Submitted to:

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Geotechnical Investigation
Fernbank Crossing
Residential Development
Block 198 - Livery Street
Ottawa, Ontario

December 2, 2015
Project: 63282.06
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1.0 INTRODUCTION

This report presents the results of a subsurface investigation carried out at the site of a proposed residential development located along the north side of Livery Street (Block 198) in Kanata, Ontario. The purpose of the investigation was to identify the general subsurface conditions at the site by means of a limited number of boreholes. Based on the factual information obtained during this investigation, together with the results of previous boreholes and test pits advanced at the site, we were to provide guidelines and recommendations on the geotechnical design aspects of the project, including construction considerations that could influence design decisions.

This investigation was carried out in general accordance with our proposal dated April 10, 2015.

2.0 PROJECT DESCRIPTION AND SITE GEOLOGY

2.1 Project Description

It is understood that plans are being prepared for the construction of two (2) low-rise residential buildings and twenty (20) semi-detached houses along the north side of Livery Street (Block 198) in Ottawa, Ontario (see Key Plan, Figure 1).

The low-rise residential buildings will have 3 levels, with the lower level partially below ground surface. At grade, asphaltic concrete surfaced parking and access roads and concrete sidewalks will be constructed as part of the development.

The semi-detached houses are anticipated to have a basement level and garage. At grade, asphaltic concrete surfaced driveways will be constructed at the front of the dwellings.

The buildings will be serviced with municipal water, storm, and sanitary sewers.

2.2 Review of Geology Maps

Surficial geology maps of the Ottawa area indicate that the subsurface conditions at the site are expected to consist of offshore marine deposits of clay and silt. The overburden deposits are underlain by interbedded limestone and dolomite bedrock of the Gull River Formation.

3.0 PREVIOUS SUBSURFACE INVESTIGATIONS

Previous test pit and borehole investigations were carried out in the vicinity of the subject site by Houle Chevrier Engineering Ltd. in 2007, 2008, and 2011. The findings of these investigations have been documented in our previous reports titled:

The results of the relevant test pits and boreholes are provided in Appendix B, along with relevant laboratory classification and oedometer consolidation tests.

4.0 SUBSURFACE INVESTIGATION

The field work for this investigation was carried out on June 23, 2015. At that time, a total of four (4) boreholes, numbered 15-1 to 15-4, were advanced at the site using a track mounted drill rig supplied and operated by George Downing Estate Drilling of Hawkesbury, Ontario. The boreholes were advanced to depths ranging between about 5.7 and 9.2 metres below ground surface (elevation 92.1 to 96.4 metres, geodetic datum).

Standard penetration tests were carried out in the boreholes, where possible, and samples of the soils encountered were recovered using a 50 millimetre diameter split barrel sampler. In situ vane shear testing was carried out where possible in the clayey deposits to measure undrained shear strength. Standpipe peizometers were installed in boreholes 15-2 and 15-4 to measure groundwater levels.

The soil samples were returned to our laboratory for examination by a geotechnical engineer following completion of the drilling. Laboratory classification testing (water content, grain size distribution, and Atterberg limits) was carried out on selected samples of the soils recovered from the boreholes. One (1) soil sample from borehole 15-3 was sent to Paracel Laboratories Ltd. for basic chemical testing relating to corrosion of buried concrete and steel.

The results of the boreholes are appended on the Record of Borehole sheets in Appendix A. The approximate locations of the boreholes are shown on the Borehole Location Plan, Figure 2. The results of the laboratory classification tests are provided on Figures A1 and A2 in Appendix A and on the Record of Borehole sheets. The results of the chemical analysis on the soil samples are provided in Appendix C.

The borehole locations were selected by Houle Chevrier Engineering Ltd. personnel and positioned at the site relative to existing site features. The ground surface elevations and the locations of the boreholes were determined using a Trimble R8 global positioning system. The elevations are referenced to geodetic datum and is considered to be accurate within the tolerance of the instrument.
5.0 SUBSURFACE CONDITIONS

5.1 General

As previously indicated, the soil and groundwater conditions identified in boreholes are given on the Record of Borehole sheets in Appendix A. The logs indicate the subsurface conditions at the specific test locations only. Boundaries between zones on the logs are often not distinct, but rather are transitional and have been interpreted. The precision with which subsurface conditions are indicated depends on the method of drilling, the frequency and recovery of samples, the method of sampling, and the uniformity of the subsurface conditions. Subsurface conditions at other than the test locations may vary from the conditions encountered in the boreholes. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties.

The groundwater conditions described in this report refer only to those observed at the place and time of observation noted in the report. These conditions may vary seasonally or as a consequence of construction activities in the area.

The soil descriptions in this report are based on commonly accepted methods of classification and identification employed in geotechnical practice. Classification and identification of soil involves judgement and Houle Chevrier Engineering Ltd. does not guarantee descriptions as exact, but infers accuracy to the extent that is common in current geotechnical practice.

The following presents an overview of the subsurface conditions encountered in the boreholes advanced during this investigation.

5.2 Topsoil/Topsoil Fill

Topsoil/topsoil fill was encountered from ground surface in boreholes 15-1, 15-2 and 15-3. The topsoil/topsoil fill consists of clayey silt with some sand, gravel and organic material and has a thickness ranging from about 80 millimetres to 250 millimetres.

5.3 Fill Material

Fill material was encountered below the topsoil fill in boreholes 15-1 and 15-2, and at ground surface in borehole 15-4. The fill material consists of brown, dark brown and dark grey brown silty clay, which contains, at some locations, variable amounts of sand, gravel, cobbles, and organic material. The thickness of the fill material ranges from about 0.4 to 0.7 metres.

The water content of recovered samples of the fill material ranges from about 13 to 32 percent.

5.4 Silty Clay

Native deposits of silty clay were encountered at all borehole locations beneath the topsoil or fill. The thickness of the silty clay ranges from about 3.9 metres to more than 8.6 metres.
The upper 2.3 to 2.8 metres of the silty clay deposits encountered consists of a very stiff to stiff grey brown weathered crust. Standard penetration tests carried out in the weathered crust gave N values ranging from “weight of hammer (WH)” to 8 blows per 0.3 metres of penetration. Atterberg limits tests carried out on samples of weathered silty clay recovered from boreholes 15-1 and 15-3 gave liquid limits of 52 and 27 and plastic limits of 25 and 16, respectively; as indicated on the plasticity chart on Figure A2, these reflect high and low plasticity values for the samples from boreholes 15-1 and 15-3, respectively. The water content of the weathered crust ranges from 24 to 61 percent.

The upper, weathered portion of the silty clay is underlain by grey silty clay. Standard penetration tests carried out within the grey silty clay deposits gave N values ranging from “weight of hammer (WH)” to 2 blows per 0.3 metres of penetration. In situ vane strength tests carried out in the grey silty clay generally gave strengths of 27 to 44 kilopascals, which indicate a firm consistency. One relatively low shear strength of 23 kilopascals was measured in the upper part of the grey silty clay at borehole 15-2; this shear strength value may be due to disturbance at the base of the borehole caused by the presence of sand/silt seams within the clay. Atterberg limits tests carried out on the samples of grey silty clay recovered from boreholes 15-1 and 15-3 gave liquid limits of 59 and 38 and plastic limits of 22, respectively; as indicated on the plasticity chart on Figure A2, these reflect low plasticity values for the samples from boreholes 15-1 and 15-3. The water content of the grey silty clay ranges from about 41 to 80 percent.

