HYDROGEOLOGICAL LEVEL 1 AND LEVEL 2 ASSESSMENTS

PROPOSED MAES PIT

Part Lots 1 and 2, Concession 2, Township of Middlesex Centre (Formerly Lobo Township), County of Middlesex, Ontario

JOHNSTON BROS. (BOTHWELL) LIMITED

Prepared for:
Johnston Bros. (Bothwell) Limited
21220 Johnston Line, RR1,
Wardsville, Ontario
N0L 2N0

Prepared by:
Novaterra Environmental Ltd.
39 Winship Close
London, Ontario
N6C 5M8

May 24, 2017

HYDROGEOLOGICAL LEVEL 1 AND LEVEL 2 ASSESSMENTS

PROPOSED MAES PIT

Part Lots 1 and 2, Concession2, Township of Middlesex Centre
(Formerly Lobo Township), County of Middlesex, Ontario

JOHNSTON BROS. (BOTHWELL) LIMITED

Prepared for:

Johnston Bros. (Bothwell) Limited
21220 Johnston Line, RR1,
Wardsville, Ontario
N0L 2N0

Prepared by:

Novaterra Environmental Ltd.
39 Winship Close
London, Ontario
N6C 5M8

May 24, 2017

Cover page photograph: Aerial photograph showing the Site and surrounding area, obtained from Google Earth. Imagery date: October 22, 2015. Eye altitude 2.43 km.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

APPENDICES

1.0 INTRODUCTION

1.1 Background

The proposed application calls for the extraction of sand and gravel deposits from above and below the established groundwater table in Part of Lots 1 and 2, Concession 2 in the Township of Middlesex Centre (Formerly Township of Lobo), County of Middlesex, Ontario. In this report, the proposed licensed area is referred to as the Maes Pit or the Site.

Novaterra Environmental Ltd. (hereinafter Novaterra) was authorized by Johnston Bros. (Bothwell) Limited to carry out a hydrogeological evaluation of the Site.

This report shall form part of a submission to the Ministry of Natural Resources and Forestry (MNRF) to comply with the requirements of the Aggregate Resources Act.

1.2 Scope and Methodology

The purpose of this report is to assess geological and hydrogeological conditions at the Site, and the potential for adverse effects of the proposed operation on water resources in the area and their uses.

1.2.1 Aggregate Resource Act Requirements

For new licence applications, Section 2.2 of the *Aggregate Resources of Ontario Provincial Standards* (Version 1.0; Ministry of Natural Resources; 1997) details the following requirements for the hydrogeological assessment of a Category 1 Class "A" Pit Below Water:

> *2.2.1 Hydrogeological Level 1: Preliminary hydrogeological evaluation to determine the final extraction elevation relative to the established groundwater table, and the potential for adverse effects to groundwater and surface water resources and their uses;*
>
> *2.2.2 Hydrogeological Level 2: Where the results of the Level 1 have identified a potential for adverse effects of the operation on groundwater and surface water and their uses, an impact assessment is required to determine the significance of the effect and feasibility of mitigation. The assessment should address the potential effects of the operation on the following features if located within the zone of influence for extraction below the established groundwater table, where applicable.*
>
> *A technical report must be prepared by a person with appropriate training and/or experience in hydrogeology to include the following items:*
>
> *(a) water wells:*
> *(b) springs;*
> *(c) groundwater aquifers;*
> *(d) surface water courses and bodies;*
> *(e) discharge to surface water;*
> *(f) proposed water diversion, storage and drainage facilities on site;*

(g) methodology;
(h) description of the physical setting, including local geology, hydrogeology, and surface water systems;
(i) water budget;
(j) impact assessment;
(k) mitigation measures including triggering mechanisms;
(l) contingency plans;
(m) monitoring plan; and
(n) technical support data in the form of tables, graphs and figures, usually attached to the report.

All of the above listed items are addressed in this document but not necessarily in the same order.

Considering the hydrogeological conditions, groundwater use in the area, the amount of collected field data, and subsequent interpretation, this report should be regarded as a Hydrogeological Level 1 and Level 2 Assessment. According to the Ontario Provincial Standards, this report includes the requirements for Category 1, Class "A" license for a pit which intends to extract aggregate material from above and below the established groundwater table.

The scope of work includes a review of published geological and water resources maps, air photographs, and water well records on file with the Ontario Ministry of the Environment and Climate Change (MOECC). Reconnaissance of the Site and the adjacent lands was carried out during the summer and autumn of 2016. Water level monitoring and groundwater temperature profiling in monitoring wells began in late August 2016 on a monthly basis and is ongoing. Water level and temperature monitoring in surface water began in May 2016.

The information contained in this report has been prepared in accordance with accepted professional standards.

1.3 The Current Use of the Site

The Site consists of several parcels of farm land generally rectangular in shape but irregularly shaped along the northern boundary. The land is currently used for agriculture to grow cash crops.

The only existing structure on the site is a larger Quonset located to adjacent to the Central Pond (Figure 1)

2.0 SITE PHYSICAL FEATURES

2.1 Location and Site Description

The Site location is shown on Figures 1 and 2. The main entrance to the site is from Glendon Drive which runs parallel to the southern Site boundary. There is also an entrance to the Site from the west boundary which abuts to Amiens Road. There is no address 911 address.

The proposed sand and gravel extraction area is roughly rectangular in shape and elongated in a southwesterly to northeasterly direction. The western boundary is 297 m long while the eastern boundary is irregularly shaped. The southern boundary is 1,033 m long and the northern boundary is irregularly shape and slightly shorter than the southern boundary (see Figure 2).

2.2 Topography and Drainage

The regional topography and contours are shown on Figure 1 with contours intervals of 5 m. It can be seen from this figure that the highest elevation within this map area is 245 m above sea level (a.s.l.) and is located near the northwest corner of the map. The lowest elevation of 212 m a.s.l. is the Komoka Creek valley at south central boundary of the map area.

The topographic elevation of the Site is 239 m a.s.l., with the exception of the topographic knoll with 240 m a.s.l. contour located at the eastern margin of the Site (Figure 1).

Detailed site topography is shown in Figure 2, which is Drawing 1 of 3 (Bradshaw, 2016) with 1 m contour intervals. According to this drawing, the highest elevation is found at the eastern part of the Site which has elevation of 241 m a.s.l.

The drainage system and hydrological features on the Site and in the immediate vicinity are depicted on Figure 1. Komoka Creek is the only watercourse located within map area and it is located 100 east of proposed license area. It flows in the southerly direction, eventually emptying into the Thames River at 3 km distance from the Site.

A pond created by aggregate removal is located near eastern boundary of the Site. Two irrigation ponds are located outside but adjacent to the proposed licence area (Figure 1). These ponds are designated as: East (or Pit) Pond, Central Pond, and West Pond. There is also a recreational pond located behind the existing residence immediately north of the northwestern corner of the license area (Figure 2).

