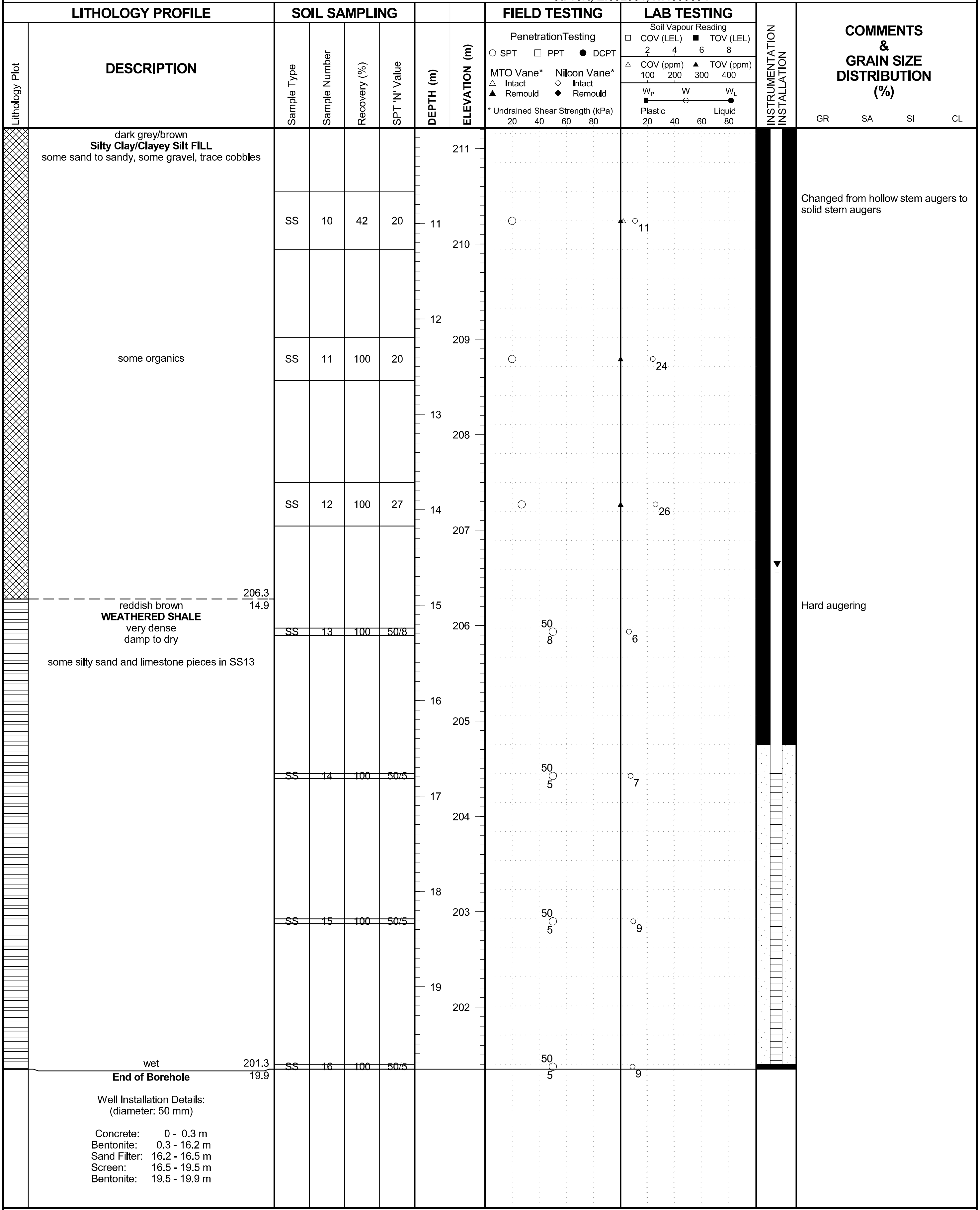
Continued on Next Page

RECORD OF BOREHOLE No. BH 1

Project Number: **TP113114**

Drilling Location: **South shoulder, Bovaird Dr. West, east of culvert, E:592931, N:4833594**

Logged by: **JF**



Elevation / Depth (m)	Description
	dark grey/brown **Silty Clay/Clayey Silt FILL** some sand to sandy, some gravel, trace cobbles
	some organics
206.3 14.9	reddish brown **WEATHERED SHALE** very dense damp to dry some silty sand and limestone pieces in SS13
201.3 19.9	wet **End of Borehole**

Sample Type	Sample Number	Recovery (%)	SPT 'N' Value	W (%)
SS	10	42	20	11
SS	11	100	20	24
SS	12	100	27	26
SS	13	100	50/8	6
SS	14	100	50/5	7
SS	15	100	50/5	9
SS	16	100	50/5	9

Well Installation Details:
(diameter: 50 mm)

Concrete: 0 - 0.3 m
Bentonite: 0.3 - 16.2 m
Sand Filter: 16.2 - 16.5 m
Screen: 16.5 - 19.5 m
Bentonite: 19.5 - 19.9 m

COMMENTS

Changed from hollow stem augers to solid stem augers

Hard augering

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 53

RECORD OF BOREHOLE No. BH 2

Project Number:	**TP113114**	Drilling Location:	**North shoulder, Bovaird Dr. West, west of culvert E:592905, N:4833590**	Logged by:	**JF**
Project Client:	**Regional Municipality of Peel**	Drilling Method:	**150 mm Solid Stem Augers / 200 mm Hollow Stem Augers**	Compiled by:	**SC**
Project Name:	**Credit River Tributary Culvert Rehabilitation on Bovaird Drive**	Drilling Machine:	**Truck Mounted Drill**	Reviewed by:	**SM**
Project Location:	**Bovaird Drive West, Brampton, Region of Peel, Ontario**	Date Started:	**Dec 10, 13** Date Completed: **Dec 10, 13**	Revision No.:	**0, 3/14/14**

LITHOLOGY PROFILE | **SOIL SAMPLING** | **FIELD TESTING** | **LAB TESTING** | INSTRUMENTATION INSTALLATION | **COMMENTS & GRAIN SIZE DISTRIBUTION (%)** GR SA SI CL

Penetration Testing: ○ SPT ☐ PPT ● DCPT

MTO Vane*: △ Intact ▲ Remould; Nilcon Vane*: ◇ Intact ◆ Remould

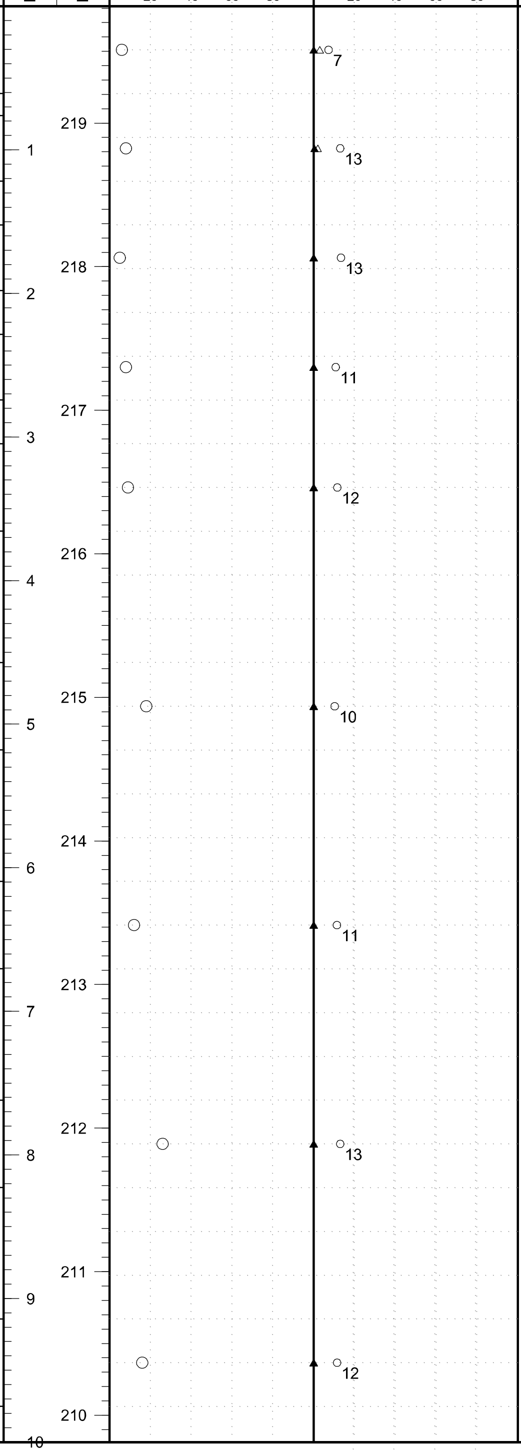
* Undrained Shear Strength (kPa) 20 40 60 80

Soil Vapour Reading: ☐ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400

W_P W W_L Plastic Liquid 20 40 60 80

Geodetic Ground Surface Elevation: 219.8 m

Lithology Plot	DESCRIPTION	Sample Type	Sample Number	Recovery (%)	SPT 'N' Value
	about 150 mm TOPSOIL 219.7 / 0.2				
	brown **Silty Sand and Gravel FILL** trace cobbles moist	SS	1	83	6
	mixed with silty clay	SS	2	100	8
	mixed with silty clay	SS	3	100	5
	some clay	SS	4	100	8
	------ grey	SS	5	33	9
		SS	6	71	18
	214.2 / 5.6 brown/grey **Sandy Silt/Silty Sand FILL** trace gravel, trace to some clay trace cobbles moist				
	pieces of wood in SS7	SS	7	79	12
	trace organics	SS	8	96	26
		SS	9	96	16



Used hollow stem augers.

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Groundwater depth on completion of drilling on 12/10/2013 at a depth of: 17.7 m.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 53

Continued on Next Page

RECORD OF BOREHOLE No. BH 2

Project Number: **TP113114**

Drilling Location: **North shoulder, Bovaird Dr. West, west of culvert E:592905, N:4833590**

Logged by: **JF**

LITHOLOGY PROFILE | SOIL SAMPLING | FIELD TESTING | LAB TESTING | INSTRUMENTATION INSTALLATION | COMMENTS & GRAIN SIZE DISTRIBUTION (%)

FIELD TESTING: PenetrationTesting ○ SPT ☐ PPT ● DCPT; MTO Vane* △ Intact ▲ Remould; Nilcon Vane* ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

LAB TESTING: Soil Vapour Reading ☐ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

GR SA SI CL

DESCRIPTION	Sample Type	Sample Number	Recovery (%)	SPT 'N' Value	ELEVATION (m) / DEPTH (m)	FIELD TESTING	LAB TESTING	COMMENTS
brown/grey **Sandy Silt/Silty Sand FILL** trace gravel, trace to some clay trace cobbles moist								
	SS	10	83	18		○	11	Changed from hollow stem augers to solid stem augers
wet some clay, trace rootlets	SS	11	100	50		○	14	
reddish brown **WEATHERED SHALE** very dense damp to dry					207.0 12.8			
some limestone	SS	12	100	50/5		50 ○ 5	12	
								Hard augering
	SS	13	100	50/5		50 ○ 5	8	
								Hard augering
	SS	14	100	50/5		50 ○ 5	5	
								Hard augering
					▽			
	SS	15	100	50/3		50 ○ 3		
								Hard augering
wet	SS	16	100	50/3	200.0	50 ○ 3	16	
End of Borehole					19.8			

DEPTH (m): 11, 12, 13, 14, 15, 16, 17, 18, 19

ELEVATION (m): 209, 208, 207, 206, 205, 204, 203, 202, 201, 200

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 53

RECORD OF BOREHOLE No. BH 3

Project Number: **TP113114**
Project Client: **Regional Municipality of Peel**
Project Name: **Credit River Tributary Culvert Rehabilitation on Bovaird Drive**
Project Location: **Bovaird Drive West, Brampton, Region of Peel, Ontario**
Drilling Location: **Old Hwy 7, west of culvert, E:592883, N:4833609**
Drilling Method: **150 mm Solid Stem Augers / 200 mm Hollow Stem Augers**
Drilling Machine: **Truck Mounted Drill**
Date Started: **Dec 9, 13** Date Completed: **Dec 9, 13**
Logged by: **JF**
Compiled by: **SC**
Reviewed by: **SM**
Revision No.: **0, 3/14/14**

LITHOLOGY PROFILE | SOIL SAMPLING | FIELD TESTING | LAB TESTING | INSTRUMENTATION INSTALLATION | COMMENTS & GRAIN SIZE DISTRIBUTION (%)

Penetration Testing: ○ SPT ☐ PPT ● DCPT
MTO Vane*: △ Intact ▲ Remould
Nilcon Vane*: ◇ Intact ◆ Remould
* Undrained Shear Strength (kPa) 20 40 60 80

Soil Vapour Reading: ☐ COV (LEL) ■ TOV (LEL) 2 4 6 8
△ COV (ppm) ▲ TOV (ppm) 100 200 300 400
W_P W W_L — Plastic Liquid 20 40 60 80

Geodetic Ground Surface Elevation: 219.8 m

DESCRIPTION	Sample Type	Sample Number	Recovery (%)	SPT 'N' Value	W	GR	SA	SI	CL
brown **about 350 mm TOPSOIL** 219.5 / 0.4									
dark brown/brown **Sandy Silt/Silty Sand FILL** some gravel, trace to some clay, organics and rootlets in SS1 moist	SS	1	83	5	16				
	SS	2	92	10	16				
	SS	3	88	7	16				
mixed with silty clay	SS	4	100	10	13				
	SS	5	92	8	15				
	SS	6	100	7	9	12	55	(33)	
	SS	7	96	9	11				
	SS	8	92	12	11				
	SS	9	96	9	15				

DEPTH (m)	ELEVATION (m)
	219
1	218
2	217
3	216
4	215
5	214
6	213
7	212
8	211
9	210
10	

Used hollow stem augers.

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▽ Groundwater depth on completion of drilling on 12/9/2013 at a depth of: 13.7 m.
▼ Groundwater depth observed on 2/4/2014 at a depth of: 11.1 m.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 53

Continued on Next Page

RECORD OF BOREHOLE No. BH 3

Project Number: **TP113114**
Drilling Location: **Old Hwy 7, west of culvert, E:592883, N:4833609**
Logged by: **JF**

LITHOLOGY PROFILE

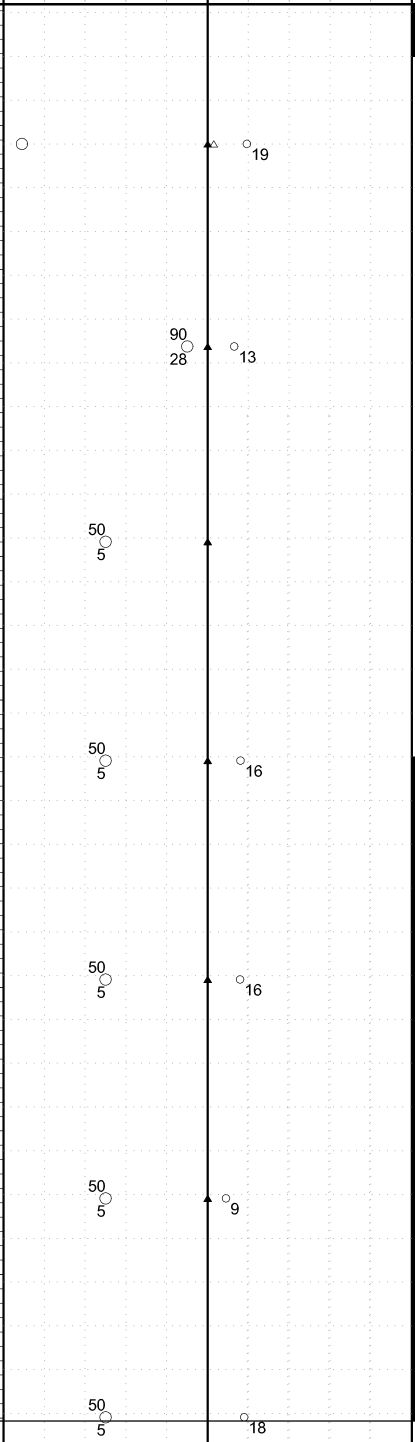
Elevation / Depth (m)	DESCRIPTION
209.6 10.2	dark grey **Silty Clay/Clayey Silt FILL** some sand, trace gravel mixed with wood pieces and rootlets
208.1 11.7	reddish brown **SILTY CLAY/CLAYEY SILT TILL** with shale fragments, some limestone trace sand and gravel hard
206.7 13.2	reddish brown **WEATHERED SHALE** very dense damp limestone pieces
200.0 19.9	**End of Borehole**

Well Installation Details:
(diameter: 50 mm)

Concrete: 0 - 0.3 m
Bentonite: 0.3 - 10.2 m
Sand Filter: 10.2 - 10.5 m
Screen: 10.5 - 13.5 m
Sand Filter: 13.5 - 15.0 m
Bentonite: 15.0 - 19.9 m

SOIL SAMPLING

Sample Type	Sample Number	Recovery (%)	SPT 'N' Value	SPT plotted	W (%)
SS	10	100	9		19
SS	11	100	90/28	90 28	13
SS	12	100	50/5	50 5	
SS	13	100	50/5	50 5	16
SS	14	100	50/5	50 5	16
SS	15	100	50/5	50 5	9
SS	16	100	50/5	50 5	18



COMMENTS & GRAIN SIZE DISTRIBUTION (%)

GR SA SI CL

Changed from hollow stem augers to solid stem augers

Hard augering

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 53

RECORD OF BOREHOLE No. BH 4

Project Number:	TP113114	Drilling Location:	Old Hwy 7, east of culvert, E:592893, N:4833625	Logged by:	JF
Project Client:	Regional Municipality of Peel	Drilling Method:	150 mm Solid Stem Augering	Compiled by:	SC
Project Name:	Credit River Tributary Culvert Rehabilitation on Bovaird Drive	Drilling Machine:	Truck Mounted Drill	Reviewed by:	SM
Project Location:	Bovaird Drive West, Brampton, Region of Peel, Ontario	Date Started:	Dec 9, 13 Date Completed: Dec 9, 13	Revision No.:	0, 3/14/14

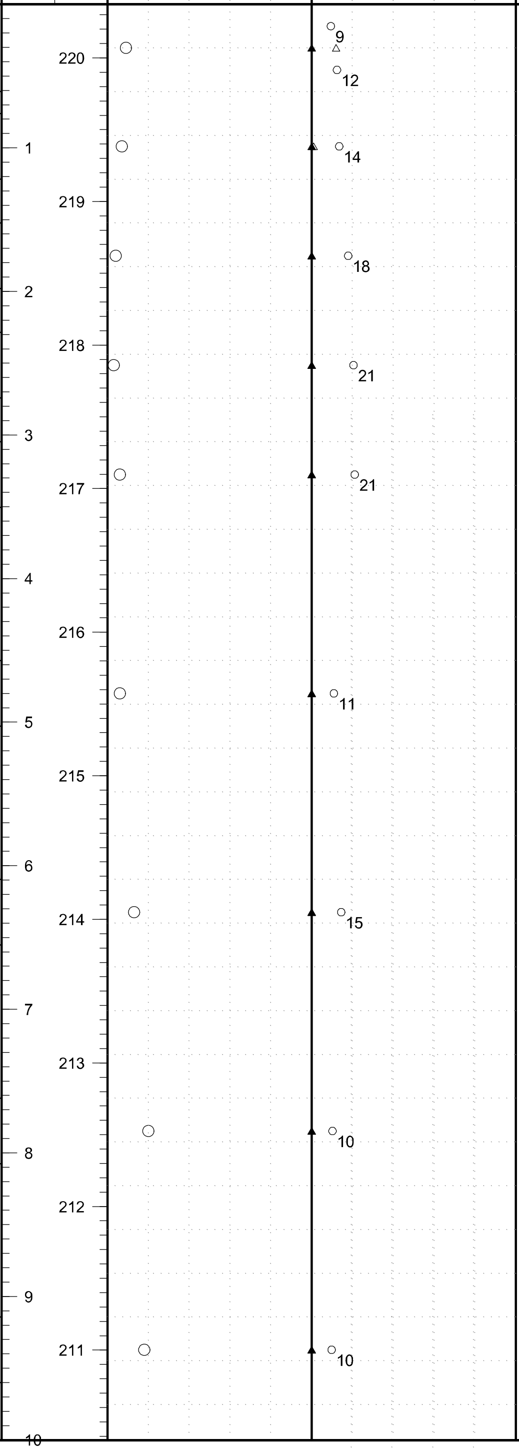
LITHOLOGY PROFILE

Geodetic Ground Surface Elevation: 220.4 m

Elevation (m) / Depth (m)	DESCRIPTION
	about 200 mm TOPSOIL
220.2 / 0.2	dark brown/brown **Sandy Silt/Silty Sand FILL** trace to some gravel, trace rootlets in SS1 moist to wet ------ some clay trace rootlets
217.5 / 2.9	brown **Silty Clay FILL** some sand
216.3 / 4.0	grey **Silty Sand FILL** trace gravel moist
214.8 / 5.6	brown **Clayey Silt FILL** some sand, trace gravel
213.3 / 7.1	brown **Silty Sand FILL** trace clay, trace to some gravel moist

SOIL SAMPLING

Sample Type	Sample Number	Recovery (%)	SPT 'N' Value	W (%)
SS	1	63	9	9 12
SS	2	44	7	14
SS	3	94	4	18
SS	4	56	3	21
SS	5	94	6	21
SS	6	89	6	11
SS	7	67	13	15
SS	8	100	20	10
SS	9	100	18	10



INSTRUMENTATION INSTALLATION

COMMENTS & GRAIN SIZE DISTRIBUTION (%)

GR SA SI CL

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Fax +1(416) 751-7592
www.amec.com

Groundwater depth on completion of drilling on 12/9/2013 at a depth of: 11.0 m.

Cave in depth after removal of augers: 11.0 m.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 53

Continued on Next Page

RECORD OF BOREHOLE No. BH 4

Project Number: TP113114

Drilling Location: Old Hwy 7, east of culvert, E:592893, N:4833625

Logged by: JF

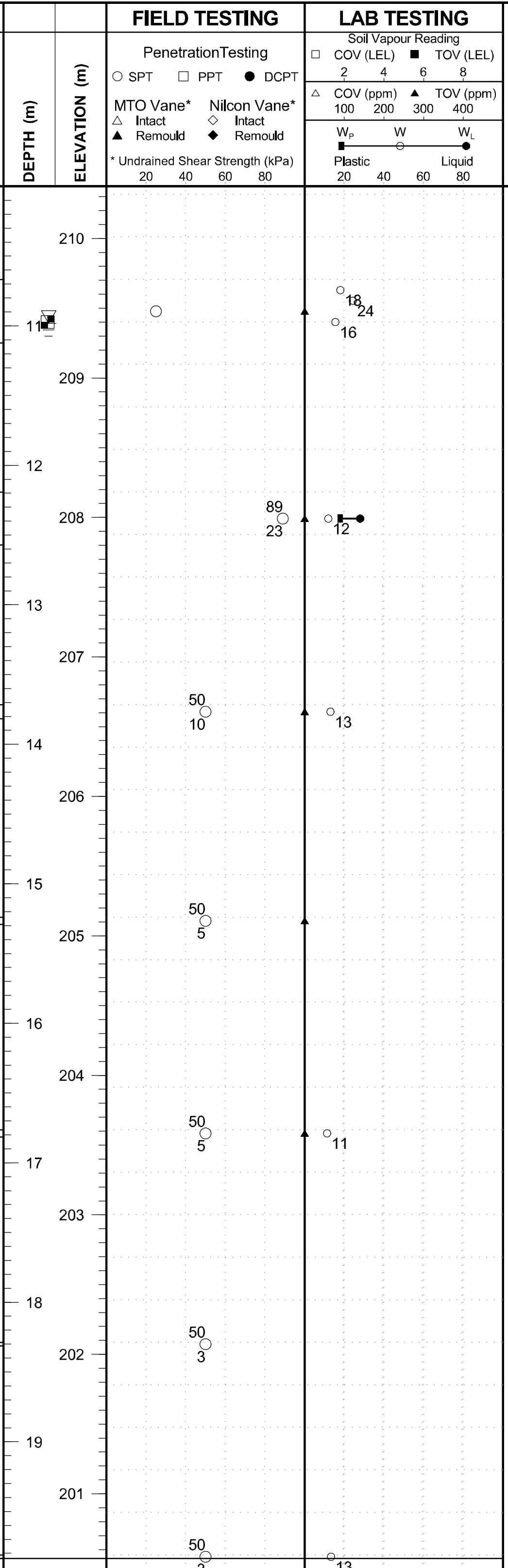
LITHOLOGY PROFILE

Elevation (m) / Depth (m)	DESCRIPTION
210.2 10.2	brown **Silty Clay/Clayey Silt FILL** mixed with silty sand, organics, wood pieces
209.4 11.0	reddish brown **SILTY CLAY/CLAYEY SILT TILL** with shale fragments and limestone trace sand and gravel hard
205.9 14.5	reddish brown **WEATHERED SHALE** very dense damp
200.5 19.8	**End of Borehole**

SOIL SAMPLING

Sample Type	Sample Number	Recovery (%)	SPT 'N' Value
SS	10	100	25
SS	11	100	89/23
SS	12	50	50/10
SS	13	100	50/5
SS	14	100	50/5
SS	15	200	50/3
SS	16	200	50/3

FIELD TESTING / LAB TESTING



INSTRUMENTATION INSTALLATION

COMMENTS & GRAIN SIZE DISTRIBUTION (%)

Elevation (m)	GR	SA	SI	CL	Comments
208	2	3	75	20	
206					Hard augering
204.5					Hard augering
203					Hard augering

