Hydrogeological Investigation and Dewatering Assessment Report

Basement Flooding Protection Program Phase 4 (BFPP4), Area 16
Area 16 - Assignment 16-12 and Assignment 16-22
Toronto, Ontario
TT183004.7000

Prepared for:

CIMA Canada Inc.
5935 Airport Road, Suite 500, Mississauga, Ontario, L4V 1W5

July 18, 2019
July 18, 2019

CIMA Canada Inc.
5935 Airport Road, Suite 500
Mississauga, ON. L4V 1W5

Attention: Alin Hutu
Associate Partner / Director, Linear Infrastructure

Dear Mr. Hutu,

RE: Hydrogeological Investigation and Dewatering Assessment Report
Basement Flooding Protection Program Phase 4 (BFPP4), Area 16,
Assignment 16-12 (Gracefield Avenue, Keele Street and Queen’s Greenbelt) and
Assignment 16-22 (Roding Park, Gade Drive, Ianhall Road, Nash Drive, Bunnel Crescent,
Hallsport Crescent and Dorking Crescent), Toronto, Ontario

Wood Environment & Infrastructure Solutions, a Division of Wood Canada Limited (hereinafter referred to as Wood), take pleasure in enclosing one (1) digital copy of our Hydrogeological Investigation Report carried out for the abovementioned project and we will be glad to discuss any questions arising from this work.

We thank you for giving us this opportunity to be of service to you.

Sincerely,

Wood Environment & Infrastructure Solutions

<Signature>
Todd Williams, M.A.Sc., P.Eng.
Associate / Geotechnical Group Lead
Hydrogeological Investigation and Dewatering Assessment Report

Basement Flooding Protection Program Phase 4 (BFPP4), Area 16
Assignment 16-12 (Gracefield Avenue, Keele Street and Queen’s Greenbelt)
Assignment 16-22 (Roding Park, Gade Drive, Ianhall Road, Nash Drive, Bunnel Crescent, Hallsport Crescent and Dorking Crescent), Toronto, Ontario
TT183004.7000

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5935 Airport Road, Suite 500, Mississauga, Ontario, L4V 1W5

Prepared by:
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July 18, 2019

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1.0 INTRODUCTION
Wood Environment & Infrastructure Solutions, a Division of Wood Canada Limited ("Wood"), was retained by CIMA Canada Inc. ("CIMA+") on behalf of the City of Toronto to conduct a hydrogeological investigation for the "Basement Flooding Protection Program Phase 4 (BFPP4) project – Assignment 16-12 and Assignment 16-22" under the City of Toronto’s RFP 9117-16-7066 as shown in Figure 1.

The City of Toronto ("City") plans to upgrade sections of the existing storm sewers and sanitary sewers by installing additional or larger sewers in identified areas subject to potential basement flooding throughout the City under the City’s Basement Flooding Protection Program (BFPP). The portion of the project considered herein is part of Area 16 and will be carried out as BFPP4 Assignment 16-12 (consisting of sections of Gracefield Avenue, Keele Street, and Queen’s Greenbelt); and Assignment 16-22 (which comprises Roding Street, Gade Drive, Ianhall Road, Nash Drive, Bunnell Crescent, Hallsport Crescent, Dorking Crescent and Roding Park) in the City of Toronto, Ontario.

Based on the findings of geotechnical investigation conducted by Wood in 2018, the groundwater level at Assignments 16-12 and 16-22 was above the inverts of the proposed storm sewers and sanitary sewers at some borehole locations and as such, a hydrogeological investigation was required to evaluate the need for a Permit To Take Water (PTTW) or an online registration on the Environmental Activity and Sector Registry (EASR) to support dewatering during the completion of construction.

Authorization to proceed with this hydrogeological investigation was received via e-mail from Mr. Alin Hutu of CIMA+ on 24 March 2019. The work carried out for this investigation was completed in accordance with CIMA+’s Purchase Order B2019-002800 and Wood’s proposal TT183004.7000 dated 29 March 2019.

This report contains the findings of the hydrogeological investigation and relevant recommendations and comments. The objectives, methodology employed, investigation results and assessments, and recommendations are provided.

2.0 SCOPE OF WORK
The field work required for this investigation consisted of groundwater level monitoring, hydraulic conductivity testing and groundwater sampling and the analysis work consisted of dewatering rate calculations, zone of influence calculations, and review of dewatering disposal options. The work completed is described in more detail in the following sections.

Drilling and monitoring well construction were completed during the geotechnical field investigation, which is discussed in a separate report by Wood, “Geotechnical Investigation Report, Basement Flooding Protection Program Phase 4 (BFPP4), Assignment 16-12 and Assignment 16-22, Toronto, Ontario" dated 19 March 2019.

The hydrogeological investigation was conducted following the completion of the geotechnical investigation, using drilling information and the monitoring wells completed as part of that field investigation. The hydrogeological investigation consisted of the following tasks:

- Review of drawings provided by CIMA+.
- Review of the geotechnical investigation completed within each area.
- Review of published geological and hydrogeological mapping for each of the Assignment areas.
• Collection of groundwater level measurements at each of the constructed monitoring wells to establish the location of the groundwater table and groundwater flow direction.
• In-situ hydraulic conductivity testing and analysis to determine the hydraulic conductivity of the screened soils present at each project site.
• Estimation of the dewatering rates required to obtain the drawdown required to complete the proposed excavations and construction.
• Provide recommendations on the need for a PTTW or an EASR registration based on the interpretation of the collected field data.

3.0 PROJECT DESCRIPTION
The project includes two (2) sites within Area 16, Assignments 16-12 and 16-22, as shown in Figure 1. Assignment 16-12 is shown in blue (south of Highway 401) while Assignment 16-22 is shown in purple (north of Highway 401).