5.5 Layered Silt and Silty Clay

A deposit of layered, grey silt and silty clay was encountered below the silty clay in boreholes 15-1, 15-2 and 15-3. The thickness of the layered deposit ranges from about 0.5 metres to 1.4 metres.

Standard penetration tests carried out within the layered silt and silty clay deposit gave N values ranging from “weight of hammer (WH)” to 4 blows per 0.3 metres of penetration.

The water content of the layered silt and silty clay ranges from about 26 to 30 percent.

5.6 Glacial Till

Deposits of glacial till were encountered below the layered silt and silty clay in boreholes 15-1 and 15-3 at depths ranging from about 5.5 to 6.4 metres below ground surface. The glacial till can generally be described as grey sandy silt to silty sand with variable amounts of clay and gravel; cobbles and boulders should also be expected in the glacial till deposit. Standard penetration tests carried out in the glacial till gave N values ranging from 13 to 18 blows per 0.3 metres of penetration, which reflect a compact relative density.
A grain size distribution curve for a sample of the glacial till recovered from borehole 15-3 is provided on Figure A1. The water content of the glacial till ranges from about 7 to 21 percent.

5.7 Practical Auger Refusal

Practical auger refusal was encountered in boreholes 15-1 and 15-2 at depths ranging from about 5.7 to 7.3 metres below ground surface. It should be noted that refusal can also occur on large boulders and may not necessarily be representative of the bedrock.

5.8 Groundwater Levels

The following groundwater levels were measured on July 13, 2015:

**Table 5.1 – Groundwater Levels**

<table>
<thead>
<tr>
<th>Borehole</th>
<th>Groundwater Depth Below Existing Ground Surface (metres)</th>
<th>Groundwater Elevation (metres, geodetic datum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-2</td>
<td>2.42</td>
<td>99.65</td>
</tr>
<tr>
<td>15-4</td>
<td>2.58</td>
<td>98.69</td>
</tr>
</tbody>
</table>

It should be noted that groundwater levels may be higher during annual wet periods, such as early spring or following periods of heavy precipitation.

5.9 Soil Chemistry Relating to Corrosion

**Table 5.2 – Soil Chemistry Relating to Corrosion of Buried Concrete and Steel**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Borehole 15-3 (Sample 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphate</td>
<td>µg/g</td>
<td>14</td>
</tr>
<tr>
<td>Chloride</td>
<td>µg/g</td>
<td>5</td>
</tr>
<tr>
<td>pH</td>
<td>pH units</td>
<td>7.62</td>
</tr>
<tr>
<td>Resistivity</td>
<td>Ohm.m</td>
<td>61.7</td>
</tr>
</tbody>
</table>
6.0 GEOTECHNICAL GUIDELINES AND RECOMMENDATIONS

6.1 General

The information in the following sections is provided for the guidance of the design engineers and is intended for the design of this project only. Contractors bidding on or undertaking the works should examine the factual results of the investigation, satisfy themselves as to the adequacy of the information for construction, and make their own interpretation of the factual data as it affects their construction techniques, schedule, safety and equipment capabilities.

The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at this site. The presence or implications of possible surface and/or subsurface contamination resulting from previous uses or activities of this site or adjacent properties, and/or resulting from the introduction onto the site from materials from off site sources are outside the terms of reference for this report.

6.2 Site Grade Raise Restrictions

The site is underlain by deposits of grey silty clay, which has a limited capacity to support loads imposed by grade raise fill material and, to a lesser extent, the foundations for the proposed residential buildings.

The placement of fill material in the areas underlain by grey silty clay must therefore be carefully controlled so that the stress imposed by the fill material does not result in excessive consolidation of the deposit. The settlement response of the silty clay deposit to the increase in stress caused by fill material and groundwater lowering is influenced by variables such as the existing effective overburden pressure, the past preconsolidation pressure for the silty clay, the compressibility characteristics of the silty clay, and the presence or absence of drainage paths, etc. It is well established that the settlement response of silty clay deposits can be significant when the stress increase is at or near the difference between the preconsolidation pressure ($P_c$) and the existing overburden stress ($P'_o$).

The settlement of silty clay deposits consists of two major components: primary settlement and secondary (creep) settlement. Primary settlement occurs as the soil responds to the increase in stress by dispelling water (dissipation of excess porewater pressure), whereas secondary settlement occurs after the excess porewater pressure has dissipated. Secondary consolidation occurs at a slower rate than primary consolidation and usually occurs over a much longer period of time.

For design purposes, the grade raise fill restriction at the site is 1.5 metres. This grade raise restriction assumes that conventional silty clay earth fill is used around the proposed structures and that the maximum groundwater lowering due to the development of the site will be 1.5 metres below the measured groundwater levels. A more detailed assessment is recommended if the thickness of the earth fill exceeds 1.5 metres. The grade raise restriction has been
calculated in order to limit the total settlement of the foundations of the buildings to about 25 millimetres in the long term.

6.3 Proposed Buildings

6.3.1 Overburden Excavation
The excavations for the foundations should be taken through any surficial fill, topsoil, or otherwise deleterious material to expose undisturbed silty clay. The sides of the excavations should be sloped in accordance with the requirements in Ontario Regulation 213/91 under the Occupational Health and Safety Act. According to the Act, the shallow native overburden deposits can be classified as Type 3 and, accordingly, allowance should be made for excavation side slopes of 1 horizontal to 1 vertical extending upwards from the base of the excavation.

6.3.2 Groundwater Pumping
Based on the measured groundwater levels and the proposed underside of footing levels provided in Section 6.3.4 of this report, it is expected that the excavations for the foundations will be above the groundwater levels. Groundwater inflow into the excavations for the structures, if any, should be controlled by pumping from filtered sumps within the excavations. It is not expected that short term pumping during excavation will have a significant effect on nearby structures and services.

A Permit to Take Water (PTTW) may be required for pumping from within the excavations in accordance with Ministry of the Environment and Climate Change (MOECC) requirements, depending on the depth of the proposed excavations. The owner currently possesses a Category 3 PTTW ( Permit No. 5313-8WYKWW) for this development. The permit is valid through September 30, 2017.

The groundwater should be detained and filtered before it is released into any ditches or creeks.

6.3.3 Subgrade Preparation and Placement of Engineered Fill
Any existing topsoil, organic material, fill, and/or disturbed soil should be removed from below the proposed structures.

Imported granular material (engineered fill) should be used to raise the grade in areas where the proposed founding level is above the level of the native soil, or where subexcavation of material is required below proposed founding level. Engineered fill may be required, for example, where the footings are located in the area of the existing north-south aligned drainage ditch. The engineered fill should consist of granular material meeting Ontario Provincial Standard Specifications (OPSS) requirements for Granular B Type II and should be compacted in maximum 200 millimetre thick lifts to at least 95 percent of the standard Proctor maximum dry density. To allow spread of load beneath the footings, the engineered fill should extend horizontally at least 0.3 metres beyond the footings and then down and out from the edges of
the footings at 1 horizontal to 1 vertical, or flatter. The excavations should be sized to accommodate this fill placement.

6.3.4 Spread Footing Design

The proposed structures could be founded on spread footings bearing on or within the native weathered silty clay or on engineered fill above the native soils. The topsoil and any fill materials are not considered suitable for the support of the proposed structures or concrete floor/basement slabs and should be removed from the proposed building areas.

