Geotechnical Investigation
West Holland Landing Sanitary Collector Sewer
Holland Landing, Ontario

Prepared for:

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1 Background and Introduction

This report presents the results of a geotechnical investigation carried out for the planning and design of the proposed West Holland Landing Collector Sewer over a length of about 1 km. The sewer is expected to be either 750 mm or 975 mm in diameter. It will flow north along Holland Landing Road under gravity until Bradford Street, where it will turn east, crossing under the GO Transit railway and the East Holland River to connect to the Bradford Street Pumping Station of the York Durham Sanitary Trunk Sewer (YDSS) system. The profile of the sewer was not available at the time of this investigation, but its invert depths are expected to vary from about 5 to 11 m. Aside from the railway and river crossings, the sewer is expected to be installed in open trenches. Tunneling would be used for the crossings.

The purpose of the investigation was to establish the subsurface conditions along the route of the sewer by putting down a limited number of boreholes, and based on the results, provide geotechnical recommendations pertinent to the design and construction of the sewer.

This investigation was authorized by Marshall Macklin Monaghan (MMM) Group Ltd.

The comments and recommendations given in this report are based on the assumption that the above-described design concept will proceed into construction. If changes are made either in the design phase or during construction, this office must be retained to review those modifications. The result of this review may be a modification of our recommendations or it may require additional field or laboratory work to check whether the changes are acceptable from a geotechnical viewpoint.
2 Method of Investigation

The scope of the investigation was specified by the Client to consist of nine (9) boreholes to depths ranging approximately from 8 to 15 m below existing ground surface. A location plan showing nine (9) borehole locations on an aerial photograph of the area, was provided by MMM, together with the proposed depths of the boreholes.

The boreholes were put down between March 20 and March 22, 2008, using a truck mounted CME 75 power auger drill rig. The boreholes were located as close to the proposed locations as possible, based on site features. A senior technician from our office supervised the drilling of the boreholes. In the boreholes, samples were taken at 0.76 m intervals of depth in the upper 4 m, and at 1.5 m intervals below, using a split spoon sampler in conformance with the standard penetration test (ASTM D-1557). A portable gas detector was lowered into the boreholes to detect the possible presence of methane gas.

The samples were identified in the field, and forwarded to our laboratory where they were again examined by a senior engineer and selectively tested. Soil samples were tested in our laboratory for their natural moisture content, and selected samples were tested for grain size distribution. The results of the moisture content are summarized on the borehole logs, and the results of the grain size analyses are shown as Figure Nos. 1 to 3 attached in Appendix ‘B’ of this report.

In addition to the index tests, three (3) soil samples were forwarded to an accredited laboratory (Entech) for environmental analysis. The environmental analysis undertaken included general and inorganic parameters listed in the MOE document entitled ‘Soil, Groundwater and Sediment Standards For Use Under Part XV.1 of the Environmental Protection Act’.

The water levels encountered in the open boreholes during and shortly after drilling were noted. In addition, observation wells were installed in six (6) of the boreholes for longer term monitoring of groundwater conditions.

The ground surface elevations at the borehole locations were referenced to a local benchmark as follows:

Local B. M.: top of manhole on the northern edge of Bradford Street, ~ 75 m to the east of East Holland River.

Geodetic Elevation: 223.34 m, as shown on a drawing provided by the Client.

The coordinates of the boreholes determined during field survey (with GPS equipment) and the borehole elevations are as shown in Table 1.
<table>
<thead>
<tr>
<th>Borehole No.</th>
<th>Elevation (m)</th>
<th>Easting</th>
<th>Northing</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH-1</td>
<td>224.1</td>
<td>620341</td>
<td>4884117</td>
</tr>
<tr>
<td>BH-2</td>
<td>226.4</td>
<td>620222</td>
<td>4884081</td>
</tr>
<tr>
<td>BH-3</td>
<td>226.1</td>
<td>620198</td>
<td>4884075</td>
</tr>
<tr>
<td>BH-4</td>
<td>227.5</td>
<td>620235</td>
<td>4883964</td>
</tr>
<tr>
<td>BH-5</td>
<td>229.5</td>
<td>620325</td>
<td>4883840</td>
</tr>
<tr>
<td>BH-6</td>
<td>225.8</td>
<td>620405</td>
<td>4883721</td>
</tr>
<tr>
<td>BH-7</td>
<td>225.8</td>
<td>620413</td>
<td>4883713</td>
</tr>
<tr>
<td>BH-8</td>
<td>230.8</td>
<td>620522</td>
<td>4883560</td>
</tr>
<tr>
<td>BH-9</td>
<td>226.7</td>
<td>620652</td>
<td>4883434</td>
</tr>
</tbody>
</table>
3 Subsurface Conditions

The boreholes encountered a variety of soil types including fill, organic deposits, non-cohesive soils (sand, silt), cohesive soils (silty clay and clayey silt), and silty sand to sandy silt till. Sand and silt form the majority of the soil profile in most of the borehole except Boreholes 6 and 7, where the silty sand to sandy silt till was found. Groundwater level is generally high. In the following paragraphs, the relevant properties of the various deposits are briefly described. For details of the subsurface conditions encountered at the borehole locations, reference should be made to the individual borehole logs, which are attached in Appendix ‘A’ of this report as Drawing Nos. 1 to 9 inclusive.

It should be noted that the soil boundaries indicated on the borehole logs are inferred from non-continuous sampling and observations during the drilling. These boundaries are intended to reflect transition zones, for the purpose of geotechnical design, and should not be interpreted as exact planes of geological change. The "Notes on Sample Description" preceding the borehole logs are an integral part of and should be read in conjunction with this report.

3.1 Pavement Structure

Six (6) boreholes (Nos. 1-3 and 6-8) along the planned collector sewer alignment were put down on the road surface through the pavement structure. The pavement structure was found to consist of 115 to 180 mm of asphaltic concrete on 270 mm to as much as 1380 mm granular base.

3.2 Fill

Fill was found in all the boreholes except for Borehole 3, where the granular base of the pavement structure appeared to be overlying the a thin layer of topsoil. The thickness of the fill material varies from 0.4 m to as much as 3.2 m.

The existing fill materials are heterogeneous in nature and are composed largely of clayey silt, sandy silt, or sand and gravel, with a trace of organic stains, topsoil inclusions or seams. Pieces of wood and brick were found occasionally in the fills.