2.3 Natural Heritage Feature

Natural environment including vegetation communities on the Site and in the adjacent area were assessed by Biologic Incorporated in their report (Biologic, 2017). Vegetation communities on the Site and adjacent area are depicted by Figure 6 given in Appendix A. The adjacent area to the north and northeast is designated as a Provincially Significant Wetland (PSW) and is identified as Komoka Creek Wetland (www.utrca.ca). The latest Upper Thames River Watershed Report Card for Komoka Creek is available for 2012, and is provided in Appendix G of this report.

2.4 Adjacent Land Use

The proposed area is currently zoned agricultural. The zoning designations for adjacent lands are shown on Figure 2.

The lands immediately to the north and to the east are zoned A1-general agriculture. For the wooded area to the west and to the south, the lands are zoned A1-general agriculture.

The land use is residential for a small parcel of land to the northwest across CNR tracks from the subject lands.

2.5 Field Investigation and Instrumentation

Field work and associated instrumentation work was carried out as part of the assessment of aggregate resources at the Site (Englobe, 2017). The field investigation and instrumentation work was described by Englobe (2017) and it is summarised below:

> *"The fieldwork, consisting of five (5) sampled boreholes and seven (7) test pits, was carried out between August 22 and November 14, 2016, at the locations shown on Drawing 2 in Appendix 1. The test pits were dug with a track-mounted excavator, and the boreholes were advanced to the sampling depths by a track mounted power auger machine, which was equipped with conventional soil sampling equipment. Fifty-millimetre diameter monitoring wells were installed in the boreholes and they are identified as MW01-16 to MW05-16.*
>
> *Geodetic top of pipe and ground surface elevations and a site plan were provided by Wm. Bradshaw, P. Eng".*

Boreholes and test pits locations are shown in Figure 2 of this report. Borehole logs prepared by Englobe are provided in Appendix B.

Field investigations performed by Novaterra at the Site are summarized below:

- Initial Site reconnaissance work was done in May 2016 when three staff gauges (SG1, SG2, and SG3) were installed and water level monitoring in them began.
- Soon after the construction of monitoring wells in late August 2016, the wells were developed, and water level and temperature monitoring were initiated.
- Falling head slug test was performed in situ at four monitoring wells in order to obtain data to be used to calculate hydraulic conductivity at the Site.
- Surface water temperatures were measured on August 10 and 30, 2016 to assess thermal conditions in Komoka Creek.
- Water samples from monitoring wells MW2, MW3, and MW5 were obtained on November 15, 2016 and submitted for chemical analyses.
- Groundwater temperature profiling in five monitoring wells, and stream water levels and temperature at four temporary staff gauges is ongoing will continue for a full year.

Field data collected during the monitoring periods mentioned above are summarized in Tables 1 to 7.

3.0 GEOLOGY

3.1 Bedrock Geology

The Hamilton Group of formations constitute the bedrock under the site (Sanford, 1969). The Hamilton Group Formation is of middle Devonian age, and consists of greyish tan crinoidal limestone and grey shale

Based on the information from the nearest bedrock well, located approximately 500 m south of the Site (MOECC water well record number 4100803 on Figure 1), bedrock is found at a depth of 56.39 m below ground surface.

3.2 Quaternary Deposits

According to the Quaternary Geology Map which includes the subject area, the Site is underlain by recent and late Wisconsin deposits of aeolian origin (Dreimanis, 1964). They consist of fine sand; low dunes and sand plains, mostly in areas of former sandy deltaic lacustrine and beach deposits (Dreimanis, 1964). The Quaternary Geology at the Site and the surrounding area is depicted in Figure 3.

The driller’s log for the nearest bedrock well located 500 m north of the Site indicates that the thickness of glacial drift is 56.39 m. This water well record (number 4100803) indicates that the glacial deposits consist of gravel and medium sand deposits to 30.78 m which are underlain by blue clay and hardpan (Appendix C).

Regional cross-section A-A’ on Figure 4 illustrates the geology at the subject site and the surrounding area.

3.3 Subsurface Condition at the Site

A detailed description of glacial deposits at the Site is given in the report on the subsurface investigation which consisted of eight test pits and six boreholes, prepared by Englobe (2017). The subsurface layers intercepted during the test drilling are given in borehole logs for five monitoring wells contained in Appendix B of this report. These borehole logs were completed in August 2017 by Englobe (2017).

The subsurface conditions at the subject site are described in the Englobe (2017) report.

Information from onsite borehole logs were used to construct vertical cross-sections B-B’ and C-C’ which are shown on Figure 5.

Subsurface conditions at the Site are also illustrated on Figures 6, 7, 8, 9, 10 and 11. Information used to construct these figures was derived from borehole logs and water level monitoring results. This information is summarized in Table 4. It should be noted that the depths of the eight test pits excavated at the Site were not deep enough to provide information to be used in the construction of these figures.

The near surface deposits at the Site are described as sand and gravel with trace of silt, fine sand, and sandy silt. As described in the borehole logs, these deposits are underlain by fine sand with some silt, grey silty sand and sandy silt (Appendix B).

Five of the boreholes were completed as monitoring wells and are designated in this report as: MW1, MW2, MW3, MW4, and MW5. The monitoring wells are identified in the Englobe (2017) report as borehole numbers MW-01-16, MW-02-16, MW-03-16, MW-04-16, and MW-05-16.

3.3.1 Aggregate Material Thickness

Using information from the five borehole logs and eight test pits, together with site topography as shown on Drawing 1 of 3 (Bradshaw, 2016; see Figure 2), the thickness of aggregate material was delineated and is shown on Figure 6.

None of the five boreholes reached silt, clay or glacial till. However, they were all terminated into fine granular deposits such as silty fine sand, fine sand with some silt, and sandy silt. Therefore, the economically viable aggregate deposits at the site are considered to be the sand and gravel which overlie these fine granular deposits. Figure 6 shows a uniform thickness of aggregate deposits, which varies between 9.2 m and 10.7 m.

3.3.2 Structure Contours on Sandy Silt

Information from five referenced boreholes was used to construct representative structure contours of sandy silt and silty fine sand. This is shown on Figure 7.

It can be seen from Figure 7 that the bottom of designated aggregates is very flat, varying in elevation between 227 and 228 m above sea level.

4.0 HYDROGEOLOGY

4.1 Regional Hydrogeology

Vertical cross-section A-A' illustrates regional hydrogeological conditions in the study area (Figure 4). This cross-section, together with information shown on Figure 1, indicate that the majority of the domestic wells for which water well records are available obtain water from wells completed in shallow overburden. But there are other domestic wells which were constructed into shallow water table aquifer. These domestic wells are actually sand points for which there are no water well records on MOECC files.

4.2 Site Hydrogeology and Water Table Aquifer

Vertical cross-sections B-B' and C-C' illustrate hydrogeological conditions in the shallow subsurface at the Site (Figure 5). They show that the deeper portions of the sand and gravel deposits are saturated, thus constituting a water table aquifer. The depth to water table from ground surface is depicted in Figure 8 while the thickness of the saturated portion of sand and gravel (i.e. the aquifer) is illustrated in Figure 9.

Figure 9 shows that the aquifer thickness varied between 6.64 m and 8.81 m in five onsite monitoring wells on October 16, 2016. The thickest portion of the aquifer is in northern-central and western segments of the Site where it is 8.81 m thick.