For Assignment 16-12, shown in Figure 2-1, construction activities will include storm sewer reconstruction along sections of Gracefield Avenue (east of Bryn Road to Keele Street), Keele Street (Gracefield Avenue to the Queen’s Greenbelt), and along the Queen’s Greenbelt near Keele Street. This construction will include excavations and potential dewatering required to replace the sewer pipelines and associated supporting infrastructure (such as manholes).

For Assignment 16-22, shown in Figure 2-2, construction activities will include storm sewer and sanitary sewer reconstruction along Roding Street, Gade Drive, Ianhall Road, Nash Drive, Bunnell Crescent, Hallsport Crescent, and Dorking Crescent, together with stormwater facility work in Roding Park. This construction will include excavations and potential dewatering required to replace the sewer pipelines and associated supporting infrastructure (such as manholes).

4.0 SITE SETTING
The land use surrounding Assignment 16-12 site includes residential dwellings, public schools, commercial establishments, and greenspace. The land use surrounding Assignment 16-22 site includes residential dwellings, a school and parkland.

4.1 Surface Water and Topography
Black Creek is located more than 1 km west of both Assignment 16-12 and Assignment 16-22, and Maple Leaf Creek is approximately 120 m east-northeast of Assignment 16-12 at the closest point. The surface water features for Assignment 16-12 are shown in Figure 3-1. The surface water features for Assignment 16-22 are shown in Figure 3-2.

The ground surface at Assignment 16-12 site is relatively flat and slopes down to the west, towards Black Creek. The local ground surface ranges between approximately 142 m and 164 m based on the surveyed elevations at the boreholes.
The ground surface of Assignment 16-22 site is relatively flat and slopes down to the west, towards Roding Park and Black Creek. The ground surface ranges between approximately 156 m and 182 m based on the surveyed elevations at the boreholes.

4.2 Physiography

The physiography for Assignment 16-12 site is shown in Figure 4-1 as mapped by Chapman and Putnam (1984) and digitized by the Ontario Geological Survey (OGS). Assignment 16-12 site is situated within the South Slope physiographic region, situated between Lake Ontario and the Oak Ridges Moraine in Southern Ontario. The South Slope physiographic region consists of till soils, with the slope smoothed and faintly drumlinized. The South Slope is cut at intervals by the valleys created by tributaries of several of the Toronto area river systems.

The physiography for Assignment 16-22 site is shown in Figure 4-2 as mapped by Chapman and Putnam (1984) and digitized by the OGS. Assignment 16-22 is situated within the beveled till plains of the Peel Plain physiographic region of Southern Ontario. The surface of the Peel Plain is characterized by level to gently rolling topography, with a consistent, gradual slope toward Lake Ontario. The Peel Plain is made up of deep deposits of dense, limestone and shale imbued till, often covered by a shallow layer of clay sediment.

4.3 Surficial Geology

The surficial geology as mapped by the OGS for Assignments 16-12 and 16-22 sites is shown in Figure 5.

The surficial geology mapping shows Assignments 16-12 site and most of 16-22 site as covered by silt to silty clay till, overlying silty/sandy deposits, commonly associated with the Halton Till.

Roding Park within Assignment 16-22 is covered by modern deposits featured by sand, silt, minor gravel and organic material.

4.4 Bedrock Geology

The bedrock geology for Assignment 16-12 and 16-22 is shown in Figure 6 as mapped by the OGS. The bedrock in this area consists of Paleozoic Upper Ordovician rocks of the Georgian Bay Formation. This consists of interbedded grey-green to dark grey shale and fossiliferous calcareous siltstone to bioclastic limestone.

Bedrock is not a major consideration for this investigation due to its relative depth compared to the depth of excavation required.

5.0 ASSIGNMENT 16-12

5.1 Geotechnical Investigation Findings

A total of fifteen (15) boreholes were drilled to depths between 3.7 m and 15.8 m below ground surface at Assignment 16-12 site, with five (5) of these boreholes constructed as monitoring wells at the storm sewer re-construction area. The locations of these boreholes and monitoring wells for Assignment 16-12 site are shown in Figure 2-1.
The findings of the geotechnical investigation revealed that the soil profile at Assignment 16-12 comprised in general, surficial asphaltic concrete or topsoil overlying fill soils (sandy gravel, gravelly sand, silty sand, sandy silt, clayey silt and silty clay) which were underlain by native soils (organic silty clay, sandy silty clay / sandy clayey silt till, and sandy silt / sand and silt till).

5.2 Groundwater Conditions

Upon completion of the drilling, groundwater was encountered at the monitoring wells located on Keele Street and Queen’s Greenbelt. The groundwater levels were later measured on 2 and 21 November 2018 during the geotechnical investigation.

Additional groundwater levels were recorded during the hydrogeological investigation, in the course of monitoring well development, hydraulic conductivity testing, and groundwater sampling between May and June 2019. The groundwater levels and elevations measured by Wood during both investigations are summarized in Table 5.1 below. The groundwater observations indicated that the groundwater elevations ranged from 146.7 m to 158.8 m at Assignment 16-12, locally inclining towards the Queen’s Greenbelt during the monitoring period.

| MW No. | Well Depth (m) | Ground Surface Elevation (m) | Groundwater Levels in Monitoring Wells
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>Depth below ground surface (mbgs) / (Elevation) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH 10</td>
<td>6.1</td>
<td>162.2</td>
<td>Dry</td>
</tr>
<tr>
<td>BH 12</td>
<td>9.1</td>
<td>162.8</td>
<td>Dry</td>
</tr>
<tr>
<td>BH 13</td>
<td>15.2</td>
<td>163.5</td>
<td>9.1 / (154.4)</td>
</tr>
<tr>
<td>BH 14</td>
<td>13.7</td>
<td>153.6</td>
<td>4.6 / (149.0)</td>
</tr>
<tr>
<td>BH 15</td>
<td>10.7</td>
<td>153.6</td>
<td>3.0 / (150.6)</td>
</tr>
</tbody>
</table>

5.3 Hydraulic Conductivity Testing and Analyses

In-situ hydraulic conductivity testing was conducted in the Assignment 16-12 monitoring wells, where sufficient water was available, between 6 and 10 May 2019. While a test was conducted in BH 12, the test results were inconclusive, possibly due to interference from heavy local traffic driving across the well lid and causing the pressure transducer to vibrate.