Some of the near surface fills were frozen at the time of the investigation. Including the effects of frozen materials, and some high values apparently affected by boulders or wood in the fill, the standard penetration blow counts (SPT ‘N’ values) of the fills vary from 4 to a high of 60 blows per 0.3 m, indicating wide variability in compaction. It may be noted that the ‘N’ values mostly vary between 4 and 10 blows per 0.3 m. The moisture contents in the fill material range from 6% to 22%.
3.3 Topsoil, Organic Silt

No topsoil was identified at the existing grade at borehole locations. However, 0.1 to 0.4 m of buried topsoil was identified below the fill or the existing pavement in three boreholes.

Organic silt was encountered in three boreholes (Boreholes 1, 6, and 9) immediately below the fill. It may be noted that the three boreholes are located close to the East Holland River or its tributaries. The organic silt deposit varies from 1.3 m to 2.8 m in thickness and contains pieces of decomposed wood, rootlets and shells.

The ‘N’ values recorded in organic silt vary from 3 to 9 blows per 0.3 m, indicating loose condition. The moisture contents of the organic silts vary from a low of about 30% to a high of about 94%.

3.4 Sand

Sand was encountered in Boreholes 1 to 4 and 7, at depths between 1.0 and 8.8 m. The thickness of the sand varies from 1.8 to 7.8 m. The sand is poorly graded, and contains a trace of silt and a trace to some gravel. Two grading curves of the sand are shown in Figure 2 and Figure 3 attached. The tested samples are composed of 0 to 19% gravel, 74 to 97% sand and 3 to 7% silt. In most boreholes the sand is underlain by silt.

SPT blow counts obtained in the sand range from 9 to 46 blows per 0.3 m, indicating loose to dense, but generally compact to dense, conditions.

The moisture contents of the sand vary from 2 to 19%. Most of the sand samples were wet to saturated.

3.5 Silt

Silt was encountered in all boreholes except Boreholes 6 and 7. It forms the majority of the soil profile in Boreholes 4, 5 and 8 where its thickness is greater than 7 m. It was found underlining the sand in Boreholes 1 to 4 and extended to the bottom of Boreholes 2 to 4.

This silt contains some sand and some clay seams. A wide range of SPT blow counts were recorded in the silt, from five to 59 blows per 0.3 m, indicating loose to very dense conditions. Other than the top 3 m in Borehole 8, the silt is generally compact to very dense.

The moisture contents of the silt vary from 8 to 23%; some of the silt samples were saturated and slowly dilatant.

3.6 Silty Clay, Clayey Silt

These cohesive deposits were identified towards the bottom of Boreholes 1 and 5. The natural moisture content of these soils range from 19 to 23%. The standard penetration ‘N’ values of more than 33 blows per 0.3 m suggests hard consistency.
3.7 Silty Sand Till

Silty sand till was encountered in Boreholes 6 and 7, from about 4 to 4.9 m below ground surface to the bottom of the boreholes. Scattered gravel and cobbles were found in the till deposit. The moisture contents measured in the till deposit ranged from 8 to 18%. With standard penetration ‘N’ values ranging from 32 to 79 blows per 0.3 m, the till is dense to very dense. Two grain size curves of the till are shown in Figure 1 in Appendix B. The samples are composed of 11 to 16% gravel, 32 to 59% sand, 18 to 47% silt, and 7 to 10% clay.

3.8 Groundwater Conditions

The groundwater levels in the open boreholes were observed during and upon completion of drilling. In addition, monitoring wells were installed in 6 boreholes to allow for longer term observation. Table 2 summarizes the observed groundwater in open boreholes on completion and Table 3 shows the observation of ground water levels in the monitoring wells.

The groundwater levels observed in the open boreholes may not represent the true groundwater conditions due to the short period of observation, the low permeability of the site soils, and possibly surface water infiltration.

A transient perched water table could exist in the fill materials in times of heavy precipitation and during thawing in Spring. In the long term, some fluctuation in the groundwater levels is expected.

<table>
<thead>
<tr>
<th>Borehole No</th>
<th>Water Depth (m)</th>
<th>Elevation (m)</th>
<th>Depth to cave (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>3.5</td>
<td>226.0</td>
<td>13.7</td>
</tr>
<tr>
<td>6</td>
<td>4.3</td>
<td>221.5</td>
<td>5.8</td>
</tr>
<tr>
<td>8</td>
<td>2.6</td>
<td>228.2</td>
<td>2.6</td>
</tr>
</tbody>
</table>

Table 2 – Groundwater Level in Open Boreholes on Completion

<table>
<thead>
<tr>
<th>Borehole No</th>
<th>Date (mm/dd)</th>
<th>Time (Days)</th>
<th>Depth (m)</th>
<th>Elev. (m)</th>
<th>Date (mm/dd)</th>
<th>Time (Days)</th>
<th>Depth (m)</th>
<th>Elev. (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>03/26</td>
<td>6</td>
<td>3.1</td>
<td>221.0</td>
<td>03/28</td>
<td>8</td>
<td>3.0</td>
<td>221.1</td>
</tr>
<tr>
<td>2</td>
<td>03/26</td>
<td>5</td>
<td>4.9</td>
<td>221.5</td>
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<td>7</td>
<td>4.8</td>
<td>221.6</td>
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<tr>
<td>3</td>
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<td>5</td>
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<td>9</td>
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<td>4</td>
<td>1.7</td>
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<td>03/28</td>
<td>6</td>
<td>1.7</td>
<td>225.0</td>
</tr>
</tbody>
</table>

Table 3 – Summary of Groundwater Level in Piezometers
3.9  Environmental Considerations

Three (3) samples listed in Table 4 below were sent for environmental tests. The test results are presented in the Certificates of Analysis attached in Appendix ‘C’.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Borehole</th>
<th>Approximate Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BH-2</td>
<td>0.7 – 1.2</td>
</tr>
<tr>
<td>2</td>
<td>BH-5</td>
<td>0.7 – 1.2</td>
</tr>
<tr>
<td>3</td>
<td>BH-8</td>
<td>0.7 – 1.2</td>
</tr>
</tbody>
</table>

The results of the chemical tests are compared with the criteria listed in Table 2 of the MOE document titled, “Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act” - March 9, 2004. The selection of Table 2 is considered the most appropriate for this study, based on the following site conditions:

- The site and surrounding area are supplied with potable water that may be derived from local groundwater.
- Full depth restoration of contamination (if encountered) is assumed.

Based on the anticipated future site activities (residential sewage disposal system within road allowances), Community property use criteria under this Standard were considered to be applicable. Soils at the site were found to be classified as predominantly coarse textured.

The results of analytical testing for inorganic parameters indicate conformance of all soil samples with the Community Property Use Criteria except that the upper limit for Sodium Adsorption Ratio (SAR) is exceeded in two of the three samples tested and Electrical Conductivity (EC) is exceeded for all the three samples.