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 53

APPENDIX A

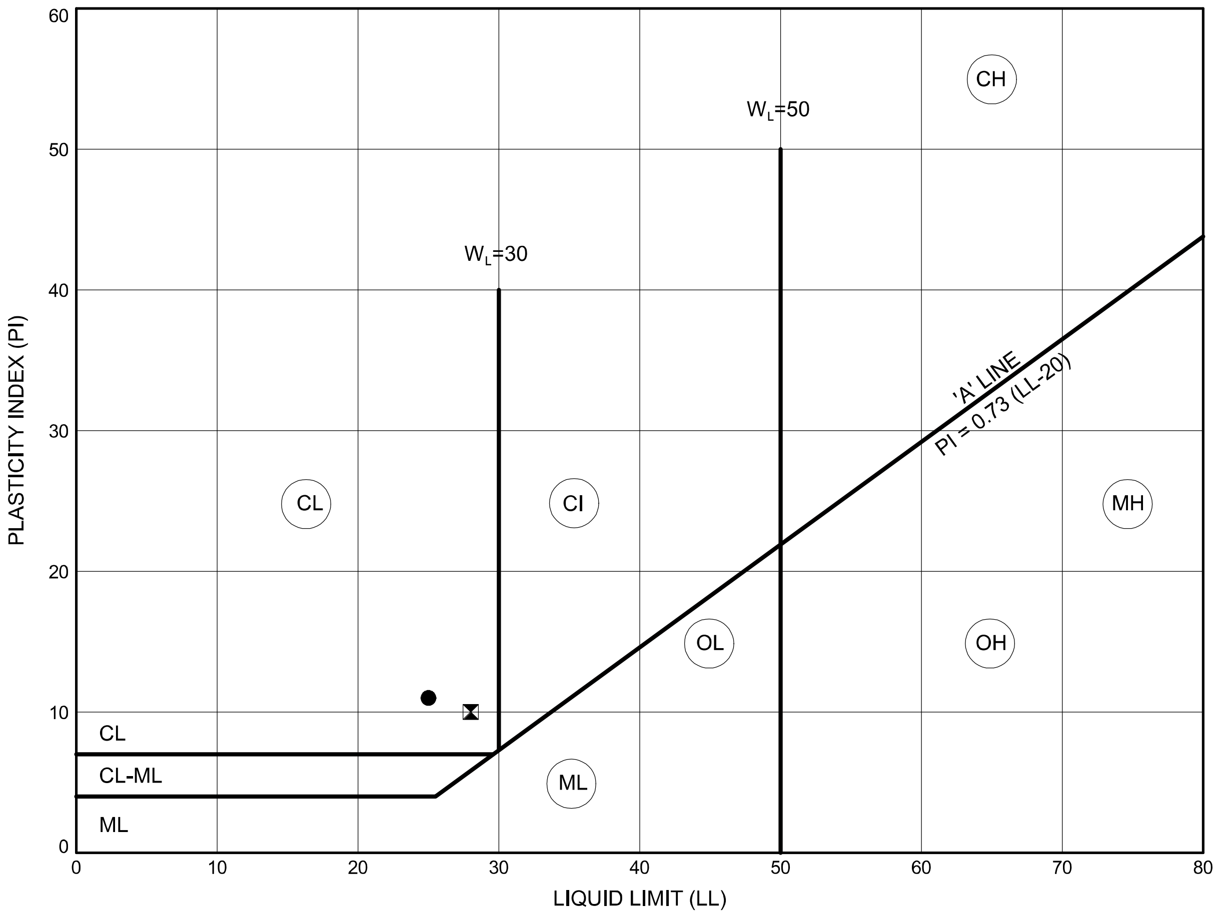
Laboratory Test Results

amec

Credit River Tributary Culvert Rehabilitation on Bovaird Drive

ATTERBERG LIMIT TEST RESULTS

FIGURE No. A1



SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)	ELEVATION (m)	LL	PL	PI
●	BH 1	SS 8	7.9	213.3	25	14	11
⧗	BH 4	SS 11	12.4	208.0	28	18	10

Date February 2014

Project TP113114

Prep'd CZ

Chkd. SB

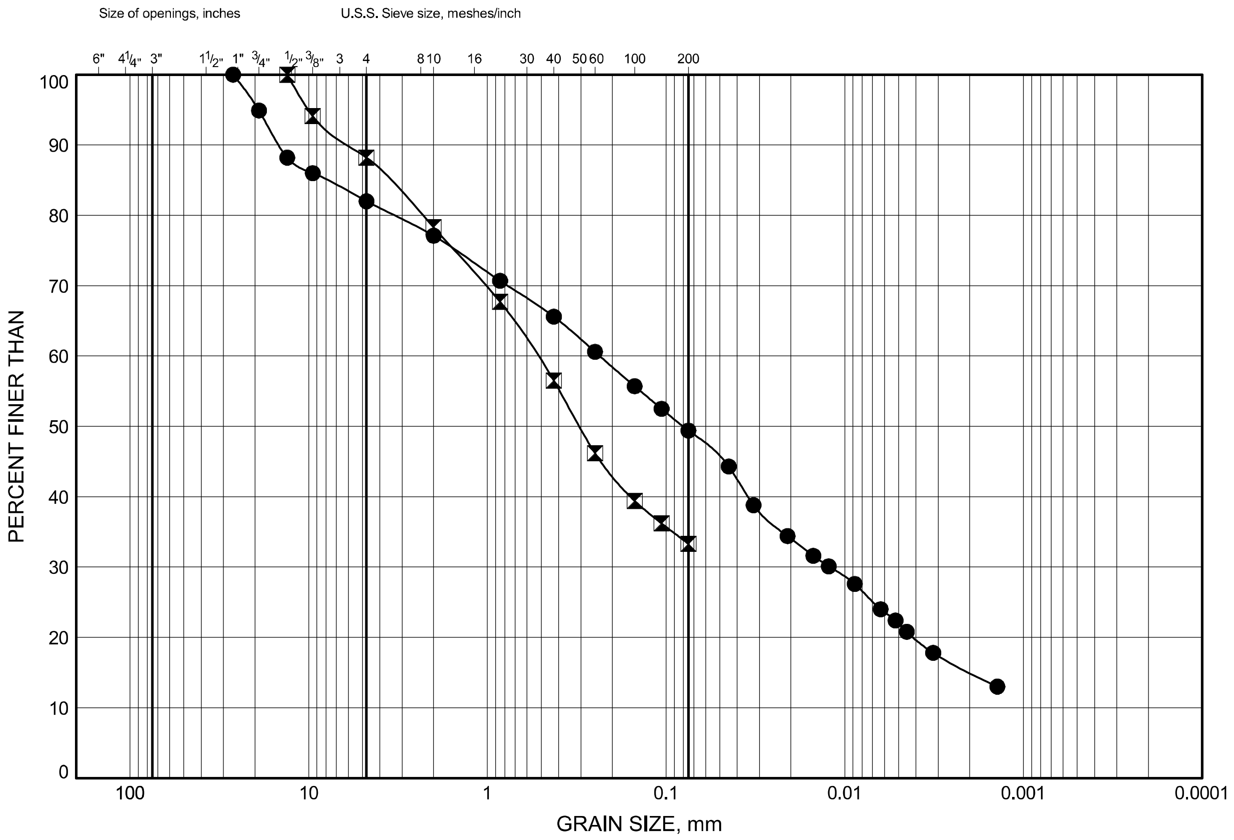
AMEC ATTERBERG LIMITS TP113114.06_12DEC13.GPJ AMEC SCARBOROUGH LOG 2009.GDT 21/02/14

Credit River Tributary Culvert Rehabilitation on Bovaird Drive

GRAIN SIZE DISTRIBUTION

Silty Sand / Sandy Silt Fill

FIGURE No. A2



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)	ELEVATION (m)
●	BH 1	SS 8	7.9	213.3
⧗	BH 3	SS 6	4.9	215.0

Date February 2014

Project TP113114

Prep'd CZ

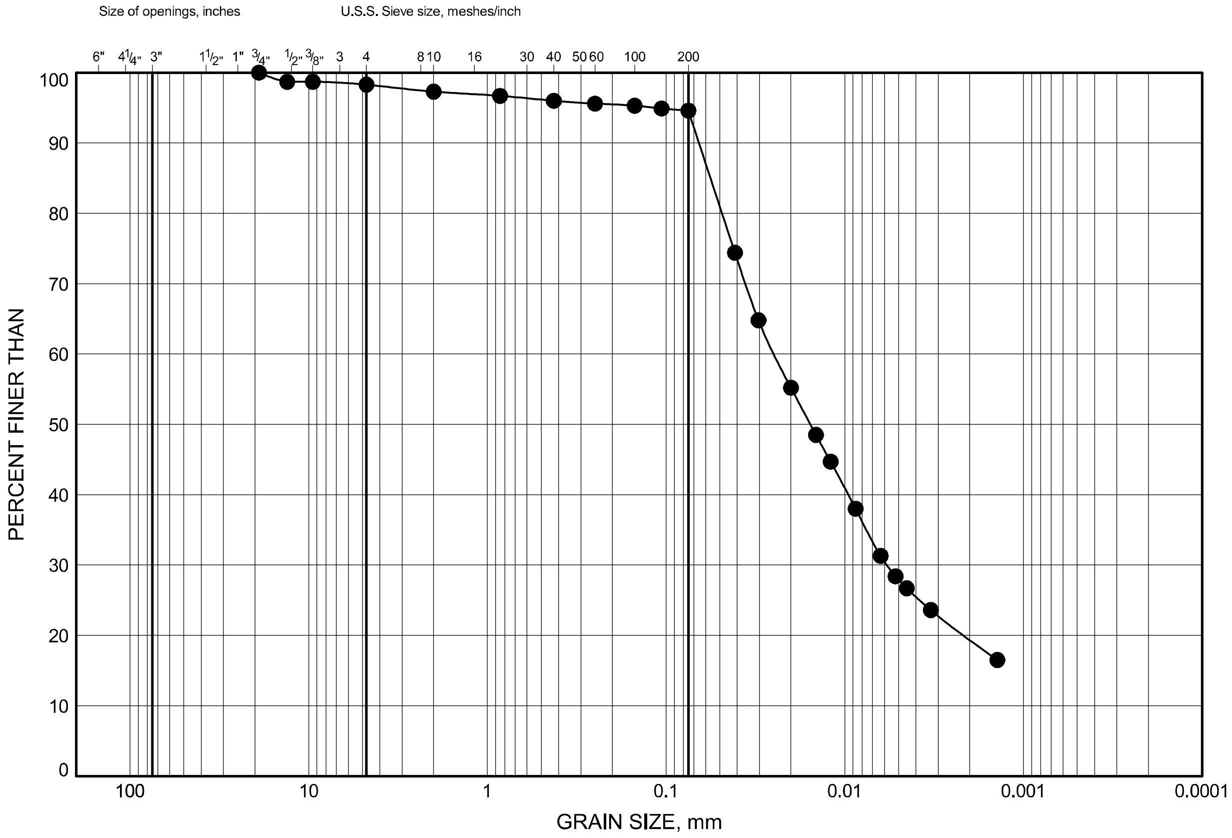
Chkd. SB

AMEC GRADATION CURVE TP113114.06_12DEC13.GPJ AMEC SCARBOROUGH LOG 2009.GDT 21/02/14

Credit River Tributary Culvert Rehabilitation on Bovaird Drive

GRAIN SIZE DISTRIBUTION
SILTY CLAY / CLAYEY SILT

FIGURE No. A3



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)	ELEVATION (m)
●	BH 4	SS 11	12.4	208.0

Date February 2014

Project TP113114

Prep'd CZ

Chkd. SB

AMEC GRADATION CURVE TP113114.06_12DEC13.GPJ AMEC SCARBOROUGH LOG 2009.GDT 21/02/14

APPENDIX B

Certificates of Analyses
(Soil Chemical Analysis and Corrosivity Test)

CERTIFICATE OF ANALYSIS
REVIEW CHECKLIST

AMEC Project Number: TP113114.60.02
Sampling Date: 11-Dec-13
Location: Bovaird Drive West, Brampton, ON
Sample Submission Number: 13T794176 (AGAT)

LABORATORY QC SAMPLES: Are All Laboratory QC Samples Within Acceptance Limits (Yes, No, Not Applicable)?

		Yes	No	NA	Comments
Surrogate Recoveries	Metals & Inorganics			X	*All lab QC within Acceptance Limits*
	Reg 558 Metals & Inorganics			X	
	Reg 558 B(a)P			X	
	Reg 558 PCB	X			
	Reg 558 VOC	X			
Method Blank Concentration	Metals & Inorganics	X			*All lab QC within Acceptance Limits*
	Reg 558 Metals & Inorganics	X			
	Reg 558 B(a)P				
	Reg 558 PCB	X			
	Reg 558 VOC	X			
Laboratory Replicate RPD	Metals & Inorganics	X			*All lab QC within Acceptance Limits*
	Reg 558 Metals & Inorganics	X			
	Reg 558 B(a)P	X			
	Reg 558 PCB	X			
	Reg 558 VOC	X			
Matrix Spike Recovery	Metals & Inorganics	X			*All lab QC within Acceptance Limits*
	Reg 558 Metals & Inorganics	X			
	Reg 558 B(a)P	X			
	Reg 558 PCB	X			
	Reg 558 VOC	X			
Spiked Blank/CRM Recovery	Metals & Inorganics	X			*All lab QC within Acceptance Limits*
	Reg 558 Metals & Inorganics	X			
	Reg 558 B(a)P	X			
	Reg 558 PCB	X			
	Reg 558 VOC	X			

FIELD QC SAMPLES: Are All Field QC Samples Within Acceptable Limits (Yes, No, Not Applicable)?

		Yes	No	NA	Comments
Trip Spike Recovery	VOC (inc. BTEX)			X	
	PHC F1-F4			X	
	PAH/SVOC			X	
	Metals/Inorganics			X	
Field Blank Concentration	VOC (inc. BTEX)			X	
	PHC F1-F4			X	
	PAH/SVOC			X	
	Metals/Inorganics			X	
Trip Blank Concentration	VOC (inc. BTEX)			X	
	PHC F1-F4			X	
	PAH/SVOC			X	
	Metals/Inorganics			X	
Field Duplicate RPD	VOC (inc. BTEX)			X	
	PHC F1-F4			X	
	PAH/SVOC			X	
	Metals/Inorganics			X	

Do all RLs meet required Reporting Limits?	*Yes*
Has CoA been signed off (Yes/No)?:	*Yes*
Was all testing conducted in accordance with the Analytical Protocol (Yes/No)?:	*Yes*
Were all samples analyzed within hold times (Yes/No)?:	*Yes*
Is Chain of Custody completed and signed (Yes/No)?:	*Yes*
Were sample temperatures acceptable when they reached lab (Yes/No)?:	*Yes*
Is the laboratory accredited for all analyses?:	*Yes*

Is data considered to be reliable (Yes/No)?: *Yes*
See QAQC Data Quality Review Appendix for detailed review of potential issues. If answer is "No", provide rationale:

Initial Data Review by (Print): *Jonathan Wakani, P.Geo.*
Date: *12-Feb-14*
Data Reviewed by (Signature): *Jeff Carson, P.Eng.*
Revision Date and Number: *12-Feb-14*

Final Data Review by (Print): *Jonathan Wakani, P.Geo.*
Date: *12-Feb-14*
Data Reviewed by (Signature): *Jeff Carson, P.Eng.*
Revision Date and Number: *12-Feb-14*

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http://www.agatlabs.com

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE
505 Woodward Avenue Unit 1
Hamilton, ON L8H6H6
(905) 312-0700

ATTENTION TO: Jonathan Wakani

PROJECT NO: TP113114

AGAT WORK ORDER: 13T794176

SOIL ANALYSIS REVIEWED BY: Inesa Alizarchyk, Inorganic Lab Supervisor

TRACE ORGANICS REVIEWED BY: Oksana Gushyla, Trace Organics Lab Supervisor

DATE REPORTED: Dec 20, 2013

PAGES (INCLUDING COVER): 12

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

*NOTES

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.

AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 13T794176

PROJECT NO: TP113114

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE

ATTENTION TO: Jonathan Wa

O. Reg. 153(511) - Metals & Inorganics (Soil)

DATE RECEIVED: 2013-12-13

DATE R

			SAMPLE DESCRIPTION:	BH1 / SS4	BH3 / SS3
			SAMPLE TYPE:	Soil	Soil
			DATE SAMPLED:	12/11/2013	12/11/2013
Parameter	Unit	G / S	RDL	5055108	5055109
Antimony	µg/g	1.3	0.8	<0.8	<0.8
Arsenic	µg/g	18	1	5	4
Barium	µg/g	220	2	70	62
Beryllium	µg/g	2.5	0.5	<0.5	<0.5
Boron	µg/g	36	5	<5	6
Boron (Hot Water Soluble)	µg/g	NA	0.10	0.21	0.13
Cadmium	µg/g	1.2	0.5	<0.5	<0.5
Chromium	µg/g	70	2	17	15
Cobalt	µg/g	21	0.5	7.1	8.8
Copper	µg/g	92	1	37	28
Lead	µg/g	120	1	14	9
Molybdenum	µg/g	2	0.5	<0.5	<0.5
Nickel	µg/g	82	1	13	15
Selenium	µg/g	1.5	0.4	<0.4	<0.4
Silver	µg/g	0.5	0.2	<0.2	<0.2
Thallium	µg/g	1	0.4	<0.4	<0.4
Uranium	µg/g	2.5	0.5	<0.5	<0.5
Vanadium	µg/g	86	1	20	22
Zinc	µg/g	290	5	46	46
Chromium VI	µg/g	0.66	0.2	<0.2	<0.2
Cyanide	µg/g	0.051	0.040	<0.040	<0.040
Mercury	µg/g	0.27	0.10	<0.10	<0.10
Electrical Conductivity (2:1)	mS/cm	0.57	0.005	1.17	0.167
Sodium Adsorption Ratio (2:1)	N/A	2.4	N/A	4.94	2.64
pH, 2:1 CaCl2 Extraction	pH Units		NA	7.82	7.77

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to T1(ALL) - Current

5055108-5055109 EC & SAR were determined on the DI water extract obtained from the 2:1 leaching procedure (2 parts DI water:1 part soil). pH was determined on the 0.01M Ca

Certified By:

Certificate of Analysis

AGAT WORK ORDER: 13T794176
PROJECT NO: TP113114

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE

ATTENTION TO: Jonathan Wa

O. Reg. 558 Metals and Inorganics

DATE RECEIVED: 2013-12-13

DATE R

			SAMPLE DESCRIPTION:	BH1 / SS5
			SAMPLE TYPE:	Soil
			DATE SAMPLED:	12/11/2013
Parameter	Unit	G / S	RDL	5055110
Arsenic Leachate	mg/L	2.5	0.010	<0.010
Barium Leachate	mg/L	100	0.100	0.948
Boron Leachate	mg/L	500	0.050	<0.050
Cadmium Leachate	mg/L	0.5	0.010	<0.010
Chromium Leachate	mg/L	5.0	0.010	<0.010
Lead Leachate	mg/L	5.0	0.010	<0.010
Mercury Leachate	mg/L	0.1	0.01	<0.01
Selenium Leachate	mg/L	1.0	0.010	<0.010
Silver Leachate	mg/L	5.0	0.010	<0.010
Uranium Leachate	mg/L	10.0	0.050	<0.050
Fluoride Leachate	mg/L	150	0.05	0.24
Cyanide Leachate	mg/L	20.0	0.05	<0.05
(Nitrate + Nitrite) as N Leachate	mg/L	1000	0.70	<0.70

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to Regulation 558

Certified By:

Certificate of Analysis

AGAT WORK ORDER: 13T794176
PROJECT NO: TP113114

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE

ATTENTION TO: Jonathan Wa

ON Regulation 558 Benzo(a) pyrene

DATE RECEIVED: 2013-12-13

DATE R

			SAMPLE DESCRIPTION:	BH1 / SS5
			SAMPLE TYPE:	Soil
			DATE SAMPLED:	12/11/2013
Parameter	Unit	G / S	RDL	5055110
Benzo(a)pyrene	mg/L	0.001	0.001	<0.001

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to Regulation 558

5055110 The sample was leached according to Regulation 558 protocol. Analysis was performed on the leachate.

Certified By:

Certificate of Analysis

AGAT WORK ORDER: 13T794176
PROJECT NO: TP113114

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE

ATTENTION TO: Jonathan Wa

ON Regulation 558 PCBs

DATE RECEIVED: 2013-12-13

DATE R

			SAMPLE DESCRIPTION:	BH1 / SS5
			SAMPLE TYPE:	Soil
			DATE SAMPLED:	12/11/2013
Parameter	Unit	G / S	RDL	5055110
Polychlorinated Biphenyls	mg/L	0.3	0.005	<0.005
Surrogate	Unit	Acceptable Limits		
Decachlorobiphenyl	%	60-130		104

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to Regulation 558
5055110 The soil sample was leached using the Regulation 558 procedure. Analysis was performed on the leachate.

Certified By:

Certificate of Analysis

AGAT WORK ORDER: 13T794176
PROJECT NO: TP113114

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE

ATTENTION TO: Jonathan Wa

ON Regulation 558 VOCs

DATE RECEIVED: 2013-12-13

DATE R

			SAMPLE DESCRIPTION:	BH1 / SS5
			SAMPLE TYPE:	Soil
			DATE SAMPLED:	12/11/2013
Parameter	Unit	G / S	RDL	5055110
Vinyl Chloride	mg/L	0.2	0.030	<0.030
1,1 Dichloroethene	mg/L	1.4	0.020	<0.020
Dichloromethane	mg/L	5.0	0.030	<0.030
Methyl Ethyl Ketone	mg/L	200	0.090	<0.090
Chloroform	mg/L	10.0	0.020	<0.020
1,2-Dichloroethane	mg/L	0.5	0.020	<0.020
Carbon Tetrachloride	mg/L	0.5	0.020	<0.020
Benzene	mg/L	0.5	0.020	<0.020
Trichloroethene	mg/L	5.0	0.020	<0.020
Tetrachloroethene	mg/L	3.0	0.050	<0.050
Chlorobenzene	mg/L	8.0	0.010	<0.010
1,2-Dichlorobenzene	mg/L	20.0	0.010	<0.010
1,4-Dichlorobenzene	mg/L	0.5	0.010	<0.010
Surrogate	Unit	Acceptable Limits		
Toluene-d8	% Recovery	60-130		107

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to Reg. 558
5055110 Sample was prepared using Regulation 558 protocol and a zero headspace extractor.

Certified By:

AGAT Laboratories

Guideline Violation

AGAT WORK ORDER: 13T794176

PROJECT NO: TP113114

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE

ATTENTION TO: Jonathan Wa

SAMPLEID	SAMPLE TITLE	GUIDELINE	ANALYSIS PACKAGE	PARAMETER
5055108	BH1 / SS4	T1(ALL) - Current	O. Reg. 153(511) - Metals & Inorganics (Soil)	Electrical Conductivity (2:1)
5055108	BH1 / SS4	T1(ALL) - Current	O. Reg. 153(511) - Metals & Inorganics (Soil)	Sodium Adsorption Ratio (2:1)
5055109	BH3 / SS3	T1(ALL) - Current	O. Reg. 153(511) - Metals & Inorganics (Soil)	Sodium Adsorption Ratio (2:1)

Quality Assurance

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE | AGAT WORK ORDER: 13T794176

PROJECT NO: TP113114 | ATTENTION TO: Jonathan Wakani

Soil Analysis

RPT Date: Dec 20, 2013			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
O. Reg. 153(511) - Metals & Inorganics (Soil)															
Antimony	1		< 0.8	< 0.8	0.0%	< 0.8	97%	70%	130%	85%	80%	120%	86%	70%	130%
Arsenic	1		3	3	0.0%	< 1	108%	70%	130%	99%	80%	120%	104%	70%	130%
Barium	1		36	35	2.8%	< 2	103%	70%	130%	109%	80%	120%	105%	70%	130%
Beryllium	1		< 0.5	< 0.5	0.0%	< 0.5	104%	70%	130%	99%	80%	120%	100%	70%	130%
Boron	1		6	5	18.2%	< 5	71%	70%	130%	102%	80%	120%	98%	70%	130%
Boron (Hot Water Soluble)	5055108	5055108	0.21	0.19	0.0%	< 0.10	108%	60%	140%	107%	70%	130%	111%	60%	140%
Cadmium	1		< 0.5	< 0.5	0.0%	< 0.5	101%	70%	130%	101%	80%	120%	99%	70%	130%
Chromium	1		8	8	0.0%	< 2	92%	70%	130%	104%	80%	120%	104%	70%	130%
Cobalt	1		4.8	4.8	0.0%	< 0.5	100%	70%	130%	101%	80%	120%	98%	70%	130%
Copper	1		16	16	0.0%	< 1	100%	70%	130%	106%	80%	120%	96%	70%	130%
Lead	1		6	6	0.0%	< 1	98%	70%	130%	108%	80%	120%	100%	70%	130%
Molybdenum	1		< 0.5	< 0.5	0.0%	< 0.5	103%	70%	130%	100%	80%	120%	105%	70%	130%
Nickel	1		7	7	0.0%	< 1	100%	70%	130%	98%	80%	120%	93%	70%	130%
Selenium	1		< 0.4	< 0.4	0.0%	< 0.4	103%	70%	130%	102%	80%	120%	105%	70%	130%
Silver	1		< 0.2	< 0.2	0.0%	< 0.2	92%	70%	130%	113%	80%	120%	108%	70%	130%
Thallium	1		< 0.4	< 0.4	0.0%	< 0.4	98%	70%	130%	100%	80%	120%	95%	70%	130%
Uranium	1		< 0.5	< 0.5	0.0%	< 0.5	93%	70%	130%	98%	80%	120%	95%	70%	130%
Vanadium	1		13	13	0.0%	< 1	98%	70%	130%	103%	80%	120%	106%	70%	130%
Zinc	1		28	29	3.5%	< 5	95%	70%	130%	115%	80%	120%	106%	70%	130%
Chromium VI	1	5055109	< 0.2	< 0.2	0.0%	< 0.2	97%	70%	130%	100%	80%	120%	95%	70%	130%
Cyanide	1		< 0.040	< 0.040	0.0%	< 0.040	98%	70%	130%	106%	80%	120%	102%	70%	130%
Mercury	1		< 0.10	< 0.10	0.0%	< 0.10	100%	70%	130%	95%	80%	120%	94%	70%	130%
Electrical Conductivity (2:1)	1	5055108	1.17	1.19	1.7%	< 0.005	100%	90%	110%	NA			NA		
Sodium Adsorption Ratio (2:1)	5055108	5055108	4.94	5.05	2.2%	N/A	NA			NA			NA		
pH, 2:1 CaCl2 Extraction	1	5055108	7.82	7.79	0.4%	NA	101%	80%	120%	NA			NA		
Comments: NA signifies Not Applicable.															
O. Reg. 558 Metals and Inorganics															
Arsenic Leachate	1		< 0.010	< 0.010	0.0%	< 0.010	95%	90%	110%	86%	80%	120%	104%	70%	130%
Barium Leachate	1		0.340	0.347	2.0%	< 0.100	105%	90%	110%	109%	80%	120%	112%	70%	130%
Boron Leachate	1		< 0.050	< 0.050	0.0%	< 0.050	102%	90%	110%	105%	80%	120%	85%	70%	130%
Cadmium Leachate	1		< 0.010	< 0.010	0.0%	< 0.010	100%	90%	110%	104%	80%	120%	101%	70%	130%
Chromium Leachate	1		< 0.010	< 0.010	0.0%	< 0.010	99%	90%	110%	108%	80%	120%	104%	70%	130%
Lead Leachate	1		< 0.010	< 0.010	0.0%	< 0.010	100%	90%	110%	105%	80%	120%	99%	70%	130%
Mercury Leachate	1		< 0.01	< 0.01	0.0%	< 0.01	99%	90%	110%	96%	80%	120%	92%	70%	130%
Selenium Leachate	1		< 0.010	< 0.010	0.0%	< 0.010	99%	90%	110%	100%	80%	120%	103%	70%	130%
Silver Leachate	1		< 0.010	< 0.010	0.0%	< 0.010	100%	90%	110%	103%	80%	120%	107%	70%	130%
Uranium Leachate	1		< 0.050	< 0.050	0.0%	< 0.050	94%	90%	110%	104%	80%	120%	97%	70%	130%
Fluoride Leachate	1		0.29	0.29	0.0%	< 0.05	99%	90%	110%	96%	90%	110%	91%	70%	130%

Quality Assurance

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE

AGAT WORK ORDER: 13T794176

PROJECT NO: TP113114

ATTENTION TO: Jonathan Wakani

Soil Analysis (Continued)

RPT Date: Dec 20, 2013			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
Cyanide Leachate	1		< 0.05	< 0.05	0.0%	< 0.05	97%	90%	110%	106%	90%	110%	101%	70%	130%
(Nitrate + Nitrite) as N Leachate	5050275		<0.70	<0.70	0.0%	< 0.70	94%	80%	120%	96%	80%	120%	96%	70%	130%

Certified By:

Quality Assurance

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE

AGAT WORK ORDER: 13T794176

PROJECT NO: TP113114

ATTENTION TO: Jonathan Wakani

Trace Organics Analysis

RPT Date: Dec 20, 2013			DUPLICATE				REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD	Method Blank	Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
ON Regulation 558 VOCs															
Vinyl Chloride	1		< 0.030	< 0.030	0.0%	< 0.030	91%	60%	140%	79%	60%	140%	87%	60%	140%
1,1 Dichloroethene	1		< 0.020	< 0.020	0.0%	< 0.020	120%	70%	130%	110%	70%	130%	113%	60%	140%
Dichloromethane	1		< 0.030	< 0.030	0.0%	< 0.030	106%	70%	130%	106%	70%	130%	108%	60%	140%
Methyl Ethyl Ketone	1		< 0.090	< 0.090	0.0%	< 0.090	84%	70%	130%	97%	70%	130%	110%	60%	140%
Chloroform	1		< 0.020	< 0.020	0.0%	< 0.020	104%	70%	130%	118%	70%	130%	118%	60%	140%
1,2-Dichloroethane	1		< 0.020	< 0.020	0.0%	< 0.020	123%	70%	130%	117%	70%	130%	123%	60%	140%
Carbon Tetrachloride	1		< 0.020	< 0.020	0.0%	< 0.020	119%	70%	130%	111%	70%	130%	107%	60%	140%
Benzene	1		< 0.020	< 0.020	0.0%	< 0.020	116%	70%	130%	110%	70%	130%	116%	60%	140%
Trichloroethene	1		< 0.020	< 0.020	0.0%	< 0.020	110%	70%	130%	116%	70%	130%	110%	60%	140%
Tetrachloroethene	1		< 0.050	< 0.050	0.0%	< 0.050	118%	70%	130%	106%	70%	130%	109%	60%	140%
Chlorobenzene	1		< 0.010	< 0.010	0.0%	< 0.010	130%	70%	130%	102%	70%	130%	102%	60%	140%
1,2-Dichlorobenzene	1		< 0.010	< 0.010	0.0%	< 0.010	120%	70%	130%	77%	70%	130%	81%	60%	140%
1,4-Dichlorobenzene	1		< 0.010	< 0.010	0.0%	< 0.010	117%	70%	130%	90%	70%	130%	89%	60%	140%
ON Regulation 558 Benzo(a) pyrene															
Benzo(a)pyrene	1		< 0.001	< 0.001	0.0%	< 0.001	110%	70%	130%	121%	70%	130%	115%	70%	130%
ON Regulation 558 PCBs															
Polychlorinated Biphenyls	1		< 0.005	< 0.005	0.0%	< 0.005	117%	60%	130%	98%	60%	130%	108%	60%	130%

Certified By:

Method Summary

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE
AGAT WORK ORDER: 13T794176
PROJECT NO: TP113114
ATTENTION TO: Jonathan Wakani

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Antimony	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Arsenic	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Barium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Beryllium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Boron	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Boron (Hot Water Soluble)	MET-93-6104	EPA SW 846 6010C; MSA, Part 3, Ch.21	ICP/OES
Cadmium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Chromium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Cobalt	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Copper	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Lead	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Molybdenum	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Nickel	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Selenium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Silver	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Thallium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Uranium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Vanadium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Zinc	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Chromium VI	INOR-93-6029	SM 3500 B; MSA Part 3, Ch. 25	SPECTROPHOTOMETER
Cyanide	INOR-93-6052	MOE CN-3015 & E 3009 A;SM 4500 CN	TECHNICON AUTO ANALYZER
Mercury	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Electrical Conductivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B	EC METER
Sodium Adsorption Ratio (2:1)	INOR 1007	McKeague 4.12 & 3.26 & EPA SW-846 6010B	ICP/OES
pH, 2:1 CaCl2 Extraction	INOR-93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Arsenic Leachate	MET-93-6103	EPA SW-846 1311 & 3010A & 6020A	ICP-MS
Barium Leachate	MET-93-6103	EPA SW-846 1311 & 3010A & 6020A	ICP-MS
Boron Leachate	MET-93-6103	EPA SW-846 1311 & 3010A & 6020A	ICP-MS
Cadmium Leachate	MET-93-6103	EPA SW-846 1311 & 3010A & 6020A	ICP-MS
Chromium Leachate	MET-93-6103	EPA SW-846 1311 & 3010A & 6020A	ICP-MS
Lead Leachate	MET-93-6103	EPA SW-846 1311 & 3010A & 6020A	ICP-MS
Mercury Leachate	MET-93-6103	EPA SW-846 1311 & 3010A & 6020A	ICP-MS
Selenium Leachate	MET-93-6103	EPA SW-846 1311 & 3010A & 6020A	ICP-MS
Silver Leachate	MET-93-6103	EPA SW-846 1311 & 3010A & 6020A	ICP-MS
Uranium Leachate	MET-93-6103	EPA SW-846 1311 & 3010A & 6020A	ICP-MS
Fluoride Leachate	INOR-93-6018	EPA SW-846-1311 & SM4500-F- C	ION SELECTIVE ELECTRODE
Cyanide Leachate	INOR-93-6052	EPA SW-846-1311 & MOE 3015 & SM 4500 CN- I	TECHNICON AUTO ANALYZER
(Nitrate + Nitrite) as N Leachate	INOR-93-6053	EPA SW 846-1311 & SM 4500 - NO3- I	LACHAT FIA

Method Summary

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE
AGAT WORK ORDER: 13T794176
PROJECT NO: TP113114
ATTENTION TO: Jonathan Wakani

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Trace Organics Analysis			
Benzo(a)pyrene	ORG-91-5114	EPA SW846 3540 & 8270	GC/MS
Polychlorinated Biphenyls	ORG-91-5112	Regulation 558, EPA SW846 3510C/8082	GC/ECD
Decachlorobiphenyl	ORG-91-5112	EPA SW846 3510C/8082	GC/ECD
Vinyl Chloride	VOL-91-5001	EPA SW-846 5230B & 8260	(P&T)GC/MS
1,1 Dichloroethene	VOL-91-5001	EPA SW-846 5230B & 8260	(P&T)GC/MS
Dichloromethane	VOL-91-5001	EPA SW-846 5230B & 8260	(P&T)GC/MS
Methyl Ethyl Ketone	VOL-91-5001	EPA SW-846 5230B & 8260	(P&T)GC/MS
Chloroform	VOL-91-5001	EPA SW-846 5230B & 8260	(P&T)GC/MS
1,2-Dichloroethane	VOL-91-5001	EPA SW-846 5230B & 8260	(P&T)GC/MS
Carbon Tetrachloride	VOL-91-5001	EPA SW-846 5230B & 8260	(P&T)GC/MS
Benzene	VOL-91-5001	EPA SW-846 5230B & 8260	(P&T)GC/MS
Trichloroethene	VOL-91-5001	EPA SW-846 5230B & 8260	(P&T)GC/MS
Tetrachloroethene	VOL-91-5001	EPA SW-846 5230B & 8260	(P&T)GC/MS
Chlorobenzene	VOL-91-5001	EPA SW-846 5230B & 8260	(P&T)GC/MS
1,2-Dichlorobenzene	VOL-91-5001	EPA SW-846 5230B & 8260	(P&T)GC/MS
1,4-Dichlorobenzene	VOL-91-5001	EPA SW-846 5230B & 8260	(P&T)GC/MS
Toluene-d8	VOL-91-5001	EPA SW-846 5230B & 8260	(P&T)GC/MS

13T794176

AGAT Laboratories

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Chain of Custody Record

Laboratory Use Only
Arrival Temperature: 8^{6} 8^{2} 8^{1}
AGAT WO #:
Lab Temperature: 8^{7} 7^{7} 77
Notes:

Client Information
Company: AMEC E& I
Contact: Jonathan Wakani / Shami Malla
Address: AMEC Hamilton / AMEC - Scarborough
905-712-0700 / 416-751-6565
Phone:
Fax:
Project: TP113114
PO:
AGAT Quotation #:

Please note, if quotation number is not provided, client will be billed full price for analysis.

Regulatory Requirements
☒ Regulation 153/04 (reg. 511 Amend.)
Table 1 Indicate one
☐ Ind/Com
☒ Res/Park
☐ Agriculture
Soil Texture (check one)
☐ Coarse ☐ Fine

☐ Sewer Use
Region ____ Indicate one
☐ Sanitary
☐ Storm

☒ Regulation 558
☐ CCME
☐ Other (specify)
☐ Prov. Water Quality Objectives (PWQO)
☐ None

Turnaround Time Required (TAT) Required*
Regular TAT
☒ 5 to 7 Working Days
Rush TAT (please provide prior notification)
Rush Surcharges Apply
☐ 3 Working Days
☐ 2 Working Days
☐ 1 Working Day
OR
Date Required (Rush surcharges may apply):

*TAT is exclusive of weekends and statutory holidays

Invoice To Same: Yes ☐ No ☐
Company: AMEC
Contact: Shami Malla
Address: 104 Crockford Blvd, Scarborough M1R3C3

Is this a drinking water sample? (potable water intended for human consumption)
☐ Yes ☐ No
If "Yes", please use the *Drinking Water Chain of Custody Form*

Is this submission for a Record of Site Condition?
☐ Yes ☐ No

Legend Matrix
GW Ground Water **O** Oil
SW Surface Water **P** Paint
SD Sediment **S** Soil

Report Information – reports to be sent to:
1. Name:
Email: Jonathan.Wakani@amec.com
2. Name:
Email: Shami.Malla@amec.com

Sample Identification	Date Sampled	Time Sampled	Sample Matrix	# of Containers	Comments Site/Sample Information	Metals and Inorganics	Metal Scan	Hydride Forming Metals	Client Custom Metals	ORPs: ☐ B-HWS ☐ Cl- ☐ CN- ☐ EC ☐ FOC ☐ Cr+6- ☐ SAR ☐ NO_3/NO_2 ☐ N-Total ☐ Hg ☐ pH	Nutrients: ☐ TP ☐ NH_3 ☐ TKN ☐ NO_3 ☐ NO_2 ☐ NO_3/NO_2	VOC: ☐ VOC ☐ THM ☐ BTEX	CCME Fractions 1 to 4	ABNs	PAHs	Chlorophenols	PCBs	Organochlorine Pesticides	TCLP Metals/Inorganics	Sewer Use	TCLP VOC	TCLP B(a)P	TCLP PCB
BH1/SS4	Dec. 11	9:15AM	S	1	1X250	X																	
BH3/SS3	Dec. 9	2:00PM	S	1	1X250	X																	
BH1/SS5	Dec. 11	9:30AM	S	3	1X250, 2X60														X		X	X	X

Samples Relinquished By (Print Name and Sign): Shami Malla.
Date/Time: Dec. 13/'13
Samples Received By (Print Name and Sign): S Dec 13/13
Date/Time: 3 15

Samples Relinquished By (Print Name and Sign):
Date/Time:
Samples Received By (Print Name and Sign):
Date/Time: 4 30

Pink Copy - Client
Yellow Copy - AGAT
White Copy- AGAT

Page 1 of 1
Nº: 30249 (a)

Document ID: DIV-78-1511.008
Date issued: May 31, 2013

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE
505 Woodward Avenue Unit 1
Hamilton, ON L8H6H6
(905) 312-0700

ATTENTION TO: Jonathan Wakani

PROJECT NO: TP113114

AGAT WORK ORDER: 13T794171

SOIL ANALYSIS REVIEWED BY: Sofka Pehlyova, Senior Analyst

DATE REPORTED: Dec 23, 2013

PAGES (INCLUDING COVER): 4

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

*NOTES

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.

AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 13T794171
PROJECT NO: TP113114

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE

ATTENTION TO: Jonathan Wa

Corrosivity Package

DATE RECEIVED: 2013-12-13

DATE R

			SAMPLE DESCRIPTION:	BH2 - SS10
			SAMPLE TYPE:	Soil
			DATE SAMPLED:	12/10/2013
Parameter	Unit	G / S	RDL	5055099
Sulphide*	%		0.01	0.04
Chloride (2:1)	µg/g		2	63
Sulphate (2:1)	µg/g		2	27
pH (2:1)	pH Units		N/A	8.20
Electrical Conductivity (2:1)	mS/cm		0.005	0.223
Resistivity (2:1)	ohm.cm		1	4480
Redox Potential (2:1)	mV		5	236

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

5055099 * Analysis was performed at AGAT's Mining Division.

EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part so

Certified By:

AGAT Laboratories

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

Quality Assurance

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE

AGAT WORK ORDER: 13T794171

PROJECT NO: TP113114

ATTENTION TO: Jonathan Wakani

Soil Analysis

RPT Date: Dec 23, 2013			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
Corrosivity Package															
Sulphide*	1		0.01	0.01	0.0%	< 0.01	100%	80%	120%	NA			NA		
Chloride (2:1)	5055226		24	24	0.5%	< 2	93%	80%	120%	99%	80%	120%	91%	70%	130%
Sulphate (2:1)	5055226		5	5	0.0%	< 2	100%	80%	120%	102%	80%	120%	99%	70%	130%
pH (2:1)	1		8.09	8.11	0.2%	NA	99%	90%	110%	NA			NA		
Electrical Conductivity (2:1)	1		1.17	1.19	1.7%	< 0.005	100%	90%	110%	NA			NA		
Redox Potential (2:1)	1		280	279	0.4%	< 5	97%	70%	130%	NA			NA		

Comments: NA - Not Applicable.

Certified By: Sofia Pehlyova

Method Summary

CLIENT NAME: AMEC ENVIRONMENT & INFRASTRUCTURE

AGAT WORK ORDER: 13T794171

PROJECT NO: TP113114

ATTENTION TO: Jonathan Wakani

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Sulphide*	MIN-200-12000	ASTM E1915-07a	LECO C_S
Chloride (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Electrical Conductivity (2:1)	INOR 1036	McKeague 4.12, SM 2510 B	EC METER
Resistivity (2:1)	INOR 1036		CALCULATION
Redox Potential (2:1)		McKeague 4.12 & SM 2510 B	REDOX POTENTIAL ELECTRODE

13T794171

AGAT Laboratories

5835 Coopers Avenue
Mississauga, ON
L4Z 1Y2
www.agatlabs.com · webearth.agatlabs.com
P: 905.712.5100 · F: 905.712.5122

Laboratory Use Only

Arrival Temperature: 3⁶ 8 + 8¹
AGAT WO #:
Lab Temperature: 8 7 9 7 7
Notes:

Chain of Custody Record

Client Information

Company: AMEC E& I
Contact: Jonathan Wakani / Shami Malla
Address: AMEC Hamilton / AMEC - Scarborough
905-712-0700 / 416-751-6565
Phone:
Fax:
Project: TP113114
PO:
AGAT Quotation #:

Please note, if quotation number is not provided, client will be billed full price for analysis.

Regulatory Requirements

☐ **Regulation 153/04** (reg. 511 Amend.)
Table ____ Indicate one
☐ Ind/Com
☐ Res/Park
☐ Agriculture
Soil Texture (*check one*)
☐ Coarse ☐ Fine

☐ **Sewer Use**
Region ____ Indicate one
☐ Sanitary
☐ Storm

☐ **Regulation 558**
☐ **CCME**
☐ **Other** (*specify*)
☐ **Prov. Water Quality Objectives (PWQO)**
☐ **None**

Is this a drinking water sample? (potable water intended for human consumption)
☐ Yes ☐ No
If "Yes", please use the **Drinking Water Chain of Custody Form**

Is this submission for a **Record of Site Condition?**
☐ Yes ☐ No

Turnaround Time Required (TAT) Required*

Regular TAT
☒ 5 to 7 Working Days

Rush TAT (please provide prior notification)
Rush Surcharges Apply
☐ 3 Working Days
☐ 2 Working Days
☐ 1 Working Day

OR

Date Required (Rush surcharges may apply):

**TAT is exclusive of weekends and statutory holidays*

Invoice To

Same: Yes ☐ No ☐
Company: AMEC
Contact: Shami Malla.
Address: 104 Crockford Blvd; Scarborough M1R3C3

Legend Matrix

GW	Ground Water	**O**	Oil
SW	Surface Water	**P**	Paint
SD	Sediment	**S**	Soil

Report Information – reports to be sent to:

1. Name:
   Email: ~~Jonathan.Wakani@amec.com~~
2. Name:
   Email: Shami.Malla@amec.com

Sample Identification	Date Sampled	Time Sampled	Sample Matrix	# of Containers	Comments Site/Sample Information	Metals and Inorganics	Metal Scan	Hydride Forming Metals	Client Custom Metals	ORPs: ☐ B-HWS ☐ Cl- ☐ CN- ☐ EC ☐ FOC ☐ Cr+6- ☐ SAR ☐ NO_3/NO_2 ☐ N-Total ☐ Hg ☐ pH	Nutrients: ☐ TP ☐ NH_3 ☐ TKN ☐ NO_3 ☐ NO_2 ☐ NO_3/NO_2	VOC: ☐ VOC ☐ THM ☐ BTEX	CCME Fractions 1 to 4	ABNs	PAHs	Chlorophenols	PCBs	Organochlorine Pesticides	TCLP Metals/Inorganics	Sewer Use	Soil Corrosivity (pH, Cl, SO_4, Resist, Cond)
BH2-SS10	Dec 10/13	12:45PM	S	1	1 x 250																

Samples Relinquished By (Print Name and Sign): Shami Malla.
Date/Time: Dec 13, 2013
Samples Received By (Print Name and Sign): Dec 13/13
Date/Time: 315

Samples Relinquished By (Print Name and Sign):
Date/Time:
Samples Received By (Print Name and Sign):
Date/Time: 4³⁰

Pink Copy - Client
Yellow Copy - AGAT
White Copy- AGAT

Page 1 of 1

Nº: 30249(b)

Document ID: DIV-78-1511.008

Date Issued: May 31, 2013

APPENDIX C

Borehole log for Borehole BC 35 (Monitoring well from previous study)
(AMEC Report No. TT93042)

RECORD OF BOREHOLE No. BH BC35

Project Number:	**TT93042**	Drilling Location:	**BH BC35**	Logged by:	**JF**
Project Client:	**The Regional Municipality of Peel**	Drilling Method:	**150 mm Solid Stem Augering**	Compiled by:	**SN**
Project Name:	**Geotechnical Investigation for Bovaird Drive Class EA Study**	Drilling Machine:	**Truck Mounted Drill**	Reviewed by:	**PB**
Project Location:	**Bovaird Drive from Lake Louise Drive to Peel/Halton Boundary at Caseley Drive, Brampton, ON.**	Date Started:	**Oct 27, 09** Date Completed: **Oct 27, 09**	Revision No.:	**0, 5/11/11**

Geodetic Ground Surface Elevation: 0.0 m

LITHOLOGY PROFILE: DESCRIPTION	Depth / Elevation (m)	Sample Type	Sample Number	Recovery (%)	SPT 'N' Value	COMMENTS & GRAIN SIZE DISTRIBUTION (%)
about 150 mm TOPSOIL	0.0 0.0					
brown **Sand and Gravel FILL** some silt, trace clay moist		A	1			Well Detail: 50 mm slotted PVC pipe (11.3 - 12.9 m) with sand pack (11.3 m - 12.9 m), bentonite plug above sand, capped with flush-mounted casing set in concrete.
--- trace organic matter and rootlets		A	2			
		A	3			
brown to grey **Clayey Silt FILL** trace sand and gravel moist	-4.0 4.0					

FIELD TESTING: Penetration Testing: ○ SPT ☐ PPT ● DCPT; MTO Vane*: △ Intact ▲ Remould; Nilcon Vane*: ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

LAB TESTING: ★ Rinse pH Values 2 4 6 8 10 12; △ Soil Vapour Reading parts per million (ppm) 100 200 300 400; ▲ Lower Explosive Limit (LEL); W_P W W_L Plastic Liquid 20 40 60 80

INSTRUMENTATION INSTALLATION

GR SA SI CL

DEPTH (m)	ELEVATION (m)
1	-1
2	-2
3	-3
4	-4
5	-5
6	

AMEC Earth & Environmental,
A division of AMEC Americas Limited
104 Crockford Boulevard
Scarborough, Ontario
Canada M1R 3C3
Tel +1(416) 751-6565
Fax +1(416) 751-7592
www.amec.com

Continued on Next Page

▽ No freestanding groundwater measured in open borehole on completion of drilling.

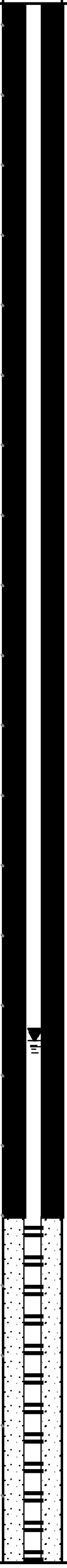
▼ Groundwater depth observed on 17 March 2010 at a depth of: 10.5 m

Scale: 1 : 32

RECORD OF BOREHOLE No. BH BC35

Project Number: **TT93042** Drilling Location: **BH BC35** Logged by: **JF**

LITHOLOGY PROFILE		SOIL SAMPLING						FIELD TESTING	LAB TESTING		COMMENTS & GRAIN SIZE DISTRIBUTION (%)
Lithology Plot	DESCRIPTION	Sample Type	Sample Number	Recovery (%)	SPT 'N' Value	DEPTH (m)	ELEVATION (m)	Penetration Testing ○ SPT □ PPT ● DCPT MTO Vane* △ Intact ▲ Remould Nilcon Vane* ◇ Intact ◆ Remould * Undrained Shear Strength (kPa) 20 40 60 80	★ Rinse pH Values 2 4 6 8 10 12 △ Soil Vapour Reading parts per million (ppm) 100 200 300 400 ▲ Lower Explosive Limit (LEL) W_P W W_L Plastic Liquid 20 40 60 80	INSTRUMENTATION INSTALLATION	GR SA SI CL
	brown to grey **Clayey Silt FILL** trace sand and gravel moist										
		A	4			7	-7				
		A	5			8	-8				
						9	-9				
						10	-10				
		SS	6	56	32			○			
	-11.0 11.0					11	-11				
	reddish brown **WEATHERED SHALE** limestone seams damp										
						12	-12				
		SS	7	100	50/5			50 ○ 5			



Scale: 1 : 32

Continued on Next Page

RECORD OF BOREHOLE No. BH BC35

Project Number: **TT93042** Drilling Location: **BH BC35** Logged by: **JF**

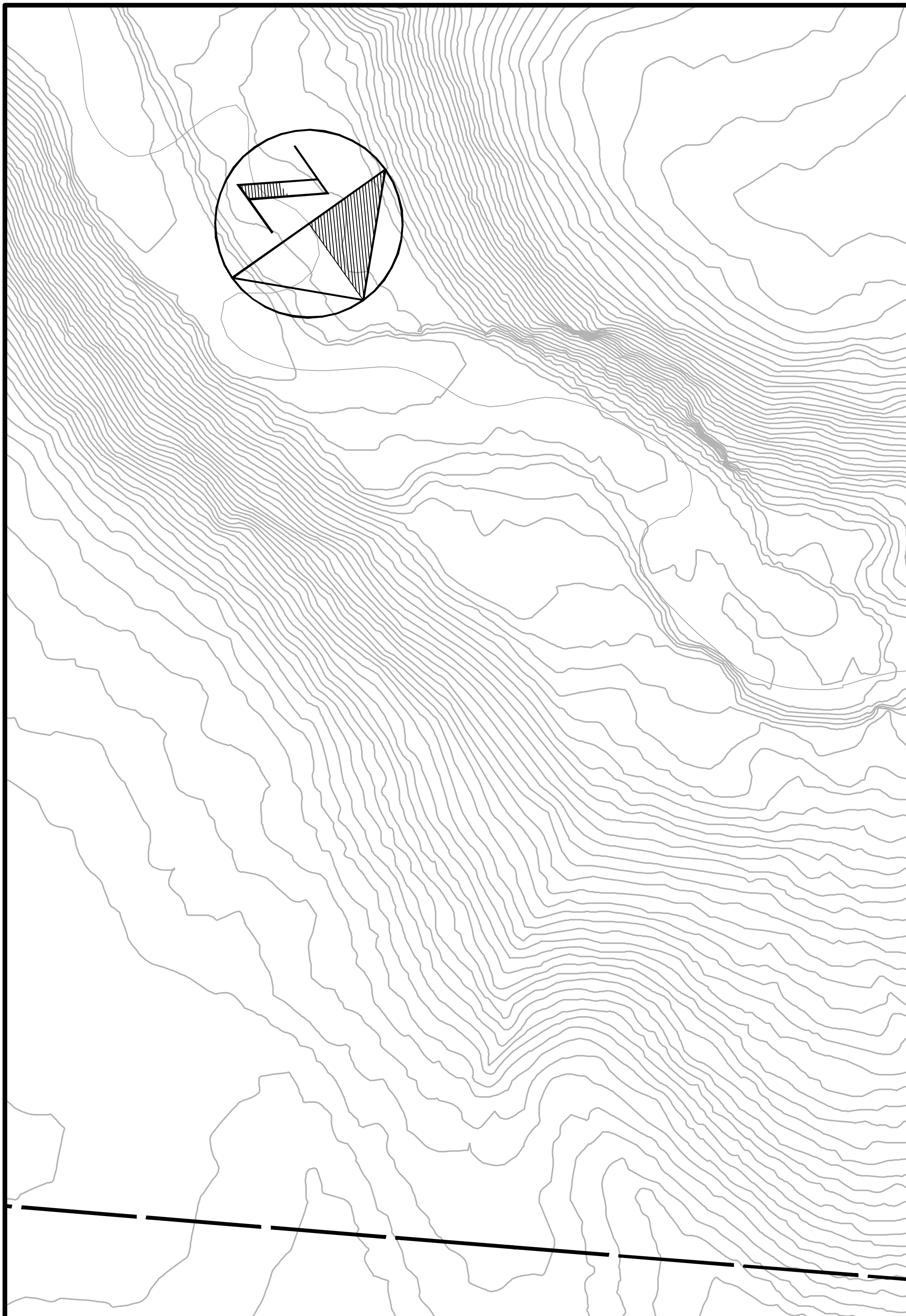
LITHOLOGY PROFILE		SOIL SAMPLING						FIELD TESTING	LAB TESTING		
Lithology Plot	DESCRIPTION	Sample Type	Sample Number	Recovery (%)	SPT 'N' Value	DEPTH (m)	ELEVATION (m)	Penetration Testing ○ SPT ☐ PPT ● DCPT MTO Vane* △ Intact ▲ Remould Nilcon Vane* ◇ Intact ◆ Remould * Undrained Shear Strength (kPa) 20 40 60 80	★ Rinse pH Values 2 4 6 8 10 12 △ Soil Vapour Reading parts per million (ppm) 100 200 300 400 ▲ Lower Explosive Limit (LEL) W_P W W_L Plastic Liquid 20 40 60 80	INSTRUMENTATION INSTALLATION	COMMENTS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	-12.9	SS	8	0	50/5			50 ○ 5			
	End of Borehole 12.9										
	Auger refusal at 13.0 m depth.						-13				

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 32

APPENDIX D

Preliminary Grading Plan



APPENDIX ‘D’

HYDROGEOLOGICAL ASSESSMENT REPORT

23 May, 2014

Project **TP113114**

Region of Peel
10 Peel Centre Drive
Suite B 4th Floor
Brampton, On L7N 4B9

Attn: Mr Dan Bennington C.E.T.
Project Manager Design and Construction

Subject: **Hydrogeological Assessment Report For Permit To Take Water**
Bovaird Drive Culvert Rehabilitation

Dear Sir:

AMEC Environmental & Infrastructure, a Division of AMEC Americas Limited (AMEC), was retained by The Region of Peel (Region) to conduct a hydrogeological assessment in the vicinity of a proposed culvert rehabilitation under Bovaird Drive. The purpose of the study was to assess the need for a Permit To Take Water (PTTW) to undertake the proposed rehabilitation.