Based on the preliminary grading plan prepared by Novatech, it is expected that the underside of footing elevations for the low-rise buildings will be about 2.1 to 2.4 metres below the proposed exterior finished grade elevation (about elevations 100.8 to 101.1 metres). The footing elevations for the proposed semi-detached houses are anticipated to be about 1.8 metres below the proposed exterior finished grades (about elevations 101.0 to 101.4 metres). The following preliminary allowable bearing pressures could be used for sizing the footings, based on these proposed preliminary founding elevations, together with the proposed preliminary finished exterior grade elevations:

Table 6.1 – Preliminary Bearing Pressures

<table>
<thead>
<tr>
<th>Building No.* (west to east)</th>
<th>Approximate Minimum Existing Grade (metres)</th>
<th>Approximate Preliminary Finished Exterior Grade Elevation (metres)</th>
<th>Approximate Grade Raise Fill Amount (metres)</th>
<th>Preliminary Underside of Footing Elevation (metres)</th>
<th>Preliminary Allowable Bearing Pressure (kPa)</th>
<th>Exterior Strip (up to 0.6 m Wide)</th>
<th>Interior Pad (up to 2 m Square)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1 &amp; 2</td>
<td>101.9</td>
<td>103.2</td>
<td>1.3</td>
<td>101.1</td>
<td>90</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Lot 1 to Lot 3</td>
<td>101.8</td>
<td>103.0 to 103.1</td>
<td>1.2 to 1.3</td>
<td>100.5 to 100.8</td>
<td>90</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Lot 4</td>
<td>101.8</td>
<td>103.0</td>
<td>1.2</td>
<td>100.5</td>
<td>75</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Lot 5</td>
<td>101.8</td>
<td>102.8</td>
<td>1.1</td>
<td>100.5</td>
<td>75</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Lot 6 &amp; 7</td>
<td>101.7</td>
<td>102.9</td>
<td>1.2</td>
<td>100.5 and 100.4</td>
<td>60</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Lot 8 to Lot 10</td>
<td>101.4 to 101.5</td>
<td>102.6 to 102.7</td>
<td>1.2</td>
<td>100.3 to 100.4</td>
<td>40</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

*: Refer to Borehole Location Plan, Figure 2, for building numbering.
At the low-rise building locations, the proposed preliminary underside of footing levels are about 1 metre below the basement floor slab elevations. The allowable bearing pressures could be increased if the underside of footing elevations are raised.

Some of the native soils at this site are sensitive to construction operations, from ponded water and frost action. The construction operations should therefore be carried out in a manner that minimizes disturbance.

Based on our previous experience in this area, it is possible that the upper 0.3 to 0.5 metre portion of the weathered silty clay deposit has been affected by past frost action and may be unavoidably disturbed during the excavation for the footings. Allowance should be made to remove and replace any disturbed silty clay with compacted sand and gravel, such as that meeting OPSS Granular B Type II, where required, up to a maximum thickness of 0.3 metres. If more than 0.3 metres of OPSS Granular B Type II is required, the bearing pressure at SLS should be reviewed by the geotechnical engineer. The Granular B Type II should be compacted in maximum 200 millimetre thick lifts to at least 95 percent of the standard Proctor dry density value.

The post construction total and differential settlement of footings should be less than 25 and 15 millimetres, respectively, provided that all loose or disturbed soil is removed from the bearing surfaces and provided that any engineered fill material is compacted to the required density.

6.3.5 Seismic Site Classification
According to Table 4.1.8.4.A of the Ontario Building Code, 2012, Site Class D should be used for the seismic design of the structures.

In our opinion the soils are not considered to be liquefiable or collapsible under seismic loads.

6.3.6 Frost Protection of Foundations
All exterior footings should be provided with at least 1.5 metres of earth cover for frost protection purposes. Isolated, unheated exterior footings adjacent to surfaces which are cleaned of snow cover during the winter months (i.e. garage area, walkways, access roads, etc.) should be provided with a minimum of 1.8 metres of earth cover. Alternatively, the required frost protection could be provided by means of a combination of earth cover and extruded polystyrene insulation. Further details regarding the insulation of foundations could be provided at the detailed design stage, if necessary.

6.3.7 Basement Foundation Wall Backfill and Drainage
In accordance with the Ontario Building Code, the following alternatives could be considered for drainage of the basement foundation walls:
• Damp proof the exterior of the foundation walls and backfill the walls with free draining, non-frost susceptible sand or sand and gravel such as that meeting OPSS requirements for Granular B Type I or II. OR
• Damp proof the exterior of the foundation walls and install an approved proprietary drainage material on the exterior of the foundation walls and backfill the walls with native material or imported soil.

A perforated plastic foundation drain with a surround of clear crushed stone should be installed on the exterior of the foundation walls. A nonwoven geotextile should be placed between the top of the clear stone and any sandy foundation wall backfill material to avoid loss of sand backfill into the voids in the clear stone (and possible post construction settlement of the ground around the houses). The top of the drain should be located below the bottom of the floor slab. The drain should outlet to a sump from which the water is pumped or should drain by gravity to a storm sewer.

6.3.8 Basement Concrete Slab Support
To provide predictable settlement performance of the basement slabs, all topsoil, fill material, disturbed soil, and other deleterious materials should be removed from the slab areas.

The base for the floor slabs should consist of 19 millimetre clear crushed stone. Allowance should be made for at least 200 millimetres of base material. Compaction of the clear stone is not considered essential.

If clear crushed stone is used below the floor slabs, underfloor drains are not considered essential provided that drains are installed to link any hydraulically isolated areas in the basement. The drains should outlet by gravity to a sump from which the water is pumped or drained by gravity to a sewer.

The floor slabs should be constructed in accordance with guidelines provided in ACI 302.1R-04 “Guide for Concrete Floor and Slab Construction”.

6.3.9 Removing Agricultural Tile Drains in Proximity to Building Foundations
Portions of the site were previously used for agricultural purposes. As such, tile drains could be encountered in some portions of the site. Any tile drains which are encountered within the building excavations could be a source of significant volumes of water, which could impact on the basements. It is suggested that any drainage tiles that are within about 2 metres horizontal distance to the buildings be removed and the excavation for the tiles backfilled with compacted silty clay to prevent any water flow through the tiles or trenches. The silty clay could be compacted with the bucket of the excavator.

Any drainage tiles that are below the proposed footings and floor slabs should be removed.
6.4 Site Services

6.4.1 Overburden Excavation

Based on the available subsurface information, the excavations for the services within the site will be carried out through topsoil, fill, and silty clay.

The sides of the excavations within overburden soils should be sloped in accordance with the requirements in Ontario Regulation 213/91 under the Occupational Health and Safety Act. According to the Act, most of the soils at this site can be classified as Type 3 soils. Therefore, for design purposes, allowance should be made for 1 horizontal to 1 vertical, or flatter, excavation slopes within the upper 5 metres of the native soils at this site. As an alternative to sloping the excavations, all services installations could be carried out within a tightly fitting, braced steel trench box, which is specifically designed for this purpose.

It is noted that sloughing occurred in the weathered silty clay during excavation of some of the test pits during previous investigations. The instability is likely due to the presence of fissures in the weathered silty clay combined with high groundwater conditions and/or significant groundwater inflow. In areas where sloughing is encountered, the excavation for the site services should be carried out within a tightly fitting, braced steel trench box.

6.4.2 Groundwater Pumping

Groundwater inflow from the overburden deposits should be controlled by pumping from within the excavations. Significant groundwater inflow was observed from fissures in the weathered silty clay in some of the test pits that were advanced during the previous phases of the ground investigation. Allowance should be made for pumping where these conditions and/or if existing agricultural tile drains are encountered.

A Permit to Take Water (PTTW) may be required for pumping from within the excavations, in accordance with Ministry of the Environment and Climate Change (MOECC) requirements, depending on the depth of the proposed excavations. The owner currently possesses a Category 3 PTTW (Permit No. 5313-8WYKWW) for this development. The permit is valid through September 30, 2017.