The SAR is higher than the permissible value of 12 for two (2) samples, with the lowest and highest values of 11.24 and 38.45 respectively, indicating generally higher value over the site. In addition, Electrical Conductivity (EC) was found to exceed the permissible limit of 1.4 mS/cm on all three (3) samples tested, with the lowest and highest values of 1.90 mS/cm and 3.03 mS/cm respectively.

In relation to the stratified site condition Standards, the SAR and EC criteria are not applicable.

The results of limited environmental tests indicate that excess site soils may be suitable for use on like sites (public roadways) requiring fill. Alternatively, excess soils may be taken to any land based sites being developed for industrial/commercial/community uses, subject to acceptance by the receiving site authorities, and for placement more than 2 m below the final grade. The excavated soils can also be disposed of at appropriately licensed landfill sites.
3.10 Gas Vapor

Monitoring for explosive gases was carried out at each borehole location using a MSA combustible gas indicator Model 60 calibrated for methane. Readings taken in the boreholes during the fieldwork operations did not detect methane gas, except for Boreholes 1, 7 and 9, where 0.4% was registered.

4 Discussion of Results

4.1 Sewer Support

A variety of soil types was encountered in the boreholes. For the support of sewers, the soils may be classified into four groups.

1. Fill

A layer of fill was found at ground surface in most of the boreholes. The fill materials are generally composed of heterogeneous mixture of sand and sandy silt but also contain gravel fractions and topsoil inclusions. A layer of old topsoil and/or organic stained materials was often found at the bottom of the fills. The fill thickness is generally less than 3 m; therefore it should have no major impact on the support of the proposed sewers. Where fill is encountered at pipe level, it should be sub-excavated and replaced with clean fills or pipe bedding materials, compacted to minimum 95% standard Proctor maximum dry density.

2. Organic Silt

The organic silt found in Boreholes 1, 6 and 9 is soft and compressible and not suitable for supporting the sewers. The organic silt should be mostly above the sewers; where encountered at pipe level, it must be sub-excavated and replaced with suitable fills or pipe bedding materials. The organic silt should also be excavated to at least one pipe diameter beyond the perimeter of the sewers to provide better lateral support.

3. Cohesive Soils and Glacial Tills

The native cohesive soils including the clayey silt, silty clay and the sany silt to silty sand tills should provide adequate to good support for the sewers on granular bedding.

4. Silty Sand, Sand, and Silt

Since the invert depths of the sewers are expected to range from 5 to 11 m, they are expected to be founded mostly on silty sand, sand, or silt.

These non-cohesive soils should provide adequate support for the sewers provided that they are not disturbed during construction. Being non-cohesive and mostly below the
groundwater table, these soils would not be stable when excavated in an open trench without temporary dewatering and/or shoring support, and caving condition likely would occur. Furthermore, the silt, sandy silt and the finer silty sand are dilatant soils, i.e. they tend to dilate (expand) when they are exposed and/or agitated by construction equipment or traffic. A sewer placed on dilated soils could experience large post construction settlements when the soils are later re-compressed by the weight of the backfill materials. Therefore it is imperative to prevent the silts and the fine sands from dilating. This can possibly be achieved by temporarily lowering the water table to below excavation level, or supporting the trench within interlocking sheet piles driven to a sufficient depth below excavation level. Once the excavation has reached the required depth, the exposed subgrades should be protected with a layer of granular materials or a skim coat of lean concrete to reduce the risk of disturbance.

4.2 Construction Conditions

The following discussion is not meant to pinpoint all potential construction problems, but to highlight the general construction conditions to be anticipated, conditions that may be taken into consideration in the design of the sewer. Except at the GO transit railway and the East Holland River tributary, the boreholes are about 200 m apart and the information revealed may not provide details relevant to actual construction conditions. The contractors bidding for the construction of the sewers, in this light, are urged to select the appropriate construction method and equipment based on their own experience with similar projects. If necessary, the contractor should carry out additional investigation to clarify the subsurface conditions and resolve any construction related issues.

4.2.1 Excavation Stability, Temporary Support and Construction Dewatering

All excavation should be carried out in accordance with the latest edition of the Occupation Health and Safety Act.

For the purpose of the Act, all the native cohesive soils and the glacial tills are classified as Type 2 soils. It should be feasible to excavate these soils to 45° and would likely remain temporarily stable during construction. Seepage through these soils should be minimal and it should be feasible to handle the flow by gravity drainage and pumping from filtered sumps. Locally where relatively thick sand seams are found in till deposits, the seepage rate could increase and it may be necessary to locally flatten the excavation.

The existing fills and the organic silts are classified as Type 3 soils. Although the organic silts are soft in some boreholes, it is expected that trenches up to 5 m deep in the organic silt should be temporarily stable when excavated to slope at 45° or flatter. To minimize the width of the trenches, the excavations could be supported by trench boxes or braced sheetings. If organic silt is found at depth greater than 5 m, or if the silt is softer than indicated in the boreholes, it may be necessary to flatten the excavation, or to provide shoring support.
The silty sand, sand, and silt are classified as Type 3 soils where they are above the water table, but they are far more likely to be found below water table, where they would be classified as Type 4 soils. OHSA suggests that positive support (i.e. shoring) is not required for 3H:1V excavation in Type 4 soils. However, even at this very gentle angle, caving conditions would likely develop due to seepage pressure. To maintain stability, these soils should either be temporarily dewatered, or be supported by interlocking sheet piles. Temporary dewatering could also inhibit dilation of the silt and the fine sands.

The conventional method of installing services in granular soils below the water table is by temporary dewatering. It may be possible to dewater the granular soils in isolated areas not near any rivers or creeks (e.g. near Boreholes 1, 6 and 7), using wells, well points, or eductor wells, with proper filter. Based on the results of grain size analyses of the non-cohesive soils, we estimate that the hydraulic conductivity of sandy and gravelly sand materials could range from $10^{-6}$ m/sec to $10^{4}$ m/sec. It should be noted that the drawdown created by dewatering for excavation along the Holland Landing road may cause the nearby residential houses to experience settlements, and/or affect the water level in domestic wells in the neighborhood. The effects of construction dewatering should be thoroughly investigated prior to construction. The dewatering system should be designed and installed by specialist contractors experienced in this field. The dewatering within the East Holland River basin may be subject to the review/approval of MOE and the conservation authority.