We acknowledge that Map 4-3-2 in the Upper Thames River Source Protection Area Assessment Report prepared by Thames-Sydenham and Region Source Protection Committee (2015) identifies Highly Vulnerable Aquifers (HVA). This map indicates that the Site is located in a HVA (Vulnerability Score of 6.0). At this point in time there are no Policies or Source Protection Plans as to which human activities may be restricted in such areas.

4.3 Shallow Groundwater Flow and Hydraulic Gradient

Water level elevations were used to construct water table configuration for two different conditions in the field. The water table configuration during hydraulic high (March 2017) is depicted by Figure 10, while the water table contours during hydraulic low (October 2016) are depicted by Figure 11.

The comparison of Figures 10 and 11 show very similar groundwater flow pattern, with groundwater flow direction from northwest to southeast. In both cases, there exists a ground water trough which extends from the Central Pond (SG3) towards MW3.

A notable difference between the low and high groundwater flow situations are reflected in the difference of water table elevation which is approximately 0.5 m higher during hydraulic high than during hydraulic low. Another difference is that there appears to exist a very small hydraulic groundwater mound which encompasses MW4 and the East (Pit) Pond (SG2) as it can be seen on Figure 11.

The existing monitoring wells at the subject Site were used to perform falling head hydraulic conductivity tests. These tests were done on August 25, 2016 at four monitoring wells (MW1, MW3, MW4, and MW5). The results are summarized in Table D2 in Appendix D, along with a more detailed description of how they were obtained.

Based on the hydraulic conductivity test, and subsequent calculations using the Hvorslev (1951) method, the approximate hydraulic conductivity at the Site is 8.28×10^{-3} cm/s.

Although there was some variation in hydraulic conductivity between the four well locations, the average value of hydraulic conductivity, together with hydraulic gradients and porosity were used to calculate groundwater velocities.

The obtained values for groundwater velocity between MW1 and MW2 for the hydrologic low on October 19, 2016 was 0.036 m/day. The value for velocity was obtained by applying Darcy's equation and using the following input parameters: $i = 1.50 \times 10^{-3}$ m/m, $k = 8.28 \times 10^{-3}$ cm/s, and porosity of 30%.

An almost identical value for groundwater velocity was obtained for the hydrologic high on March 17, 2017 (Figure 10) between MW1 and MW2.

4.4 Water Level Fluctuations

Depths to water levels in five monitoring wells were measured on a monthly basis from August 26, 2016 to March 17, 2017 inclusive, and are ongoing. Additionally, water level stages in the local watercourse Komoka Creek (staff gauges SG1), and in three ponds (SG2, SG3, and SG4) were also monitored on a monthly basis since May 2016. The collected depth to water level data are summarized in Table 2, and the water level elevations in Table 3.

Depths to water level data given in Table 2 were used to produce depth to water level hydrographs which are shown on Figure 12. The water levels on this figure depict the depth to water level in metres below top of casing. The shallowest depth to groundwater is in MW2 and MW5, followed by MW1, MW4, and MW3. In the first two wells, depth to water level varies between 2.71 and 2.18 m below the ground surface, while in MW1 and MW4 it varies between 3.33 and 2.57 m below top of casing (Figure 12). The deepest groundwater level is in MW3, which varied between 4.29 and 3.85 m below top of casing. This is consistent with the ground surface elevation at MW3 which is the highest of all the monitoring wells.

Water level elevation data given in Table 3 were used to produce water level elevation hydrographs which are shown on Figure 13. This figure also includes water level elevation at the surface water monitoring stations. For the entire monitoring period, the highest water level elevation occurred in mid-March 2017, while the lowest was in October 2016. The influence of precipitation, which is also plotted on Figures 12 and 13, on water level elevation is evident. For example, there was a significant amount of precipitation in August 2016 prior to the hydrographs attaining relatively high water level elevations.

4.5 Surface Water Courses and Water Bodies

The nearest watercourse is Komoka Creek which is located east of the Site, with its nearest portion approximately 100 m from the Site (Figure 1). In this portion, the Creek flows in the southeasterly direction for about 700 m then, after passing under Glendon Drive, it changes to a southwesterly flow direction. After 2.2 km, it empties into the Thames River.

In this portion, Komoka Creek is part of a Provincially Significant Wetland and it is inhabited, among others, with 21 fish species which also include Brown and Rainbow Trout (see Appendix G).

There are three dugout ponds on the subject site. Two of them (Central and West) are used for crop irrigation, while East pond is the result of aggregate extraction.

There are no groundwater springs or groundwater seepages on the Site.

There is no watercourse on the Site itself. There is no proposed water diversion or storage, nor any existing or proposed construction of drainage facilities on the Site.

4.6 Relationship Between Groundwater and Local Watercourse

There is one temporary staff gauge installed in Komoka Creek, and it is designated as SG1 see Figures 1 and 2). This staff gauge was installed perpendicular to monitoring well MW4 in order to assess interaction between groundwater at the Site and the surface water of Komoka Creek.

In this regard, the water level elevation hydrograph for Komoka Creek (SG1) is compared with the water level elevation hydrograph for the nearest monitoring well MW4 in order to assess the relationship between the Creek water and groundwater (see Figure 13). It can be seen from Figure 13 that the groundwater elevation in MW4 is consistently higher than the elevation in Komoka Creek which signifies that there is a groundwater hydraulic gradient toward Komoka Creek. This means that the water course receives groundwater, enabling it to maintain flow even if there is no precipitation during prolonged dry summer months. In this situation, Komoka Creek is defined as an effluent stream (Delleur, 1999) which means that the stream *does* receive groundwater.

The flow in Komoka Creek was measured on April 22, 2017 to be approximately 390 L/sec. Based on temperature measurements by Novaterra in August 2016, the Komoka Creek is classified as a cool water stream (see Table 5.1 in Section 5.0). Based on this measurement, and using the staff gauge readings, it is estimated that the low flow condition on October 19, 2016 is approximately 135 L/s.

4.7 Groundwater and Surface Water Use

Water well records on file with the MOECC were obtained and analyzed. Available water well records within the map area of Figure 1 were plotted on this figure. Five water well records were plotted on Figure 1 and are also summarized in Appendix C. Two additional water well records summarized in Appendix C are located outside of the map area. These are water well record numbers 4112864 and 4106751 which are located in the northwestern parts of Lots 1 and 2, Concession 2.

Of these seven water well records, six wells were completed in overburden and one well was completed into bedrock. The existence of the wells plotted on Figure 1 was not field verified except for the bored well which has water well record number 4113244 which is located southeast of the site, on Glendon Drive. However, the exact water well record numbers for other locations cannot be confirmed because the wells were all completed prior to 2003 when the Ontario Well Tag requirement was instituted.

A door-to-door survey was performed, and identified the existence of numerous domestic wells along Glendon Drive, south of the Site. The survey results are shown on Table 1, and the survey locations are also identified on Figure 1. All surveyed residences obtain water from the shallow water table aquifer by means of sand points or dug wells. It would not be possible to measure the depths of these sand points and depths to water levels even if access to these groundwater structures were granted by the well owners. Many of the surveyed residents do not know the locations of their sand points.