1.0 BACKGROUND

The location of the culvert (shown in the centre of Figure 1, denoted as tributary crossing) to be rehabilitated is located under Bovaird Drive about 2.5 km east of Georgetown, Ontario and 1.1 km west of Heritage Road. The box culvert has dimensions 1.2 m x 2.43 m with an approximate length of 95 m. The base of the culvert is at elevation 205 masl at the location under Bovaird Drive. Some deficiencies and issues were identified with the culvert, namely:

The invert of the existing culvert is about 15 m below the existing ground surface of Bovaird Drive West. The existing culvert is about 98 m in total length and consists of the following three distinct barrels, as described in the RFP, located under Bovaird Drive West and the old Highway 7:

- *Under Bovaird Drive West:* Approximately 65 m long "south barrel", which has been constructed with 1.2 m wide x 2.8 m high pre-cast concrete boxes.
- *Under the old Highway 7:* Approximately 33 m long culvert, which consists of:
  - "Centre barrel", constructed with cast-in-place concrete.
  - "North barrel", constructed with masonry.

The entire length of the culvert under the old Highway 7 (centre and north barrels) is showing signs of deterioration and is proposed to be removed, together with the old Highway 7 embankment, and replaced by an open channel with stable sideslopes. The existing south barrel of the culvert under Bovaird Drive West is in fairly good condition and will remain in place.

In addition, the proposed culvert rehabilitation may consist of one or more of the following works:

- Construction of a headwall/retaining wall at the north end (and possibly south end) of the remaining south section of the existing culvert under Bovaird Drive West, and associated embankment slope(s); and/or
- Extension of the existing culvert under Bovaird Drive West (i.e. south barrel) to the north, after removal of the culvert underneath the old Highway 7; and/or
- Construction of a new supplementary culvert under Bovaird Drive West, adjacent to the existing culvert, to augment hydraulics, which will possibly be constructed using trenchless technique.

Currently, a ditch with catch basins to collect stormwater is located between the embankments of Bovaird Drive and the old Highway 7. The sideslopes of the existing embankments, approximately 15 m high, are covered with grass and/or trees.

A more detailed plan of the location of the culvert and boreholes is provided in Figure 2.

1.1 Surrounding Land Uses

Surrounding land uses near the Site are mainly single family rural residential properties and agricultural properties as can be seen on Figure 1.

1.2 Topography

According to the Ontario Geologic Survey (OGS) maps, the Site is underlain by Till Plains with some recent and sand sediments locally in the immediate vicinity of the tributary. The topography slopes to the south along the culvert length with a gradient of 0.04.

1.3 Drainage

The area is drained by widely spaced tributaries and drains that discharge into the Credit River. The soil has been described as having good drainage characteristics in the Soil Survey of Peel County (Hoffman, D.W. and Richards, N.R., 1953)

1.4 Geology

Overburden sediments in this area are variable, clayey to silty glacial till, with local glaciolacustrine sands and recent alluvial deposits in the tributary channel. South of Bovaird Drive, bedrock is reported to be very near the base of the tributary.

1.5 Hydrogeology

The geologic logs from 5 boreholes (provided in Appendix A), drilled in the immediate vicinity of the culvert, provide the following distribution of overburden and bedrock materials. Immediately north and south of Bovaird Drive 12 to 14 m of silty clayey fill overlie the weathered red shale bedrock. At BH 2, the upper 5.6 m of fill material is sand and gravel fill. The fill materials are reported to be unsaturated.

At locations BH 3 and 4, about 11 m of silty clayey fill overlies 1.5 to 3.5 m of reddish silty clay to clayey silt till with incorporated shale fragments, which overlies the red weathered shale bedrock.

At BH 1 the static water level is reported to be in the shale at an elevation of about 205.2 masl and at BH 3 the static water level is reported to be at an elevation of about 207.1 masl, in the silty clayey till which overlies the bedrock.

1.6 Current PTTW

There are no known current PTTW in the vicinity of the Site.

2.0 HYDROGEOLOGICAL INVESTIGATION

The hydrogeological information and investigation for the Site consisted of a desk-top study of available information from government records and geotechnical reports completed in the study area as well as the information gathered from drilling boreholes at 4 locations and installing monitors at two of these locations, which are shown on Figure 2. Single well response tests were completed on monitors BH1, BH3 and BC35 to estimate the hydraulic conductivity of the saturated materials in the immediate vicinity of the culvert.

The analysis results of the single well response tests are provided in Appendix B. A summary of the calculated hydraulic conductivity of the saturated soils is provided on Table 1.

TABLE 1 Summary of Hydraulic Conductivities

Monitor	Screened Soil	Hydraulic Conductivity
		m/s
BH 1	Upper 1.5 m Shale bedrock	5.0E-07
BH 3	Shale native silty clay and silty clay fill	2.0E-06
BC 35	Shale bedrock > 1.5 m below bedrock surface	7.0E-08

The hydraulic conductivity calculated decreases from the clayey silty fill and native till to the upper weathered bedrock to the less weathered bedrock as shown in the results from BH1, BH3 and BC 35, respectively.

The data were incorporated into a generic conceptual model and analyzed using the 3-D computer model Visual Modflow.

2.1 Conceptual Site Model and Simulations

The model domain used in Visual Modflow consisted of an area approximately 800 by 700 m bounded by constant head boundaries on all layers, with no boundary-defined vertical flow. The saturated soils were modeled as being 20 m thick with a hydraulic conductivity of 1×10^{-6} metres per second (m/s). The horizontal gradient of 0.1 was calculated from north to south.

Dewatering under the drain was simulated by using drain cells under the culvert about 4 m wide and 100 m long. The drawdown simulated was from 3.5 m at the north end of the culvert to 0.5 m at the south end. These drawdowns are considered to be a very conservative selection for the dewatering.

Using this conceptual model and its inherent assumptions, it is predicted that the maximum rate of dewatering of groundwater that may be expected will be less than 50 m^3/d. Consequently, a PTTW is deemed to be unnecessary.

It is noted that in fact the base of the culvert appears to be at about the elevation of the winter static water level in the bedrock at BH1. If this condition remains at the time of rehabilitation, it appears that no dewatering at all may be required.

The potential for the need for a PTTW to divert tributary water to complete the rehabilitation is not within the scope of this assessment. It is MOE policy that if pumping of water to divert tributary flow around the construction area is proposed, a surfacewater PTTW is generally required. Such a PTTW is not required if the diversion is completed solely by gravity flow.

3.0 CONCLUSIONS

The following conclusions are presented related to dewatering for rehabilitation of the culvert under Bovaird Drive:

1. The results of the simulations predict that a Category 3 PTTW will not be required to dewater the saturated soils during rehabilitation of the culvert.

2. It is MOE policy that if pumping of water to divert tributary flow around the construction area is proposed, a surfacewater PTTW is generally required. Such a PTTW is not required if the diversion is completed solely by gravity flow.

4.0 CLOSURE

We trust this is satisfactory for your requirements. Should you have any questions, please contact the undersigned.

Yours truly,

AMEC Environment and Infrastructure,

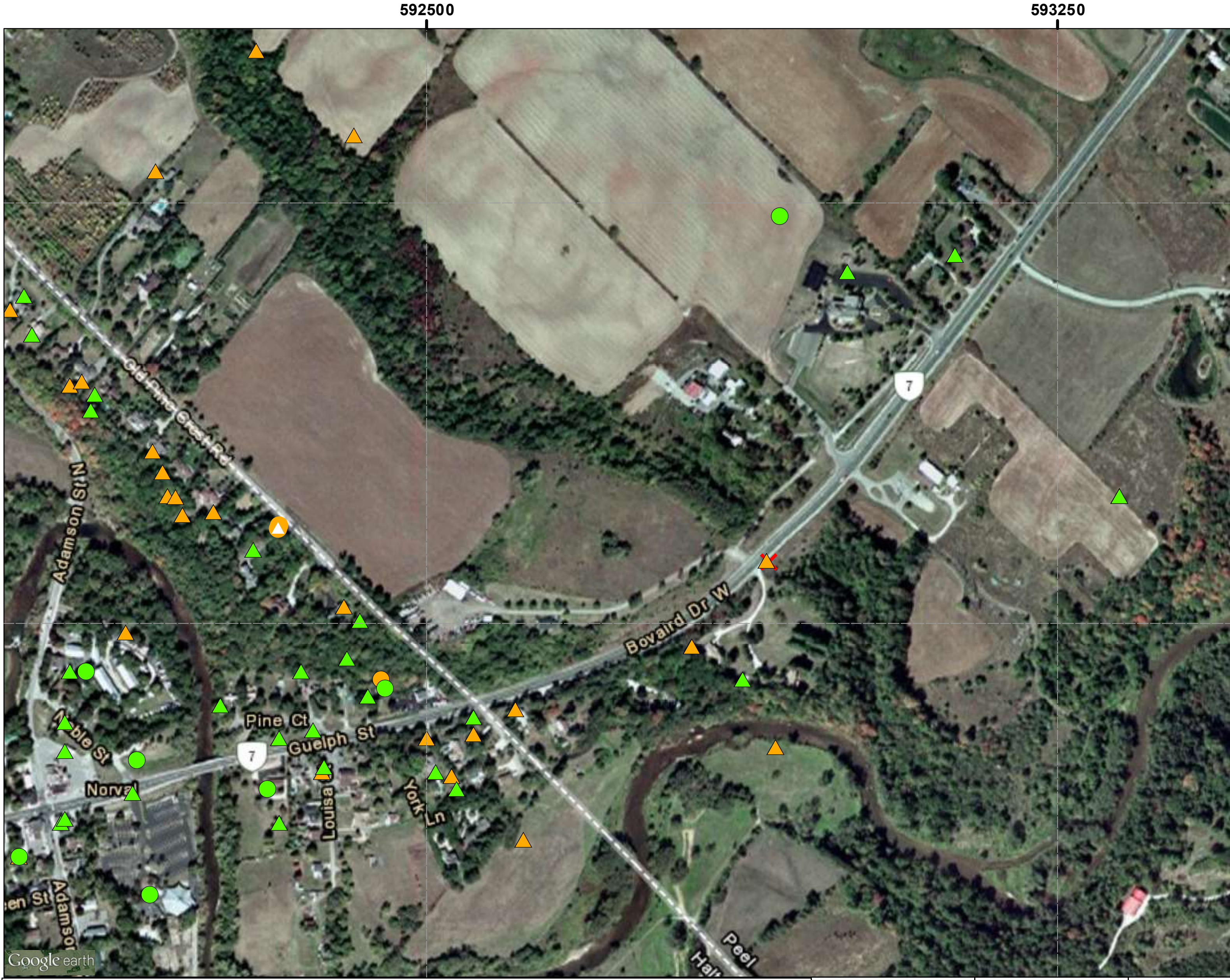
Dirk Gevaert M.Sc., P.Geo.
Associate Hydrogeologist

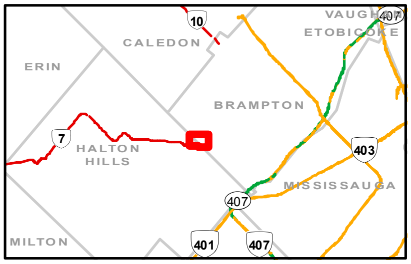
PROFESSIONAL GEOSCIENTIST
23/May/14
DIRK M. GEVAERT
PRACTISING MEMBER
0258
ONTARIO

Limitations

1. The work performed in the preparation of this report and the conclusions presented are subject to the scope of services set out in AMEC's proposal of 2013.
2. No other warranties or representations, either expressed or implied, are made as to the professional services provided under the terms of our Contract, or the conclusions presented.
3. The conclusions presented in this report were based, in part, on visual observations of the site and attendant structures. Our conclusions cannot and are not extended to include those portions of the site or structures which were not reasonably available, in AMEC's opinion, for direct observation.
4. The environmental conditions at the site were assessed, within the limitations set out above, having due regard for applicable environmental regulations as of the date of the inspection. A review of compliance by past owners or occupants of the site with any applicable local, provincial or federal by-laws, orders-in-council, legislative enactments and regulations was not performed.
5. The site history research included obtaining information from third parties and employees or agents of the owner. No attempt has been made to verify the accuracy of any information provided, unless specifically noted in our report.
6. Where testing was performed, it was carried out in accordance with the terms of our contract providing for testing. Other substances, or different quantities of substances testing for, may be present on site and may be revealed by different of other testing not provided for in our contract.
7. Because of the limitations referred to above, different environmental conditions from those stated in our report may exist. Should such different conditions be encountered, AMEC must be notified in order that it may determine if modifications to the conclusions in the report are necessary.
8. The utilization of AMEC's services during the implementation of any remedial measures will allow AMEC to observe compliance with the conclusions and recommendations contained in the report. AMEC's involvement will also allow for changes to be made as necessary to suit field conditions as they are encountered.
9. This report is for the sole use of the party to whom it is addressed unless expressly stated otherwise in the report or contract. Any use which any third party makes of the report, in whole or in part, or any reliance thereon, or decisions made based on any information of conclusions in the report, is the sole responsibility of such third party. AMEC accepts no responsibility whatsoever for damages or loss of any nature or kind suffered by any such third party as a result of actions taken or not taken or decisions made in reliance on the report or anything set out therein.
10. This report is not to be given over to any third party for any purpose whatsoever without the written permission of AMEC.
12. This report was prepared for The Region of Peel and is intended to provide a Hydrogeological Site Assessment related to the rehabilitation of the Bovaird Road Culvert. AMEC agrees that all work products may be relied on by the Region of Peel.

AMEC Environment & Infrastructure





Legend

✕ Tributary Crossing

Well Type and Completed in Bedrock or Overburden

- ● Monitoring Well, completed in bedrock
- ● Monitoring Well, completed in overburden
- ▲ Water Supply Well, completed in bedrock
- ▲ Water Supply Welll, completed in overburden
- △ Unknown Well, completed in overburden

NOTES:

LOCATION OF FEATURES IS APPROXIMATE

THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. TR1413015 DATED January 2014.

Conditions encountered in the field may be different from the interpreted information presented on this figure.

Source: Google Earth, 2014. Water Well Information System, Ontario Ministry of the Environment, © Queen's Printer, 2013 (Accessed January, 2014)

CLIENT: CLIENT	
Drawn By: DF	Checked By: DG
Revision: A	Projection: UTM Zone 17N
SCALE:	1:7,000

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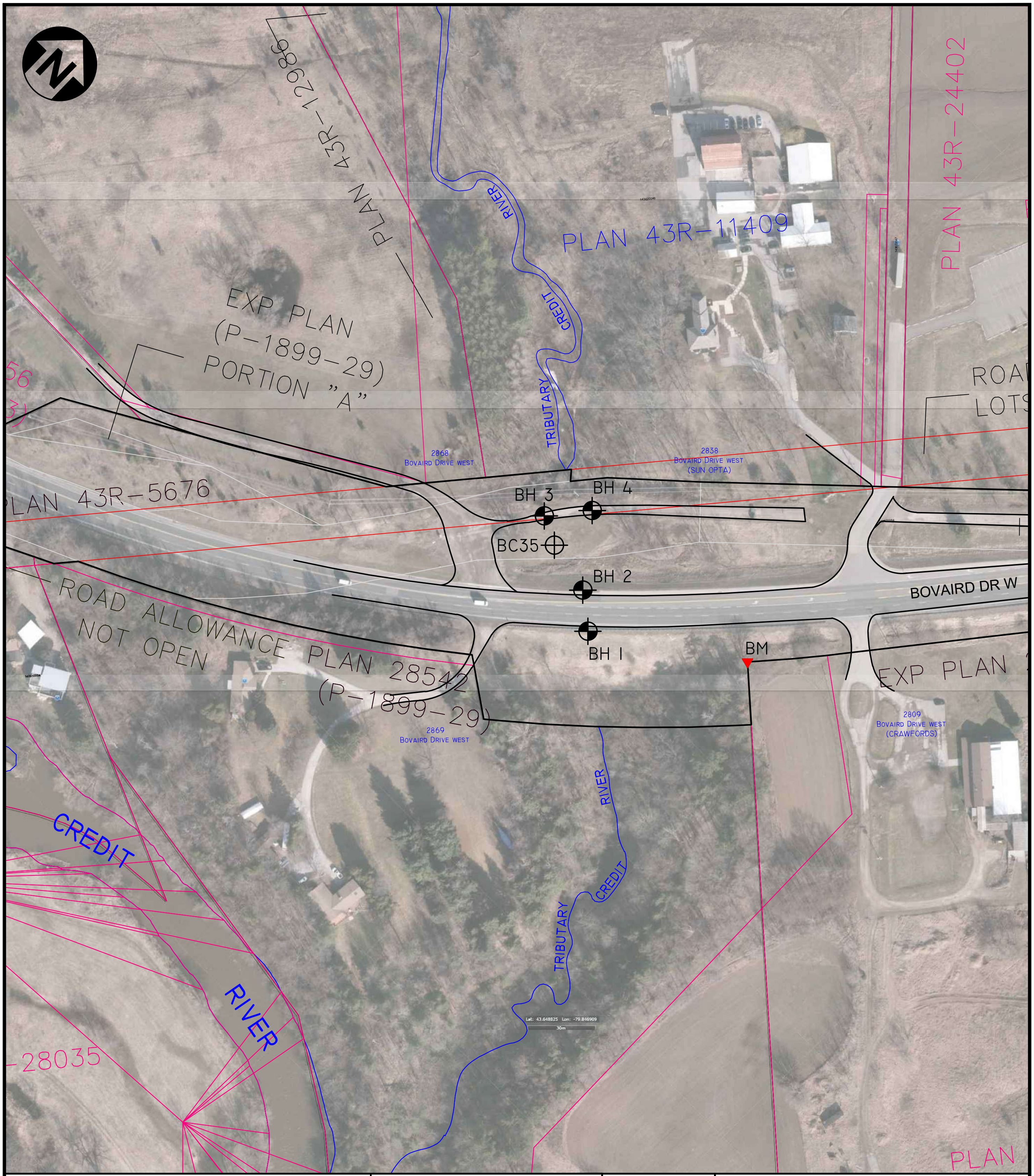
AMEC Enviro

505 Woodward A
tel: 905-312-



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Region of Peel
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OF PEEL

TITLE
BOREHOLE LOCATION PLAN

PROJECT
GEOTECHNICAL INVESTIGATION
CREDIT RIVER TRIBUTARY CULVERT REHABILITATION
BOVAIRD DRIVE, CITY OF BRAMPTON, ON

DWN BY: KW	DATUM: -	DATE: JANUARY 2014
CHK'D BY: SM	REV. NO.: -	PROJECT NO: TP113114.60.02
PROJECTION: -	SCALE: AS SHOWN	FIGURE No. 2

Z:\Projects\2013\TP - Burlington\TP113114.60 - Credit River Tributary\Locates\TP113114.60 - Borehole Location Plan_Fig2.dwg - BHPlan - Feb. 26, 2014 5:01pm - kent.wong

APPENDIX A

BOREHOLE

LOGS

RECORD OF BOREHOLE No. BH BC35

Project Number: **TT93042**
Project Client: **The Regional Municipality of Peel**
Project Name: **Geotechnical Investigation for Bovaird Drive Class EA Study**
Project Location: **Bovaird Drive from Lake Louise Drive to Peel/Halton Boundary at Caseley Drive, Brampton, ON.**

Drilling Location: **BH BC35**
Drilling Method: **150 mm Solid Stem Augering**
Drilling Machine: **Truck Mounted Drill**
Date Started: **Oct 27, 09** Date Completed: **Oct 27, 09**

Logged by: **JF**
Compiled by: **SN**
Reviewed by: **PB**
Revision No.: **0, 5/11/11**

LITHOLOGY PROFILE | **SOIL SAMPLING** | **FIELD TESTING** | **LAB TESTING**

Field Testing: Penetration Testing: ○ SPT ☐ PPT ● DCPT; MTO Vane*: △ Intact ▲ Remould; Nilcon Vane*: ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Lab Testing: ★ Rinse pH Values 2 4 6 8 10 12; △ Soil Vapour Reading parts per million (ppm) 100 200 300 400; ▲ Lower Explosive Limit (LEL); W_P W W_L Plastic Liquid 20 40 60 80

INSTRUMENTATION INSTALLATION

COMMENTS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Geodetic Ground Surface Elevation: 0.0 m

Depth / Elevation (m)	Description
0.0 / 0.0	**about 150 mm TOPSOIL**
	brown **Sand and Gravel FILL** some silt, trace clay moist
	--- trace organic matter and rootlets
4.0 / -4.0	brown to grey **Clayey Silt FILL** trace sand and gravel moist

Sample Type	Sample Number	Recovery (%)	SPT 'N' Value
A	1		
A	2		
A	3		

Depth (m): 1 2 3 4 5 6
Elevation (m): -1 -2 -3 -4 -5

Well Detail:
50 mm slotted
PVC pipe (11.3 - 12.9 m)
with sand pack (11.3 m - 12.9 m),
bentonite plug above sand, capped
with flush-mounted casing
set in concrete.

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▽ No freestanding groundwater measured in open borehole on completion of drilling.

▼ Groundwater depth observed on 17 March 2010 at a depth of: 10.5 m

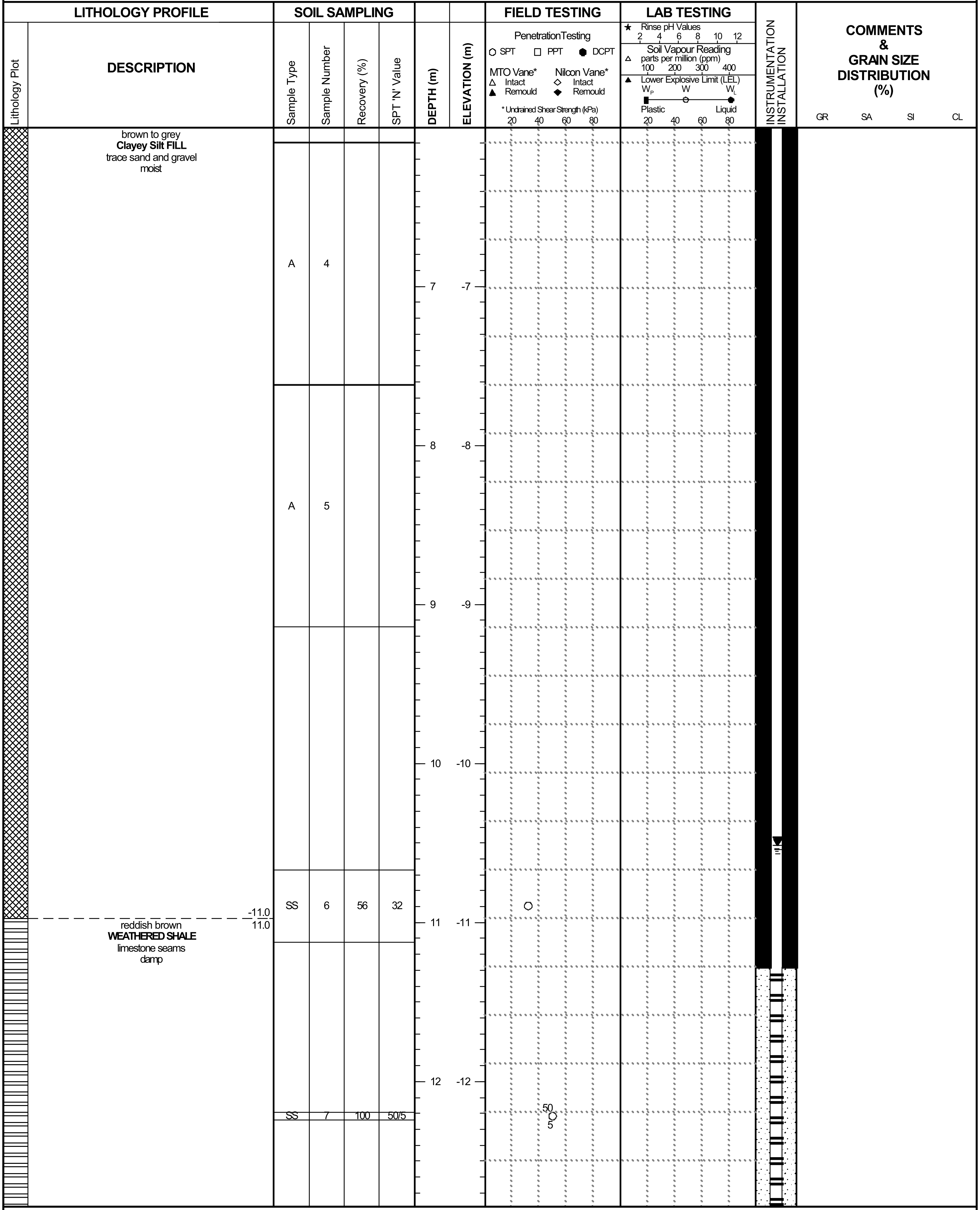
Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 32

Continued on Next Page

RECORD OF BOREHOLE No. BH BC35

Project Number: **TT93042** Drilling Location: **BH BC35** Logged by: **JF**



Description	Sample Type	Sample Number	Recovery (%)	SPT 'N' Value
brown to grey **Clayey Silt FILL** trace sand and gravel moist	A	4		
	A	5		
	SS	6	56	32
-11.0 11.0 reddish brown **WEATHERED SHALE** limestone seams damp				
	SS	7	100	50/5

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 32

Continued on Next Page

RECORD OF BOREHOLE No. BH BC35

Project Number: **TT93042** Drilling Location: **BH BC35** Logged by: **JF**

LITHOLOGY PROFILE		SOIL SAMPLING						FIELD TESTING	LAB TESTING		COMMENTS & GRAIN SIZE DISTRIBUTION (%)
Lithology Plot	DESCRIPTION	Sample Type	Sample Number	Recovery (%)	SPT 'N' Value	DEPTH (m)	ELEVATION (m)	Penetration Testing ○ SPT ☐ PPT ● DCPT MTO Vane* △ Intact ▲ Remould Nilcon Vane* ◇ Intact ◆ Remould * Undrained Shear Strength (kPa) 20 40 60 80	★ Rinse pH Values 2 4 6 8 10 12 Soil Vapour Reading △ parts per million (ppm) 100 200 300 400 ▲ Lower Explosive Limit (LEL) W_P W W_L Plastic Liquid 20 40 60 80	INSTRUMENTATION INSTALLATION	GR SA SI CL
	-12.9	SS	8	0	50/5			○ 50/5			
	End of Borehole 12.9 Auger refusal at 13.0 m depth.						-13				

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 32

RECORD OF BOREHOLE No. BH 1

amec

Project Number: **TP113114**
Project Client: **Regional Municipality of Peel**
Project Name: **Credit River Tributary Culvert Rehabilitation on Bovaird Drive**
Project Location: **Bovaird Drive West, Brampton, Region of Peel, Ontario**

Drilling Location: **South shoulder, Bovaird Dr. West, east of culvert, E:592931, N:4833594**
Drilling Method: **150 mm Solid Stem Augers / 200 mm Hollow Stem Augers**
Drilling Machine: **Truck Mounted Drill**
Date Started: **Dec 11, 13** Date Completed: **Dec 11, 13**

Logged by: **JF**
Compiled by: **SC**
Reviewed by: **SM**
Revision No.: **0, 3/14/14**

LITHOLOGY PROFILE | SOIL SAMPLING | FIELD TESTING | LAB TESTING

Geodetic Ground Surface Elevation: 221.2 m

Penetration Testing: ○ SPT ☐ PPT ● DCPT
MTO Vane*: △ Intact ▲ Remould
Nilcon Vane*: ◇ Intact ◆ Remould
* Undrained Shear Strength (kPa) 20 40 60 80

Soil Vapour Reading: ☐ COV (LEL) ■ TOV (LEL) 2 4 6 8
△ COV (ppm) ▲ TOV (ppm) 100 200 300 400
W_P W W_L Plastic Liquid 20 40 60 80

Elevation (m) / Depth (m)	Description
221.2 / 0.0	brown **Sand and Gravel FILL** moist
220.8 / 0.4	brown **Sandy Silt/Silty Sand FILL** trace to some gravel, trace cobbles ------ trace to some clay ------ grey -------- wet
212.5 / 8.7	dark grey/brown **Silty Clay/Clayey Silt FILL** some sand to sandy, some gravel, trace cobbles

Sample Type	Sample Number	Recovery (%)	SPT 'N' Value	Water Content (%)	GR	SA	SI	CL
SS	1	83	18	7 5				
SS	2	92	17	5				
SS	3	83	19	10				
SS	4	92	18	10				
SS	5	92	34	8				
SS	6	92	35	8				
SS	7	96	15	11				
SS	8	92	20	12	18	33	34	15
SS	9	75	27	11				

COMMENTS & GRAIN SIZE DISTRIBUTION (%): Used hollow stem augers.