Due to the difficulties associated with dewatering, we envisage that part of the sewer installation would be carried out within interlocking sheet piles. Where used, the sheet piles should be driven to a sufficient depth below the excavation level to prevent piping failure, and should be braced as necessary. With the trenches enclosed within sheet piles, there will still be some minor seepage into the excavation, but the rate of flow will be greatly reduced. We estimate that for a 3 m deep trench with sheet piles driven to 3 m below excavation level, the rate of seepage into the excavation should be less than 30 l/day per metre of trench. The drawdown outside the sheet piles should be less than 1 m, and the cone of influence should extend to less than 50 m from the trench. The sheet piles will also reduce the width of the trench and limit the disturbance to the environmentally sensitive areas.

4.2.2 Creek Crossing

The sewers will cross a creek that is a tributary of the East Holland River. Boreholes 6 and 7 are located respectively just north and south of the creek. The boreholes encountered 2 to 2.5 m of fill, underlain by either organic silt or sand, which are in turn underlain by dense to very dense silty sand till. Groundwater in the area was at about 3 m depth (elevation 222.8 m) at the time of this study.

Subject to the approval of the appropriate authorities, this crossing could be accomplished in a sheet pile enclosed cut with temporary diversion of the creek. Alternatively the sewer could be installed inside a tunnel. The existing fill, organic silt, and the sand would not be stable at either the crown or the face of the tunnel, which should be constructed within the silty sand till stratum. The silty sand till is classified as a slow raveling to rapid raveling material, depending on the fines content of the soil. The crown of the tunnel should be
supported at all times, but the face of the tunnel should have sufficient stand up time for either a full face mechanical tunnel boring machine (TBM), or hand mining using hydraulic equipment within a shield with a forward hood. The silty sand till is dense to very dense and contain some cobbles and boulders. The tunneling equipment and method must be able to handle the boulders, which could be 0.3 m or larger. The crown of the tunnel should be at least one metre or 1.5 tunnel diameter, whichever is greater, below the top of the silty sand till to maintain stability. It should also be at least 1.5 diameter below creek bed. Some groundwater seepage into the tunnel is expected. The seepage rate should be moderate to slow, but could vary depending on the proportion of sand seams within the till.

In our opinion, a tunnel could be constructed in the silty sand till using hand mining or by mechanical TBM, with hand mining being more suitable for smaller diameter (up to about 1.5 m). Primary support can be provided by jacking a steel pipe; or by segmental steel plate liners (for larger diameter tunnels), or steel rib with timber laggings, erected within a shield. Any voids behind the primary linings should be grouted as soon as possible to reduce ground settlements. We estimate that with a 1.5 m diameter tunnel, at a depth of about 6 m below road surface, and with good workmanship, the road directly above the tunnel center line should experience less than 15 mm of settlement.

The access shafts for the tunnel construction will be excavated to a variety of materials including fill, organic silt, sand, and silty sand till. The shafts could be excavated within and supported by interlocking sheet piles driven into the silty sand till. Soldier piles with timber laggings could also be considered as the shoring support, provided that the water table in the sand is drawn down before excavation begins.

4.2.3 GO Transit Track Crossing

Along the Bradford Street, Boreholes 2 and 3 were put down to the east and west respectively of the GO Transit railway line to evaluate conditions for tunneling at the crossing. The stable ground water elevation was observed to be at elevation of about 221.6 m (4.5 to 4.8 m depth) at the time of this investigation. The boreholes encountered about 1 to 2 m of fill with topsoil inclusions, underlain by non-cohesive materials consisting of silty sand, sand, and silt to the full depths of exploration. The non-cohesive native soils are classified as fast raveling or flowing soils according to the Tunnelman's Ground Classification. These soils are not expected to be stable at either the crown or the unsupported face of a tunnel. Several methods could be considered for construction of the tunnel in the sand and silt soils:

1. The soils could be stabilized by temporary dewatering. The water table in the sand could be temporarily lowered by pumping from eductor wells. Since it will not be possible to install any wells within the railway right of way, it would be necessary to install a large number of wells parallel to the railway line, to a sufficient distance away from the tunnel. Dewatering could cause ground settlement, affecting the railway and or any domestic wells in the vicinity. Before dewatering is carried out, the effect of dewatering should be carefully investigated.
2. The tunnel could be constructed using a full face TBM with a slurry shield. Slurry shields are also available with some micro tunneling machines. The slurry pressure balances the soil and groundwater pressure and maintain stability of the face of the tunnel.

3. Depending on the depth of the tunnel and the fines content of the sand, compressed air could be used to stabilize the sand. Using compressed air will require the installation of air tight bulkheads, and will slow down the progress of construction. All compressed air works must comply with the regulations of the Occupational Health and Safety Act.

4. The sewer could also be installed using horizontal directional drilling. Directional drilling has been successfully used to install pipes up to about 900 mm in Ontario. Larger and more powerful equipment are reportedly available in the U.S. This method has the advantage of eliminating the need for access shafts, and is feasible in unstable ground such as wet sand and silt materials. The drill hole is stabilized using a drilling fluid (drilling mud) to counteract soil and hydrostatic pressures. With this method, the utility pipelines are often pulled into a fluid stabilized drilled hole, without the need to install an oversized liner, therefore field weldable flexible material must be used for the sewer. Otherwise an oversized flexible liner would have to be installed first and then the sewer pipes pulled through and installed in place.

The crown of the tunnel should be at least 1.5 diameter below the underside of any existing fill or topsoil. Primary support can be provided by jacking a steel pipe, or by other means as discussed in the preceding section of this report. With proper construction procedures to prevent unexpected ground losses, and good workmanship, the railway directly above the tunnel is expected to experience less than 20 mm of settlement. Careful monitoring of the railway and the adjacent grounds should be carried out before, during, and after construction to verify the amount of actual ground/rail settlement.

The shafts for the tunnel can be excavated within interlocking sheet piles, driven to a sufficient depth below the bottom of the excavation to cut off the groundwater. Alternatively the sand can also be temporarily dewatered, after which the shaft can be supported by conventional soldier piles with timber laggings.

4.2.4 East Holland River Crossing

The sewer will cross the East Holland River at a location of about 50 m north of Bradford Street. Due to property issue, a borehole could not be put down at that location. Instead, Borehole 1 was put down on Bradford Street west of the river. In an investigation competed by Trow (Ref. brge0069842d), a borehole (Borehole 522) was put down on the east side of the river. These boreholes encountered organic silt, underlain by gravelly sand, or sand and gravel, followed by layers of clayey silt and silty clay. Borehole 1 also encountered about 4 m of fill above the organic silt. Groundwater level was at about 221 m at the time of the investigations.
Neither the organic silt, nor the underlying sand is expected to be stable in a tunnel excavation. In particular, the sand layer could be hydraulically connected to the river. Any excavation through this layer, could encounter substantial groundwater seepage. For this river crossing, the tunnel should be located in the clayey silt or the silty clay stratum, at a depth of at least 1 m or 1.5 tunnel diameter below the underside of the sand. In this regard, since Borehole 1 is located 50 m away from the crossing location, other boreholes should be put down close to the crossing to more clearly define the depth of the sand layer. The crown of the tunnel should also be at least two tunnel die meters below the river bed. Even at this depth, the crown of the tunnel should be supported at all times. The tunneling methods discussed in Section 4.2.2 above are applicable to this crossing. Horizontal directional drilling may also be considered.