Four of the seven water well records given in Appendix C have well screen bottoms varying between 9.75 and 15.24 m below ground surface. One well is 0.91 m diameter and 11.28 m deep bored well. Another one is 1.2 m diameter and 24.5 m deep monitoring well, and another is 56.69 m deep, and is completed into the bedrock.

There are two irrigation ponds located north and just outside of the proposed licensed area. These two ponds are identified in this document as the Central Pond and West Pond, and each have temporary staff gauges SG3 and SG4, respectively (Figures 1 and 2). They are both authorized by MOECC Permit to Take Water number 1273-8WKH89 to irrigate the local farming operation. The PTTW authorizes Grand Bend Producing Co. Ltd. to pump 2,700,000 L/day from each irrigation pond.

The next nearest existing PTTW is outside of the map area of Figure 1 and is located approximately 300 m west of the western boundary of the proposed Maes pit. This PTTW authorizes the Permit Holder to take 2,700,000 L/day.

4.8 Groundwater Temperature Profiles

During the period from August 26, 2016 to March 17, 2017, inclusive, a Temperature/ Level/Conductivity (TLC) instrument (made by Solinst Canada Ltd.) was used to measure depths to water levels and temperatures at depth in all five monitoring wells (MW1, MW2, MW3, MW4, MW5). The obtained temperatures at interval depths in five monitoring wells are given in Table 5. These data are presented graphically for each monitoring well on Figures 14, 15, and 16.

Temperature monitoring was done on a monthly basis with the first temperature measurement at each location being within 0.1 m below the top of groundwater level. Subsequent measurements were at 0.5 m depth increments. Therefore, the tops of the temperature profiles are a reasonable indicator of the depth to the groundwater table below the ground surface at the time of measurement.

Examination of Figures 14, 15 and 16 indicates that the shape and position of the temperature profiles depends on the time of year, the depth to water level below ground surface, and the depth at which measurement were taken. Significantly, the shallow groundwater exhibits relatively wide temperature differences, while the deeper groundwater has a much narrower range of temperature fluctuations.

There are significant similarities in the temperature profile graphs for all monitoring wells; in particular for MW1, MW2, and MW5. Depth to water level in these monitoring wells is 2.5 m to 3 m below ground surface. Temperature profiles in these three monitoring wells exhibit conical shapes which gets narrower from water surface to about 5.5 m to 6 m below groundwater surface. At depths greater than 6 m below ground (2.5 to 3 m below water level), the average groundwater temperature is approximately 10°C. Temperature spread in this zone becomes very narrow, with a spread of about 2°C (between 9°C and 11°C) and maintains this constant spread to the bottom of water column throughout the year (Figures 14 and 16).

Temperature profiles at monitoring wells MW3 and MW4 are quite similar with a less sharp reduction in the temperature spread at 6.5 m below ground (i.e. 3 to 4 m below water level). Temperature spreads below this depth are approximately 3°C and they approach an average groundwater temperature of 10°C near the bottom of the wells (Figure 15).

It is worth noting that coldest temperature at the bottom of the monitoring wells is reported to be in the August to September time period and the warmest is during the January to February time period. In the shallower groundwater zones, the conditions are reversed.

As the air and ground surface cools off in the fall, the colder air temperatures progressively move into the subsurface. Consequently, temperature profiles start shifting to the left, beginning in November. We could think of it as a transient cool wave, slowly moving into the subsurface. This continues until the spring snowmelt in late February, March, and early April, when large quantities of cold water infiltrate into the ground, reaching the saturated zone of the water table and then mixing with groundwater. This is applicable for the shallow saturated zone when the depth to water table is less than 1.5 m. But as we move deeper into the aquifer the temperature spread becomes narrower.

Typical examples to be observed and compared for shallow groundwater are in MW1 and MW2 where the temperature spread is between 7°C and 16°C and the depth to water levels are between 2.5 and 3.5 m below ground surface. At monitoring well MW3 the water levels are slightly deeper at 4.0 to 4.5 m below ground, and the temperature spread is slightly narrower between 9°C and 15°C (Figure 15).

4.9 Chemical Quality of Groundwater

Water quality sampling of groundwater was undertaken at three of the onsite monitoring wells: MW2, MW3, and MW5. The purpose of the groundwater sampling was to establish a groundwater quality baseline for future references.

Four groups of chemical parameters were analyzed, which include: general inorganics, anions, metals, and volatiles. The rationale for selecting the sampling locations was that two groundwater samples be taken downgradient from the proposed aggregate extraction area (MW2 and MW3) and one sample be taken from upgradient and adjacent to the Provincially Significant Wetland (woodlot) which would serve as a groundwater quality background.

Sampling procedures consisted of pumping at least three volumes of water from each well, allowing water levels to stabilize, and then taking samples using bailers. Collected samples were immediately placed into sampling bottles obtained from the analytical laboratory, and stored in a cooler with ice packs to preserve sample temperature and quality. Water samples were delivered to Paracel Laboratories in London, Ontario, in accordance with the acceptable chain of custody procedure.

The results of the chemical quality analysis of groundwater in these three wells are given in Table 7 while the Laboratory Certificate of Analysis is given in Appendix E.

The analytical results were compared with Ontario Drinking Water Standards (ODWS) which are given in column 4 in Table 7. It can be seen from this table that all chemical parameters for which water samples were analysed are lower than ODWS except for manganese in MW5. Content of manganese in MW5 is 5.5 times higher than the ODWS for this chemical parameter. This monitoring well is located approximately 18 m south of the ditch along the CN railway tracks. It is theorized that the elevated manganese in MW5 is the result of the application of herbicide on the railway right of way to control weeds.

5.0 PROPOSED OPERATION AND POTENTIAL IMPACT

5.1 Proposed Mining of Aggregate Deposits

The field investigations have revealed that the site contains considerable quantities of sand and gravel with commercial value, as indicated in the Englobe (2017) report.

The thickness of the potential aggregate deposits, including topsoil, can be observed on Figure 6. A portion of these deposits are saturated, as shown by the inferred depth to water table on Figure 8, and the thickness of saturated sand and gravel on Figure 9. Extraction of saturated sand and gravel material requires mining below the water table. Therefore, the approximate areal distribution and thickness of aggregate deposits that would be mined from below water table is shown on Figure 9.

It is proposed to extract sand and gravel from above and below the water table by using a hydraulic excavator or dragline. Where possible, sand and gravel will be completely removed until the sandy silt or silty sand are reached. The elevation of the sandy silt and silty sand which underlie the aggregate deposits, are delineated on Figure 7.

Based on the above information, the approximate depth of sand and gravel extraction is shown on Drawing 2 of 3, and Drawing 3 of 3 (Bradshaw, 2016). This can be observed on cross-sections B-B’ and C-C’, as shown on Figure 5 in this report, where the aggregate extraction would take place relative to the underlying sandy silt, silty sand, and fine sand and silt.