Hydraulic conductivity testing consisted of rising head tests. Rising head hydraulic conductivity testing consisted of quickly removing a known volume of water from the monitoring well and recording regular groundwater level measurements as it recovered to equilibrium.
During the hydraulic conductivity tests, groundwater levels at the monitoring wells were recorded using pressure transducers installed in each monitoring well. Manual water level readings were collected for confirmation.

The data collected during the hydraulic conductivity testing was analyzed to determine a hydraulic conductivity value for the soils at the same horizon as the well screen placement and the results are summarized in Table 5.2. The hydraulic conductivity test results for the completed tests are shown graphically in Appendix C.

### Table 5.2: Hydraulic Conductivity Test Results (Assignment 16-12)

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Test Date</th>
<th>Hydraulic Conductivity Test Method</th>
<th>Analytical Solution</th>
<th>Hydraulic Conductivity Value (m/s)</th>
<th>Screened Soil Horizon</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH 10</td>
<td>10 May 2019</td>
<td>Rising Head</td>
<td>Bouwer-Rice</td>
<td>$1.1 \times 10^{-6}$</td>
<td>Sandy Silty Clay / Sandy Clayey Silt Till</td>
</tr>
<tr>
<td>BH 12</td>
<td>Test conducted 6 May 2019 but result was inconclusive</td>
<td></td>
<td></td>
<td></td>
<td>Sandy Silty Clay / Sandy Clayey Silt Till</td>
</tr>
<tr>
<td>BH 13</td>
<td>6 May 2019</td>
<td>Rising Head</td>
<td>Bouwer-Rice</td>
<td>$8.4 \times 10^{-8}$</td>
<td>Sandy Silty Clay / Sandy Clayey Silt Till</td>
</tr>
<tr>
<td>BH 14</td>
<td>10 May 2019</td>
<td>Rising Head</td>
<td>Bouwer-Rice</td>
<td>$9.0 \times 10^{-8}$</td>
<td>Sandy Silt / Sand and Silt Till</td>
</tr>
<tr>
<td>BH 15</td>
<td>27 May 2019</td>
<td>Rising Head</td>
<td>Bouwer-Rice</td>
<td>$8.1 \times 10^{-8}$</td>
<td>Sandy Silt / Sand and Silt Till</td>
</tr>
</tbody>
</table>

It should be noted that the initial water level, prior to hydraulic conductivity testing, was within the screened interval at BH 13, and as a result, the groundwater levels collected at the very beginning of these tests were affected by drainage of, or flow into, the sand pack and were largely ignored.

The soils in which the monitoring wells were screened in is reported as predominantly sandy silty clay / sandy clayey silt till and sandy silt / sand and silt till at Assignment 16-12. Representative published values (Domenico and Schwartz (1998) included in Schwartz and Zhang, 2003) for similar grain sizes are as follows:

- Fine to Medium Sand – $9.0 \times 10^{-7}$ to $2.0 \times 10^{-4}$ m/s;
- Silt – $1.0 \times 10^{-9}$ to $2.0 \times 10^{-5}$ m/s; and,
- Clay – $1.0 \times 10^{-11}$ to $4.7 \times 10^{-9}$ m/s.

The resulting hydraulic conductivity values ranged by a couple of orders of magnitude, between $8.1 \times 10^{-8}$ m/s (BH 15) and $1.1 \times 10^{-6}$ m/s (BH 10). All of the hydraulic conductivity results are within the range that might be expected based on the soil descriptions included in the monitoring well logs.

It should be noted that geologic materials and fill materials can vary in characteristics even over short distances, and some higher and lower permeability materials may be present in each of the defined sections that were not encountered during the field investigation.
5.4 Dewatering Rates and ZOI

The hydraulic conductivity values determined during the field investigation were used to estimate the dewatering rates required for completion of the excavations and construction. For construction dewatering rates calculated between 50 m$^3$/day and 400 m$^3$/day, then an Environmental Activity and Sector Registry (EASR) registration may be sufficient to support construction. For calculated dewatering rates in excess of 400 m$^3$/day a Permit To Take Water (PTTW) will be required.

The proposed construction consists of excavations to replace/install pipes and associated manholes. The dewatering rates calculated in this investigation are based on conditions encountered at the site during the hydrogeological investigation and construction dimensions provided on drawings provided to Wood by CIMA+ (Drawing Nos. 18-01231-005 to 18-01231-008 dated 14 December 2017).

The dewatering rates for this project have been calculated using industry-standard analytical equations (taken from Powers et al., 2007), with trench equations applied to the sewer pipeline segments and radial flow equations applied to the manholes. The analytical equations are included in the dewatering calculation pages in Appendix E for Assignment 16-12. The dewatering calculations in Appendix E also include the equation and resulting calculation for the zone of influence (ZOI) using the Sichert equation.