The shafts for the tunnel can be excavated within interlocking sheet piles, driven to a sufficient depth into the clayey silt layer to cut off the groundwater. It may not be feasible to stabilize the sand layer by drawing down the groundwater level, especially if this layer is hydraulically connected to the river.

4.2.5 Re-use of Excavated Materials for Backfilling

Where a high degree of compaction is not required, which would apply to all areas not under roads, driveways or walkways, all excavated materials may be re-used for backfilling above the pipe zone.

In areas where long term settlement is to be avoided, only materials which can be compacted to a high density and which do not decay should be reused. Materials containing topsoil, organic silt and organic sand, and fill materials containing a high proportion of organic matter, should not be used. The inorganic native soils and most of the existing fill materials should be suitable to be re-used, but proper adjustment of moisture content may be necessary before re-using for efficient compaction.

4.2.6 Other Construction Issues

Most of the sanitary collector sewer aligns along the west bank of East Holland River. In view of the environmentally sensitive nature of the river basin, every effort should be made to preserve the natural ground cover and minimize damage to the natural environment.

5 Recommendations

5.1 Pipe Support and Bedding

The sewers should be founded on inorganic native soils, and should be provided with granular bedding in accordance with OPSD 802.030 to 802.032, or the equivalent Region of York standard.
If organic deposit is found at pipe level, all the organic soils under the sewer should be sub-excavated and replaced with clean fills or pipe bedding materials compacted to 95% standard Proctor maximum dry density (SPMDD). The organic soils should also be excavated laterally to one pipe diameter beyond the sewer pipe.

If fill materials are found at pipe level, the fills should be visually inspected. Unsuitable fills (materials that are wet, soft, have a high percentage of topsoil inclusions or organics) should be sub-excavated and replaced as described above.

Where the sewer is founded on silt or silty fine sand, the soils must be prevented from dilatation and excessive disturbance as discussed in Section 4.1 above.

Pipe bedding materials should be well graded (e.g. Granular ‘A’). If the subgrades are wet, clear stone or ‘High Performance Bedding’ may be used as pipe bedding provided that they are completely wrapped with a non woven filter fabric.

5.2 Earth Pressure and Temporary Shoring

Flexible retaining structures for the temporary support of trenches should be designed for the lateral earth pressures, deformations and stability conditions given in Chapter 26 of the Canadian Foundation Engineering Manual (CFEM), 4th Edition.

For internally braced (strutted) retaining structures for the temporary support of trenches in cohesionless soils (sand, silt, or gravel) the apparent earth pressure distribution shown in Figure 26.8 (a) of the CFEM should be used, with \( K_A = 0.3 \). Where it is necessary to limit the deflection of the shoring (e.g. near existing structures), the value of \( K_A \) should be increased to 0.5.

For all other inorganic stiff to hard cohesive soils, the pressure distribution shown in Figure 26.8 (c) may be used, with the maximum pressure being \( 0.25\sigma_{z=H} \). Where necessary, the maximum design pressure should be increased to \( 0.45\sigma_{z=H} \) to limit the deflection of the shoring.

For organic silt, the pressure distribution shown in Figure 26.8 (b) should be used, with the maximum pressure being \( 0.25\sigma_{z=H} \).

For layered soils, the method illustrated in Figure 26.8 (d) may be utilized to estimate the earth pressure to be supported using an earth pressure coefficient of 0.3 and a factor of 1.5 to account for partial mobilization of soil strength.

Water pressure and surcharge loads should be taken into consideration as appropriate in all cases.
5.3 Monitoring

For the crossing of the GO Transit Railway, a monitoring program should be implemented to verify the performance of the tunneling system and the effects on the railway. The program should consist of periodic monitoring of settlement and/or lateral movements of the rail embankment in the area of the tunnel, before, during, and after the construction. If significant movements are observed, the tunneling method will have to be revised.

5.4 Design Review

The design of the tunnel, including shop drawings and proposed construction method, should be reviewed by a geotechnical engineer to ensure that the recommendations provided in this report are correctly interpreted.

5.5 Backfill

Under roads, walkways, and other areas where long term ground settlement is not acceptable, the backfill materials should be placed in 300 mm loose lifts and compacted to minimum 95% SPMDD. In the upper 0.6 m of the backfills under roads and sidewalks, the degree of compaction should be increased to 98%.

It should be feasible to re-use most of the existing fill materials for backfilling the trenches in areas where a high degree of compaction is not required. Some of the more organic materials may have to be taken off site for disposal.
6 General Comments

Trow Associates Inc. should be retained for a general review of the final design and specifications to verify that this report has been properly interpreted and implemented. If not accorded the privilege of making this review, Trow Associates Inc. will assume no responsibility for interpretation of the recommendations in the report.

The comments given in this report are intended only for the guidance of design engineers. The number of boreholes required to determine the localized underground conditions between boreholes affecting construction costs, techniques, sequencing, equipment, scheduling, etc., could be substantially greater than has been carried out for design purposes. Contractors bidding on or undertaking the works should, in this light, decide on their own investigations, as well as their own interpretations of the factual borehole results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

More specific information with respect to the conditions between samples, or the lateral and vertical extent of materials may become apparent during excavation operations. The interpretation of the borehole information must, therefore, be validated during excavation operations. Consequently, during the future development of the property, conditions not observed during this evaluation may become apparent; should this occur, Trow Consulting Engineers Ltd. should be contacted to assess the situation, based on which additional testing and reporting may be required. Trow has qualified personnel to provide assistance in regards to future geotechnical and environmental issues related to this project.
7 Closure

We trust that this report has provided all the necessary information for the design of the sewer. Should you have any questions regarding this report, please do not hesitate to call the undersigned.

Trow Associates Inc.

Madan Karkee, PhD, PE
Senior Engineer
Geotechnical Division

James Ng, P.Eng., M.Eng., MICE
Senior Engineer
Geotechnical Division
Appendix 'A':
Notes on Sample Description;
Borehole Location Plan (Drawing No. 1)
Borehole Logs (Drawing No. 2 to 10)
Notes On Sample Descriptions

1. All sample descriptions included in this report follow the Canadian Foundations Engineering Manual soil classification system. This system follows the standard proposed by the International Society for Soil Mechanics and Foundation Engineering. Laboratory grain size analyses provided by Trow also follow the same system. Different classification systems may be used by others; one such system is the Unified Soil Classification. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually. Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems.