INSTRUMENTATION INSTALLATION

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▽ No freestanding groundwater measured in open borehole on completion of drilling.

▼ Groundwater depth observed on 2/4/2014 at a depth of: 14.6 m.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying 'Explanation of Borehole Log'.

Scale: 1 : 53

Continued on Next Page

RECORD OF BOREHOLE No. BH 1

Project Number: **TP113114** Drilling Location: **South shoulder, Bovaird Dr. West, east of culvert, E:592931, N:4833594** Logged by: **JF**

LITHOLOGY PROFILE | SOIL SAMPLING | FIELD TESTING | LAB TESTING | INSTRUMENTATION INSTALLATION | COMMENTS & GRAIN SIZE DISTRIBUTION (%)

Penetration Testing: ○ SPT ☐ PPT ● DCPT

MTO Vane*: △ Intact ▲ Remould; Nilcon Vane*: ◇ Intact ◆ Remould

* Undrained Shear Strength (kPa) 20 40 60 80

Soil Vapour Reading: ☐ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400

W_P W W_L — Plastic 20 40 60 80 Liquid

GR SA SI CL

Elevation / Depth (m)	DESCRIPTION	Sample Type	Sample Number	Recovery (%)	SPT 'N' Value	Field Testing (SPT)	Lab Testing (W)	COMMENTS
	dark grey/brown **Silty Clay/Clayey Silt FILL** some sand to sandy, some gravel, trace cobbles							
		SS	10	42	20	○	11	Changed from hollow stem augers to solid stem augers
	some organics	SS	11	100	20	○	24	
		SS	12	100	27	○	26	
206.3 14.9	reddish brown **WEATHERED SHALE** very dense damp to dry							Hard augering
	some silty sand and limestone pieces in SS13	SS	13	100	50/8	50 8	6	
		SS	14	100	50/5	50 5	7	
		SS	15	100	50/5	50 5	9	
201.3 19.9	wet **End of Borehole**	SS	16	100	50/5	50 5	9	

DEPTH (m): 11, 12, 13, 14, 15, 16, 17, 18, 19

ELEVATION (m): 211, 210, 209, 208, 207, 206, 205, 204, 203, 202

Well Installation Details:
(diameter: 50 mm)

Concrete: 0 - 0.3 m
Bentonite: 0.3 - 16.2 m
Sand Filter: 16.2 - 16.5 m
Screen: 16.5 - 19.5 m
Bentonite: 19.5 - 19.9 m

Scale: 1 : 53

RECORD OF BOREHOLE No. BH 2

Project Number:	**TP113114**	Drilling Location:	**North shoulder, Bovaird Dr. West, west of culvert E:592905, N:4833590**	Logged by:	**JF**
Project Client:	**Regional Municipality of Peel**	Drilling Method:	**150 mm Solid Stem Augers / 200 mm Hollow Stem Augers**	Compiled by:	**SC**
Project Name:	**Credit River Tributary Culvert Rehabilitation on Bovaird Drive**	Drilling Machine:	**Truck Mounted Drill**	Reviewed by:	**SM**
Project Location:	**Bovaird Drive West, Brampton, Region of Peel, Ontario**	Date Started:	**Dec 10, 13** Date Completed: **Dec 10, 13**	Revision No.:	**0, 3/14/14**

LITHOLOGY PROFILE

DESCRIPTION

Geodetic Ground Surface Elevation: 219.8 m

about 150 mm TOPSOIL 219.7 / 0.2

brown
Silty Sand and Gravel FILL
trace cobbles
moist

mixed with silty clay

mixed with silty clay

some clay

------
grey

214.2 / 5.6

brown/grey
Sandy Silt/Silty Sand FILL
trace gravel, trace to some clay
trace cobbles
moist

pieces of wood in SS7

trace organics

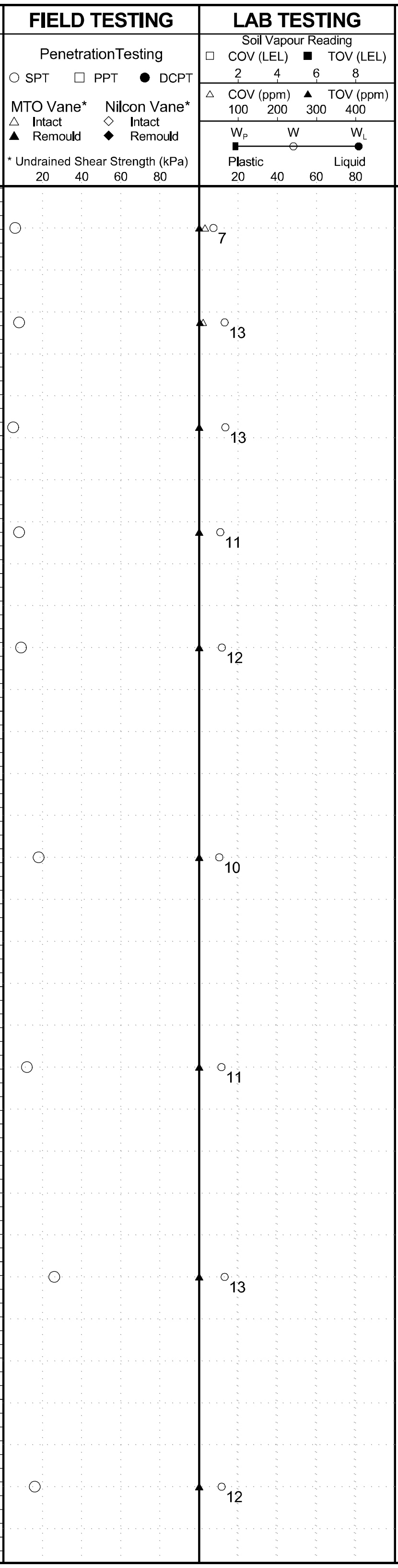
SOIL SAMPLING

Sample Type	Sample Number	Recovery (%)	SPT 'N' Value
SS	1	83	6
SS	2	100	8
SS	3	100	5
SS	4	100	8
SS	5	33	9
SS	6	71	18
SS	7	79	12
SS	8	96	26
SS	9	96	16

DEPTH (m): 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

ELEVATION (m): 219, 218, 217, 216, 215, 214, 213, 212, 211, 210

FIELD TESTING / LAB TESTING



INSTRUMENTATION INSTALLATION

COMMENTS & GRAIN SIZE DISTRIBUTION (%)

GR SA SI CL

Used hollow stem augers.

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Groundwater depth on completion of drilling on 12/10/2013 at a depth of: 17.7 m.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 53

Continued on Next Page

RECORD OF BOREHOLE No. BH 2

Project Number: **TP113114**

Drilling Location: **North shoulder, Bovaird Dr. West, west of culvert E:592905, N:4833590**

Logged by: **JF**

LITHOLOGY PROFILE		SOIL SAMPLING						FIELD TESTING	LAB TESTING		
Lithology Plot	DESCRIPTION	Sample Type	Sample Number	Recovery (%)	SPT 'N' Value	DEPTH (m)	ELEVATION (m)	PenetrationTesting ○ SPT ☐ PPT ● DCPT MTO Vane* △ Intact ▲ Remould Nilcon Vane* ◇ Intact ◆ Remould * Undrained Shear Strength (kPa) 20 40 60 80	Soil Vapour Reading ☐ COV (LEL) ■ TOV (LEL) 2 4 6 8 △ COV (ppm) ▲ TOV (ppm) 100 200 300 400 W_P W W_L Plastic Liquid 20 40 60 80	INSTRUMENTATION INSTALLATION	COMMENTS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	brown/grey **Sandy Silt/Silty Sand FILL** trace gravel, trace to some clay trace cobbles moist										
		SS	10	83	18	11	209	○	11		Changed from hollow stem augers to solid stem augers
	wet some clay, trace rootlets	SS	11	100	50	12	208	○	14		
	207.0 12.8					13	207				
	reddish brown **WEATHERED SHALE** very dense damp to dry										
	some limestone	SS	12	100	50/5	14	206	50 5	12		Hard augering
		SS	13	100	50/5	15	205	50 5	8		Hard augering
		SS	14	100	50/5	17	203	50 5	5		Hard augering
							202 ▽				
		SS	15	100	50/3	18	201	50 3			Hard augering
	wet 200.0 19.8	SS	16	100	50/3	19	200	50 3	16		
	End of Borehole										

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 53

RECORD OF BOREHOLE No. BH 3

Project Number: **TP113114**
Project Client: **Regional Municipality of Peel**
Project Name: **Credit River Tributary Culvert Rehabilitation on Bovaird Drive**
Project Location: **Bovaird Drive West, Brampton, Region of Peel, Ontario**
Drilling Location: **Old Hwy 7, west of culvert, E:592883, N:4833609**
Drilling Method: **150 mm Solid Stem Augers / 200 mm Hollow Stem Augers**
Drilling Machine: **Truck Mounted Drill**
Date Started: **Dec 9, 13** Date Completed: **Dec 9, 13**
Logged by: **JF**
Compiled by: **SC**
Reviewed by: **SM**
Revision No.: **0, 3/14/14**

LITHOLOGY PROFILE | SOIL SAMPLING | FIELD TESTING | LAB TESTING | COMMENTS & GRAIN SIZE DISTRIBUTION (%)

Penetration Testing: ○ SPT ☐ PPT ● DCPT
MTO Vane*: △ Intact ▲ Remould
Nilcon Vane*: ◇ Intact ◆ Remould
* Undrained Shear Strength (kPa) 20 40 60 80

Soil Vapour Reading: ☐ COV (LEL) ■ TOV (LEL) 2 4 6 8
△ COV (ppm) ▲ TOV (ppm) 100 200 300 400
W_P W W_L Plastic Liquid 20 40 60 80

Geodetic Ground Surface Elevation: 219.8 m

Elevation / Depth (m)	Description
	brown **about 350 mm TOPSOIL**
219.5 0.4	dark brown/brown **Sandy Silt/Silty Sand FILL** some gravel, trace to some clay, organics and rootlets in SS1 moist
	mixed with silty clay

Sample Type	Sample Number	Recovery (%)	SPT 'N' Value	W (%)	GR	SA	SI	CL
SS	1	83	5	16				
SS	2	92	10	16				
SS	3	88	7	16				
SS	4	100	10	13				
SS	5	92	8	15				
SS	6	100	7	9	12	55	(33)	
SS	7	96	9	11				
SS	8	92	12	11				
SS	9	96	9	15				

DEPTH (m): 1 2 3 4 5 6 7 8 9 10
ELEVATION (m): 219 218 217 216 215 214 213 212 211 210

Comments: Used hollow stem augers.

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▽ Groundwater depth on completion of drilling on 12/9/2013 at a depth of: 13.7 m.
▼ Groundwater depth observed on 2/4/2014 at a depth of: 11.1 m.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 53

Continued on Next Page

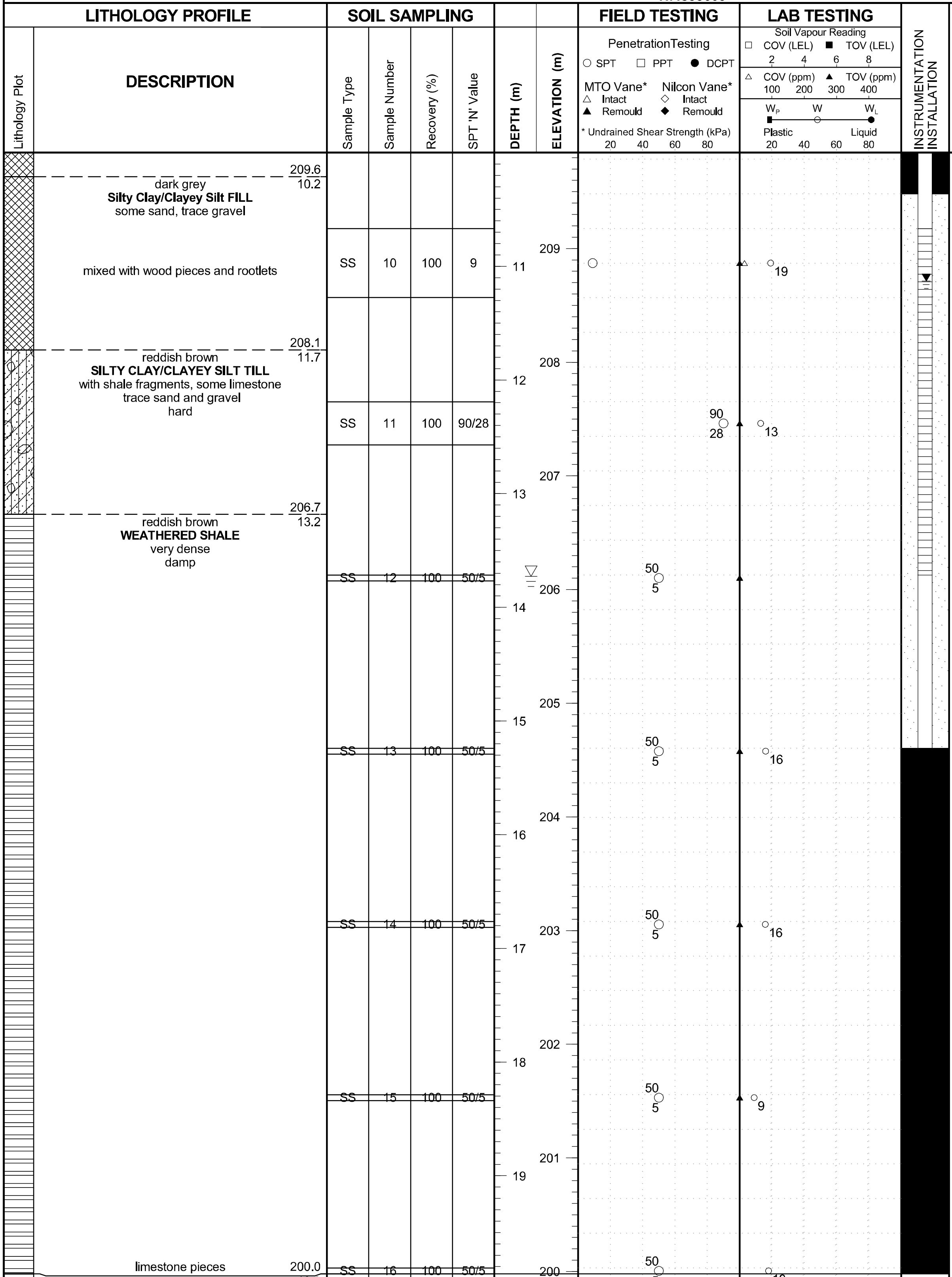
RECORD OF BOREHOLE No. BH 3

Project Number: TP113114

Drilling Location: Old Hwy 7, west of culvert, E:592883, N:4833609

Logged by: JF

Elevation / Depth (m)	DESCRIPTION	Sample Type	Sample Number	Recovery (%)	SPT 'N' Value	W (%)	COMMENTS
209.6 10.2	dark grey **Silty Clay/Clayey Silt FILL** some sand, trace gravel						Changed from hollow stem augers to solid stem augers
	mixed with wood pieces and rootlets	SS	10	100	9	19	
208.1 11.7	reddish brown **SILTY CLAY/CLAYEY SILT TILL** with shale fragments, some limestone trace sand and gravel hard	SS	11	100	90/28	13	
206.7 13.2	reddish brown **WEATHERED SHALE** very dense damp	SS	12	100	50/5		
							Hard augering
		SS	13	100	50/5	16	
		SS	14	100	50/5	16	
		SS	15	100	50/5	9	
200.0 19.9	limestone pieces **End of Borehole**	SS	16	100	50/5	18	



Well Installation Details:
(diameter: 50 mm)

Concrete: 0 - 0.3 m
Bentonite: 0.3 - 10.2 m
Sand Filter: 10.2 - 10.5 m
Screen: 10.5 - 13.5 m
Sand Filter: 13.5 - 15.0 m
Bentonite: 15.0 - 19.9 m

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 53

RECORD OF BOREHOLE No. BH 4

Project Number: **TP113114**
Project Client: **Regional Municipality of Peel**
Project Name: **Credit River Tributary Culvert Rehabilitation on Bovaird Drive**
Project Location: **Bovaird Drive West, Brampton, Region of Peel, Ontario**
Drilling Location: **Old Hwy 7, east of culvert, E:592893, N:4833625**
Drilling Method: **150 mm Solid Stem Augering**
Drilling Machine: **Truck Mounted Drill**
Date Started: **Dec 9, 13** Date Completed: **Dec 9, 13**
Logged by: **JF**
Compiled by: **SC**
Reviewed by: **SM**
Revision No.: **0, 3/14/14**

LITHOLOGY PROFILE

Geodetic Ground Surface Elevation: 220.4 m

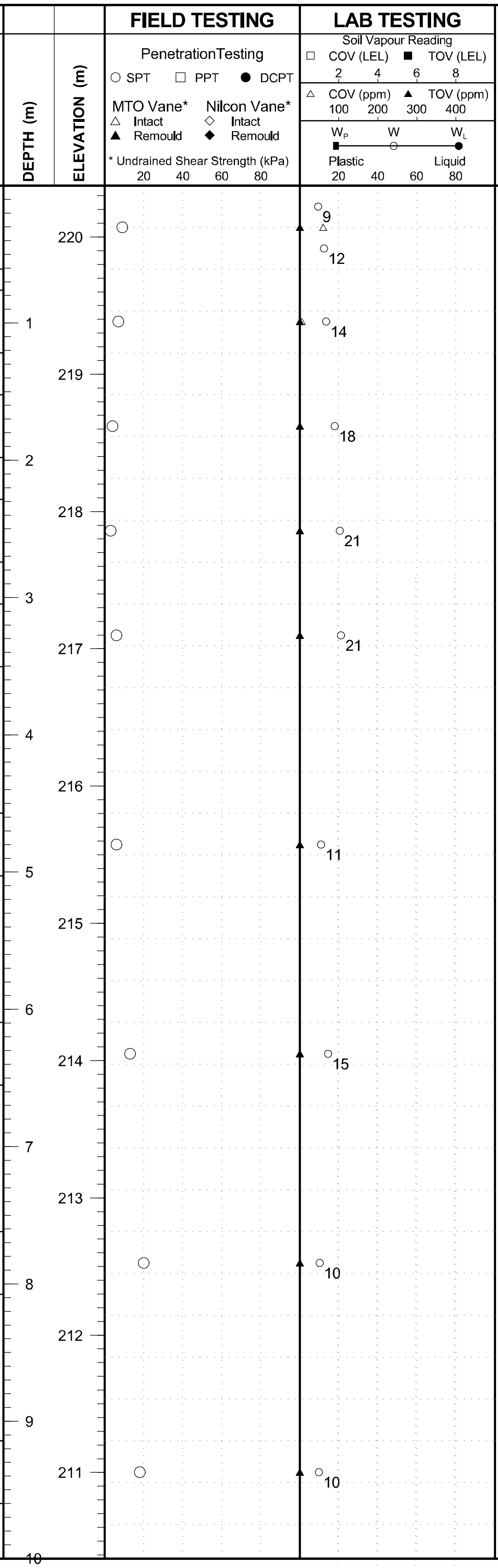
Elevation / Depth (m)	DESCRIPTION
	about 200 mm TOPSOIL
220.2 0.2	dark brown/brown **Sandy Silt/Silty Sand FILL** trace to some gravel, trace rootlets in SS1 moist to wet ------ some clay trace rootlets
217.5 2.9	brown **Silty Clay FILL** some sand
216.3 4.0	grey **Silty Sand FILL** trace gravel moist
214.8 5.6	brown **Clayey Silt FILL** some sand, trace gravel
213.3 7.1	brown **Silty Sand FILL** trace clay, trace to some gravel moist

SOIL SAMPLING

Sample Type	Sample Number	Recovery (%)	SPT 'N' Value
SS	1	63	9
SS	2	44	7
SS	3	94	4
SS	4	56	3
SS	5	94	6
SS	6	89	6
SS	7	67	13
SS	8	100	20
SS	9	100	18

FIELD TESTING

LAB TESTING



INSTRUMENTATION INSTALLATION

COMMENTS & GRAIN SIZE DISTRIBUTION (%)

GR SA SI CL

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Groundwater depth on completion of drilling on 12/9/2013 at a depth of: 11.0 m.

Cave in depth after removal of augers: 11.0 m.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 53

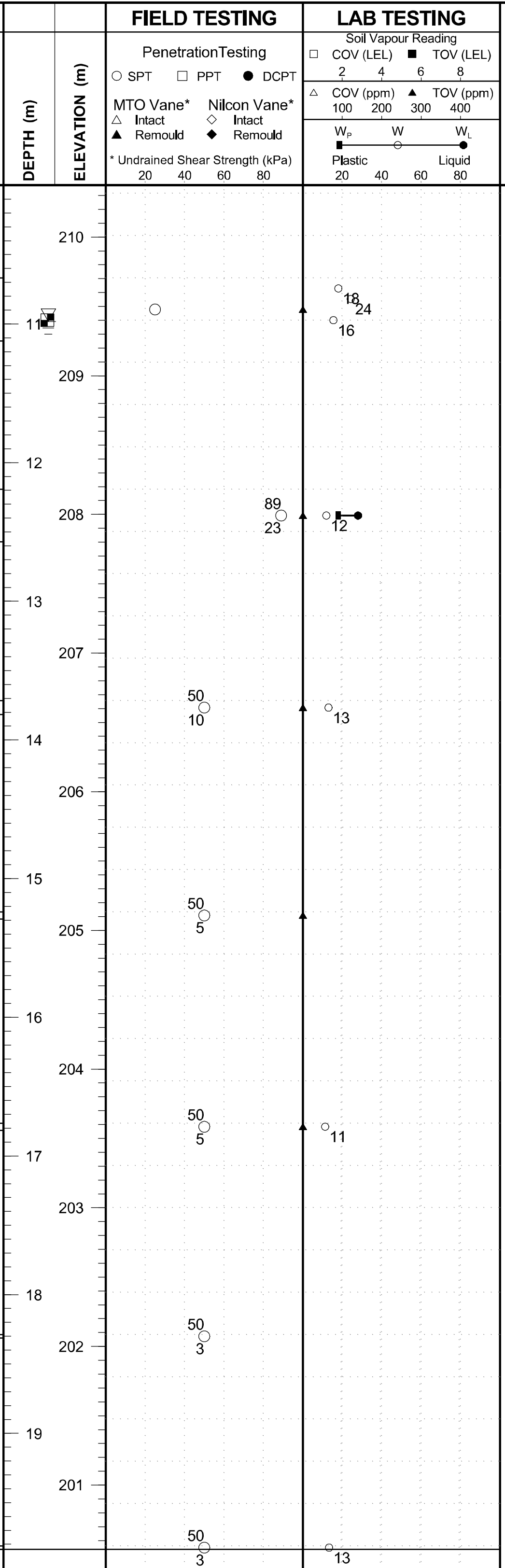
Continued on Next Page

RECORD OF BOREHOLE No. BH 4

Project Number: **TP113114**
Drilling Location: **Old Hwy 7, east of culvert, E:592893, N:4833625**
Logged by: **JF**

LITHOLOGY PROFILE / SOIL SAMPLING

Elevation / Depth (m)	DESCRIPTION	Sample Type	Sample Number	Recovery (%)	SPT 'N' Value
210.2 10.2	brown **Silty Clay/Clayey Silt FILL** mixed with silty sand, organics, wood pieces				
		SS	10	100	25
209.4 11.0	reddish brown **SILTY CLAY/CLAYEY SILT TILL** with shale fragments and limestone trace sand and gravel hard				
		SS	11	100	89/23
		SS	12	50	50/10
205.9 14.5	reddish brown **WEATHERED SHALE** very dense damp				
		SS	13	100	50/5
		SS	14	100	50/5
		SS	15	200	50/3
200.5 19.8	**End of Borehole**	SS	16	200	50/3



COMMENTS & GRAIN SIZE DISTRIBUTION (%)

Elevation (m)	GR	SA	SI	CL	Comments
208	2	3	75	20	
206					Hard augering
204.5					Hard augering
203					Hard augering

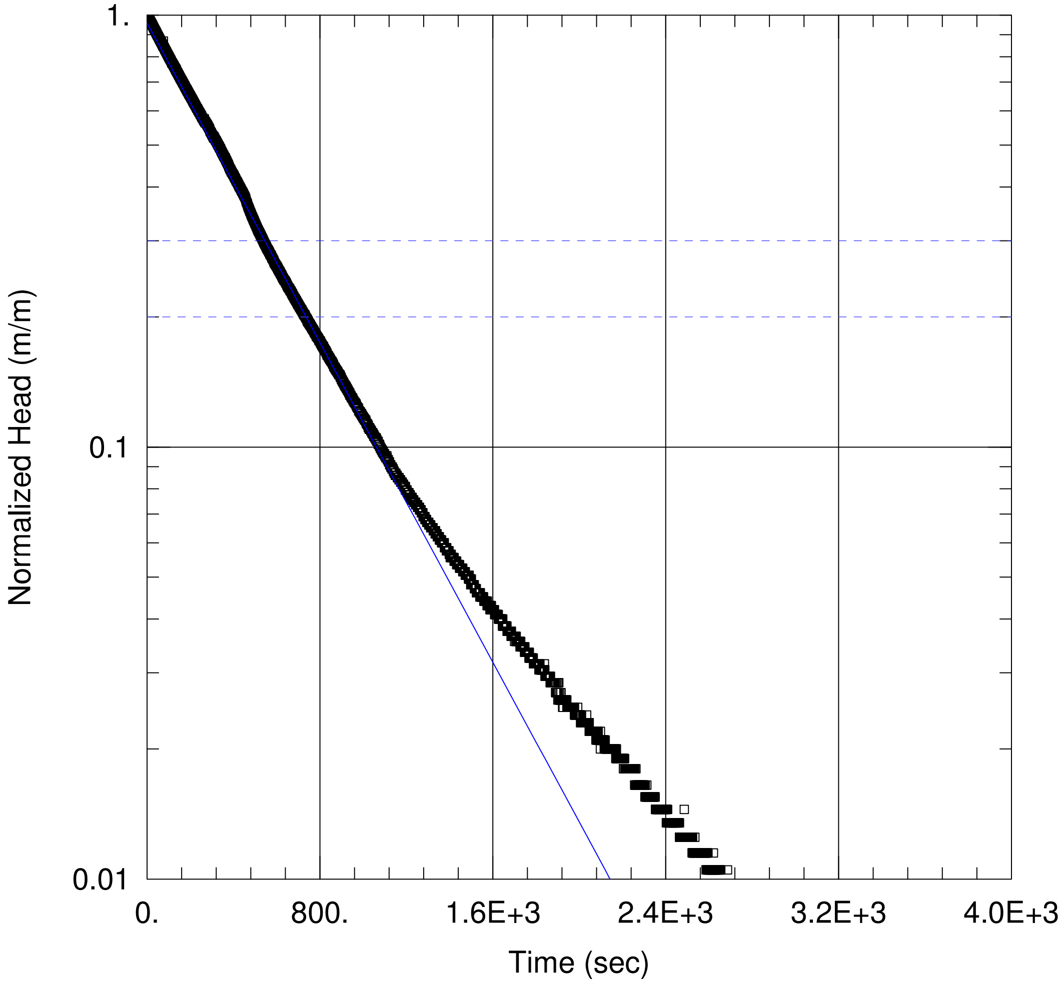
INSTRUMENTATION INSTALLATION

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 53

APPENDIX B

HYDROGEOLOGIC ANALYSIS



RISING HEAD TEST - BH-1

Data Set: C:\...\BH-1 - Rising Head - Bouwer-Rice.aqt
Date: 02/09/14 Time: 19:11:57

PROJECT INFORMATION

Company: AMEC
Client: Regional Municipality of Peel
Project: TP133114
Location: Bovaird Drive West
Test Well: BH-1
Test Date: 04 February 2014

AQUIFER DATA

Saturated Thickness: 7.2 m
Anisotropy Ratio (Kz/Kr): 1.