The groundwater should be detained and filtered before it is released into any ditches or creeks.

6.4.3 Pipe Bedding

The bedding for the sanitary sewers, storm sewers and watermains should be in accordance with Ontario Provincial Standard Drawing (OPSD) 802.010/802.013 and 802.031/802.033 for flexible and rigid pipes, respectively. The pipe bedding should consist of at least 150 millimetres of well graded crushed stone meeting OPSS requirements for Granular A. City of Ottawa documents allow recycled asphaltic concrete and concrete to be used in Granular A and Granular B Type II material. Since the source of recycled material cannot be determined, it is
suggested that any granular materials used in the service trenches be composed of virgin (i.e., not recycled) material only.

Allowance should be made for subexcavation of any existing fill, organic deposits or disturbed material encountered at subgrade level. In areas where grey silty clay is encountered in the bottom of the excavation, we suggest that the excavation and final trimming to subgrade level be carried out with a shovel equipped with a flat blade bucket.

Allowance should be made to place a subbedding layer composed of 150 to 300 millimetres of OPSS Granular B Type II in areas where wet, grey silty clay is encountered at the pipe subgrade level to reduce the potential for disturbance.

Cover material, from pipe spring line to at least 300 millimetres above the top of the pipe, should consist of granular material, such as OPSS Granular A.

The use of clear crushed stone should not be permitted on this project, since it could exacerbate groundwater lowering of the overburden materials due to “French Drain” effects.

The subbedding, bedding and cover materials should be compacted in maximum 200 millimetre thick lifts to at least 95 percent of the standard Proctor maximum dry density using suitable vibratory compaction equipment.

6.4.4 Trench Backfill

The general backfilling procedures should be carried out in a manner that is compatible with the future use of the area above the service trenches.

In areas where the service trench will be located below or in close proximity to existing or future roadway or parking areas areas, acceptable native materials should be used as backfill between the roadway subgrade level and the depth of seasonal frost penetration in order to reduce the potential for differential frost heaving between the area over the trench and the adjacent section of roadway. Where native backfill is used, it should match the native materials exposed on the trench walls. Backfill below the zone of seasonal frost penetration could consist of either acceptable native material or imported granular material conforming to OPSS Granular B Type I. The depth of frost penetration in areas that are kept clear of snow is expected to be about 1.8 metres. Where cover requirements are not practicable, the pipes could be protected from frost using a combination of earth cover and insulation. Further details regarding insulation could be provided, if required.

It is anticipated that most of the inorganic overburden materials encountered during the subsurface investigation will be acceptable for reuse as trench backfill. Topsoil or other organic material should be wasted from the trench.
To minimize future settlement of the backfill and achieve an acceptable subgrade for the roadways, curbs, driveways, etc., the trench backfill should be compacted in maximum 300 millimetre thick lifts to at least 95 percent of the standard Proctor dry density value. The specified density for compaction of the backfill materials may be reduced where the trench backfill is not located below or in close proximity to existing or future areas of hard surfacing and/or structures.

The lower portion of the weathered silty clay and the grey silty clay have water contents that are above optimum for compaction. Furthermore, most of the overburden deposits at this site are sensitive to changes in moisture content. Unless these materials are allowed to dry, the specified densities will not likely be possible to achieve and, as a consequence, some settlement of these backfill materials could occur. Consideration could be implementing one or a combination of the following measures to reduce post construction settlement above the trenches, depending on the weather conditions encountered during the construction:

- Allow the overburden materials to dry prior to compaction.
- Reuse any wet materials in the lower part of the trenches and make provision to defer final paving of any roadways for 6 months, or longer, to allow some the trench backfill settlement to occur and thereby improve the final roadway appearance.
- Reuse any wet materials outside hard surfaced areas and where post construction settlement is less of a concern (such as landscaped areas).

The soils that exist at this site are highly frost susceptible and are prone to significant ice lensing. In order to carry out the work during freezing temperatures and maintain adequate performance of the trench backfill as a roadway subgrade, the service trenches should be opened for as short a time as practicable and the excavations should be carried out only in lengths which allow all of the construction operations, including backfilling, to be fully completed in one working day. The sides of the trenches should not be allowed to freeze. In addition, the backfill should be excavated, stored and replaced without being disturbed by frost or contaminated by snow or ice.

### 6.4.5 Seepage Barriers

The granular bedding in the service trench could act as a “French Drain”, which could promote groundwater lowering. As such, we suggest that seepage barriers be installed along the service trenches for the residential blocks just inside the property line, and that seepage barriers be installed at a spacing of about 100 metres along the storm sewers for the parking areas/access roadways. The seepage barriers should begin at subgrade level and extend vertically through the granular pipe bedding and granular surround to within the native backfill materials, and horizontally across the full width of the service trench excavation. The seepage barriers could consist of 1.5 metre wide dykes of compacted weathered silty clay. The weathered silty clay
should be compacted in maximum 300 millimetre thick lifts to at least 95 percent of the standard Proctor dry density value. The locations of the seepage barriers should be reviewed by us as the design progresses.

6.5 Access Roadway and Parking Areas

6.5.1 Subgrade Preparation

In preparation for roadway construction at this site, all surficial topsoil and any soft, wet or deleterious materials should be removed from the proposed roadway and parking areas. This would include the removal of any organic material and/or disturbed soil along the existing agricultural ditches.

Prior to placing granular material for the roadway, the exposed subgrade should be heavily proof rolled with a large (10 tonne) vibratory steel drum roller under dry conditions and inspected and approved by geotechnical personnel. Any soft areas evident from the proof rolling should be subexcavated and replaced with suitable (dry) earth borrow that is frost compatible with the materials exposed on the sides of the area of subexcavation.

Similarly, should it be necessary to raise the roadway grades at this site, material which meets OPSS specifications for Select Subgrade Material or earth borrow should be used. The select subgrade material or earth borrow should be placed in maximum 300 millimetre thick lifts and compacted to at least 95 percent of the standard Proctor maximum dry density value using vibratory compaction equipment.

Truck traffic should be avoided on the native soil subgrade, especially under wet conditions.

6.5.2 Pavement Design

The following minimum pavement structure should be used for the two access roadways within the residential development,

90 millimetres of hot mix asphaltic concrete (40 millimetres of Superpave 12.5 (Traffic Level A or B) over 50 millimetres of Superpave 19.0 (Traffic Level A or B)), over
150 millimetres of OPSS Granular A base over
450 millimetres of OPSS Granular B, Type II subbase

The following minimum pavement structure should be used for the parking areas within the residential development,

50 millimetres of hot mix asphaltic concrete (50 millimetres of Superpave 12.5 (Traffic Level A or B), over
150 millimetres of OPSS Granular A base over
375 millimetres of OPSS Granular B, Type II subbase
A somewhat thicker subbase layer is suggested for the parking areas than would normally be used (375 vs. 300 millimetres), since the parking areas will provide access to some heavy vehicles, such as garbage trucks, moving vans, etc. A similar pavement structure could be used for the driveways for the semi-detached houses, but the subbase layer can be reduced to 300 millimetres.

6.5.3 Effects of Soil Disturbance

If the roadway/parking area subgrade surface is disturbed or wetted due to construction operations or precipitation, the granular thickness given above may not be adequate and it may be necessary to increase the thickness of the Granular B Type II subbase and/or to incorporate a woven geotextile separator between the roadway subgrade surface and the granular subbase material. The adequacy of the design pavement thickness should be assessed by geotechnical personnel at the time of construction. In our experience, a geotextile will likely be required if the roadway construction is planned during the wet period of the year (such as the spring or fall).