<table>
<thead>
<tr>
<th>ISSMGE SOIL CLASSIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLAY</td>
</tr>
<tr>
<td>FINE</td>
</tr>
<tr>
<td>0.002</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EQUIVALENT GRAIN DIAMETER IN MILLIMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLAY (PLASTIC) TO SILT (NONPLASTIC)</td>
</tr>
<tr>
<td>FINE</td>
</tr>
<tr>
<td>CLAY</td>
</tr>
</tbody>
</table>

2. Fill: Where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc., none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.

3. Till: The term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.
4. Excerpt from “OHSA Regulations for Construction Projects,” Part III, Section 226:

**Soil Types**

**Type 1 Soil**
- a) is hard, very dense and only able to be penetrated with difficulty by a small sharp object;
- b) has a low natural moisture content and a high degree of internal strength;
- c) has no signs of water seepage; and
- d) can be excavated only by mechanical equipment.

**Type 2 Soil**
- a) is very stiff, dense and can be penetrated with moderate difficulty by a small sharp object;
- b) has a low to medium natural moisture content and a medium degree of internal strength; and
- c) has a damp appearance after it is excavated.

**Type 3 Soil**
- a) is stiff to firm and compact to loose in consistency or is previously excavated soil;
- b) exhibits signs of surface cracking;
- c) exhibits signs of water seepage;
- d) if it is dry, may run easily into a well-defined conical pile; and
- e) has a low degree of internal strength.

**Type 4 Soil**
- a) is soft to very soft and very loose in consistency, very sensitive and upon disturbance is significantly reduced in natural strength;
- b) runs easily or flows, unless it is completely supported before excavating procedures;
- c) has almost no internal strength;
- d) is wet or muddy; and
- e) exerts substantial fluid pressure on its supporting system. O. Reg. 213/91, s. 226.
Log of Borehole 1

Project No: BRGE00301290A
Project: Geo. Investigation - West Holland Landing Sanitary Collector Sewer
Location: Bradford Street and Holland Landing Road, Holland Landing, Ontario

Datum: Geodetic

Date Drilled: March 20, 2008
Drill Type: CME 75 Drill

Soil Description

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Soil Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>224.10</td>
<td>PAVEMENT STRUCTURE 180mm asphaltic concrete over 620mm granular material</td>
</tr>
<tr>
<td>223.1</td>
<td>FILL - sandy silt; brown, moist, compact</td>
</tr>
<tr>
<td>222.6</td>
<td>- topsoil mixed with sand; dark brown and brown, moist</td>
</tr>
<tr>
<td>221.9</td>
<td>- sand and gravel; brown, moist, compact</td>
</tr>
<tr>
<td>221.4</td>
<td>- silty sand to sandy silt, some gravel; grey, moist to very moist, compact</td>
</tr>
<tr>
<td>221.10</td>
<td>- wood (partly decayed)</td>
</tr>
<tr>
<td>219.9</td>
<td>ORGANIC SILT - rootlets and pieces of decomposed wood; dark brown, moist to saturated, loose</td>
</tr>
<tr>
<td>216.6</td>
<td>GRAVELLY SAND - silt inclusions; brown, wet, dense</td>
</tr>
<tr>
<td>215.6</td>
<td>SILT - clay seams; grey, moist, dense to very dense</td>
</tr>
<tr>
<td>212.4</td>
<td>CLAYEY SILT - clay seams; grey, moist, hard</td>
</tr>
<tr>
<td>208.6</td>
<td>END OF BOREHOLE</td>
</tr>
</tbody>
</table>

End of borehole: 5.49m

Notes:
1. Gas reading in open borehole: 0.4% (using MSA Model 80)
2. Groundwater monitoring well installed to 9.14m; sealed with bentonite from surface to 5.49m.

- Shear Strength
- N Value
- Soil Unit Weight

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Shear Strength (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Natural Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Natural Module Content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Atterberg Limits (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>75</td>
</tr>
</tbody>
</table>

Natural Unit Weight (kN/m)

<table>
<thead>
<tr>
<th>Time</th>
<th>Water Level (m)</th>
<th>Depth to Cave (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On completion</td>
<td>4.3</td>
<td></td>
</tr>
<tr>
<td>After 8 days</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>After 8 days</td>
<td>3.0</td>
<td></td>
</tr>
</tbody>
</table>

Trow
Log of Borehole 2

Project No. BRGE00301290A
Project: Geo. Investigation - West Holland Landing Sanitary Collector Sewer
Location: Bradford Street and Holland Landing Road, Holland Landing, Ontario

(Bradford Street, East of GO Transit Tracks)

Date Drilled: March 21, 2008
Drill Type: CME 75 Drill
Datum: Geodetic

Soil Description
- PAVEMENT STRUCTURE 140mm asphaltic concrete
- FILL - heterogeneous mixture of fine sand and sandy silt, some gravel, topsoil inclusions, brown, moist, compact
- TOPSOIL - silt, dark brown, moist
- SILTY SAND - topsoil remains in upper level, rusty brown, moist, loose
- SAND - light brown to brown, moist to ~5m, wet below, compact to dense
- gravel and cobbles
- SILT - wet silty fine sand seams, brown, moist to saturated, dense to very dense

END OF BOREHOLE

NOTES:
1. Gas reading in open borehole: 0% (using MSA Model 60).
2. Groundwater monitoring well installed to 7.54m, sealed with bentonite from surface to 3.89m.

Trow
Log of Borehole 3

Project No. BRGE00301290A
Project: Geo. Investigation - West Holland Landing Sanitary Collector Sewer
Location: Bradford Street and Holland Landing Road, Holland Landing, Ontario.