The calculated dewatering rates and ZOI, including the construction details as obtained from the construction drawings and the excavation dimensions used in the dewatering calculations, are summarized in Table 5.3 below. The excavation dimensions assumed an additional 0.5 m applied to each edge to allow for some replacement of undesirable soils, etc. in the course of completion of the construction.

Based on the calculations, Assignment 16-12 could require dewatering up to 96 m$^3$/day, which would require an EASR registration at a minimum. It should be noted that for the sewer pipelines, the calculations were completed assuming the full segment was dewatered and excavated at one time. Dewatering and excavations of smaller segments could result in lower required dewatering effort. At a minimum, an EASR will be required to support construction.
Table 5.3: Dewatering Assessment Summary - Assignment 16-12

<table>
<thead>
<tr>
<th>Wood Structure ID</th>
<th>Diameter – Manholes Only* (m)</th>
<th>Length &amp; Width – Pipelines Only* (m)</th>
<th>Maximum Depth* (m)</th>
<th>Modified Diameter* (m)</th>
<th>Modified Length &amp; Width* (m)</th>
<th>Modified Depth* (m)</th>
<th>Dewatering Rate$ (m³/day)</th>
<th>Calculated Zone of Influence% (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manholes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GA1</td>
<td>1.8</td>
<td>n/a</td>
<td>3.6</td>
<td>2.8</td>
<td>n/a</td>
<td>4.1</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>KS1</td>
<td>1.8</td>
<td>n/a</td>
<td>8.0</td>
<td>2.8</td>
<td>n/a</td>
<td>8.5</td>
<td>28</td>
<td>15</td>
</tr>
<tr>
<td>KS2</td>
<td>3.6</td>
<td>n/a</td>
<td>13.3</td>
<td>4.6</td>
<td>n/a</td>
<td>13.8</td>
<td>73</td>
<td>44</td>
</tr>
<tr>
<td>KS3</td>
<td>1.8</td>
<td>n/a</td>
<td>7.1</td>
<td>2.8</td>
<td>n/a</td>
<td>7.6</td>
<td>23</td>
<td>17</td>
</tr>
<tr>
<td>Sewer Pipelines</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GA1 to KS1</td>
<td>n/a</td>
<td>82.5 x 0.9</td>
<td>6.9</td>
<td>n/a</td>
<td>83.5 x 1.9</td>
<td>7.4</td>
<td>77</td>
<td>34</td>
</tr>
<tr>
<td>KS1 to KS2</td>
<td>n/a</td>
<td>78.5 x 0.9</td>
<td>7.9</td>
<td>n/a</td>
<td>79.5 x 1.9</td>
<td>8.4</td>
<td>85</td>
<td>21</td>
</tr>
<tr>
<td>KS2 to headwall</td>
<td>n/a</td>
<td>36.1 x 2.4</td>
<td>12.7</td>
<td>n/a</td>
<td>37.1 x 3.4</td>
<td>13.2</td>
<td>96</td>
<td>48</td>
</tr>
<tr>
<td>KS2 to existing MH</td>
<td>n/a</td>
<td>61.7 x 2.4</td>
<td>4.3</td>
<td>n/a</td>
<td>62.7 x 3.4</td>
<td>4.8</td>
<td>41</td>
<td>12</td>
</tr>
<tr>
<td>KS2 to KS3</td>
<td>n/a</td>
<td>0.5 x 1.1</td>
<td>12.7</td>
<td>n/a</td>
<td>1.5 x 2.1</td>
<td>13.2</td>
<td>44</td>
<td>48</td>
</tr>
</tbody>
</table>

Notes:
* - Values obtained from construction drawings provided by CIMA+
$ - Values include 0.5 m assumed additional excavation construction dimension
% - Sichert’s equation assumes steady state conditions and therefore tends to overestimate the actual ZOI for short-term excavations.
$ - Dewatering rate includes 3x multiplier to account for variability in conditions between monitoring well locations.

It should be noted that some activities or events can occur that result in higher inflow rates than those considered in the calculation of the dewatering rates presented in this report. These may include:

- Heavy precipitation events. A review of Toronto-area historical climate data indicates that precipitation events on the order of 25 mm or more occur on an average of five (5) days per year. These events can provide large direct inputs of water into an excavation and these kinds of precipitation events have become more prevalent in recent years.

- Variations in soil and groundwater conditions in areas between and beyond the boreholes drilled during the geotechnical investigations. Although the geotechnical boreholes have not encountered any significant depth of permeable fill material, this cannot be entirely discounted.
• Seasonal variations, such as spring snowmelt. Spring snowmelt can lead to an increase in the groundwater table by 1.0 m to 2.0 m in southern Ontario. Spring groundwater conditions were not encountered during this hydrogeological investigation.

• If the excavation dimensions are significantly greater than those used in the dewatering calculations included in this report.

• If runoff to the excavation is not effectively controlled and diverted from the excavation by the Contractor.

• Initially, loss of storage in the aquifer – this is a temporary response and dewatering rates should fall to expected volumes once equilibrium conditions are approached. However, it is unlikely that storage release will increase the inflow above a factor of two (2) or three (3) times.

Additionally, consideration should be given to potential inflows from saturated pipe (gravel) beds should they be exposed or encountered. These pipe beds could be saturated due to the presence of groundwater, or if there was a leak in one (1) or more of the pipes. These beds tend to allow for rapid movement of water when they are saturated so dewatering of this material may be required also. In practice, the actual amount of dewatering required from these beds may be limited by the presence of clay plugs along the length of the pipes, which serve to limit preferential flow through these beds. Depending on the spacing of such plugs, the amount of saturated gravel that could require dewatering could be small or substantial, if encountered.