Similarly, if the granular pavement materials are to be used by construction traffic, it may be necessary to increase the thickness of the Granular B Type II, install a woven geotextile separator between the roadway subgrade surface and the granular subbase material, or a combination of both, to prevent pumping and disturbance to the subbase material. The contractor should be made responsible for their construction access.

6.5.4 Granular Material Compaction

The pavement granular materials should be compacted in maximum 300 millimetre thick lifts to at least 98 percent of standard Proctor maximum dry density using suitable vibratory compaction equipment.

6.5.5 Asphaltic Concrete Types

The asphaltic concrete for the access roadways should consist of 40 millimetres of Superpave 12.5 over one 50 millimetre lift of Superpave 19.0. Performance grade PG 58-34 asphaltic cement should be specified.

The asphaltic concrete for the parking areas should consist of 50 millimetres of Superpave 12.5. Performance grade PG 58-34 asphaltic cement should be specified.

6.5.6 Transition Treatments and Frost Tapers

Where the new pavement structure will abut the existing pavement on Livery Street, the depths of the granular materials should taper up or down at 5 horizontal to 1 vertical, or flatter, to match the depths of the granular material(s) exposed in the existing pavement.

Granular frost tapers should be installed in accordance with OPSD 205.030 in areas where there is an abrupt transition from bedrock to overburden.
6.5.7 Pavement Drainage

The subgrade surface should be shaped and crowned to promote drainage of the roadway granular materials.

Adequate drainage if the pavement granular materials and subgrade is important for the long term performance of the pavement at this site. As such it is recommended that catch basins be provided with perforated stub drains extending about 3 metres out from the catch basins in two directions parallel to the roadway. These drains should be installed at the bottom of the subbase layer. Furthermore, it is suggested that full length drainage pipes be installed along the north, east and west sides of the proposed parking area to minimize possible localized frost heaving of the pavement.

6.6 Other Considerations

6.6.1 Corrosion of Buried Concrete and Steel

The measured sulphate concentration in the samples of soil recovered from boreholes 15-3 is 14 micrograms per gram. According to the Canadian Standards Associated (CSA) “Concrete Materials and Methods of Concrete Construction”, the concentration of sulphate in the groundwater samples can be classified as low. For low exposure conditions, any concrete that will be in contact with the native soil or groundwater should be batched with General Use (formerly Type 10) cement. The effects of freeze thaw in the presence of de-icing chemicals (sodium chloride) near the structures should be considered in selecting the air entrainment and the concrete mix proportions for any concrete.

Based on the conductivity and pH of the groundwater, the soil can be classified as non-aggressive towards unprotected steel. It is noted that the corrosivity of the soil/groundwater could vary throughout the year due to the application of sodium for de-icing.

6.6.2 Construction Induced Vibration

Some of the construction operations (such as granular material compaction, excavation, truck traffic, etc.) will cause ground vibration on and off of the site. The vibrations will attenuate with distance from the source, but may be felt at nearby structures. The magnitude of the vibrations should be much less than that required to cause damage to the nearby structures or services, but may be felt at the nearby structures. We recommend that preconstruction surveys be carried out on the adjacent structures and that vibration monitoring be carried out during the construction.

6.6.3 Winter Construction

In the event that construction is required during freezing temperatures, the soil below the footings should be protected immediately from freezing using straw, propane heaters and insulated tarpaulins, or other suitable means.
Any service trenches should be opened for as short a time as practicable and the excavations should be carried out only in lengths which allow all of the construction operations, including backfilling, to be fully completed in one working day. The materials on the sides of the trenches should not be allowed to freeze. In addition, the backfill should be excavated, stored and replaced without being disturbed by frost or contaminated by snow or ice.

Provision must be made to prevent freezing of any soil below the level of any existing structures or services. Freezing of the soil could result in heaving related damage to structures or services.

6.6.4 Excess Soil Management Plan
This report does not constitute an excess soil management plan. The disposal requirements for excess soil from the site have not been assessed.

6.6.5 Landscape Design
Based on the results of the geotechnical investigation, the site is underlain by deposits of silty clay, a material which is known to be susceptible to shrinkage with a change/reduction in moisture content. Research by the Institute for Research in Construction (formerly the Division of Building Research) of the National Research Council of Canada has shown that trees can cause a reduction of moisture content in the silty clay soils in the Ottawa area, which can result in significant settlement/damage to nearby buildings supported on shallow foundations bearing on or within these deposits. To minimize the potential for this, the separation distance between deciduous trees and structures should be greater than the ultimate height of the tree. For multiple trees, the separation distance should be increased to 1.5 times the trees’ ultimate height.

The landscape design plan should take into account the effects of all existing and future trees on structures, roads/hard surfaced areas, and services.

7.0 DESIGN REVIEW AND CONSTRUCTION OBSERVATION

The details for the proposed construction were not available to us at the time of preparation of this report. It is recommended that the design drawings be reviewed by the geotechnical engineer as the design progresses to ensure that the guidelines provided in this report have been interpreted as intended.

The engagement of the services of Houle Chevrier Engineering Ltd. during construction is recommended to confirm that the subsurface conditions throughout the proposed excavations do not materially differ from those given in the report and that the construction activities do not adversely affect the intent of the design.
The subgrade surfaces for the proposed structures, utilities and roadways should be inspected by experienced geotechnical personnel to ensure that suitable materials have been reached and properly prepared. The placing and compaction of earth fill and imported granular materials should be inspected to ensure that the materials used conform to the grading and compaction specifications.

In accordance with City of Ottawa requirements, all foundation subgrades and footings should be inspected and approved by geotechnical personnel. In accordance with Section 4.2.2.2 of the Ontario Building Code, full time inspection is required during placing and compaction of engineered fill and imported granular materials to ensure that the materials used conform to the grading and compaction specifications.

We trust this report provides sufficient information for your present purposes. If you have any questions concerning this report, please do not hesitate to contact our office.

Andrew Chevrier, M.Eng., P.Eng.
Senior Geotechnical Engineer
APPENDIX A

Record of Boreholes
Figures A1 and A2
LIST OF ABBREVIATIONS AND TERMINOLOGY

SAMPLE TYPES

AS  auger sample
CS  chunk sample
DO  drive open
MS  manual sample
RC  rock core
ST  slotted tube
TO  thin-walled open Shelby tube
TP  thin-walled piston Shelby tube
WS  wash sample

SOIL DESCRIPTIONS

Relative Density     ‘N’ Value
Very Loose           0 to 4
Loose                4 to 10
Compact              10 to 30
Dense                30 to 50
Very Dense           over 50

Consistency    Undrained Shear Strength (kPa)
Very soft        0 to 12
Soft             12 to 25
Firm             25 to 50
Stiff            50 to 100
Very Stiff       over 100

LIST OF COMMON SYMBOLS

c_u  undrained shear strength
e  void ratio
C_c  compression index
c_v  coefficient of consolidation
k  coefficient of permeability
I_p  plasticity index
n  porosity
u  pore pressure
w  moisture content
w_l  liquid limit
w_p  plastic limit
\phi'  effective angle of friction
\gamma_u  unit weight of soil
\gamma'  unit weight of submerged soil
\sigma  normal stress

PENETRATION RESISTANCE

Standard Penetration Resistance, N
The number of blows by a 63.5 kg hammer dropped 760 millimetres required to drive a 50 mm drive open sampler for a distance of 300 mm. For split spoon samples where less than 300 mm of penetration was achieved, the number of blows is reported over the sampler penetration in mm.