Date Drilled: March 21, 2008
Drill Type: CME 75 Drill
Datum: Geodetic

Soil Description

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Soil Type</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0-1.0</td>
<td>PAVEMENT STRUCTURE 130mm asphaltic concrete over 680 mm granular material</td>
<td></td>
</tr>
<tr>
<td>1.0-2.0</td>
<td>TOPSOIL - sandy silt; black, moist</td>
<td></td>
</tr>
<tr>
<td>2.0-3.0</td>
<td>SILTY SAND - topsoil remains in upper level; rusty brown, moist, loose</td>
<td></td>
</tr>
<tr>
<td>3.0-11.0</td>
<td>SAND - light brown to dark brown, damp/moist to ~4.5m, wet below, compact to dense</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- becoming gravelly sand with some cobbles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- gravel and cobbles</td>
<td></td>
</tr>
<tr>
<td>11.0-11.5</td>
<td>SILT - brown, saturated, compact to dense</td>
<td></td>
</tr>
</tbody>
</table>

END OF BOREHOLE

NOTES:
1. Gas reading in open borehole: 0% (using MSA Model 60).
2. Groundwater monitoring well installed to 7.70m; sealed with bentonite from surface to 4.04m.
3. * G: Grain size analysis

Time | Water Level (m) | Depth to Cave (m)
-----|----------------|-----------------|
On completion | 4.6 | |
After 5 days | 4.6 | |
After 7 days | 4.5 | |

Trow
Log of Borehole 4

Project No: BRGE00301290A
Project: Geo. Investigation - West Holland Landing Sanitary Collector Sewer
Location: Bradford Street and Holland Landing Road, Holland Landing, Ontario.

(Holland Landing Road)

Date Drilled: March 22, 2008
Drill Type: CME 75 Drill
Datum: Geodetic

<table>
<thead>
<tr>
<th>Soil Description</th>
<th>ELEV. m</th>
</tr>
</thead>
<tbody>
<tr>
<td>FILL - sand and gravel; brown, frozen; to ~0.55m, followed by silty sand to sandy silt, some gravel, topsoil inclusions; brown, moist to very moist, loose</td>
<td>227.50</td>
</tr>
<tr>
<td>SILTY SAND - topsoil remains in upper level; rusty brown to brown, very moist to wet, loose to compact</td>
<td>225.8</td>
</tr>
<tr>
<td>SILT - clay seams, brown changing to grey at ~7m, saturated, very stiff to hard</td>
<td>223.5</td>
</tr>
</tbody>
</table>

END OF BOREHOLE

NOTES:
1. Gas reading in open borehole: 0% (using MSA Model 60)
2. Groundwater monitoring well installed to 10.67m; sealed with bentonite from surface to 7.01m.

Time | Water Level (m) | Depth to Cave (m)
--- | --- | ---
On completion | 2.5 | 
After 4 days | 2.5 | 
After 6 days | 2.5 | 

Trow
**Log of Borehole 5**

**Project No.: BRGE00301290A**

**Project:** Geo. Investigation - West Holland Landing Sanitary Collector Sewer

**Location:** Bradford Street and Holland Landing Road, Holland Landing, Ontario (Holland Landing Road)

**Date Drilled:** March 24, 2008

**Drill Type:** CME 75 Drill

**Datum:** Geodetic

<table>
<thead>
<tr>
<th>Soil Description</th>
<th>ELEV. (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fill - sand and gravel; brown, frozen; to ~0.4m; followed by heterogeneous mixture of silt and topsoil, some gravel; brown and dark brown, moist to very moist</td>
<td>229.50</td>
</tr>
<tr>
<td>Silt - brown, moist to saturated, compact</td>
<td>228.1</td>
</tr>
<tr>
<td>Silt - clay seams and traces of sand; brown changing to grey at ~5.5m; moist to saturated, very stiff to hard</td>
<td>226.2</td>
</tr>
<tr>
<td>Silty Clay - silt seams, grey, moist, hard</td>
<td>217.8</td>
</tr>
<tr>
<td>End of borehole</td>
<td>215.4</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Gas reading in open borehole: 0% (using MSA Model 80)

**Trow**

<table>
<thead>
<tr>
<th>Time</th>
<th>Water Level (m)</th>
<th>Depth to Cave (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On completion</td>
<td>3.5</td>
<td>13.7</td>
</tr>
</tbody>
</table>
Log of Borehole 6

Project No.: BRGE00301290A
Project: Geo. Investigation - West Holland Landing Sanitary Collector Sewer
Location: Bradford Street and Holland Landing Road, Holland Landing, Ontario.

(Holland Landing Road, North of Creek)

Date Drilled: March 20, 2008
Drill Type: CME 75 Drill
Datum: Geodetic

---

<table>
<thead>
<tr>
<th>Soil Description</th>
<th>ELEV. m</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAVEMENT STRUCTURE 120mm asphaltec concrete over 1380mm granular material</td>
<td>225.80</td>
</tr>
<tr>
<td></td>
<td>225.70</td>
</tr>
<tr>
<td>FILL - topsoil; black and dark brown, moist to very moist</td>
<td>224.3</td>
</tr>
<tr>
<td>ORGANIC SILT- some gravel, rootlets and shells; dark grey and brown, saturated, loose</td>
<td>220.9</td>
</tr>
<tr>
<td>- Some boulders</td>
<td></td>
</tr>
</tbody>
</table>

---

END OF BOREHOLE

NOTES:
1. Gas reading in open borehole: 0% (using MSA Model 60)

---

<table>
<thead>
<tr>
<th>Time</th>
<th>Water Level (m)</th>
<th>Depth to Cave (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On completion</td>
<td>4.3</td>
<td>5.8</td>
</tr>
</tbody>
</table>
Log of Borehole 7

Project No. BRGE00301290A
Project: Geo. Investigation - West Holland Landing Sanitary Collector Sewer
Location: Bradford Street and Holland Landing Road, Holland Landing, Ontario.

Date Drilled: March 21, 2008
Drill Type: CME 75 Drill
Datum: Geodetic

Soil Description

- **PAVEMENT STRUCTURE 180mm**
  - asphaltic concrete
  - over 510mm granular material

- **FILL** - heterogeneous mixture of sand, sandy silt and topsoil; brown and dark brown, moist to very moist

- **SAND** - fine to medium grained:
  - brown, moist and loose to ~3m, wet and compact below
  - gravel content

- **SILTY SAND TILL** - some gravel and cobbles; brown, moist with wet sand seams, dense to very dense
  - Some boulders
  - becoming sandy silt till

END OF BOREHOLE

**NOTES:**
1. Gas reading in open borehole: 0.4% (using MSA Model 50)
2. Groundwater monitoring well installed to 6.10m; sealed with bentonite from surface to 2.44m.
3. *G*: Grain size analysis

**Trow**
Log of Borehole 8

Project No. BRGE00301290A

Project: Geo. Investigation - West Holland Landing Sanitary Collector Sewer

Location: Bradford Street and Holland Landing Road, Holland Landing, Ontario

(Holland Landing Road)

Date Drilled: March 22, 2008

Drill Type: CME 75 Drill

Datum: Geodetic

Soil Description

PAVEMENT STRUCTURE AND FILL
- 115mm asphaltic concrete over ~270 mm over ~500 mm fill
- ~400 mm of TOPSOIL
SILT - clay seams, organic staining in upper level, brown changing to grey at ~5.5m, moist to saturated, firm to ~3m, stiff to hard below