If the excavations for the maintenance holes encounter geological formations that are more conductive or exhibits upward pressure, then additional groundwater flow could be encountered. Additionally, it should be noted that the incorporation of measures during the excavation and construction that would seal the excavation from surrounding hydraulically productive units could result in lower dewatering rates being required.

Timing the completion of the dewatering and excavations to periods of the year when groundwater table levels are typically lower, such as during the summer months, could also result in lower dewatering rates being required.

5.5 Groundwater Chemistry

During construction dewatering, the resulting water is typically discharged to nearby sewer systems, where available. By-laws are often in place that restricts the release of water to these sewer systems based on the chemistry and sometimes, the quantity.

Due to the location of the proposed excavation and construction, this water will likely be discharged into the City of Toronto’s sewer system. The City of Toronto has By-laws in place for disposal of water, regulating the chemistry of the water released (City of Toronto’s Storm and Sanitary Sewer By-laws - Chapter 681 of the City of Toronto’s Municipal Code). The By-law includes separate discharge restrictions for storm sewers and sanitary and combined sewer overflow (CSO) sewers. The preferred disposal option for disposal of the dewatering discharge during this construction is the sanitary sewer.

Wood collected samples of the groundwater to determine whether water collected from the construction dewatering could be directly discharged to the nearby sanitary/CSO and/or storm sewers, or whether other
arrangements or treatment of the water may be required. The samples were sent to ALS Laboratories in Mississauga, Ontario, a Canadian Association for Laboratory Accreditation Inc. (CALA) certified laboratory for analysis.

The results from the groundwater samples analyzed were compared to the parameter limits included in Table 1 in Section 681-2 (Limits for Sanitary and Combined Sewers Discharge) and Table 2 in Section 681-4 (Limits for Storm Sewer Discharge) of the City of Toronto’s Storm and Sanitary Sewer By-laws (Chapter 681 of the City of Toronto’s Municipal Code).

A total of two (2) samples were collected for Assignment 16-12 (BH 10 and BH 14, Figure 2-1). Exceedances to the City of Toronto’s Storm and Sanitary Sewer By-laws are summarized in Table G-1 (Appendix G). The results received from the laboratory are included in Appendix G.

The groundwater chemistry analysis indicated exceedances for both the Sanitary and Storm Sewer By-laws. Exceedances were noted for the Sanitary Sewer Bylaw for total suspended solids (TSS), total aluminum, total manganese and total polyaromatic hydrocarbons (PAHs).

Exceedances noted for the Storm Sewer Bylaw were TSS, total phosphorus, total arsenic, total chromium, total copper, total manganese, total nickel, total zinc and total PAHs.

### 6.0 ASSIGNMENT 16-22

#### 6.1 Geotechnical Investigation Findings

A total of twenty-two (22) boreholes were drilled to depths between 6.6 m and 9.8 m below ground surface at Assignment 16-22 site, with nine (9) of these boreholes constructed as monitoring wells along each road section and in Roding Park. The locations of these boreholes and monitoring wells for Assignment 16-22 are shown in Figure 2-2.

The findings of the geotechnical investigation revealed that the soil profile at Assignment 16-22 comprised in general, surficial asphaltic concrete or topsoil overlying fill soils (sandy gravel, gravelly sand, sand, sandy silt, silty sand, clayey silt and silty clay) which were underlain by native soils (clayey silt / silty clay / silt and clay, sandy silty clay / sandy clayey silt till, sand and silt till, and sand).

#### 6.2 Groundwater Conditions

Most of the boreholes were dry upon completion of the drilling, except for BH 16 and BH 23 located within Roding Park and at the intersection of Nash Drive and Dorking Crescent, respectively. The groundwater levels were measured on 2 and 21 November 2018 during the geotechnical investigation.

Additional groundwater levels were measured during the hydrogeological investigation between May and June 2019. The groundwater levels and elevations for Assignment 16-22 are summarized in Table 6.1 below. The groundwater observations indicated that the groundwater elevations ranged from 150.4 m to 177.9 m during the monitoring period, with groundwater flowing locally towards Roding Park.
### Table 6.1: Groundwater Level Measurement in Monitoring Wells (Assignment 16-22)

<table>
<thead>
<tr>
<th>MW No.</th>
<th>Well Depth (m)</th>
<th>Ground Surface Elevation (m)</th>
<th>Groundwater Levels in Monitoring Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Depth below ground surface (mbgs) / (Elevation) (m)</td>
</tr>
<tr>
<td>BH 16</td>
<td>9.1</td>
<td>156.9</td>
<td>4.6 / (152.3)</td>
</tr>
<tr>
<td>BH 18</td>
<td>6.1</td>
<td>171.1</td>
<td>Dry</td>
</tr>
<tr>
<td>BH 19</td>
<td>7.6</td>
<td>173.6</td>
<td>Dry</td>
</tr>
<tr>
<td>BH 21</td>
<td>7.6</td>
<td>171.1</td>
<td>Dry</td>
</tr>
<tr>
<td>BH 23</td>
<td>6.1</td>
<td>172.4</td>
<td>4.6 / (167.8)</td>
</tr>
<tr>
<td>BH 28</td>
<td>6.1</td>
<td>179.1</td>
<td>Dry</td>
</tr>
<tr>
<td>BH 29</td>
<td>6.1</td>
<td>179.6</td>
<td>Dry</td>
</tr>
<tr>
<td>BH 31</td>
<td>6.1</td>
<td>179.3</td>
<td>Dry</td>
</tr>
<tr>
<td>BH 33</td>
<td>6.1</td>
<td>175.1</td>
<td>Dry</td>
</tr>
</tbody>
</table>

### 6.3 Hydraulic Conductivity Testing and Analyses

In-situ hydraulic conductivity testing was conducted in the Assignment 16-22 monitoring wells, where sufficient water was available, between 6 and 10 May 2019. Tests were attempted in BH 28 or BH 31, but the results were inconclusive.