Dynamic Penetration Resistance
The number of blows by a 63.5 kg hammer dropped 760 mm to drive a 50 mm diameter, 60° cone attached to ‘A’ size drill rods for a distance of 300 mm.

WH  Sampler advanced by static weight of hammer and drill rods.

WR  Sampler advanced by static weight of drill rods.

PH  Sampler advanced by hydraulic pressure from drill rig.

PM  Sampler advanced by manual pressure.

SOIL TESTS

C  consolidation test
H  hydrometer analysis
M  sieve analysis
MH  sieve and hydrometer analysis
U  unconfined compression test
Q  undrained triaxial test
V  field vane, undisturbed and remoulded shear strength
### Record of Borehole 15-1

#### Soil Profile

<table>
<thead>
<tr>
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<th>Description</th>
<th>Elevation</th>
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<th>Type</th>
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<td>0.08</td>
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#### Boring Method

Power Auger

#### Additional Details

- Backfilled with soil cuttings
- Grey brown clayey silt, some gravel, trace organic material (TOPSOIL/FILL)
- Dark grey brown silty clay, trace gravel, trace organic material and wood (FILL)
- Very stiff to stiff, grey brown SILTY CLAY (Weathered Crust)

#### Additional Lab Testing

- Hydrometric Testing
- Dynamic Penetration Resistance, Blows/0.3m
- Shear Strength
- Natural V, Rem. V
- U - C
- Water Content, Percent
- Hydraulic Conductivity, k, cm/s

#### Sampling

- الطبقات المتبقيَة:
  - 0.01: Surface Level
  - 0.02: Grey brown clayey silt, some gravel, trace organic material (TOPSOIL/FILL)
  - 0.03: Dark grey brown silty clay, trace gravel, trace organic material and wood (FILL)
  - 0.04: Very stiff to stiff, grey brown SILTY CLAY (Weathered Crust)
  - 0.05: Firm, grey SILTY CLAY
  - 0.06: Layered, grey, SILT, trace clay and SILTY CLAY
  - 0.07: Grey sandy silt, trace clay, trace gravel, probably cobbles and boulders (GLACIAL TILL)
  - 0.08: Borehole terminated due to power auger refusal on inferred boulders or bedrock

#### Boring Details

- **Project:** 63282.06
- **Location:** See Borehole Location Plan, Figure 2
- **Boring Date:** June 23, 2015

---

**Note:** This document contains a detailed log of a borehole, including descriptions of soil layers, measurements, and additional testing results. It is part of a larger report on geotechnical investigations.
## RECORD OF BOREHOLE 15-3

**LOCATION:** See Borehole Location Plan, Figure 2  
**BORING DATE:** June 23, 2015  
**SPT HAMMER:** 63.5 kg; drop 0.76 metres

### SOIL PROFILE

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<td>8.23</td>
</tr>
<tr>
<td>7</td>
<td>D.O.</td>
<td>End of borehole</td>
<td>8.23</td>
<td>-</td>
</tr>
</tbody>
</table>

### BACKFILLED WITH SOIL CUTTINGS

- Backfilled with soil cuttings at depth 0.05 m.
### SOIL PROFILE

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>STRATA PLOT</th>
<th>ELEV (m)</th>
<th>DEPTH (m)</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Surface</td>
<td></td>
<td>101.27</td>
<td></td>
<td>G.S.</td>
</tr>
<tr>
<td>Brown silty clay, trace to some sand, trace gravel and cobbles (FILL MATERIAL)</td>
<td></td>
<td>100.69</td>
<td>0.58</td>
<td>O.</td>
</tr>
<tr>
<td>Very stiff to stiff, brown SILTY CLAY, trace fine sand (Weathered Crust)</td>
<td></td>
<td>98.22</td>
<td>3.08</td>
<td>O.</td>
</tr>
<tr>
<td>Piece gravel and sea shell fragments encountered between depths 2.3 to 2.7 metres</td>
<td></td>
<td>92.12</td>
<td>9.15</td>
<td>O.</td>
</tr>
<tr>
<td>Stiff to firm, grey brown SILTY CLAY</td>
<td></td>
<td>98.69</td>
<td>2.58</td>
<td>O.</td>
</tr>
<tr>
<td>End of borehole</td>
<td></td>
<td>98.22</td>
<td>2.7</td>
<td>O.</td>
</tr>
</tbody>
</table>

### ADDITIONAL LAB. TESTING

- **Dynamic Penetration Resistance, BLOWS/0.3m**
- **Hydraulic Conductivity, k, cm/s**
- **Shear Strength, Cu, kPa**
- **Water Content, Percent**
- **Additional**

### BORING METHOD

- **Power Auger**
- **200 mm Diameter Hollow Stem**
- **Stick up protector**
- **Bentonite seal**
- **Filler sand**
- **51 mm Diameter, 1.52 metres long well screen**
- **Backfilled with soil cuttings**

### RECORD OF BOREHOLE 15-4

**PROJECT:** 63282.06  
**LOCATION:** See Borehole Location Plan, Figure 2  
**BORING DATE:** June 23, 2015  
**LOGGED:** M.L.  
**CHECKED:**

**SPT HAMMER:** 63.5 kg; drop 0.76 metres
GRAN SIZE DISTRIBUTION
GLACIAL TILL

FIGURE A1

GRAIN SIZE DISTRIBUTION

% Passing

Sieve Size, mm

Grain Size, mm

Legend

Borehole

Sample

Depth (m)

% Gravel

% Sand

% Silt & Clay

- 15-3  8  6.9 - 7.5  21  40  40
**Group Symbol**

CL = Lean Clay  
ML = Silt  
CH = Fat Clay  
MH = Elastic Silt  
CL - ML = Silty Clay  
OL (Above "A" Line) = Organic Clay  
OL (Below "A" Line) = Organic Silt  
OH (Above "A" Line) = Organic Clay  
OH (Below "A" Line) = Organic Silt

**Legend**

<table>
<thead>
<tr>
<th>Legend</th>
<th>Borehole</th>
<th>Sample</th>
<th>Depth (m)</th>
<th>LL %</th>
<th>PL %</th>
<th>PI %</th>
</tr>
</thead>
<tbody>
<tr>
<td>●</td>
<td>15-1</td>
<td>3</td>
<td>0.9 - 1.5</td>
<td>52.0</td>
<td>25.0</td>
<td>27.1</td>
</tr>
<tr>
<td>□</td>
<td>15-1</td>
<td>6</td>
<td>3.2 - 3.7</td>
<td>43.8</td>
<td>22.3</td>
<td>21.5</td>
</tr>
<tr>
<td>▲</td>
<td>15-3</td>
<td>3</td>
<td>1.5 - 2.1</td>
<td>26.6</td>
<td>16.1</td>
<td>10.5</td>
</tr>
<tr>
<td>★</td>
<td>15-3</td>
<td>6</td>
<td>4.6 - 5.2</td>
<td>37.5</td>
<td>22.4</td>
<td>15.1</td>
</tr>
</tbody>
</table>

**Project:** 63282.06  
**Date:** July 2015
APPENDIX B

Record of Borehole and Test Pits
Previous Investigations by Houle Chevrier Engineering Ltd.
Groundwater inflow at 2.49 metres below ground surface on completion of excavation.
### Topsoil

- Very stiff, grey brown Silty Clay, trace to some fine sand (weathered crust)
- Soft, grey Silty Clay, trace fine sand