END OF BOREHOLE

NOTES:
1. Gas reading in open borehole: 0% (using MSA Model 60)

<table>
<thead>
<tr>
<th>Time</th>
<th>Water Level (m)</th>
<th>Depth to Cave (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On completion</td>
<td>2.8</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Trow
Log of Borehole 9

Project No. BRGE000301290A
Project: Geo. Investigation - West Holland Landing Sanitary Collector Sewer
Location: Bradford Street and Holland Landing Road, Holland Landing, Ontario

Date Drilled: March 22, 2008
Drill Type: CME 75 Drill
Datum: Geodetic

Soil Description

226.70
FILL - sand and gravel; brown, frozen; to ~0.25 m; followed by heterogeneous mixture of silt and topsoil, some gravel; grey and dark brown, moist

225.3
ORGANIC SILT - rootlets and pieces of decomposed wood; dark brown, moist to saturated, loose

222.5
SILT - clay seams; brown changing to grey at ~5.5 m; saturated and stiff to ~6 m; very moist and hard below

END OF BOREHOLE

NOTES:
1. Gas reading in open borehole: 0.4% (using MSA Model 50)
2. Groundwater monitoring well installed to 7.62 m; sealed with bentonite from surface to 3.96 m.

Trow
Appendix 'B':
Grain Size Distribution Analysis
Appendix 'C':
Chemical Test Results
**CERTIFICATE OF ANALYSIS - SOIL STANDARDS FOR USE UNDER PART XV.1 OF THE ENVIRONMENTAL PROTECTION ACT (GENL. & INORGANIC)**

Data Pertain To Specific Sample(s) Tested

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>Standards (µg/g)</th>
<th>Method Detection</th>
<th>CONTROL SAMPLE</th>
<th>SAMPLE DATA (µg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tables 2</td>
<td>Tables 2 &amp; 3</td>
<td>Tables 4 &amp; 5</td>
<td>Expected</td>
</tr>
<tr>
<td>Dry Matter (%)</td>
<td>-</td>
<td>5 to 9</td>
<td>5 to 11</td>
<td>-</td>
</tr>
<tr>
<td>pH (units)</td>
<td>5 to 9</td>
<td>5 to 9</td>
<td>5 to 11</td>
<td>-</td>
</tr>
<tr>
<td>EC (mS/cm)</td>
<td>0.7</td>
<td>0.7/1.4</td>
<td>N.A./N.A.</td>
<td>-</td>
</tr>
<tr>
<td>SAR</td>
<td>5</td>
<td>5/12</td>
<td>N.A./N.A.</td>
<td>-</td>
</tr>
<tr>
<td>Arsenic</td>
<td>20</td>
<td>20/40</td>
<td>40/N.V</td>
<td>1</td>
</tr>
<tr>
<td>Cadmium</td>
<td>3</td>
<td>12/12</td>
<td>41/41</td>
<td>0.5</td>
</tr>
<tr>
<td>Chromium (VI) *</td>
<td>8</td>
<td>8/8</td>
<td>600/1100</td>
<td>1</td>
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<tr>
<td>Chromium (total)</td>
<td>750</td>
<td>750/750</td>
<td>2500/5000</td>
<td>0.5</td>
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<tr>
<td>Cobalt</td>
<td>40</td>
<td>40/80</td>
<td>2500/3400</td>
<td>0.5</td>
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<tr>
<td>Copper</td>
<td>150</td>
<td>225/225</td>
<td>2500/2500</td>
<td>0.5</td>
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<tr>
<td>Lead</td>
<td>200</td>
<td>200/1000</td>
<td>1000/N.V.</td>
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<tr>
<td>Mercury</td>
<td>10</td>
<td>10/10</td>
<td>57/57</td>
<td>0.05</td>
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<tr>
<td>Molybdenum</td>
<td>5</td>
<td>40/40</td>
<td>550/550</td>
<td>0.5</td>
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<tr>
<td>Nickel</td>
<td>150</td>
<td>150/150</td>
<td>710/710</td>
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<tr>
<td>Boron(HWE) *</td>
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<td>2.0/N.V</td>
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<tr>
<td>Cyanide Free</td>
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<td>100/100</td>
<td>100/200</td>
<td>0.1</td>
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<tr>
<td>Selenium</td>
<td>2</td>
<td>10/10</td>
<td>2500/2500</td>
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<tr>
<td>Silver</td>
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<td>20/40</td>
<td>240/240</td>
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<td>Zinc</td>
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<td>2500/5000</td>
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<td>Antimony</td>
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<tr>
<td>Barium</td>
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<td>750/1500</td>
<td>2500/4100</td>
<td>1</td>
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<tr>
<td>Beryllium</td>
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<td>1.2/1.2</td>
<td>1.2/3.1</td>
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<tr>
<td>Vanadium</td>
<td>200</td>
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<td>910/910</td>
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<td>Thallium</td>
<td>4.1</td>
<td>4.1/32</td>
<td>32/150</td>
<td>1</td>
</tr>
</tbody>
</table>

a) Table 2: Full Depth Generic Site Condition Standards in a potable groundwater condition
b) Table 3: Full Depth Generic Site Condition Standards in a non-potable groundwater condition
c) Table 4: Stratified Site Condition Standards in a potable groundwater condition (subsurface soil)
d) Table 5: Stratified Site Condition Standards in a non-potable groundwater condition (subsurface soil)

Sample Disposal: 30 Days from the Reporting Date.

* Control Sample Unit is µg/mL for the specified parameter instead of µg/g unless otherwise specified.

**Method:**
- pH: Entech # ISA-5; Extraction/Electrometric (EPA 9045)
- EC: Entech # ISA-6; Extraction/Electrometric (EPA 120.1)
- As, Se, Sb: Entech # ISA-2; Digestion/HGFAAS (EPA 3050A/7062/7742)
- Hg: Entech # ISA-3; Digestion/CV-AAS (EPA 7471A/245.5)
- SAR: Entech # ISA-7; Extraction/ICP-AES (EPA 200.7)
- Metals: Entech # ISA-1; Digestion/ICP-AES (EPA 3050A/200.7)
- Cyanide Free: Entech # ISA-11; Extraction/Auto-Color (EPA 335.4)
- B (HWE): Entech # ISA19/ISA1; Extraction/ICP-AES (EPA 3050A/200.7)
- Cr(VI): Entech # ISA-8; Alkaline Digestion/Colorimetry (EPA 3060A/7196)

**Analyst(s):** PZ, QS, OZ, MA

**Laboratory Manager:** Asit Rakshit, Ph. D., C. Chem