Hydraulic conductivity testing consisted of rising head tests. Rising head hydraulic conductivity testing consisted of quickly removing a known volume of water from the monitoring well and recording regular groundwater level measurements as it recovered to equilibrium. Recovery in BH 16 was rapid and a constant head test was completed at that location to determine the hydraulic conductivity. A constant head test is a short-term single well pumping test where the well is pumped at a known rate and the initial and pumped groundwater level was recorded when the groundwater level stabilized at a new level. These numbers were inputted into an analytical equation (shown with results) to determine the hydraulic conductivity.

During the hydraulic conductivity tests, groundwater levels at the monitoring wells were recorded using pressure transducers installed in each monitoring well. Manual water level readings were collected for confirmation.
The data collected during the hydraulic conductivity testing was analyzed to determine a hydraulic conductivity value for the screened soils and the results are summarized in Table 6.2. The hydraulic conductivity test results are provided in Appendix D.

### Table 6.2: Hydraulic Conductivity Test Results (Assignment 16-22)

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Test Date</th>
<th>Hydraulic Conductivity Test Method</th>
<th>Analytical Solution</th>
<th>Hydraulic Conductivity Value (m/s)</th>
<th>Screened Soil Horizon</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH 16</td>
<td>18 June 2019</td>
<td>Constant Head</td>
<td>Thiem-Dupuit</td>
<td>$4.2 \times 10^{-5}$</td>
<td>Sand</td>
</tr>
<tr>
<td>BH 18</td>
<td>5 June 2019</td>
<td>Rising Head</td>
<td>Bouwer-Rice</td>
<td>$7.7 \times 10^{-8}$</td>
<td>Sandy Silty Clay / Sandy Clayey Silt Till to Sand and Silt Till</td>
</tr>
<tr>
<td>BH 19</td>
<td>5 June 2019</td>
<td>Rising Head</td>
<td>Bouwer-Rice</td>
<td>$1.9 \times 10^{-8}$</td>
<td>Silty Clay to Sandy Silty Clay / Sandy Clayey Silt Till</td>
</tr>
<tr>
<td>BH 28</td>
<td></td>
<td>Test result inconclusive</td>
<td></td>
<td></td>
<td>Sandy Silty Clay / Sandy Clayey Silt Till</td>
</tr>
<tr>
<td>BH 29</td>
<td>17 May 2019</td>
<td>Rising Head</td>
<td>Bouwer-Rice</td>
<td>$8.5 \times 10^{-8}$</td>
<td>Sandy Silty Clay / Sandy Clayey Silt Till</td>
</tr>
<tr>
<td>BH 31</td>
<td></td>
<td>Test result inconclusive</td>
<td></td>
<td></td>
<td>Sandy Silty Clay / Sandy Clayey Silt Till</td>
</tr>
<tr>
<td>BH 33</td>
<td>17 May 2019</td>
<td>Rising Head</td>
<td>Bouwer-Rice</td>
<td>$7.6 \times 10^{-8}$</td>
<td>Sandy Silty Clay / Sandy Clayey Silt Till</td>
</tr>
</tbody>
</table>

It should be noted that the initial groundwater level, prior to hydraulic conductivity testing, was within the screened interval for Boreholes BH 16 and BH 33. Where this occurred, the groundwater levels collected at the very beginning of the hydraulic conductivity test indicated the influence of the sand pack, instead of the formation. In these cases, these early data were ignored, and the analysis began where consistent recovery indicative of the screened formation was recorded.

The soils in which the monitoring wells were screened in is reported as predominantly sandy silty clay / sandy clayey silt till at Assignment 16-22 site, at Borehole BH 16 located in the Roding Park, the monitoring well was screened in the sand fill soils and native sand. Representative published values (Domenico and Schwartz (1998) included in Schwartz and Zhang, 2003) for similar grain sizes are as follows:

- Fine to Medium Sand – $9.0 \times 10^{-7}$ to $2.0 \times 10^{-4}$ m/s;
- Silt – $1.0 \times 10^{-9}$ to $2.0 \times 10^{-5}$ m/s; and,
- Clay – $1.0 \times 10^{-11}$ to $4.7 \times 10^{-9}$ m/s.

The resulting hydraulic conductivity values ranged by a couple of orders of magnitude, between $1.9 \times 10^{-8}$ m/s (BH 19) and $8.5 \times 10^{-6}$ m/s (BH 29) for sandy silty clay / sandy clayey silt till, and $4.2 \times 10^{-5}$ m/s (BH 16) for sandy soil. All of the hydraulic conductivity results are within the range that might be expected based on the soil descriptions included in the monitoring well logs.

It should be noted that geologic materials and fill materials can vary in characteristics even over short distances, and some higher and lower permeability materials may be present in each of the defined sections that were not encountered during the field investigation.
6.4 Dewatering Rates and ZOI

The hydraulic conductivity values determined during the field investigation were used to estimate the dewatering rates required for completion of the excavations and construction. For construction dewatering rates calculated between 50 m$^3$/day and 400 m$^3$/day, then an Environmental Activity and Sector Registry (EASR) registration may be sufficient to support construction. For calculated dewatering rates in excess of 400 m$^3$/day a Permit To Take Water (PTTW) will be required.

The proposed construction consists of excavations to replace/install pipes and associated manholes. The dewatering rates calculated in this investigation are based on conditions encountered at the site during the hydrogeological investigation and construction dimensions provided on drawings provided to Wood by CIMA+ (Drawing Nos. 17-03309-001 to 17-03309-018 dated 14 December 2017).