5.2 Final Land Use

The proposed mining of sand and gravel would result in the creation of a pond 17.6 hectares in size. The pond depths will be influenced by the topography of sandy silt and silty sand which is shown on Figure 7. Final rehabilitation configurations showing the shape, size, and bottom elevation of the future ponds are shown on Drawing 3 of 3 (Bradshaw, 2016) as well as Figure 18 of this report.

It can be seen from Figure 18 that the lowest elevation of the sandy silt which mainly underlies the sand and gravel deposits is in the north central portion of the Site. That is, in the area of monitoring well MW5 where the pond bottom has an elevation of +/-227m. There is an insignificant drop in elevation of sandy silt across the Site from west and east of 2 m (from MW1 and MW4 to MW5; Figure 7). Accordingly, the depth of the future pond would vary between 6.6 and 8.8 metres in the east to west direction (Figure 18).

Based on the groundwater level data it is surmised that the elevation of the future pond water would be in the range of (+/-) 235 m a.s.l. This value was obtained by taking the average of the water level elevation in all five on-site monitoring stations MW1, MW2, MW3, MW4 and MW5 throughout the monitoring period of August 26, 2016 to March 17, 2017 (Figure 13).

5.3 Water Budget and Assessment of Potential for Groundwater Impact

The proposed mining of sand and gravel from below the water table could theoretically cause temporary lowering of the water table in the vicinity of the proposed operation. This can be caused in two ways:

1. The potential change in water budget due to the increase in evaporation from an open water body and increased surface runoff into the pond.
2. The removal of sand and gravel may initially and temporarily generate water level lowering near the outside edges of the pond when the pond is small.

Both aspects were examined, and subsequent calculations were made to see if these aspects have any realistic chances of having any negative impacts. A detailed description of the calculations is given in Appendix F and is summarized in this Section.

The annual water budget for the site in its current state indicates that: of the 954 mm of annual precipitation, 550 mm is lost to evapotranspiration, 308 mm infiltrates into the ground, and 132 mm leaves the site as runoff (Table F1 in Appendix F).

After rehabilitation, evapotranspiration would be replaced by lake evaporation which is 634.5 mm, runoff would not exist and instead the remaining precipitation, which is 319.5 mm would remain onsite and eventually contribute to the groundwater system (Table F3 in Appendix F). This means that final site conditions would have more water lost to evaporation but runoff would not exist. Any water that currently leaves the site as runoff would instead be captured in the pond, resulting in overall gain in the groundwater system of 120.5 mm.

Removal of aggregate material may cause a small lowering of the water level in the pond as the extraction progresses. The water level in the pond during the early phase of extraction may show daily lowering of 0.110 m but is expected to be temporary and to recover between work days. During late phase of extraction when the pond approaches its final size of 17.6 ha., this lowering is expected to be even smaller, reaching less than 0.01 m daily (see Appendix F). This value is insignificant and would not cause any groundwater drawdown for any significant distance outside of the very immediate pond area.

Six domestic wells nearest to the Site are located approximately within 50 m from the future pond. All of them obtain water from the water table aquifer, and lowering water levels in the pond due to the proposed operation would be inconsequential to the water quantity in these domestic wells. They are too far away from the pit to show any measurable effect.

Water in the future pond has the potential to warm up during the summer months. However, water from the future pond would move downgradient which is the southeasterly direction and away from the Komoka Wetland. Therefore, there will not be any effect to adjacent water courses and the natural environment by the proposed operation.

5.4 Thermal Condition in Komoka Creek and On-Site Ponds

The method developed by Stoneman and Jones (1996) was used to establish the thermal condition in the nearest watercourse which is Komoka Creek. The results are shown in Table 5.1.

Table 5.1. Thermal Condition in Komoka Creek and onsite Ponds.

Monitoring station	Temperature °C		Time of measure	Thermal status of stream*
	Water	Air[1]		
August 10, 2016				
SG1 at Komoka Creek	23.1	32.9	16:00	Cool water
SG2 at East (Pit) Pond	30.2	32.9	16:20	N/A
SG3 at Central Pond	26.6	32.9	16:26	N/A
SG4 West Pond	27.1	32.9	16:30	N/A
August 30, 2016				
SG1 at Komoka Creek	19.7	27.7	17.34	Cool water
SG2 at East (Pit) Pond	27.4	27.7	17.48	N/A
SG3 Central Pond	22.6	27.7	17.58	N/A
SG4 West Pond	22.7	27.7	18.05	N/A
MW4 (groundwater)	13.8	27.7	17.40	N/A

* Based on criteria developed by Stoneman and Jones (1996)

[1] London Airport Climate Station; N/A –not applicable.

The results indicate that Komoka Creek is a cool water stream. Groundwater temperature in the future onsite pond would have a temperature close to 30°C which can be seen on Table 5.1 and Figure 17 (see SG2 for August 10, 2016). Therefore, it would have a theoretical potential to affect temperature in Komoka Creek. This is aspect discussed in the following section of this report (Section 5.5).

5.5 Potential for Thermal Impact on Komoka Creek

The groundwater flow system shown on Figures 10 and 11 was examined with respect to groundwater flow direction, hydraulic gradient, and groundwater velocity in the area of the Site and areas nearest to Komoka Creek.

Groundwater velocity between MW1 and MW2 is calculated to be 0.18 m/day for hydrologic high and 0.16 m/day for hydrologic low condition.

It is recognized from these figures and associated information that there is very small hydraulic mound in the area of the East Pond staff gauge, (SG2) and the area of MW4. Some of the radial groundwater flow from the groundwater hydraulic mound includes an easterly component towards Komoka Creek in the area of SG1. Using data from Figures 10 and 11, the hydraulic groundwater gradients between SG2 and Komoka Creek were calculated for the hydrologic high (Figure 10) and for the hydrologic low (Figure 11). The obtained values are 0.00283 m/m for hydrologic high and 0.000833 m/m for hydrologic low condition.

The field value of hydraulic conductivity obtained for monitoring well MW4 (Table D2 in Appendix D) which is $1.60x10^{-3}$ cm/s was used as one of the input parameters. Using this value, together with hydraulic gradients as noted above, and porosity of 30%, the Darcy equation was applied to calculate groundwater velocity in the direction of Komoka Creek. The calculated groundwater velocities are 0.013 m/day for the hydrologic high and 0.0038 m/day for the hydrologic low situations.

The obtained groundwater velocities indicate that it would take several thousand years for groundwater to travel from the edge of the future pond near MW4 to Komoka Creek. Because the groundwater gradient is much smaller during hydrologic low, it would take even longer for groundwater to travel from the future pond to Komoka Creek.

With this in mind, groundwater reaching Komoka Creek from the proposed future pond would have ample time to cool to the current average groundwater temperature of 10°C. Based on these calculations, it is concluded that there is no potential for the proposed operation to have any hydrogeological impact on Komoka Creek or on the Komoka Wetland.

5.6 Potential for Cumulative Impact

There is only one other pit pond within the Komoka Creek Watershed. It is located approximately 350 m northeast from the proposed Maes Pit.