### Soil Profile

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Description</th>
<th>ELEV</th>
<th>Number</th>
<th>Type</th>
<th>Dynamics Penetration Resistance, Blow/0.3m</th>
<th>Shear Strength Cu, kPa</th>
<th>Hydraulic Conductivity, k cm/s</th>
<th>Dynamic Penetration Resistance, Blow/0.3m</th>
<th>Shear Strength Cu, kPa</th>
<th>Hydraulic Conductivity, k cm/s</th>
<th>Water Content, Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<td>0.30</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>TOPSOIL</td>
<td>101.40</td>
<td>1</td>
<td>508.7</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Very stiff, grey brown Silty Clay, trace to some fine sand (weathered crust)</td>
<td>1</td>
<td>503.2</td>
<td>O.O.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Soft, grey Silty Clay, trace fine sand</td>
<td>1</td>
<td>502.0</td>
<td>O.O.</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Soft, grey Clayey Silt</td>
<td>1</td>
<td>501.2</td>
<td>O.O.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>End of borehole</td>
<td>91.94</td>
<td>6</td>
<td>504.0</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>
### RECORD OF BOREHOLE 11-8

**PROJECT:** 11-190  
**LOCATION:** See Borehole Location Plan, Figure 2  
**BORING DATE:** July 18, 2011  
**DATUM:** Geodetic

**SOIL PROFILE**

<table>
<thead>
<tr>
<th>STRATA PLOT</th>
<th>DESCRIPTION</th>
<th>ELEV (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Surface</td>
<td>102.12</td>
<td></td>
</tr>
<tr>
<td>TOPSOIL</td>
<td>Very stiff, grey brown SILTY CLAY, trace sand (weathered crust)</td>
<td>101.97</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100.66</td>
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<tr>
<td></td>
<td>Stiff to firm, brown grey SILTY CLAY</td>
<td>100.52</td>
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<tr>
<td></td>
<td></td>
<td>98.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>95.16</td>
</tr>
<tr>
<td></td>
<td>Very loose, grey SILT, trace clay</td>
<td>95.26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>88.08</td>
</tr>
<tr>
<td></td>
<td>Compact to dense, grey silty sand, some gravel, trace clay containing cobbles and boulders (GLACIAL TILL)</td>
<td>95.26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>89.13</td>
</tr>
<tr>
<td></td>
<td>End of borehole</td>
<td>8.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.75</td>
</tr>
</tbody>
</table>

**SPT HAMMER:** 63.5 kg; 0.76 m drop

**ADDITIONAL LAB TESTING**

- Backfilled with soil cuttings

**Dynamic Penetration Resistance, Blows/0.3m**

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>TYPE</th>
<th>STRATA PLOT</th>
<th>BLOWS/0.3m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tr>
<tr>
<td>2</td>
<td>DO</td>
<td>98.17</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>DO</td>
<td>95.26</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>DO</td>
<td>68.08</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>DO</td>
<td>89.13</td>
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**Hydraulic Conductivity, k cm/s**

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<th>K cm/s</th>
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</thead>
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<td>DO</td>
<td>100.66</td>
<td>10^{-5}</td>
</tr>
<tr>
<td>2</td>
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</tr>
<tr>
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<td>DO</td>
<td>95.26</td>
<td>10^{-3}</td>
</tr>
<tr>
<td>4</td>
<td>DO</td>
<td>68.08</td>
<td>10^{-2}</td>
</tr>
<tr>
<td>5</td>
<td>DO</td>
<td>89.13</td>
<td>10^{-1}</td>
</tr>
</tbody>
</table>

**Piezometer or Standpipe Installation**

- Backfilled with soil cuttings

**Additional Lab Testing**

- Sample - Water content, percent
- Dynamic Penetration Resistance, blows/0.3m
- Shear Strength, Cu, kPa
- Hydraulic Conductivity, k cm/s

**Diagram:**

- Soil profile
- Depth scale
- Borehole log

**Log:**

- M.L.
- C.

**Checked:**

- M.L.
- C.

**Logged:**

- M.L.
- C.
**PROJECT:** 11-190  
**LOCATION:** See Borehole Location Plan, Figure 2  
**BORING DATE:** July 18, 2011  
**DATUM:** Geodetic  
**SPT HAMMER:** 63.5 kg; 0.76 m drop  

---

**SOIL PROFILE**

<table>
<thead>
<tr>
<th>STRATA PLOT</th>
<th>ELEV. (m)</th>
<th>TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>101.99</td>
<td>1</td>
<td>Ground Surface</td>
</tr>
<tr>
<td>1</td>
<td>101.33</td>
<td>5</td>
<td>loose, brown SILTY SAND, trace clay</td>
</tr>
<tr>
<td>2</td>
<td>99.70</td>
<td>4</td>
<td>Very stiff grey brown SILTY CLAY, trace to some sand (weathered crust)</td>
</tr>
<tr>
<td>3</td>
<td>99.22</td>
<td>2</td>
<td>Firm grey SILTY CLAY, trace sand</td>
</tr>
<tr>
<td>4</td>
<td>93.61</td>
<td>2</td>
<td>Very loose, grey SILT, trace clay</td>
</tr>
<tr>
<td>5</td>
<td>92.84</td>
<td>1</td>
<td>Very loose, grey silty sand, some gravel, trace clay containing cobbles and boulders (GLACIAL TILL)</td>
</tr>
<tr>
<td>6</td>
<td>92.23</td>
<td>1</td>
<td>End of borehole</td>
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**SAMPLES**

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<tbody>
<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
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</tbody>
</table>

---

**HYDRAULIC CONDUCTIVITY, k, cm/s**

<table>
<thead>
<tr>
<th>DEPTH (m)</th>
<th>k</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td></td>
</tr>
</tbody>
</table>

---

**DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m**

<table>
<thead>
<tr>
<th>DEPTH (m)</th>
<th>BLOWS/0.3m</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>60</td>
<td>80</td>
</tr>
</tbody>
</table>

---

**SHEAR STRENGTH, Cu, kPa**

<table>
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<th>DEPTH (m)</th>
<th>Cu</th>
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<tbody>
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</tr>
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<td>40</td>
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<tr>
<td>60</td>
<td></td>
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<tr>
<td>80</td>
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**WATER CONTENT, PERCENT**

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<th>DEPTH (m)</th>
<th>Water Content</th>
</tr>
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<tbody>
<tr>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>80</td>
<td>80</td>
</tr>
</tbody>
</table>

---

**ADDITIONAL LAB TESTING**

- Wp
- Wl

---

**LOGGED:** M.L.  
**CHECKED:**

---

**Note:** Proposed sewer invert at about 94.36 metres, geodetic

---

**PROJECT LOG:**  
**LOCATION LOG:** See Borehole Location Plan, Figure 2  
**BORING DATE:** July 18, 2011  
**DATUM:** Geodetic  
**SPT HAMMER:** 63.5 kg; 0.76 m drop  

---

**GUARDIAN**

---

**Houle Chevrier Engineering**

---

**Groundwater level observed at 1.22 metres below ground surface on August 11, 2011.
Void Ratio, (e)

Pressure, (kPa)

Borehole Sample Depth (m)
BH 10-7 TP 2 5.3 - 5.9

Determined Properties:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>W</td>
<td>66</td>
</tr>
<tr>
<td>W_L</td>
<td>53</td>
</tr>
<tr>
<td>W_p</td>
<td>22</td>
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</tbody>
</table>

Test Results:

<p>| | |</p>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C_r</td>
<td>0.15</td>
</tr>
<tr>
<td>C_o</td>
<td>1.26</td>
</tr>
<tr>
<td>σ'_p</td>
<td>120 kPa</td>
</tr>
</tbody>
</table>

Date: February 2011
Project: 10-418
VOID RATIO, (e)

Determined Properties:

<table>
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<th>Value</th>
</tr>
</thead>
<tbody>
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<td>W</td>
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<td>W_L</td>
<td>51</td>
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<tr>
<td>W_p</td>
<td>22</td>
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<tr>
<td>C_i</td>
<td>0.12</td>
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<tr>
<td>C_o</td>
<td>1.14</td>
</tr>
<tr>
<td>σ'_p</td>
<td>155 kPa</td>
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</tbody>
</table>

Test Results:

Date: February 2011
Project: 10-418
APPENDIX C

Results of Chemical Testing Related to Corrosion
Certificate of Analysis

Houle Chevrier
32 Steacie Drive
Kanata, ON K2K 249
Attn: Blasco Vitayabaskaran

Client PO: Order #: 1527330
Project: 63282.06 (15-183)
Custody: 22554

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

<table>
<thead>
<tr>
<th>Paracel ID</th>
<th>Client ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1527330-01</td>
<td>BH15-3 SA-4/7'6&quot;-9'6&quot;</td>
</tr>
</tbody>
</table>

Approved By: Mark Foto, M.Sc. For Dale Robertson, BSc
Laboratory Director

Any use of these results implies your agreement that our total liability in connection with this work, however arising shall be limited to the amount paid by you for this work, and that our employees or agents shall not under circumstances be liable to you in connection with this work.
## Analysis Summary Table

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Method Reference/Description</th>
<th>Extraction Date</th>
<th>Analysis Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anions</td>
<td>EPA 300.1 - IC, water extraction</td>
<td>8-Jul-15</td>
<td>8-Jul-15</td>
</tr>
<tr>
<td>pH</td>
<td>EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.</td>
<td>6-Jul-15</td>
<td>6-Jul-15</td>
</tr>
<tr>
<td>Resistivity</td>
<td>EPA 120.1 - probe, water extraction</td>
<td>8-Jul-15</td>
<td>8-Jul-15</td>
</tr>
<tr>
<td>Solids, %</td>
<td>Gravimetric, calculation</td>
<td>6-Jul-15</td>
<td>6-Jul-15</td>
</tr>
</tbody>
</table>
# Certificate of Analysis

**Client:** Houle Chevrier  
**Client PO:**  
**Project Description:** 63282.06 (15-183)  
**Order #:** 1527330  
**Report Date:** 09-Jul-2015  
**Order Date:** 3-Jul-2015

### Physical Characteristics

<table>
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<tr>
<th>Characteristic</th>
<th>Value</th>
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<tbody>
<tr>
<td>% Solids</td>
<td>0.1 % by Wt. 63.2</td>
</tr>
</tbody>
</table>

### General Inorganics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.62 (0.05 pH Units)</td>
</tr>
<tr>
<td>Resistivity</td>
<td>61.7 (0.10 Ohm.m)</td>
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</table>

### Anions

<table>
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<tr>
<th>Anion</th>
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<tbody>
<tr>
<td>Chloride</td>
<td>5 u/g dry</td>
</tr>
<tr>
<td>Sulphate</td>
<td>14 u/g dry</td>
</tr>
</tbody>
</table>

---

P: 1-800-749-1947  
E: PARACEL@PARACELLABS.COM  
W: WWW.PARACELLABS.COM  
OTTAWA - EAST  
300-2315 St. Laurent Blvd.  
Ottawa, ON K1G 4J8  
OTTAWA - WEST  
104-165 Stafford Rd. W.  
Nepean, ON K2H 9C1  
MISSISSAUGA  
6545 Kipling Rd. Unit #27  
Mississauga, ON L5N 6J3  
NIAGARA  
380 York Rd. Unit 16B  
Niagara-on-the-Lake, ON L0S 1J0  
SARNIA  
219-764 Mira St.  
Point Edward, ON N7V 1X4  
KINGSTON  
1658 Gardiners Rd.  
Kingston, ON K7P 1R7  
Page 3 of 7
### Method Quality Control: Blank

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<th>%REC RPD</th>
<th>RPD Limit</th>
<th>Notes</th>
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<td>ug/g</td>
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**General Inorganics**

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<th>Reporting Limit</th>
<th>Units</th>
<th>Source</th>
<th>%REC Limit</th>
<th>%REC RPD</th>
<th>RPD Limit</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistivity</td>
<td>ND</td>
<td>0.10</td>
<td>Ohm.m</td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>
## Method Quality Control: Duplicate

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Result</th>
<th>Reporting Limit</th>
<th>Units</th>
<th>Source Result</th>
<th>%REC Limit</th>
<th>RPD Limit</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anions</strong></td>
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<tr>
<td>Chloride</td>
<td>ND</td>
<td>5</td>
<td>ug/g dry</td>
<td>5.2</td>
<td>0.0</td>
<td>20</td>
<td></td>
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<tr>
<td>Sulphate</td>
<td>12.4</td>
<td>5</td>
<td>ug/g dry</td>
<td>14.3</td>
<td>13.9</td>
<td>20</td>
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<td><strong>General Inorganics</strong></td>
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<td></td>
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<tr>
<td>pH</td>
<td>7.21</td>
<td>0.05</td>
<td>pH Units</td>
<td>7.15</td>
<td>0.8</td>
<td>10</td>
<td></td>
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<tr>
<td>Resistivity</td>
<td>41.7</td>
<td>0.10</td>
<td>Ohm.m</td>
<td>42.0</td>
<td>0.8</td>
<td>20</td>
<td></td>
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<tr>
<td><strong>Physical Characteristics</strong></td>
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<tr>
<td>% Solids</td>
<td>76.4</td>
<td>0.1</td>
<td>% by Wt.</td>
<td>80.0</td>
<td>4.6</td>
<td>25</td>
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</table>
## Method Quality Control: Spike

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<th>Analyte</th>
<th>Result</th>
<th>Units</th>
<th>Source Result</th>
<th>%REC</th>
<th>%REC Limit</th>
<th>RPD</th>
<th>RPD Limit</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride</td>
<td>9.8</td>
<td>mg/L</td>
<td>0.5</td>
<td>92.9</td>
<td>78-113</td>
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<tr>
<td>Sulphate</td>
<td>10.7</td>
<td>mg/L</td>
<td>1.43</td>
<td>92.3</td>
<td>78-111</td>
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Certificate of Analysis

Client: Houle Chevrier

Order #: 1527330

Report Date: 09-Jul-2015
Order Date: 3-Jul-2015

Client PO: Project Description: 63282.06 (15-183)

Qualifier Notes:
None

Sample Data Revisions
None

Work Order Revisions / Comments:
None

Other Report Notes:
n/a: not applicable
ND: Not Detected
MDL: Method Detection Limit
Source Result: Data used as source for matrix and duplicate samples
%REC: Percent recovery.
RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'. Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.
<table>
<thead>
<tr>
<th>Paracel Order Number:</th>
<th>1527330</th>
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</table>

<table>
<thead>
<tr>
<th>Sample ID/Location Name</th>
<th>Matrix</th>
<th>Air Volume</th>
<th>Sample Taken</th>
<th>Date</th>
<th>Time</th>
<th>Chloride</th>
<th>pH</th>
<th>Resistivity</th>
<th>Sulphate</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH 15-3 SA-9 76'-9' 6&quot;</td>
<td>S</td>
<td>1</td>
<td>X</td>
<td>23/06/2017</td>
<td></td>
<td></td>
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Comments:

Refused By (Sign): Blasco V5
Refused By (Print): Hector Young
Date/Time: 07/06/2017

Method of Delivery: walk-in
geotechnical
environmental
hydrogeology
materials testing & inspection