The dewatering rates for this project have been calculated using industry-standard analytical equations (taken from Powers et al., 2007), with trench equations applied to the sewer pipeline segments and radial flow equations applied to the manholes. The analytical equations are included in the dewatering calculation pages in Appendix E for Assignment 16-22. The dewatering calculations in Appendix E also include the equation and resulting calculation for the zone of influence (ZOI) using the Sichert equation.

The calculated dewatering rates and ZOI, including the construction details as obtained from the construction drawings and the excavation dimensions used in the dewatering calculations, are summarized in Table 6.3 below. The excavation dimensions assumed an additional 0.5 m applied to each edge to allow for some replacement of undesirable soils, etc. in the course of completion of the construction.

Based on the calculations, Assignment 16-22 could require dewatering up to 22 m$^3$/day, which falls below the threshold to require an EASR registration or a PTTW. It should be noted that for the sewer pipelines, the calculations were completed assuming the full segment was dewatered and excavated at one time. Dewatering and excavations of smaller segments could result in lower required dewatering effort. At a minimum, an EASR will be required to support construction.
Table 6.3: Dewatering Assessment Summary - Assignment 16-22

<table>
<thead>
<tr>
<th>Wood Structure ID</th>
<th>Diameter – Manholes Only* (m)</th>
<th>Length &amp; Width – Pipelines Only* (m)</th>
<th>Maximum Depth* (m)</th>
<th>Modified Diameter* (m)</th>
<th>Modified Length &amp; Width* (m)</th>
<th>Modified Depth* (m)</th>
<th>Dewatering Rate$^1$ (m$^3$/day)</th>
<th>Calculated Zone of Influence% (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manholes</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>4.9</td>
<td>2.8</td>
<td>n/a</td>
<td>5.4</td>
<td>3</td>
<td>6</td>
</tr>
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<td>4</td>
<td>9</td>
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<td>6.7</td>
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</tr>
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<td>4.9</td>
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</tr>
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<td>5.1</td>
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<td>n/a</td>
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</tr>
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<td>5.0</td>
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<td>5.5</td>
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<td>7</td>
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<td>Length &amp; Width – Pipelines Only* (m)</td>
<td>Maximum Depth* (m)</td>
<td>Modified Diameter# (m)</td>
<td>Modified Length &amp; Width# (m)</td>
<td>Modified Depth* (m)</td>
<td>Dewatering Rate$ (m^3/day)</td>
<td>Calculated Zone of Influence% (m)</td>
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<td>-------------------</td>
<td>-------------------</td>
<td>-----------------</td>
<td>----------------</td>
<td>-------------------</td>
</tr>
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Notes:
* - Values obtained from construction drawings provided by CIMA+
# - Values include 0.5 m assumed additional excavation construction dimension
% - Sichart’s equation assumes steady state conditions and therefore tends to overestimate the actual ZOI for short-term excavations.
$ - Dewatering rate includes 3x multiplier to account for variability in conditions between monitoring well locations.
It should be noted that some activities or events can occur that result in higher inflow rates than those considered in the calculation of the dewatering rates presented in this report. These may include:

- **Heavy precipitation events.** A review of Toronto-area historical climate data indicates that precipitation events on the order of 25 mm or more occur on an average of five (5) days per year. These events can provide large direct inputs of water into an excavation and these kinds of precipitation events have become more prevalent in recent years.

- **Variations in soil and groundwater conditions in areas between and beyond the boreholes drilled during the geotechnical investigations.** Although the geotechnical boreholes have not encountered any significant depth of permeable fill material, this cannot be entirely discounted.

- **Seasonal variations, such as spring snowmelt.** Spring snowmelt can lead to an increase in the groundwater table by 1.0 m to 2.0 m in southern Ontario. Spring groundwater conditions were not encountered during this hydrogeological investigation.

- **If the excavation dimensions are significantly greater than those used in the dewatering calculations included in this report.**

- **If runoff to the excavation is not effectively controlled and diverted from the excavation by the Contractor.**

- **Initially, loss of storage in the aquifer – this is a temporary response and dewatering rates should fall to expected volumes once equilibrium conditions are approached. However, it is unlikely that storage release will increase the inflow above a factor of two (2) or three (3) times.**

Additionally, consideration should be given to potential inflows from saturated pipe (gravel) beds should they be exposed or encountered. These pipe beds could be saturated due to the presence of groundwater, or if there was a leak in one (1) or more of the pipes. These beds tend to allow for rapid movement of water when they are saturated so dewatering of this material may be required also. In practice, the actual amount of dewatering required from these beds may be limited by the presence of clay plugs along the length of the pipes, which serve to limit preferential flow through these beds. Depending on the spacing of such plugs, the amount of saturated gravel that could require dewatering could be small or substantial if encountered.

If the excavations for the maintenance holes encounter geology that is more conductive or exhibits upward pressure, than additional groundwater flow could be encountered. Additionally, it should be noted that the incorporation of measures during the excavation and construction that would seal the excavation from surrounding hydraulically productive units could result in lower dewatering rates being required.

Timing the completion of the dewatering and excavations to periods of the year when groundwater table levels are typically lower, such as during the summer months, could also result in lower dewatering rates being required.
6.5 Groundwater Chemistry

During construction dewatering, the resulting water is typically discharged to nearby sewer systems, where available. By-laws are often in place that restricts the release of water to these sewer systems based on the chemistry and sometimes, the quantity.