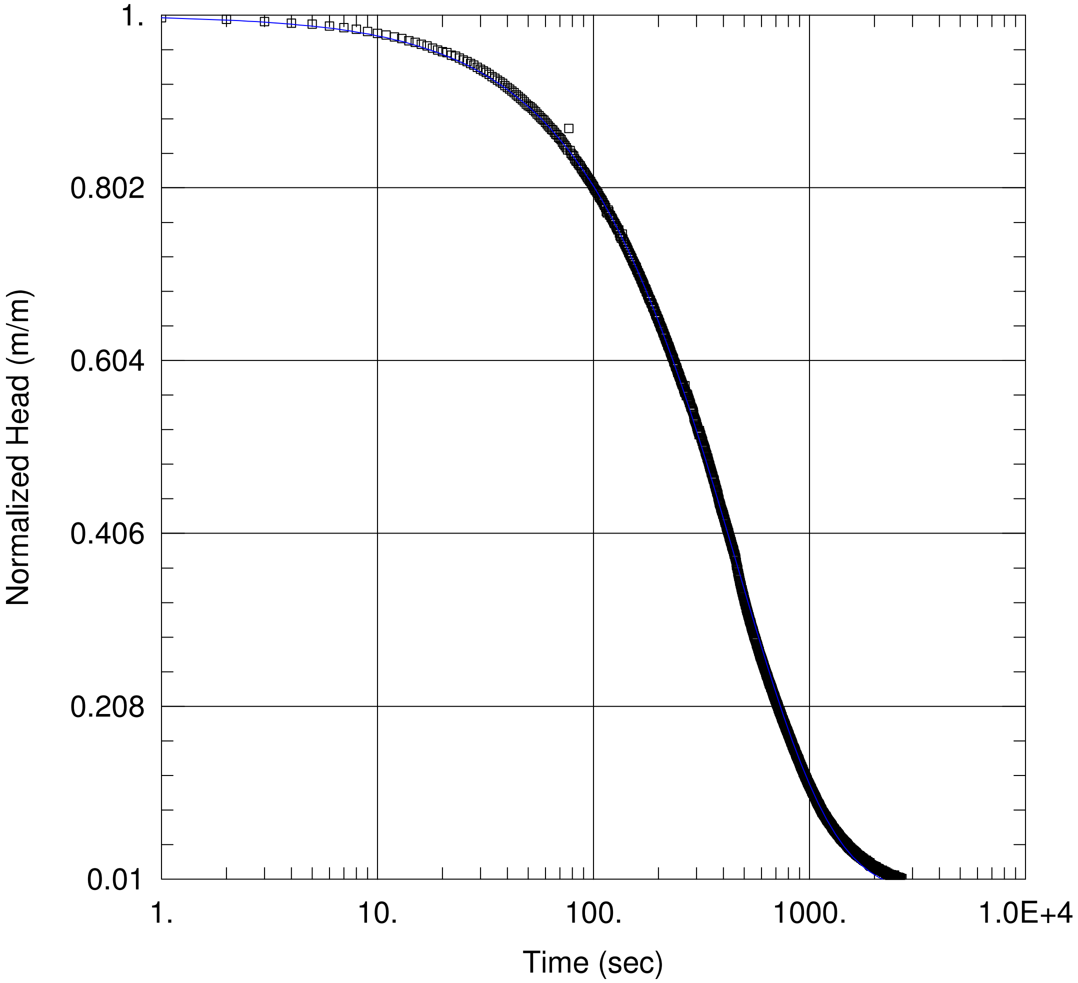
WELL DATA (BH-1)

Initial Displacement: 2.001 m
Static Water Column Height: 3.87 m
Total Well Penetration Depth: 3.87 m
Screen Length: 3.05 m
Casing Radius: 0.025 m
Well Radius: 0.1 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 5.103E-7 m/sec
y0 = 1.917 m



RISING HEAD TEST - BH-1

Data Set: C:\Users\jason.homewood\Desktop\TP133114 - Bovaird Road\BH-1 - Rising Head - KGS.aqt
Date: 02/09/14 Time: 19:10:16

PROJECT INFORMATION

Company: AMEC
Client: Regional Municipality of Peel
Project: TP133114
Location: Bovaird Drive West
Test Well: BH-1
Test Date: 04 February 2014

AQUIFER DATA

Saturated Thickness: 7.2 m

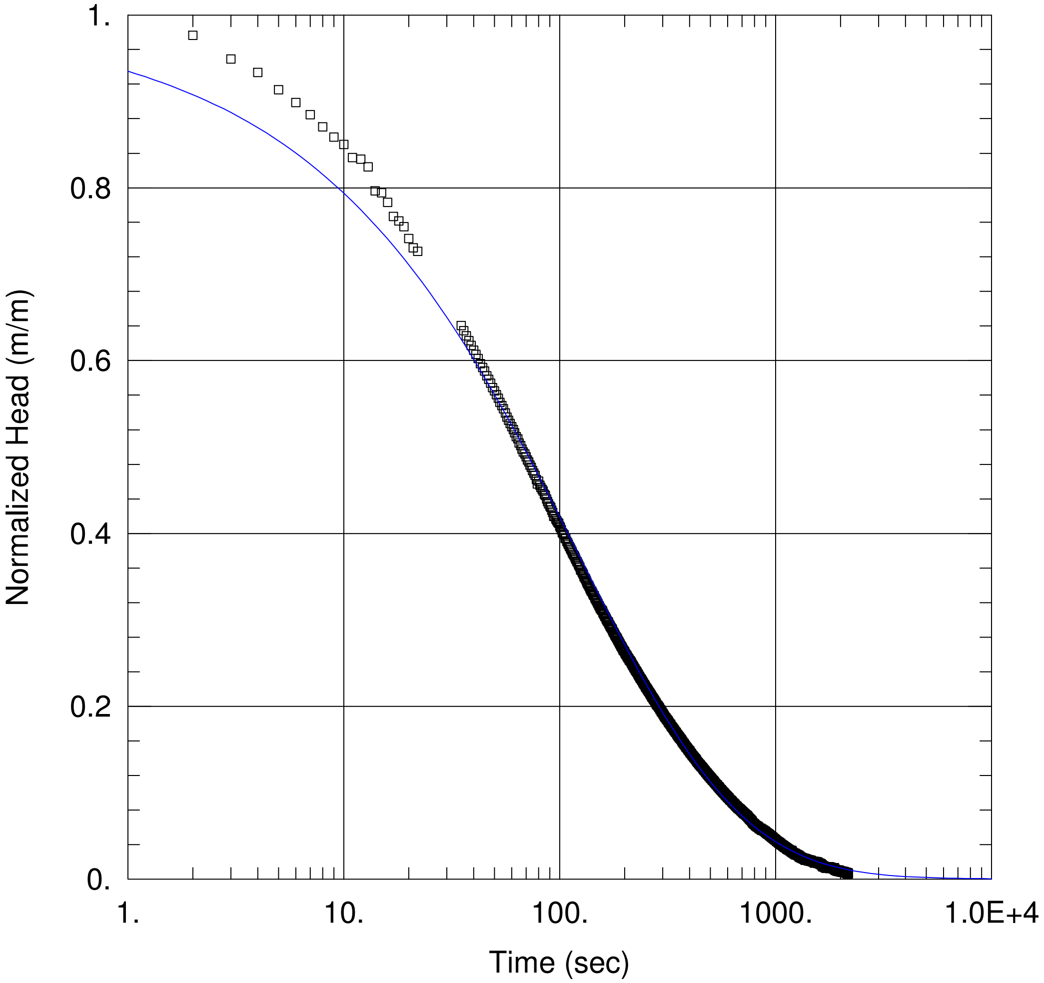
WELL DATA (BH-1)

Initial Displacement: 2.001 m
Total Well Penetration Depth: 3.87 m
Casing Radius: 0.025 m
Static Water Column Height: 3.87 m
Screen Length: 3.05 m
Well Radius: 0.1 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 6.268E-7 m/sec
Kz/Kr = 1.
Ss = 1.274E-6 m^{-1}



RISING HEAD TEST - BH-3

Data Set: C:\Users\jason.homewood\Desktop\TP133114 - Bovaird Road\BH-3 - Rising Head - KGS.aqt
Date: 02/09/14 Time: 16:22:13

PROJECT INFORMATION

Company: AMEC
Client: Regional Municipality of Peel
Project: TP133114
Location: Bovaird Drive West
Test Well: BH-3
Test Date: 04 February 2014

AQUIFER DATA

Saturated Thickness: 7.2 m

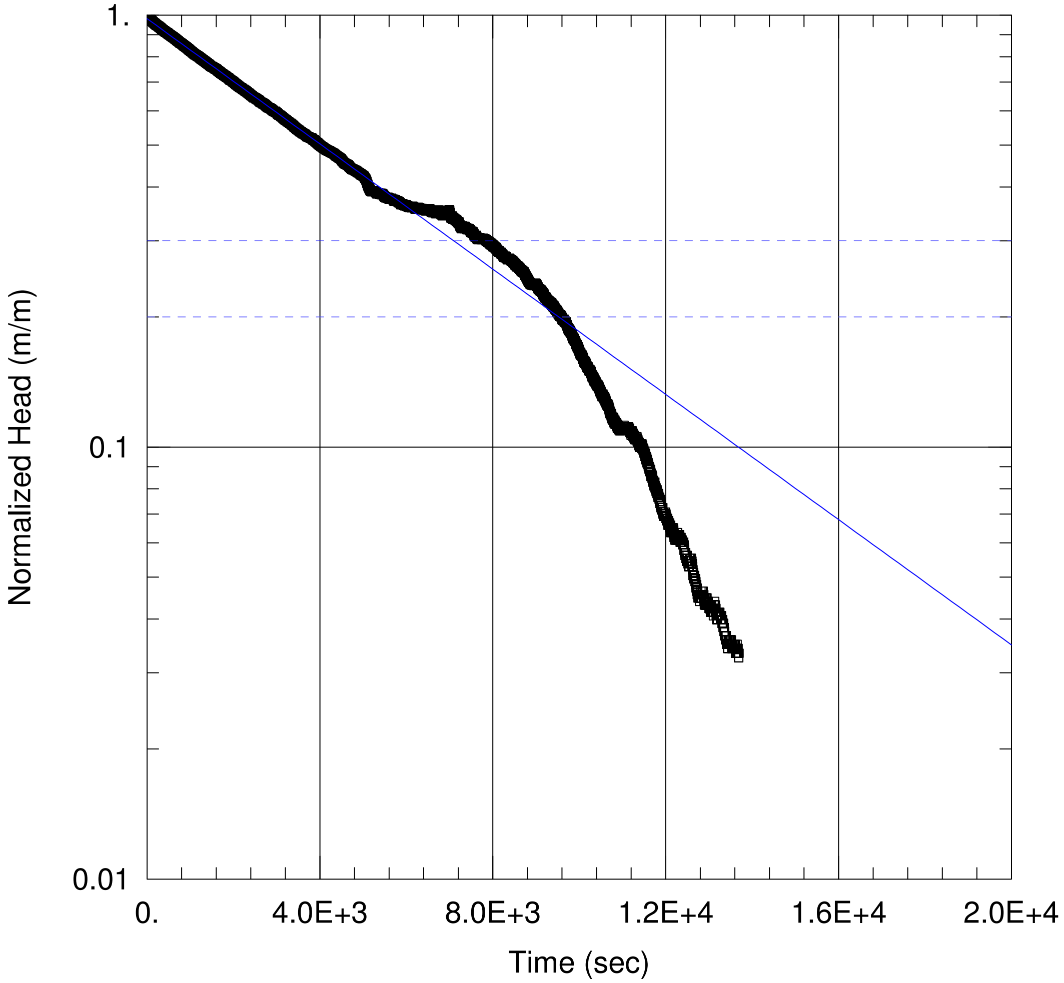
WELL DATA (BH-3)

Initial Displacement: 0.5086 m
Total Well Penetration Depth: 1.44 m
Casing Radius: 0.025 m
Static Water Column Height: 1.44 m
Screen Length: 1.44 m
Well Radius: 0.1 m
Gravel Pack Porosity: 0.25

SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 1.798E-6 m/sec
Kz/Kr = 1.
Ss = 0.008171 m^{-1}



RISING HEAD TEST - BH-35

Data Set: C:\...\BH-35 - Rising Head - Bouwer-Rice.aqt
Date: 02/09/14 Time: 18:46:16

PROJECT INFORMATION

Company: AMEC
Client: Regional Municipality of Peel
Project: TP133114
Location: Bovaird Drive West
Test Well: BH-35
Test Date: 29 January 2014

AQUIFER DATA

Saturated Thickness: 7.2 m
Anisotropy Ratio (Kz/Kr): 1.

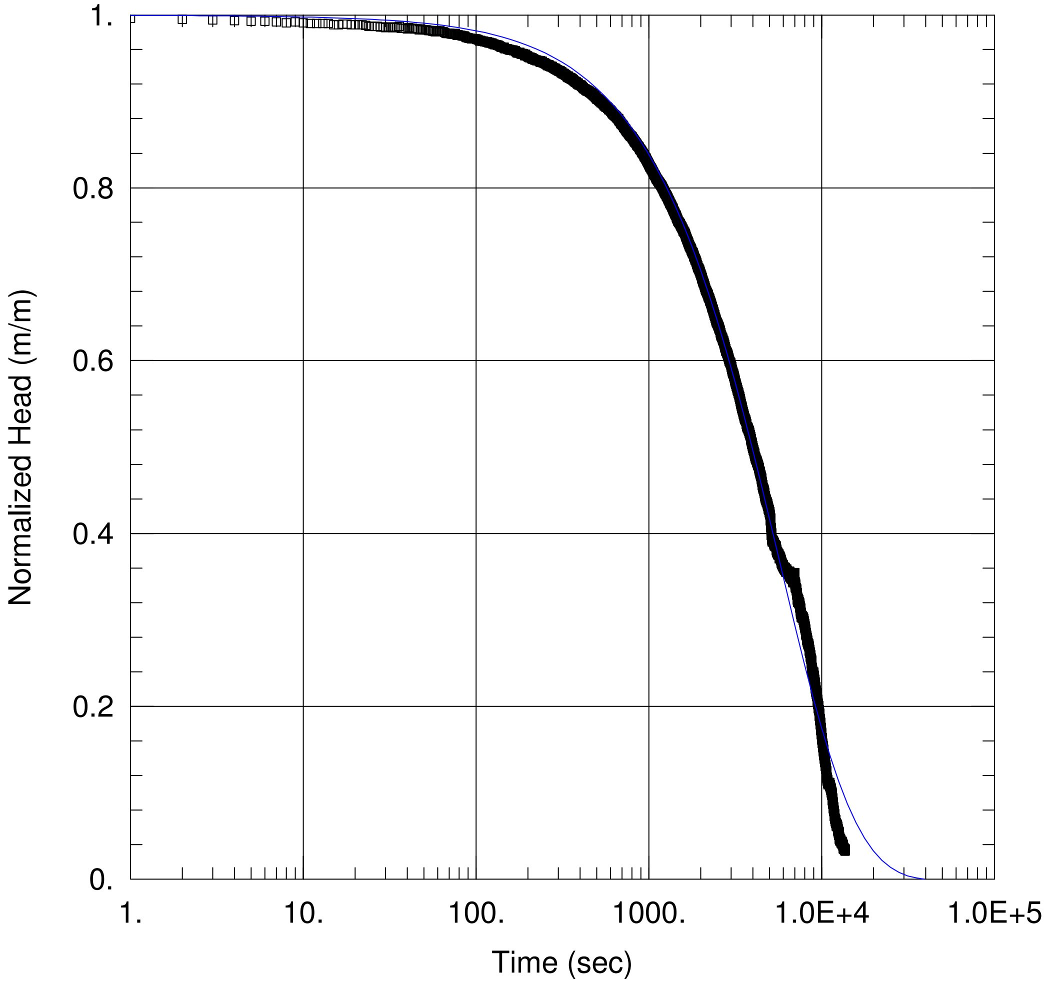
WELL DATA (BH-35)

Initial Displacement: 1.23 m
Static Water Column Height: 1.47 m
Total Well Penetration Depth: 1.47 m
Screen Length: 1.47 m
Casing Radius: 0.025 m
Well Radius: 0.1 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 5.645E-8 m/sec
y0 = 1.206 m



RISING HEAD TEST - BH-35

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Date: 02/09/14
Time: 18:49:54

PROJECT INFORMATION

Company: AMEC
Client: Regional Municipality of Peel
Project: TP133114
Location: Bovaird Drive West
Test Well: BH-35
Test Date: 29 January 2014

AQUIFER DATA

Saturated Thickness: 7.2 m

WELL DATA (BH-35)

Initial Displacement: 1.23 m
Static Water Column Height: 1.47 m
Total Well Penetration Depth: 1.47 m
Screen Length: 1.47 m
Casing Radius: 0.025 m
Well Radius: 0.1 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 6.962E-8 m/sec
Ss = 2.707E-6 m^{-1}
Kz/Kr = 1.

APPENDIX ‘E’

STAGE 2 ARCHAEOLOGICAL ASSESSMENT

ORIGINAL REPORT:

STAGE 2 ARCHAEOLOGICAL ASSESSEMENT: CULVERT REHABILITATION ON BOVAIRD DRIVE WEST BETWEEN OLD PINE CREST ROAD AND HERITAGE ROAD CITY OF BRAMPTON, ONTARIO

Submitted to:
Dan Bennington, C.E.T.
Regional Municipality of Peel
10 Peel Centre Drive, Ste A,
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AND

THE ONTARIO MINISTRY OF TOURISM, CULTURE AND SPORT

Submitted by:
AMEC Environment and Infrastructure, a Division of AMEC Americas Limited
505 Woodward Avenue, Unit 1
Hamilton, Ontario L8H 6N6
Ph: (905) 312-0700, Fax: (905) 312-0771

Archaeological Consulting License # P141 (Austin)
PIF # P141-0212-2014

AMEC Project # TP113114.6000
July 2014

Distribution:
Region of Peel – 1 Copy
Ontario Ministry of Tourism, Culture and Sport – 1 Electronic Copy
AMEC Environment & Infrastructure – 1 Copy

EXECUTIVE SUMMARY

AMEC Environment & Infrastructure, a division of AMEC Americas Limited ("AMEC"), was retained by the Region of Peel (the "Client" and "Owner") to conduct a Stage 2 archaeological assessment of two areas of archaeological potential that may be impacted by the proposed rehabilitation of a culvert on Bovaird Drive West, in the City of Brampton, Region of Peel. The culvert handles water from a tributary of the Credit River along Bovaird Drive West, between Old Pine Crest Road and Heritage Road. The study area is comprised of two 30 metre by 30 metre squares of upland terrain on either side of the culvert (Appendix A: Figures 1-3).

The assessment was directed by Devon Brusey (R410) on 17 June 2014. The weather was hot and sunny and did not impede the assessment in any way.

The test pit survey provided full coverage of both portions of the study area and nothing of cultural heritage value or interest was encountered (Appendix A: Figure 6; Appendix B: Photographs 1-5).

In light of these results, the following recommendation is made:

1) No further archaeological assessment is required for the study area.

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TABLES

APPENDICES

Appendix A: Figures

PROJECT PERSONNEL

Project Manager:	Devon Brusey, Hons. B.A. (R410)
Field Director:	Devon Brusey, Hons. B.A. (R410)
Field Crew:	Cara Howell, B.A. (R180)
Report Preparation:	Devon Brusey, Hons. B.A. (R410)
Graphics:	Cara Howell, B.A. (R180) Devin Funovitz M.Sc
Report Reviewer:	Shaun Austin, Ph.D, (P141)

1.0 PROJECT CONTEXT

1.1 Development Context

AMEC Environment & Infrastructure, a division of AMEC Americas Limited ("AMEC"), was retained by the Region of Peel (the "Client" and "Owner") to conduct a Stage 2 archaeological assessment of two areas of archaeological potential that may be impacted by the proposed rehabilitation of a culvert on Bovaird Drive West, in the City of Brampton, Region of Peel. The culvert handles water from a tributary of the Credit River along Bovaird Drive West, between Old Pine Crest Road and Heritage Road. The study area is comprised of two 30 metre by 30 metre squares of upland terrain on either side of the culvert (Appendix A: Figures 1-3).

The Stage 2 assessment was completed prior to construction activities as a condition for municipal heritage approval, and was carried out in accordance with the Ministry of Tourism, Culture and Sport ("MTCS") *Standard and Guidelines for Consultant Archaeologists* (2011) under an Ontario Professional Licence to Conduct Archaeological Fieldwork (No. P141) held by Dr. Shaun Austin of AMEC. The project information was acknowledged by the MTCS on 02 June 2014 with the approval of PIF# P141-0212-2014. Permission to enter the lands to conduct all required archaeological fieldwork activities, including the recovery of artifacts, was granted to AMEC by the client on 16 June 2014. There were no limitations placed on access.

The assessment was directed by Devon Brusey (R410) on 17 June 2014. The weather was hot and sunny and did not impede the assessment in any way.

This report presents the results of this assessment and makes pertinent recommendations.

1.1.1 Scope of Work

The scope of work consisted of the following tasks:

- Prepare a complete safety package including a pre-assessment safety meeting, site hazard analysis, job safety analysis (and an onsite information package with the AMEC Health and Safety Policy). AMEC field personnel require: safety glasses, protective gloves, high visibility vests, and safety boots;

- Review the Stage 1 report and all other related background materials;.

- Test pit survey within areas of archaeological potential employing strategies that adhere to the technical standards for Stage 2 archaeological assessments as prescribed by the MTCS (2011);

- Mapping, photographing and other relevant graphics;

- Artifact processing and analysis, where applicable; and,

- Prepare a report of findings with recommendations regarding the need for further archaeological work if deemed necessary.

1.1.2 Physical Setting

The study area consists of two 30 metre by 30 metre parcels situated on elevated terrain on the southwestern and northeastern sides of the culvert for a tributary of the Credit River crossing under Bovaird Drive, in Brampton, Ontario.

The study area lies within the Peel Plain physiographic region of Ontario. This region consists of approximately 777 square kilometers of fertile clay soils that cover the central portion of the Regional Municipalities of York, Peel, and Halton (Chapman and Putnam 1984: 174). According to Chapman and Putnam (1984) this general area would originally have been covered by hardwood forests. The underlying geological material consists of shale and limestone. Deeply incised valleys are present alongside the main branch of the Credit River, while more gently sloped banks are found alongside tributaries such as the one that bisects the current study area.

The Peel Plain was settled during the early part of the nineteenth century (Chapman and Putnam 1984: 176). Until the 1940's, most land was used for agricultural purposes, beginning with the growing of wheat, hay and alfalfa. In addition, various racehorse farms and orchards, small fruit, vegetable and poultry farms were established. According to Chapman and Putnam (1984:176), most farms were 100 acres in size and had the following configuration: the majority of land was used for field crops, a small portion of for pasture and about 6-7% remained as woodlots. The study area is located in what is now known as the City of Brampton. By the 1980's, the City had developed the majority of its available land, with the exception of some farmland used to grow cash crops (Chapman and Putnam 1984:176).

1.2 Historic Context

1.2.1 Review of Historical Records

Historically, the study area was located on Lot 11, Concession VI West of Hurontario Street, in the Southern Part of Chinguacousy Township, County of Peel. In the late 1800s, the then Town of Brampton was located to the east and the Village of Norval was located to the west.

In 1877, the Township of Chinguacousy comprised 83,199.7 acres (33,669.85 ha). According to Walker and Miles (1877: 90), the Township was first settled by Euro-Canadians in ca. 1818. The earliest White settlers came from New Brunswick, other parts of Ontario (then Upper Canada,) and the United States. In 1821, the Township had a population of 412, with a mere 230 acres (93.1 ha) of land under cultivation (Walker and Miles 1877: 90). The Township grew to a population of 6,219 by 1877. This area, known for its rich soils, was by then the home of numerous substantial farm residences. Brampton was incorporated as a village in 1852 and as a town in 1873 (Walker and Miles 1877: 87).

The *1859 Tremaine's Map* of the County of Peel (Tremaine 1859) was examined to help determine the potential for historic archaeological remains within the study area (Figure 4). The following table provides a summary of ownership and features identified in close proximity to the study area:

Table 1: Residents and Historical Features illustrated in the 1859 Tremaine's Map of the County of Peel

Lot	Concession	Township & County	Resident(s)	Historical Feature (s)
11	VI, WHS	Chinguacousy Township, County of Peel	Peter Laird	• A structure is located immediately northeast of the eastern study area parcel. • A roadway is located immediately southwest of the western study area parcel. • Bovaird Drive West is shown in its approximate current location. A tributary of the Credit River is shown bisecting the eastern and western study area parcels, as it does today.

The *1877 Illustrated Historical Atlas of the County of Peel, Ontario* (Walker and Miles 1877) (Figure 5) was also examined to help determine the potential for historic archaeological remains within the study area. The following table provides a summary of ownership and features identified in close proximity to the study area:

Table 2: Residents and Historical Features illustrated in the 1877 Illustrated Historical Atlas of the County of Peel

Lot	Concession	Township & County	Resident(s)	Historical Feature (s)
11	VI, WHS	Chinguacousy Township, County of Peel	Peter Laird	• A structure is located immediately northeast of the eastern study area parcel. • Orchards are depicted encompassing the eastern study area parcel. • A roadway is located immediately southwest of the western study area parcel. • Bovaird Drive West is shown in its approximate current location. • A tributary of the Credit River is shown bisecting the eastern and western study area parcels, as it does today.