Because there is no potential for thermal impact from the proposed Maes Pit, there is no justification for considering cumulative thermal impact on Komoka Creek.

It should also be recognized that there are currently large water withdrawals from the two existing irrigation ponds (SG3 and SG4) for irrigation purposes. As extraction proceeds, the farmed areas requiring irrigation will lessen. Intuitively one can see that the irrigation needs will lessen over time.

6.0 CONTINGENCY PLAN AND MITIGATION MEASURES

The proposed sand and gravel operation calls for aggregate extraction above and below the water table. In such a situation, the use of equipment for Site operations may pose a potential risk of petroleum hydrocarbons such as fuels, oil and grease to enter the exposed groundwater system unless the proper operation and refuelling procedures are followed. To address these potential risks, a **Spills Plan** shall be incorporated into the Site Plans.

The following water well interference complaint shall be incorporated into the site plans:

Water Supply Interference Complaint Response Procedures:

This response applies to domestic and farm water supplies for properties located in the vicinity of the licensed boundary.

1. Owners of domestic and farm water supplies experiencing disruption or quality problems shall immediately notify the Licensee. The Licensee shall, upon receipt of any water supply disruption complaint, notify the Ministry of Natural Resources and Forestry (MNRF) and the Ministry of Environment and Climate Change (MOECC).

2. Should the owner of domestic and farm water supplies experience a significant disruption in their supply of water, or should they experience significant adverse effects upon their water supply; and if the operation of the pit cannot obviously and definitively be excluded as the cause, the licensee shall supply such resident with a temporary water supply within 24 hours and thereafter until such time as the cause of the disturbance can be determined and the situation addressed. The Licensee shall investigate the cause of the water supply disturbance and shall report to the MNRF, MOECC and the resident.

3. If, after consultation with the affected resident and the Licensee, the MNRF and/or the MOECC concur that the operation of the pit has caused a domestic or farm water supply to be adversely affected, the Licensee shall, at the Licensee's expense, either restore or replace the water supply to ensure that historic water supply and quality are restored for such a resident.

4. If MNRF and/or MOECC have concurred that the operation of the pit has not caused any domestic or farm water supply to be adversely affected the Licensee shall maintain the temporary water supply provided for under Item 2 for an additional 24 hours to allow the resident to make alternate water supply arrangements.

7.0 MONITORING PROGRAM

There is no proposed dewatering of the gravel pit. Aggregate extraction is proposed for excavation below the water table using an excavator or a drag line. Changes to water balance are small and inconsequential. As such, measurable interference with local water supplies is highly unlikely.

A monitoring program is in place which includes five monitoring wells (MW1, MW2, MW3, MW4, and MW5), and four staff gauges (SG1, SG2, SG3, and SG4). The monitoring program commenced in May 2016 at staff gauges and in August 2016 at monitoring wells on a monthly basis and included water levels and groundwater temperature profiles in monitoring wells, and water levels and water temperatures at four staff gauges. Monitoring will continue as noted in the Recommendations Section.

Water samples were obtained from monitoring well MW2, MW3 and MW5 and were analyzed for four groups of parameters which included: general inorganics, anions, metals, and volatiles. Groundwater quality from MW2 and MW3 are used as downgradient background onsite groundwater quality monitoring while water quality obtained from MW5 serves as upgradient background water quality monitoring from the proposed operation.

8.0 CONCLUSIONS

Based on the information collected in the field and analysis of available data, the following conclusions are made:

1. There exists a substantial quantity of sand and gravel at the Site. The thickness of sand and gravel deposits varies between 9.2 m and 10.7 m. The deeper portion of these deposits is saturated with the depth to water table varying between 1.80 m and 3.42 m below ground surface, as measured on October 19, 2016. The saturated zone constitutes a water table aquifer with flow generally in the southeasterly direction.

2. Hydraulic conductivity was obtained by performing falling head slug tests in four monitoring wells. Applying the Hvorslev method to the collected field data resulted in an approximate hydraulic conductivity of $8.28\text{x}10^{-3}$ cm/s.

3. All adjacent residences obtain water from the shallow water table aquifer mainly by means of shallow sand points. Door-to-door survey at these residences did not reveal that there are water supply problems at these residences. All of them except one are located along Glendon Drive. The other residence is along Amiens Road, on the north side of the railway right-of-way, adjacent to the western corner of the Site.

4. It is proposed to have aggregate extraction from above and below the water table. Site rehabilitation will result in the creation of a pond 17.6 hectares in size and up to 8 m in depth.

5. After site rehabilitation, evapotranspiration will be replaced by lake evaporation due to the creation of a 17.6 hectare pond. Water budget calculations show that, although lake evaporation is higher than evapotranspiration, there would be a gain in the water budget of 120.5 mm. This is because once the pond is created, runoff will no longer exist in the area of the pond, and any precipitation remaining at the site will be retained by the pond and eventually recharge the groundwater.

6. All parameters for which water samples were analysed were within Ontario Drinking Water Standards, except for manganese in MW5. The elevated manganese in this monitoring well is thought to be the result of the application of herbicides on the adjacent railroad right-of-way.

7. The hydrogeological site assessment and associated calculations indicate that the proposed mining of sand and gravel deposits will not have any adverse effect on water resources, including the natural environment in the area and domestic water wells.

9.0 RECOMMENDATIONS

Based on the conclusions drawn from the work described herein, the following recommendations are made and should be incorporated into the site plans:

1. Fuel storage onsite shall be in compliance with the Technical Standards and Safety Act 2000 and the Liquid Fuels Handling Code 2001, as may be amended.

2. Maintenance and refueling of mobile excavation equipment and other vehicles shall take place in the fuel storage area. Crushers, stackers, and screening plants shall be refueled and maintained on the pit floor during daylight hours. Any minor drips or spills shall be immediately cleaned up and properly disposed of.

3. A “Spills Plan” shall be incorporated into the Site Plans.

4. If any water well is encountered onsite during aggregate extraction, such well shall be decommissioned in accordance to O. Reg. 903.

5. Background water levels and groundwater temperature profiles in five monitoring wells (MW1, MW2, MW3, MW4 and MW5) and at three staff gauges (SG1, SG2, and SG3) shall continue to be monitored on a monthly basis for one full year. Manual water level monitoring at five monitoring wells (MW1, MW2, MW3, MW4 and MW5) shall continue after a pit license is issued, four times a year for the duration of pit operations.

6. Background groundwater chemical quality in monitoring wells MW2, MW3 and MW5 have been established and shall be used as a baseline for future water quality sampling at the site, if required.

7. After issuance of the pit license, an initial report summarizing background conditions at the Site shall be prepared within 2 months after the end of the calendar year in which the license was issued. Subsequent annual monitoring reports will summarize monitoring data and assess changes in groundwater at the Site. The reports shall be prepared by a qualified hydrogeologist with recommendations, if any, and shall be submitted to the MNRF in Aylmer and to the MOECC in London.