Due to the location of the proposed excavation and construction, this water will likely be discharged into the City of Toronto’s sewer system. The City of Toronto has By-laws in place for disposal of water, regulating the chemistry of the water released (City of Toronto’s Storm and Sanitary Sewer By-laws - Chapter 681 of the City of Toronto’s Municipal Code). The By-law includes separate discharge restrictions for storm sewers and sanitary and combined sewer overflow (CSO) sewers. The preferred disposal option for disposal of the dewatering discharge during this construction is the sanitary sewer.

Wood collected samples of the groundwater to determine whether water collected from the construction dewatering could be directly discharged to the nearby sanitary/CSO and/or storm sewers, or whether other arrangements or treatment of the water may be required. The samples were sent to ALS Laboratories in Mississauga, Ontario, a Canadian Association for Laboratory Accreditation Inc. (CALA) certified laboratory for analysis.

The results from the groundwater samples analyzed were compared to the parameter limits included in Table 1 in Section 681-2 (Limits for Sanitary and Combined Sewers Discharge) and Table 2 in Section 681-4 (Limits for Storm Sewer Discharge) of the City of Toronto’s Storm and Sanitary Sewer By-laws (Chapter 681 of the City of Toronto’s Municipal Code).

A total of three (3) samples were collected for Assignment 16-22 (BH 10 and BH 14, Figure 2-2). Exceedances to the City of Toronto’s Storm and Sanitary Sewer By-laws are summarized in Table G-2 (Appendix G). The results received from the laboratory are included in Appendix G.

The groundwater chemistry analysis indicated exceedances for both the Sanitary and Storm Sewer Bylaws. Exceedances were noted for the Sanitary Sewer Bylaw for total suspended solids (TSS), total aluminum, total manganese and total polyaromatic hydrocarbons (PAHs). Exceedances for the Storm Seer Bylaw were noted for TSS, total phosphorus, total arsenic, total chromium, total copper, total manganese, total nickel, total zinc and total PAHs.

7.0 CONCLUSIONS AND RECOMMENDATIONS

For construction dewatering takings between 50,000 L/day and 400,000 L/day an EASR is required under O.Reg.63/16. Where construction dewatering effort exceeds 400,000 L/day, a PTTW is required.

Based on the construction drawings provided and the assumptions discussed in this report, the calculated construction dewatering rates for Assignment 16-12 fall within the range of 50 m$^3$/day and 400 m$^3$/day, where an EASR will be required. For Assignment 16-22, the calculated rates were less than 50% of the 50 m$^3$/day EASR threshold, but if the construction for the two areas is to be completed at the same time or are scheduled to be completed close together, the EASR obtained for Assignment 16-12 could be extended to include Assignment 16-22 as a precaution.

To support the EASR a water taking plan and a discharge plan will be required. The water taking plan must be signed and stamped by a qualified hydrogeologist licensed to practice in Ontario while the discharge
plan must be prepared by an experienced scientist. These plans will be required to be maintained onsite for the duration of construction.

The estimated dewatering rates do not include surface water runoff from precipitation events or account for higher inflow rates during periods of high groundwater table and initial releases from storage, which could temporarily increase the dewatering effort. In addition, should dewatering be concurrently required for various excavations at the same time, all pumping rates from proximal excavations would need to be added together to confirm that the upper limit for the EASR are still met, as the combined dewatering for multiple locations could exceed 400 m$^3$/day.

It will ultimately be the responsibility of the Construction Contractor to ensure that all dewatering discharge complies with the appropriate City of Toronto Sewer Bylaw for the duration of dewatering and that the appropriate sewer discharge permit is in place prior to the start of construction dewatering.

8.0 CLOSURE

The information and recommendations contained in this report should be used solely for the purpose of a hydrogeological investigation of the subject site. Should you have any questions about this report, please do not hesitate to contact the undersigned.

This report has been prepared by Kimberly Gilder, B. Sc., P.Geo and reviewed by Gil Violette, M.Sc.E., P.Eng.

The Report Limitations included in Appendix H are an integral part of this report.

Sincerely,

Wood Environment & Infrastructure Solutions,  
a Division of Wood Canada Limited

DRAFT

Senior Hydrogeologist  Senior Associate Hydrogeologist
Figures

Figure 1: Site Location Plan
Figure 2-1: Borehole and Monitoring Well Location - Assignment 16-12
Figure 2-2: Borehole and Monitoring Well Location Plan - Assignment 16-22
Figure 3-1: Surface Water Features and Topography – Assignment 16-12
Figure 3-2: Surface Water Features and Topography – Assignment 16-22
Figure 4-1: Physiography - Assignment 16-12
Figure 4-2: Physiography - Assignment 16-22
Figure 5: Surficial Geology
Figure 6: Bedrock Geology
NOTES:
LOCATION OF FEATURES ARE APPROXIMATE

This drawing should be read in conjunction with the Wood Environment & Infrastructure Solutions Report No. TT183004.7000. Conditions encountered in the field may be different from the interpreted information presented on this figure.

SOURCE: Some data presented in this figure is from the Ontario open dataset Hillshade (2012) ORN, 2012; Canvec10 (contours).

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HYDROGEOLOGICAL INVESTIGATION
Basement Flooding Protection Program Phase 4 (BFPP4) Assignment 16-12 and Assignment 16-22, Toronto, ON

SITE LOCATION PLAN

SCALE: 1:20,000

FIGURE: 1

DATE: June 2019

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NOTES:
LOCATION OF FEATURES ARE APPROXIMATE

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CLIENT:

HYDROGEOLOGICAL INVESTIGATION
Basement Flooding Protection Program Phase 4 (BFPP4)
Assignment 16-12, Toronto, ON

SCALE: 1:4,010

Borehole with Monitoring Well Installed
Borehole