1.3 Archaeological Context

In Ontario, information concerning archaeological sites is stored in the Ontario Archaeological Sites Database (OASD). This database contains archaeological sites registered within the Borden system. The Borden Number listed for each site is a geographic reference indicator, based on longitude and latitude, utilized under the Canadian Borden System. A Borden block is approximately 13 km east to west, and approximately 18.5 km north to south. Each Borden block is referenced by a four letter designator, and sites within a block are numbered sequentially as they are found. The study area under review is located in Borden Block AjGx.

A search of the OASD resulted in the identification of 29 archaeological sites discovered within approximately two kilometres of the study area. None of these sites are located within the study area. Table 3 provides a listing of these sites:

Table 3: Registered Archaeological Sites within 2 km of the Study Area

Borden Number	Site Name	Cultural Affiliation	Site Type	Researcher
AjGw-355	1-1	Euro-Canadian (1840s-1870s)	Homestead	Christine Dodd
AjGw-372	Bluegrass	Aboriginal (Early Archaic)	Camp	Christine Dodd
AjGw-373	Helport 1	Aboriginal (Paleo?)	Undetermined	Christine Dodd
AjGw-383	Findspot P2	Aboriginal	Findspot	ASI
AkGw-104	-	-	-	-
AkGw-106	Appaloosa	Aboriginal (Archaic)	Findspot	ASI, 1998
AkGw-114	Baker Lundy	Euro-Canadian	Homestead	ASI, 1998
AkGw-115	-	Aboriginal	Lithic Scatter	ASI, 1998
AkGw-127	-	Aboriginal	Findspot	ASI, 1999
AkGw-233	6-4	Aboriginal (Early-middle Woodland)	Findspot	Poulton, D.R. 2003
AkGw-234	6-5	Aboriginal – Archaic	Findspot	Poulton, D.R. 2003
AkGw-274	Helport 2	Aboriginal	Lithic Scatter	Christine Dodd
AkGw-275	Helport 3	Aboriginal – Archaic	Findspot	Christine Dodd 2004
AkGw-276	Helport 4	Aboriginal (Early Woodland)	Findspot	Christine Dodd
AkGw-322	-	Euro-Canadian	Homestead	Adam Hossack, 2007
AkGw-323	-	Euro-Canadian	Homestead	Adam Hossack, 2007
AkGw-324	-	Euro-Canadian	Homestead	Adam Hossack, 2007
AkGw-325	-	Aboriginal	Lithic Scatter	Adam Hossack, 2007
AkGw-67	Avida	Aboriginal (Middle Woodland)	Special Purpose	Dana R. Poulton and Mark Douglas Borland
AkGw-68	Samuel McClure	Euro-Canadian	Homestead	Dana R. Poulton and Mark Douglas Borland
AkGw-71	Samuel McClure II	Euro-Canadian	Homestead	Dana R. Poulton 1993
AkGw-71	Location 2	-	-	-
AkGw-77	Primont H1	-	-	-
AjGx-183	Curry Dump	Euro-Canadian (late 19th C)	Dump	ASI, 2008
AjGx-20	Norval 1	Aboriginal	Campsite	York University Arch.
AjGx-21	Norval 2	Aboriginal (Archaic)	Campsite	York University Arch.
AjGx-22	Lloyd Laidlaw	-	-	Roberta O'Brien
AjGx-241	Samuel Currie	Euro-Canadian	-	AMICK
AjGx-7	Laird	Aboriginal (Early Woodland)	Campsite	ROM and University of Toronto

1.3.1 History of Archaeological Investigations

Prior to the Stage 2 assessment, AMEC reviewed the Stage 1 background assessment for the study area (PIF No. 329-008-2009) (AMEC 2012). To the best of our knowledge, this is the only archaeological assessment previously conducted within 50 metres.

The Stage 1 assessment (AMEC 2012) indicated that both portions of the current study area had archaeological potential due to their proximity to: 1) 29 previously registered archaeological sites within a 2-km radius; 2) a tributary of the Credit River; 3) an historic transportation route (Bovaird Drive West); and 4) one historic structure as shown in the Tremaine's Map of 1859 and the Illustrated Historical Atlas of 1877.

2.0 STAGE 2 PROPERTY ASSESSMENT

2.1 Methodology

The Stage 2 property assessment was conducted on 17 June 2014 with advance, unconditional permission-to-enter obtained by the City of Brampton. The weather was hot and sunny and did not impede the assessment in any way.

The required survey method was test pitting since ploughing for pedestrian survey was impracticable. Before shovel testing began, utility locates were completed and the study areas were visually inspected.

All areas with archaeological potential were thoroughly shovel tested. Test pits were hand dug approximately 30 cm in diameter, through the clay loam topsoil and into the clay loam subsoil approximately five centimetres. The depths to subsoil averaged 25 cm. Test pit soils were screened through six-millimetre mesh in order to facilitate artifact recovery. Test pits profiles were also examined for cultural layering before all test pits were completely backfilled.

2.2 Field Observations and Results

Both portions of the study area were subjected to comprehensive test pit survey at five-metre intervals (Figure 6). The clay loam topsoil (10YR 3/2, very dark greyish brown) was approximately 0-25 cm deep. The subsoil also consisted of clay loam (10YR 3/6, dark yellowish brown). The average subsoil depth was 25 cm.

A concerted effort was made to find any archaeological evidence of the structure depicted northeast of the eastern study area parcel. However, the test pit survey yielded no culturally significant artifacts or deposits in any location and no archaeological sites were identified (Appendix A: Figure 6 – Stage 2 Results).

Photographic documentation of the Stage 2 assessment can be found in Appendix B: Photographs 1-5. Photographic locations and directions can be found in Appendix A: Figure 6.

3.0 INVENTORY OF DOCUMENTARY RECORD

The following table provides the inventory of documentary records accumulated as part of this assessment:

Table 4: Inventory of Documentary Record

Study Area	Map and Photo(s)	Field Notes
Two 30 metre by 30 metre parcels of archaeological potential that may be impacted by the proposed refurbishing or replacement of a culvert on Bovaird Drive West between Old Pine Crest Road and Heritage Road, City of Brampton, Region of Peel.	Two Field Maps and 5 Photographs	Stage 2 Survey Forms, GPS waypoint form, Photo Logs and Field Notes

The documentation related to this archaeological assessment will be curated by AMEC until such time that the arrangements for their ultimate transfer to Her Majesty the Queen in right of Ontario, or other public institutions, can be made to the satisfaction of the project owner(s), the Ontario Ministry of Tourism, Culture and Sport, and any other legitimate interest groups.

4.0 STAGE 2 ANALYSIS AND CONCLUSION

The test pit survey provided full coverage of both portions of the study area and nothing of cultural heritage value or interest was encountered (Appendix A: Figure 6; Appendix B: Photographs 1-5).

5.0 RECOMMENDATIONS

AMEC Environment & Infrastructure, a division of AMEC Americas Limited ("AMEC"), was retained by the Region of Peel to conduct a Stage 2 archaeological assessment of two areas of archaeological potential that may be impacted by the proposed refurbishing or replacement of a culvert on Bovaird Drive West, in the City of Brampton, Region of Peel. The culvert handles water from a tributary of the Credit River along Bovaird Drive West, between Old Pine Crest Road and Heritage Road. The study area is comprised of two 30 metre by 30 metre squares of upland terrain on either side of the culvert (Appendix A: Figures 1-3).

The Stage 1 assessment (AMEC 2012) indicated that both portions of the current study area had archaeological potential due to their proximity to: 1) 29 previously registered archaeological sites within a 2-km radius; 2) a tributary of the Credit River; 3) an historic transportation route (Bovaird Drive West); and 4) one historic structure as shown in the Tremaine's Map of 1859 and the Illustrated Historical Atlas of 1877.

A comprehensive test pit survey was conducted at five-metre intervals and nothing of cultural heritage value or interest was encountered.

In light of these results, the following recommendation is made:

1) No further archaeological assessment is required for the study area.

6.0 ADVICE ON COMPLIANCE WITH LEGISLATION

This report is submitted to the Minister of Tourism, Culture and Sport as a condition of licensing in accordance with Part IV of the *Ontario Heritage Act, R.S.O. 1990, c 0.18.* The report is reviewed to ensure that it complies with the standards and guidelines that are issued by the Minister, and that the archaeological fieldwork and report recommendations ensure the conservation, protection and preservation of the cultural heritage of Ontario. When all matters relating to archaeological sites within the project area of a development proposal have been addressed to the satisfaction of the Ministry of Tourism and Culture, a letter will be issued by the ministry stating that there are no further concerns with regard to alterations to archaeological sites by the proposed development.

It is an offence under Sections 48 and 69 of the *Ontario Heritage Act* for any party other than a licensed archaeologist to make any alteration to a known archaeological site or to remove any artifact or other physical evidence of past human use or activity from the site, until such a time as a licensed archaeologist has completed archaeological fieldwork on the site, submitted a report to the Minister stating that the site has no further cultural heritage value or interest, and the report has been filed in the Ontario Public Register of Archaeological Reports referred to in Section 65.1 of the *Ontario Heritage Act*.

Should previously undocumented archaeological resources be discovered, they may be a new archaeological site and therefore subject to Section 48 (1) of the *Ontario Heritage Act*. The proponent or person discovering the archaeological resources must cease alteration of the site immediately and engage a licensed consultant archaeologist to carry out archaeological fieldwork, in compliance with Section 48 (1) of the *Ontario Heritage Act*.

The *Funeral, Burial and Cremation Services Act,* 2002, S.O. 2002, c.33 requires that any person discovering human remains must notify the police or corner and the Registrar of Cemeteries at the Ministry of Consumer Services.

7.0 ASSESSOR QUALIFICATIONS

This report was prepared and reviewed by the undersigned, employees of AMEC Environment & Infrastructure, a division of AMEC Americas Limited, AMEC is one of North America's leading engineering firms, with more than 50 years experience in the consulting industry. The qualifications of the assessors involved in the preparation of this report are provided in Appendix C.

8.0 CLOSURE

This report was prepared for the exclusive use of the Region of Peel and is intended to provide a Stage 2 archaeological assessment of the study area located along Bovaird Drive at the Credit River, in the City of Brampton, Ontario.

The land is currently owned by the City of Brampton and the Stage 2 archaeological assessment was a municipal heritage condition placed on the development prior to construction activities.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of the third party. Should additional parties require reliance on this report, written authorization from AMEC will be required. With respect to third parties, AMEC has no liability or responsibility for losses of any kind whatsoever, including direct or consequential financial effects on transactions or property values, or requirements for follow-up actions and costs.

The report is based on data and information collected during the Stage 2 property assessment conducted by AMEC. It is based solely on the conditions of the property encountered at the time of the Stage 2 property assessment on the 17 June 2014, supplemented by a review of previous assessments and historical information and data obtained by AMEC as described in this report. Except as otherwise maybe specified, AMEC disclaims any obligation to update this report for events taking place, or with respect to information that becomes available to AMEC after the time during which AMEC conducted the archaeological assessment.

In evaluating the property, AMEC has relied in good faith on information provided by other individuals noted in this report. AMEC has assumed that the information provided is factual and accurate. In addition, the findings in this report are based, to a large degree, upon information provided by the current owner/occupant. AMEC accepts no responsibility for any deficiency, misstatement or inaccuracy contained in this report as a result of omissions, misinterpretations or fraudulent acts of persons, interviewed or contacted.

AMEC makes no other representations whatsoever, including those concerning the legal significance of its findings, or as to other legal matters touched on in this report, including, but not limited to, ownership of any property, or the application of any law to the facts set forth herein. With respect to regulatory compliance issues, regulatory statutes are subject to interpretation and change. Such interpretations and regulatory changes should be reviewed with legal counsel.

This report is also subject to the further Standard Limitations contained in Appendix D.

We trust that the information presented in this report meets your current requirements. Should you have any questions, or concerns, please do not hesitate to contact the undersigned.

Respectfully Submitted,

AMEC Environment & Infrastructure
a Division of AMEC Americas Limited

Prepared by,	Reviewed by,
DBrusey	Shaun Austin
Devon Brusey Hons. B.A. Staff Archaeologist	Shaun Austin, Ph.D. Associate Archaeologist (P141)

9.0 BIBLIOGRAPHY

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APPENDIX A

FIGURES

LEGEND

🟥	Study area

NOTES:

THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. TP113114DATE June2014

Conditions encountered in the field may be different from the interpreted information presented on this figure.

SOURCE: ESRI

CLIENT: REGIONAL MUNICIPALITY OF PEEL

Drawn By: CH

Checked By: SA

Revision N°: 1

Scale: 1: 2,500

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STAGE
Credit River

Aerial Photo

PROJECT N°:

DATE:

AMEC Environ

505 Woodward A
tel: 905-312-

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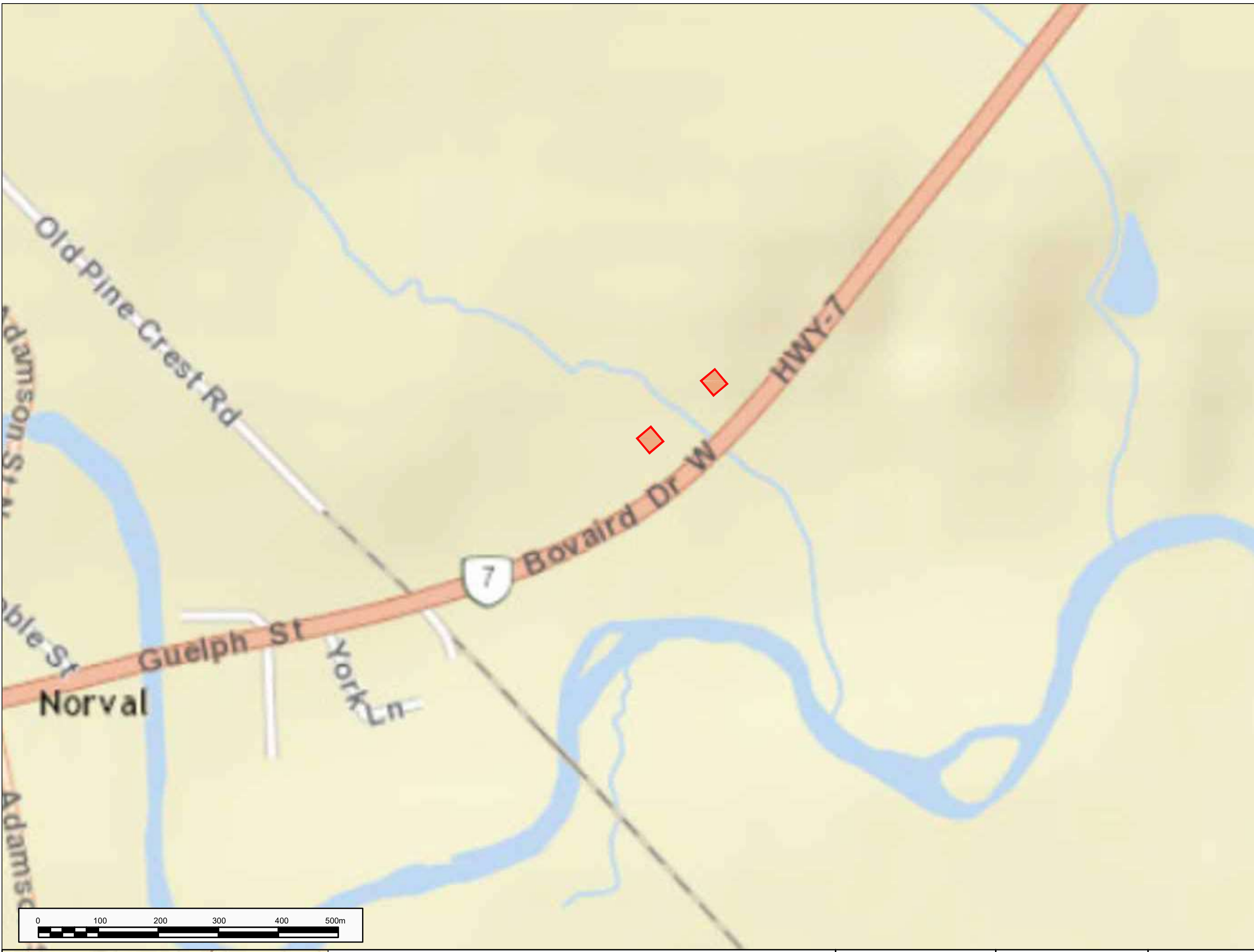

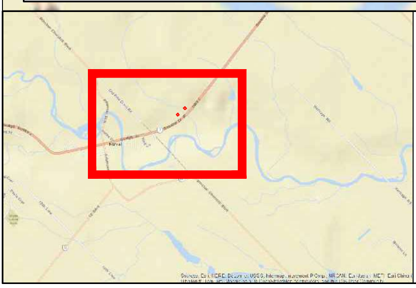

LEGEND

🟥 Study area

NOTES:

THIS DRAWING SHOULD BE READ
IN CONJUNCTION WITH THE
AMEC ENVIRONMENT &
INFRASTRUCTURE
REPORT No. TP113114DATE
June2014

Conditions encountered in the field
may be different from the interpreted
information presented on this figure.

SOURCE: ESRI

CLIENT:	REGIONAL MUNICIPALITY OF PEEL
Drawn By:	CH
Checked By:	SA
Revision N °:	1
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505 Woodward A
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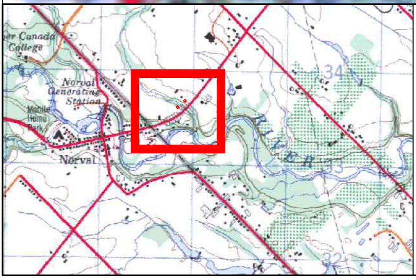

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🟥 Study area

NOTES:

THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. TP113114DATE June2014

Conditions encountered in the field may be different from the interpreted information presented on this figure.

SOURCE: ESRI

CLIENT: REGIONAL MUNICIPALITY OF PEEL

Drawn By: CH

Checked By: SA

Revision N°: 1

Scale: 1: 10,000

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STAGE
Credit River

Topographic

PROJECT N°:

DATE:

AMEC Environ
505 Woodward A
tel: 905-312-

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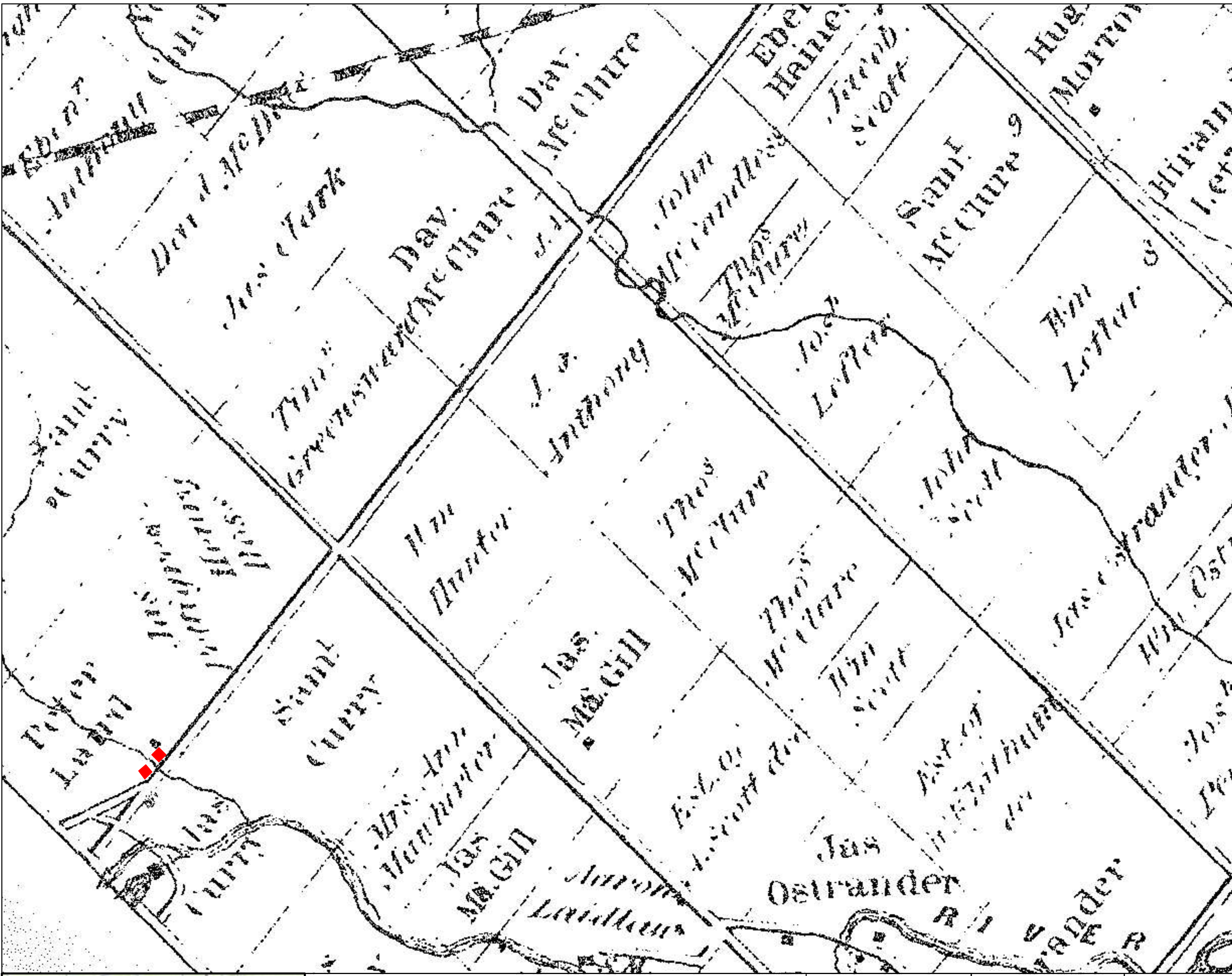

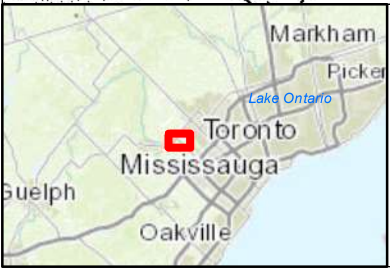

LEGEND

🟥 Study Area

NOTES:

LOCATION OF FEATURES ARE APPROXIMATE

This drawing should be read in conjunction with the AMEC Environment and Infrastructure Report No. TP113114.

Conditions encountered in the field may be different from the interpreted information presented on this figure.

SOURCE: 1859 Tremaine Map of the County of Peel

CLIENT:
REGIONAL MUNICIPALITY OF PEEL

Drawn By: DF
Checked By: DB
Revision: A
Projection: UTM Zone 17N
SCALE: 1:20,000

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AMEC Enviro
505 Woodward Av
tel: 905-312-

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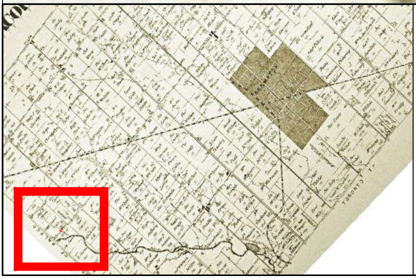

LEGEND

🟥 Study area

NOTES:

THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. TP113114DATE June2014

Conditions encountered in the field may be different from the interpreted information presented on this figure.

SOURCE: 1877 Illustrated Historical Atlas of the County of Peel

CLIENT: REGIONAL MUNICIPALITY OF PEEL

Drawn By: CH

Checked By: SA

Revision N°: 1

Scale: 1: 10,000

STAGE
Credit River

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LEGEND

🟥 Study area

🟩 Test pitted at 5 m intervals

\# Photograph location, number and direction

NOTES:

THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. TP113114DATE June2014

Conditions encountered in the field may be different from the interpreted information presented on this figure.

SOURCE: 1859 Tremaine Map of the County of Peel

CLIENT: REGIONAL MUNICIPALITY OF PEEL

Drawn By: CH

Checked By: SA

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APPENDIX B

PHOTOGRAPHS

APPENDIX B - PHOTOGRAPHIC RECORD

PROJECT NO. **TP113114.6000**

PROJECT **Stage 2 Archaeological Assessment**

LOCATION **Credit River Culvert, Bovaird Drive, Brampton, Ontario**

ENCLOSURE 1

PHOTOGRAPH	1

Description

Looking southeast at AMEC archaeologist conducting Stage 2 test pit survey in area assessed to have archaeological potential.

PHOTOGRAPH	2

Description

Looking northwest at AMEC archaeologist conducting Stage 2 test pit survey in area assessed to have archaeological potential.

PHOTOGRAPH **3**

Description

Looking down at test pit stratigraphy. Topsoil was from 0-25 cm and was clay-loam (10YR 3/2, very dark greyish brown) and the subsoil was from 25-32 cm, clay-loam (10YR 3/6, dark yellowish brown).

PHOTOGRAPH **4**

Description

Looking northwest at AMEC archaeologist conducting Stage 2 test pit survey in area assessed to have archaeological potential.

APPENDIX B - PHOTOGRAPHIC RECORD

PROJECT NO. TP113114.6000

PROJECT Stage 2 Archaeological Assessment

LOCATION Credit River Culvert, Bovaird Drive, Brampton, Ontario

ENCLOSURE 3

PHOTOGRAPH	**5**

Description
Looking south at AMEC archaeologist conducting Stage 2 test pit survey in area assessed to have archaeological potential.

APPENDIX C

ASSESSOR QUALIFICATIONS

ASSESSOR QUALIFICATIONS

Shaun Austin, Ph.D., Associate Archaeologist – Dr. Austin is the leader of AMEC's cultural heritage resources group and is based in the AMEC Hamilton Office. He has been working in Canadian archaeology and heritage since 1976 and as an archaeological and heritage consultant in Ontario since 1987. He is a dedicated cultural heritage consultant with repeated success guiding projects through to completion to the satisfaction of the development proponent, the cultural heritage community and all other stakeholder groups. His areas of interest and expertise include pre-contact Aboriginal lithics and ceramics. Dr. Austin holds a **Professional Archaeology License** (**P141**) issued by the Ontario Ministry of Tourism, Culture and Sport, is MTO RAQs certified in Archaeology/Heritage and is a member of the Ontario Association of Professional Archaeologists.

Devon Brusey B.A. Hon., Staff Archaeologist – Ms. Brusey has worked as a consultant archaeologist since 2007. She holds an honorary bachelors degree in Anthropology and Japanese Studies from McMaster University. Ms. Brusey has worked on over 250 Stage 1 through Stage 4 archaeological assessments throughout Ontario, many of which have been completed as part of the environmental assessment process for the development of wind and solar farms, hydro line corridors and municipal roadway improvements. Ms. Brusey has also been instrumental in the processing and analysis of artifacts and other data in the laboratory. Recently, she acted as crew supervisor for the Stage 4 salvage excavation of an extensive multi-component pre-contact and historic site in Burlington, Ontario. She has also acted as the project manager, field director and report writer for numerous other projects. Ms. Brusey holds an **Applied Research License (R410)** issued by the Ontario Ministry of Tourism, Culture and Sport.