8. If complaints regarding groundwater interferences are received, “Water Supply Interference Complaint Response Procedures” shall be followed and the licensee shall take appropriate measures as deemed necessary by the MOECC and/or MNRF to rectify the

problem(s). The "Water Supply Interference Complaint Response Procedures" (noted in section 6) shall be implemented on the Site Plans."

9. Establishment of background water quality in the shallow neighbouring domestic wells will not be necessary because background water quality sampling was already done in three onsite monitoring wells. One of the sampled monitoring wells is in the upgradient portion of the Site and the two others are in the downgradient portion of the Site. They are strategically placed upgradient from the nearest neighbouring domestic wells.

Respectfully Submitted,

Novaterra Environmental Ltd.

Blagy Novakovic, M. Sc. P. Eng.
Principal/Senior Hydrogeologist

Sasha Novakovic, B.A.Sc. EIT
Intermediate Hydrogeologist

LICENSED PROFESSIONAL ENGINEER
B. NOVAKOVIC
34345017
2017/05/29
PROVINCE OF ONTARIO

10.0 REFERENCES

BioLogic Incorporated, 2017.
Natural Environment Level 1 & 2 Report, Maes Pit, Komoka, Ontario. Johnston Bros. (Bothwell) Limited. Draft Figures 1 to 8, inclusive. May 2017. (Revised Final Version dated November 28, 2017).

Dreimanis, A, 1964.
Pleistocene Geology of the St. Thomas Area (West Half) Southern Ontario. Preliminary Geological Map No. 238. Ontario Department of Mines.

Blackport Hydrogeology Inc. and Golder Associates, 2006.
Applied Research on source water protection issues in the aggregate industry phase 1 findings: Prepared for: The Ministry of Natural Resources: November, 2006.

Bradshaw, W. L 2016.
Johnston Brothers (Bothwell) Limited, Maes Pit, Part Lots 1 and 2, Concession 2, Township of Middlesex Centre, Formerly Township of Lobo, County of Middlesex, Drawings: Existing Features, Operational Plan, Consultants Recommendations and Progressive Rehabilitation and Final Rehabilitation Plans. Scale 1:2000. October, 2016.

Chapman, L.J. and Putnam, D.F., 1984.
The Physiography of Southern Ontario Third Edition. Ontario Geological Survey Special Volume 2. Ministry of Natural Resources.

Delleur, J. W. (Editor), 1999.
The Handbook of Groundwater Engineering, CRC Press LLC. Boca Raton.

Dreimanis, A. 1964.
Pleistocene Geology of the St. Thomas Area (West Half), Ontario Geological Survey, Map No. P. 238, scale 1:50,000.

Environment Canada, 2015.
Canadian Climate Normals, Volume 9, Soil Temperature, Lake Evaporation, Days with Blowing Snow, Hail, Fog, Smoke or Haze, Frost, 1981 -2010.

Englobe, 2017.
Johnston Brothers (Bothwell) Ltd., Geotechnical Investigation, Part of Lots 1 and 2, Concession 2, Municipality of Middlesex Centre, Middlesex County, Aggregate Assessment Report. March 6, 2017.

Freeze, R.A., and Cherry, J.A., 1979.
Groundwater. Englewood Cliffs, N.J.: Prentice-Hall.

Hvorslev, M.J., 1951.
Time lag and soil permeability in ground water observations. U.S. Army Corps of Engineers Waterway Experimentation Station, Bulletin 36.

Ontario Ministry of the Environment, 1981.
Thames River Basin, Water Management Study, Technical Report, Groundwater Resources. Water Resources Report 14.

Ontario Ministry of Environment and Energy 1995.
MOEE Hydrogeological Technical Information Requirements for Land Development Application, April 1995.

Ontario Ministry of Natural Resources, 1997.
Aggregate Resources of Ontario, Provincial Standards, Version 1.0. Queen's Printer for Ontario.

Sanford, B.V., 1969.
Geology of Toronto-Windsor Area, Ontario. Geol. Surv. Canada, Map 1263A, scale 1:250,000

Stoneman, C. and M. L. Jones, 1996.
A simple method to classify stream thermal stability with single observations of daily maximum water and air temperatures. North American Journal of Fisheries Management 16: 728-737.

Thames-Sydenham and Region Source Protection Committee, 2010.
Thames-Sydenham & Region, Tier 1 Water Budget, Version 1.0 (Draft Accepted), September 15, 2010.

Thames-Sydenham and Region Source Protection Committee, 2015.
Thames-Sydenham and Region Source Protection Committee, Upper Thames River Source Protection Area, Assessment Report, Approved September 17, 2015.

Upper Thames River Conservation Authority 2012. Komoka Creek 2012 Watershed Report Card.

11.0 LIMITATIONS

This report was prepared by Novaterra Environmental Ltd. (Novaterra) for the exclusive use of Johnston Bros. (Bothwell) Limited. The material in it reflects Novaterra's best judgement in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Novaterra accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

The report was prepared based, in part, on information and data for the Site provided to Novaterra Environmental Ltd., by other parties. It is assumed that the information provided is factual and accurate. We accept no responsibility for any deficiencies, misstatements or inaccuracies contained in this report as a result of omissions, misinterpretations or fraudulent acts of these other parties.