Cara Howell B.A., Staff Archaeologist – Ms. Howell has been working in consulting archaeology since 1999. During this time she has acquired a full range of archaeological skills, from background research to Stage 4 excavation. She has developed a comprehensive understanding of all aspects of material culture and has a specialized interest in historic Euro-Canadian artifacts. As Laboratory Director for AMEC's Archaeology Group, she was instrumental in creating and implementing cataloguing systems for all types of recovered artifacts. Mr. Howell also serves as lead liaison with First Nations communities. She holds a B.A. in Physical Anthropology and a B.A. in Classical Archaeology from McMaster University, and an **Applied Research License (R180)** issued by the Ontario Ministry of Tourism, Culture and Sport.

Devin Funovtiz M.Sc., GIS Technician - Ms. Funovitz joined AMEC Environment and Infrastructure in July 2012; she currently works with the Hydrogeology Group in AMEC's Hamilton, Ontario office as a GIS Analyst. She has been involved in GIS and hydrogeological investigations and analysis regarding various mine sites, water pollution control plants, and sewage investigations. Her areas of expertise include GIS mapping and data analysis, and stratigraphic cross section generation. Ms. Funovitz has completed an Honours Bachelors Degree in Earth and Environmental Science from McMaster University with a focus on hydrology and GIS, along with a Master's in Environment and Sustainability.

APPENDIX D

LIMITATIONS

LIMITATIONS

1. The work performed in the preparation of this report and the conclusions presented are subject to the following:
   (a) The Standard Terms and Conditions which form a part of our Professional Services Contract;
   (b) The Scope of Services;
   (c) Time and Budgetary limitations as described in our Contract; and,
   (d) The Limitations stated herein.
2. No other warranties or representations, either expressed or implied, are made as to the professional services provided under the terms of our Contract, or the conclusions presented.
3. The conclusions presented in this report were based, in part, on visual observations of the Study Area. Our conclusions cannot and are not extended to include those portions of the Study Area which were not reasonably available, in AMEC's opinion, for direct observation.
4. The potential for archaeological resources, and any actual archaeological resources encountered, at the Study Area were assessed, within the limitations set out above, having due regard for applicable heritage regulations as of the date of the inspection.
5. Services including test-pitting was performed. AMEC's work, including test-pitting was conducted in a professional manner and in accordance with the Ministry of Tourism and Culture's guidelines. It is possible that unforeseen and undiscovered archaeological resources may be present at the Study Area between areas test-pitted and in areas which were pedestrian surveyed.
6. The utilization of AMEC's services during the implementation of any further archaeological work recommended will allow AMEC to observe compliance with the conclusions and recommendations contained in the report. AMEC's involvement will also allow for changes to be made as necessary to suit field conditions as they are encountered.
7. This report is for the sole use of the parties to whom it is addressed unless expressly stated otherwise in the report or contract. Any use which any third party makes of the report, in whole or in part, or any reliance thereon, or decisions made based on any information of conclusions in the report, is the sole responsibility of such third party. AMEC accepts no responsibility whatsoever for damages or loss of any nature or kind suffered by any such third party as a result of actions taken or not taken or decisions made in reliance on the report or anything set out therein.
8. This report is not to be given over to any third-party other than a governmental entity, for any purpose whatsoever without the written permission of AMEC, which shall not be unreasonably withheld.

APPENDIX ‘F’

UTILITIES ASSESSMENT

AMEC Environmental & Infrastructure

Credit River Tributary
Bovaird Drive West

Report
Subsurface Utility Engineering Services

Project #61000267

Report Date: March 25, 2014

Statement of Qualifications and Limitations

The attached Report (the "Report") has been prepared by T2 Utility Engineers Inc. ("Consultant") for the benefit of the AMEC Environmental & Infrastrucutre ("Client) in accordance with the agreement between Consultant and Client, including the scope of work detailed therein (the "Agreement").

The information, data, recommendations and conclusions contained in the Report (collectively, the "Information"):

> is subject to the scope, schedule, and other constraints and limitations in the Agreement and the qualifications contained in the Report (the "Limitations"), represents Consultant's professional judgement in light of the Limitations and industry standards for the preparation of similar reports, may be based on information provided to Consultant which has not been independently verified, has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued, must be read as a whole and sections thereof should not be read out of such context, was prepared for the specific purposes described in the Report and the Agreement, in the case of subsurface conditions, may be based on limited inspections and on the assumption that such conditions are uniform and not variable either geographically or over time.

Consultant shall be entitled to rely upon the accuracy and completeness of information that was provided to it and has no obligation to update such information. Consultant accepts no responsibility for any events or circumstances that may have occurred since the date on which the Report was prepared and, in the case of subsurface conditions, is not responsible for any variability in such conditions, geographically or over time.

Consultant agrees that the Report represents its professional judgement as described above and that the Information has been prepared for the specific purpose and use described in the Report and the Agreement, but Consultant makes no other representations, or any guarantees or warranties whatsoever, whether express or implied, with respect to the Report, the Information or any part thereof.

The Report is to be treated as confidential and may not be used or relied upon by third parties, except:

as agreed in writing by Consultant and Client,
as required by law,
for use by governmental reviewing agencies.

Consultant accepts no responsibility, and denies any liability whatsoever, to parties other than Client who may obtain access to the Report or the Information for any injury, loss or damage suffered by such parties arising from their use of, reliance upon, or decisions or actions based on the Report or any of the Information ("improper use of the Report"), except to the extent those parties have obtained the prior written consent of Consultant to use and rely upon the Report and the Information. Any damages arising from improper use of the Report or parts thereof shall be borne by the party making such use.

This Statement of Qualifications and Limitations is attached to and forms part of the Report and any use of the Report is subject to the terms hereof.

Report Revision Log

Revision #	Revised By	Date	Issue / Revision Description
0	B. Hunt	Mar 25, 2014	Preliminary

Signatures

Report Prepared By:

Blaine Hunt, P. Eng.
Project Manager

Mark Cavanaugh
Senior Utility Coordinator

Table of Contents:

Statement of Qualifications and Limitations

Report Revision Log

1. Project Summary

T2 Utility Engineers (T2ue) completed a Subsurface Utility Engineering (SUE) mapping investigation in accordance with CI/ASCE 38-02, for AMEC Environmental & Infrastructure (AMEC) as part of the Credit River Tributary Culvert crossing Bovaird Drive West. AMEC's project includes the design of the replacement of the existing concrete box culvert. AMEC has requested the SUE investigation in order to determine the aerial and underground utilities impacted by the project. T2ue's investigation involves Record Request Circulation, SUE Mapping and Invert Investigations.

1.1 Project Area

Bovaird Drive West (Regional Road 107), formerly Highway 7 extends east-west across Brampton. The Project Area is a 2 lane road right of way approximately 1000 meters west of Heritage Road, including mainly undeveloped rural areas. Shoulders are gravel with surface drainage ditches on either side of the road.

According to the record documents obtained and field investigations the project area contains aerial and subsurface utilities.

Aerial utilities within the project area include:

- Hydro One Brampton primary and secondary distribution,
- Bell and Peel Region - Public Service Network Fiber telecommunications.

Underground utilities within the project area include:

- Bell telecommunications,
- Union Gas mains.

1.2 Limits of Investigation

The limits of field investigation are as described below:

- 60 meters east of Credit River Tributary,
- 50 meters west of Credit River Tributary,
- 60 meters south of Bovaird Drive West,
- 180 meters north of Bovaird Drive West.

2. Equipment

The following paragraphs represent a description of some of the common equipment used by T2ue to complete the investigation. T2ue uses the latest equipment and techniques available to designate all varieties of subsurface utilities and underground structures. We have assessed the merits of every technology outlined in the ASCE Standard 38-02 and CSA S250-11 for use in utility designating. Field Technicians utilize each technology according to the manufacturer's instructions and the project conditions. Based on the project scope and discussions with the

AMEC, T2ue has selected the appropriate equipment to ensure that our field technicians are trained and equipped with the latest information, techniques and technology.

2.1 Electromagnetic Designating Equipment

T2ue primarily uses single frequency and multi-frequency electromagnetic designating equipment. Electromagnetic designating equipment does not locate the actual pipes or cables, but instead locate the magnetic fields. Electromagnetic fields are either naturally present on conductors or are induced onto a target line by a transmitter. Signals may be distorted by any of the following:

- ground conductivity
- construction layout (i.e. bends, connections)
- utility congestion causing bleed off of magnetic fields
- materials and/or age (i.e. PVC without tracer wire, corrosion in metallic pipes)

2.2 Survey Technologies

Survey equipment collects the three dimensional position of points using both total station and survey grade Global Positioning System (GPS). T2ue survey crews will collect the data from the SUE Mapping investigation and tie in the results to local features and points that are obtained from the topographical base map.

2.3 Chamber Investigations

Chambers information is collected from the surface. Inspections can identify the sewer type, invert elevation, pipe material and pipe diameter, chamber sizes, chamber offsets and chimney sizes. Inspections are typically limited to line of sight, maintenance platforms, larger offsets or excessively deep chambers may require confined space entry. Information gathered within the chamber inspections is specific to the project requirements.

3. SUE Investigation Methodology

T2 Utility Engineers Inc. performs SUE mapping investigations in accordance with the CI/ASCE Standard 38-02: Standard Guideline for the Collection and Depiction of Existing Subsurface Utility.

3.1 CI/ASCE Standard 38-02 Summary:

All utility information is assigned a quality level in accordance with the CI/ASCE Standard 38-02:

Quality Level D (QL-D) – Information derived from existing utility records, or verbal recollections.
Quality Level C (QL-C) – Information obtained by surveying and plotting visible above-ground utility features and by using professional judgment in correlating this information to Quality Level D information.

Quality Level B (QL-B) – Information obtained through the application of appropriate surface geophysical methods to determine the existence and approximate horizontal position of subsurface utilities.
Quality Level A (QL-A) – Precise horizontal and vertical location of utilities obtained by the actual exposure (or verification of previously exposed and surveyed utilities) and subsequent measurement of subsurface utilities, usually at a specific point.

3.2 SUE Investigation Scope of Work

The following is a breakdown of the methodology used for the SUE investigation:

- Records research completed by T2ue includes the review of record documents obtained through the utility circulation request (see Appendix B), information received from AMEC and gathered records information to create the utility drawing up to QL-D for the entire project area.
- AMEC provided T2ue with a base map for the area that is tied into proper coordinate systems (horizontal and vertical survey control points within the project area) including:
    - Surface topographical features: curbs, asphalt, buildings, utility poles, signs, CB's, MH's, etc.
    - Elevations and horizontal information related to a local coordinate system.
    - Surface topographic detail to measure the visible surface features including sufficient overlap onto adjacent properties.
- Utilized the topographic survey information provided to verify the position of surface features such as valves and pedestals that indicate the location of underground utilities.
- Utilized geophysical utility designating techniques to determine the horizontal position of utilities identified within the project limits. Utilities investigated included water, gas, hydro and telecommunications. The investigation also included induction scanning in key areas to help identify utilities that were not identified on the record drawings. Equipment used included single frequency and multi-frequency electromagnetic designating equipment. Utilities that were not identified by the records research are termed "undocumented". T2ue used reasonable means in an attempt to determine the location of undocumented utilities however cannot be responsible for finding all undocumented utilities.
- Inspected chambers and culverts to confirm the actual pipe sizes, materials, offsets, elevations and drainage direction. Mapping of the system, alignments and interconnections were confirmed according to the record documents.
- All designating marks were surveyed using local coordinates in order to generate the initial utility composite plan.
- T2ue produced a composite utility drawing based on the field findings and the records research (Quality Level D, C and B as per ASCE 38-02 – SUE guidelines).
- T2ue reviewed the results and prepared the report.

4. Field Investigation

The field investigation was completed within the limits described above. The details from the investigation are provided in the following sections.

The field investigation was completed in February 2014. The initial field investigation for the SUE Mapping was completed and the preliminary drawings and report have been prepared for review by AMEC. Preliminary utility conflict matrix was developed based on the field investigation (see Appendix C).

Winter conditions, during the time of the field investigation within the project resulted in heavy ice and snow build up. T2ue have made every attempt to complete a thorough inspection, however the results of the investigation may be affected by hidden or buried utility features (i.e. valves, pedestals, culvert inlets).

4.1 Hydro

Records obtained by T2ue indicate Hydro One Brampton wooden poles, and aerial distribution lines were present within the project area. Field investigations confirmed the alignment of the hydro aerial utilities.

4.2 Telecommunications

Records obtained by T2ue indicated Bell aerial and Bell underground utilities were present within the project area. Field investigations confirmed the alignment of the Bell telecommunications and the Peel Region - Public Service Network aerial alignment.

4.3 Gas

Records obtained by T2ue indicated Union Gas mains were present within the project area. Field investigations confirmed the alignment of the gas mains.

4.4 Municipal Sewers

Field investigations of the chambers confirmed the invert information and system mapping of the drainage culverts. The ditch inlet within the existing concrete box culvert was unable to be field verified and has been shown on the drawings based on information received.

5. Utility Circulation Request

T2ue completed the utility circulation request on February 11, 2014. Record documents have been provided by the utility companies for the project area. A summary of the Utility Circulation Request completed by T2ue is attached in Appendix B.

6. Utility Coordination

Upon the successful completion of the first stage of SUE investigations as summarized above, the information gathered must be compared to the proposed contract work and analyzed to determine the extent of impacted utilities. The conflict analysis will be completed for the following contract phases as discussed with AMEC:

- Phase 1 – large excavation required for replacement of culvert on north side of Bovaird Drive West.
- Phase 2 – large excavation required for replacement of the remainder of the culvert on south side of Bovaird Drive West.

6.1 Utility Conflict Assessment

To completely assess the conflicts with each of the phases listed above, AMEC is to provide T2ue with the digital design file of the proposed grading limits of the culvert excavation for both the north culvert replacement phases. Without the exact limits of excavation, T2ue foresees the following potential conflicts with each of the construction phases:

Phase 1 – North Side Culvert Replacement

1. Hydro One Brampton pole line (3 x 3 Phase primary overhead) c/w a Peel Region fiber as a third party attachment. A minimum of one (1) pole is located within the future excavation limits and must be removed. In order to remove the pole line will either have to move to another location (potentially to the south side), or new structural poles must be placed on either side of the grading limits to accommodate the large span (100m+/-) over the proposed excavation area. If pole alignment is to be shifted to the south side consideration must be given to the anticipated excavation limits required for Phase 2 of the culvert replacement.
2. Bell and Union Gas have underground plant within close vicinity to the proposed excavation limits. Confirmation of exact limits of excavation must be provided to determine if impacts are present. Relocations should be avoided if possible by altering excavation limits, however if relocations are required each utility must be contacted to discuss local relocations solutions.

Phase 2 – South Side Culvert Replacement

1. An existing Union Gas 100mm PE IP is crossing high above the existing culvert. Through discussions with AMEC, the anticipated culvert replacement methodology is to excavate via sloped large open excavation, which would leave this gas main suspended over the open excavation for an extended length. A relocation of this gas main would be required to a location outside of excavation limits, as suspending active gas over open excavations for a long period of time if a large safety concern for both the project sponsor and the Utility company.
2. Bell Canada has an existing aerial cable that spans the existing culvert. Detailed limits of the excavation must be provided to confirm if the poles at either end are impacted. If no impact is foreseen the cable may remain suspended above the excavation.
3. Bell Canada has an existing duct structure passing beyond the south end of the culvert below the creek bed. No conflicts are anticipated based on discussions with AMEC, however excavation limits will need to be identified to ensure there are no conflicts.

6.2 Utility Coordination – Next Steps

If not already completed, AMEC must provide notification of project commencement to all utilities operating with the Region of Peel, regardless as to whether conflicts with existing infrastructure is anticipated or not. The purpose of the notice is notice is to ensure that any utilities that anticipate infrastructure placement within the project limits are afforded the opportunity to input on the Region of Peel's design scope at an early stage.

Following the initial notification listed above, communications with each of the utilities (typically via meetings) must occur to relay design scope, schedule and the extent of anticipated conflicts. At this initial meeting it is expected that AMEC will provide the Utility with all information required to begin a detailed relocation design. It shall be noted that many utilities will typically not begin relocation designs until a contract has reached a high percentage of design completion (often 60-90%), however in instances where conflicts appear to be unavoidable (i.e. Hydro One Brampton pole on north side) exceptions are often made.

APPENDIX A

COMPOSITE UTILITY DRAWING


3x PRIMARY-HYDRO ONE BRA
1x SECONDARY-HYDRO ONE BRA
1x ANCHOR/GROUN
2x WHITE WRAP FOCS-PEEL
HP
SW
UNABLE TO
DUE
CB

APPENDIX B

UTILITY CIRCULATION CONTACT LIST

Utility Contact Sheet: BRAMPTON

Project Name: Credit River Tributary
Project Number: 61000267
Client: AMEC

Completed by: A. Jackson-Wyatt
Checked by:
Updated (dd/mm/yy) 27-Mar-14

Job Limits:

Utility	Email Address	Contact Name	Contact Information	Info Requested (MM/DD/YY)	Info Received (MM/DD/YY)	MATERIAL RECEIVED	Notes
Bell Canada	moc.bell@bell.ca bell.moc@netricom.com	Elaine Oakley (Toronto) Chris Gill (Hamilton)	100 Borough Drive, Floor F5 Toronto, ON M1P 4W2 tel: 416-296-6587		01/16/14 FROM CLIENT	DWG FILE	For records request use bell.moc@prestigetel.com . For more det she will put you in touch with the local "Outside Implementation
Enbridge Gas Distribution	mark-ups@enbridge.com	Joe Marozzo	500 Consumers Road 4th Floor - Post A2 - VPC North York, ON M2J 1P8 tel: (416) 758-7956 fax:(416) 758-4374		01/16/14 FROM CLIENT	PDF FILE	
Group Telecom	GT.moc@netricom.com	Indira Sharma	Prestige Telecom 200 Town Centre Blvd., Suite 300, Markham, ON. L3R 8G5 Tel: 905-470-2112 ext. 40265	02/11/14	02/24/14	NO CONFLICT	
Hydro One	tpumarkup@hydroone.com	Mark Hamilton	49 Sarjeant Dr. Barrie, ON L4N 4V9 tel: 705-797-4142 fax: 705-792-3116	02/11/14			Mark provides mark-ups for buried Hydro One High-voltage cab
Hydro One	WestCentralZoneScheduling@HydroOne.com		tel: 905-627-6050 fax: 905-627-6059	02/11/14			Mark-ups for Aerial Hydro One High Voltage facilities
MTS-Allstream	Utility.Circulations@mtsallstream.com	Corey Knight	50 Worcester Rd Etobicoke, ON M9W 5X2 tel: 416-649-7509	02/11/14	02/12/14	NO CONFLICT	
Rogers Cable Communications Inc.	GTA.Markups@rci.rogers.com	Manel De Silva	Markup Coordinator, OPE GTAC Tel: 416 446-6794	02/11/14			
Telus	telusutilitymarkups@netricom.com	Stephen Hoy	2696 Matheson Blvd. E, 1st Floor, West Tower, Mississauga, ON L4W 4V5 tel: 905-804-6219	02/11/14	02/13/14	NO CONFLICT	
City of Brampton			tel: 905-874-2500				Contact # for Sewer drawings

Utility Contact Sheet: BRAMPTON

Project Name: Credit River Tributary
Project Number: 61000267
Client: AMEC

Completed by: A. Jackson-Wyatt
Checked by:
Updated (dd/mm/yy) 27-Mar-14

Job Limits:

Utility	Email Address	Contact Name	Contact Information	Info Requested (MM/DD/YY)	Info Received (MM/DD/YY)	MATERIAL RECEIVED	Notes
Region of Peel (Water)			tel:905-791-7800			ONE CALL TICKET CONFIRMATION NO CONFLICT	Contact # for Water Records
PSN Fiber Network (Peel Fiber)						NO CONTACT INFO	
Street Lights (City of Brampton)	susan.evans@brampton.ca	Susan Evans	tel: 905-874-2500	02/11/14			Contact for Street Lighting information
Union Gas					03/04/13	PDF FILE	Data Licensing Agreement with Union Gas signed March 4, 201

APPENDIX C

UTILITY CONFLICT MATRIX

APPENDIX ‘G’

ASSESSMENT OF ALTERNATIVES

ting tially ructure s the vert	Option 2: Implement Option 1, With a Maximum 4% Slope from the Culvert Extension to the Existing Creek	Option 3: Remove North Portion of the Culvert and Install Permanent Retaining Wall
channel m^2 of f a mix ly ich are eas leys of native	Disturbance would occur to channel banks and valley wall greater than Option 1 and 3. Impact to approximately 2,750 m^2 of cultural meadows which consists of a mix of native and exotic vegetation. Temporary impact to approximately 5,972 m^2 of cultural woodlands which are typically associated with upland areas near the Credit River, tributary valleys of the Credit River. Opportunity for improvement of native riparian vegetation.	Disturbance would occur to channel banks and valley wall. Impact to approximately 2,750 m^2 of cultural meadows which consists of a mix of native and exotic vegetation. Temporary impact to approximately 1,675 m^2 of cultural woodlands which are typically associated with upland areas near the Credit River, tributary valleys of the Credit River. Opportunity for improvement of native riparian vegetation.
would 0 m^2 of	Area available for wildlife habitat would increase with the creation of 2,750 m^2 of valley lands	Area available for wildlife habitat would increase with the creation of 2,750 m^2 of valley lands
eam of y up to age for le as a moval.	Reconstruction of 260 m +/- upstream of the culvert would be required. Culvert would continue to convey up to the 100 year storm event. Additional non-riparian flood storage for all storm events would be available as a result of the 19,500 m^3 of earth removal.	Reconstruction 85 m +/- upstream of the culvert would be required. Culvert would continue to convey up to the 100 year storm event. Additional non-riparian flood storage for all storm events would be maximized as a result of the 21,000 m^3 of earth removal.

ting tially ructure ns the vert	**Option 2: Implement Option 1, With a Maximum 4% Slope from the Culvert Extension to the Existing Creek**	**Option 3: Remove North Portion of the Culvert and Install Permanent Retaining Wall**
ides a annel. uralized nproves e ng the ert and culvert -bodied	Shortened culvert length provides a longer length of natural stream channel. Improved light penetration to naturalized section of creek which in turn improves fish feeding area, and fish passage Shortening the culvert, minimizing the gradient in the replacement culvert and installing baffles through the entire culvert will improve fish passage for large-bodied species though the culvert.	Shorter culvert length provides maximum length of natural stream channel. Light penetration maximized which in turn improves fish feeding area. Shortening the culvert improves fish passage.
eam of channel tentially t inlet.	Reconstruction of 260 m +/- upstream of the culvert would be required. Increase in area for natural channel function. Installation of fish baffles would potentially increase backwater and pooling at inlet.	Reconstruction 85 m +/- upstream of the culvert would be required. Increase in area for natural channel function maximized. Installation of fish baffles would potentially increase backwater and pooling at inlet.
ent has s were ns are	A Stage 2 archaeological assessment has been completed, and no artifacts were found. No further investigations are required.	A Stage 2 archaeological assessment has been completed, and no artifacts were found. No further investigations are required.
latform, ents as . Direct project djacent	Removal of old Highway 7 platform, currently being used by local residents as an access road will be required. Direct access to Highway 7 outside of the project area will be utilized for the adjacent properties.	Removal of old Highway 7 platform, currently being used by local residents as an access road will be required. Direct access to Highway 7 outside of the project area will be utilized for the adjacent properties.

ting tially ructure s the vert	Option 2: Implement Option 1, With a Maximum 4% Slope from the Culvert Extension to the Existing Creek	Option 3: Remove North Portion of the Culvert and Install Permanent Retaining Wall
o and s will be	Relocation of overhead hydro and associated third party attachments will be required.	Relocation of overhead hydro and associated third party attachments will be required.
due to	Some delays to traffic will occur due to lane reductions.	Some delays to traffic will occur due to lane reductions.
uld be with a	Structurally deficient culvert would be removed, and partially replaced with a cast-in-place structure.	Structurally deficient culvert would be removed, and replaced with a permanent retaining wall.
ening of equired modate	Lane closures and temporary widening of the pavement surface would be required on Bovaird Drive to accommodate construction of the culvert.	Some lane closures would be required on Bovaird Drive to accommodate construction of retaining wall.
m^3) = cast-in- temp 46,250 **ST =**	Earth Excavation (@ \$30 / m^3) = \$250,000 20m x 1.2m span x 2.8m rise cast-in-place culvert extension (incl. temp shoring) = \$625,000 260m of Creek Reconstruction = \$585,000 Road Detour = \$215,000 Landscaping = \$75,000 **TOTAL INCREMENTAL COST = \$1,750,000**	Earth Excavation (@ \$30 / m^3) = \$350,000 60m long x 18m deep permanent retaining wall = \$840,000 85m of Creek Reconstruction = \$191,250 Road Detour = \$215,000 Landscaping = \$100,000 **TOTAL INCREMENTAL COST = \$1,696,250**

ting tially ructure s the vert	Option 2: Implement Option 1, With a Maximum 4% Slope from the Culvert Extension to the Existing Creek	Option 3: Remove North Portion of the Culvert and Install Permanent Retaining Wall
plans.	Compatible with Regional and City plans.	Compatible with Regional and City plans.
Heights staged easible.	Compatible with Heritage Heights Subwatershed Study as staged construction of ultimate culvert is feasible.	Less compatible with the Heritage Heights Subwatershed Study as the culvert proposed by the study would conflict with the permanent retaining wall.
olution.	Not carried forward, as the impact to the existing valley upstream of the culvert would be extensive.	Not carried forward, as the permanent retaining wall would conflict with the ultimate replacement of the culvert.

Option 1: **end Existing 1200mm dia. CSP to Accommodate the Proposed Road Widening**	**Option 2:** **Replace Existing 1200mm dia. CSP with a 3.2m span x 1.5m high Precast Arch Culvert**
urbance would occur to the riparian habitat ounding the existing culvert.	Disturbance would occur to the riparian habitat surrounding the existing culvert.
reased potential for wildlife passage.	By enlarging the culvert openness ration and providing an open footing bottom increases potential small wildlife passage.
vert would continue to convey the 50 year storm event.	Culvert would convey the Regional storm event.
ulvert extension would decrease the potential for fish sage. A culvert extension decreases natural stream om.	Increases the length of natural stream bottom through the entire length. A larger span and natural bottom increases the potential for seasonal fish passage. A natural stream bottom provides greater opportunity for invertebrate production for downstream fish feeding opportunities.
sting CSP is inappropriate for the watercourse.	Provides improved structure with a better and more functional connection to Huttonville Creek.
mpact to archaeological or heritage resources.	No impact to archaeological or heritage resources.
mpact to existing entrances.	No impact to existing entrances.
mpact to existing utilities.	Potential impact to existing/future watermain and sanitary sewers.
uptions to traffic patterns and dust would occur, but be mitigated during construction.	Disruptions to traffic patterns and dust would occur, but can be mitigated during construction.
mpact to safety.	No impact to safety.
nporary lane closures may be required during struction.	Temporary lane closures may be required during construction.

Option 1: end Existing 1200mm dia. CSP to Accommodate the Proposed Road Widening	Option 2: Replace Existing 1200mm dia. CSP with a 3.2m span x 1.5m high Precast Arch Culvert
end existing culvert (incl. traffic staging) = $30,000 n of creek construction = $112,500 dscaping = $30,000 **TAL = $172,500**	Replace existing culvert (incl. traffic staging) = $560,000 50m of creek construction = $112,500 Landscaping = $30,000 **TOTAL = $702,500**
npatible with Regional plans to widen Mississauga d.	Compatible with Regional plans to widen Mississauga Road.
carried forward, as it does not accommodate the ds of the Redside Dace	Carried forward as the preferred solution