FIGURES

Figures 1 to 18 inclusive

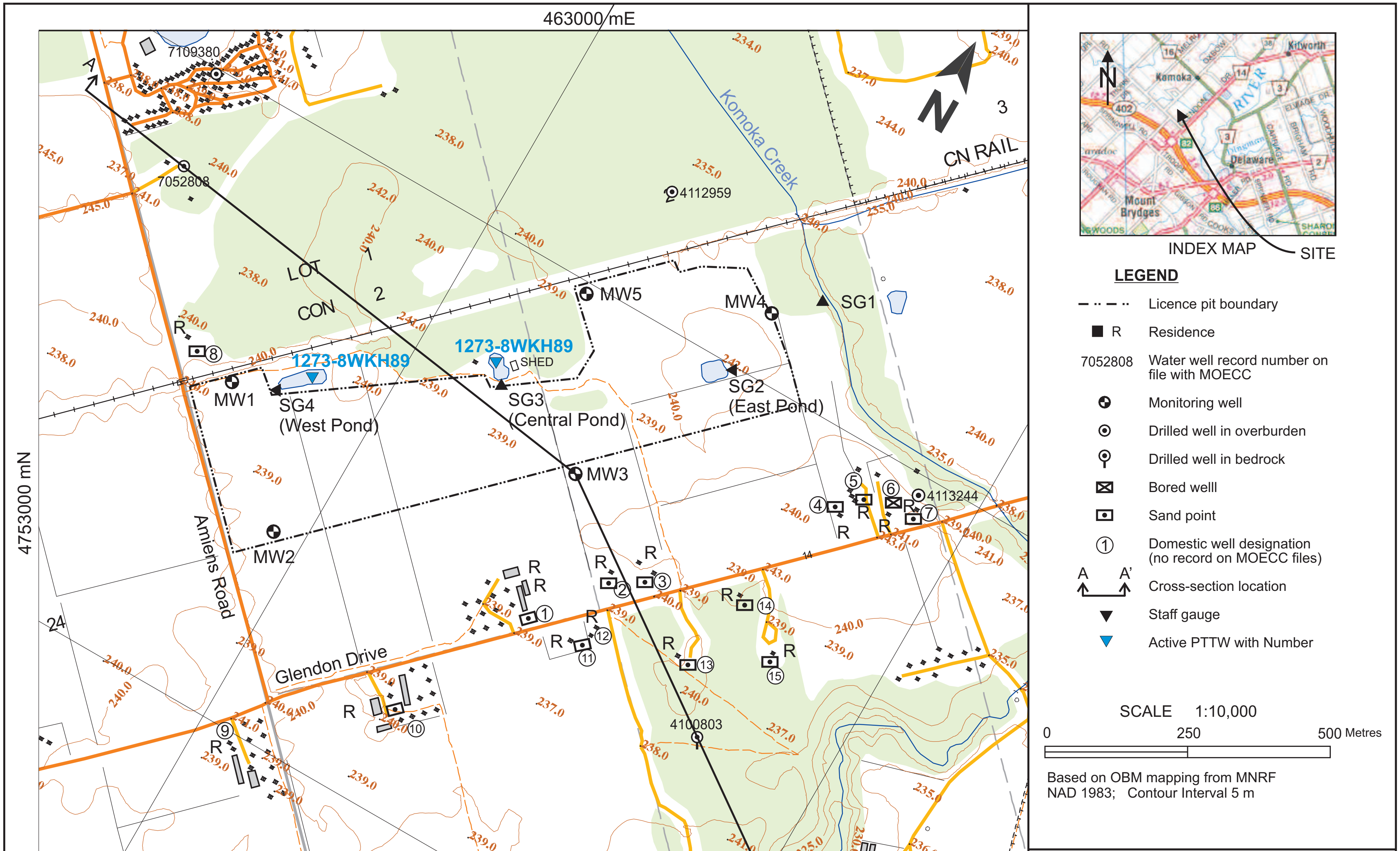


Figure 1

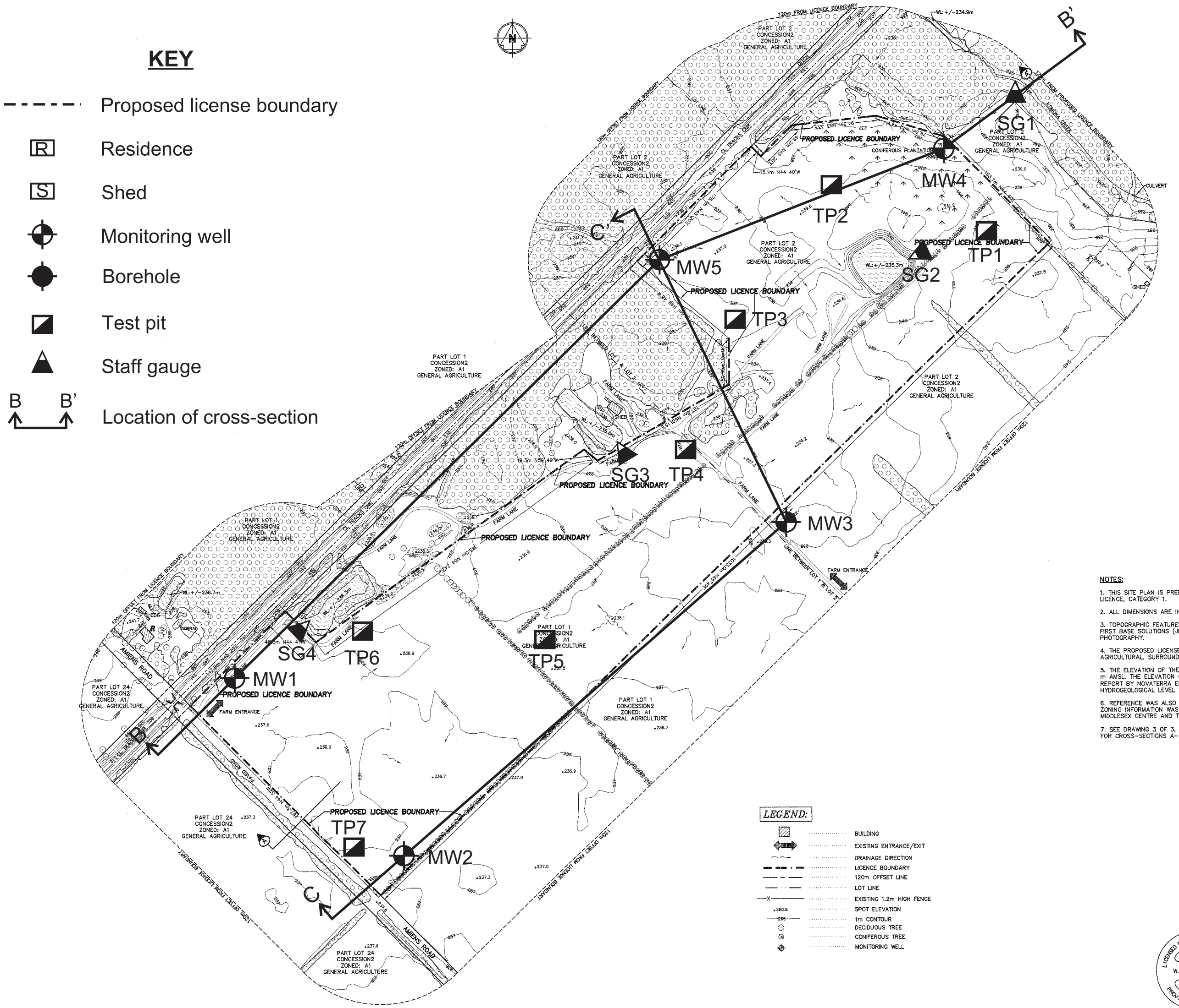
Subject site, well locations, topography and hydrology map

Part Lots 1 and 2, Concession 2, Township of Middlesex Centre (formerly Township of Lobo), County of Middlesex

Novaterra ENVIRONMENTAL

Maes Pit
Johnston Bros. (Bothwell) Limited

March 20, 2017



NOTES:

1. THIS SITE PLAN IS PREPARED UNDER THE AGGREGATE RESOURCES ACT FOR A CLASS A LICENCE, CATEGORY 1.

2. ALL DIMENSIONS ARE IN METRIC UNITS. ELEVATIONS ARE GEODETIC, ASL.

3. TOPOGRAPHIC FEATURES & PARCEL INFORMATION FROM PHOTOGRAMMETRIC MAPPING BY FIRST BASE SOLUTIONS (JD BARNES), BRAMPTON, ONTARIO, UTILIZING 2015 AIR PHOTOGRAPHY.

4. THE PROPOSED LICENSED AREA IS 24.7 HECTARES AND IS ZONED A1, GENERAL AGRICULTURAL. SURROUNDING ZONING DESIGNATIONS ARE SHOWN ON THE PLAN.

5. THE ELEVATION OF THE WATER TABLE VARIES FROM ________m AMSL TO ________ m AMSL. THE ELEVATION OF THE WATER TABLE WAS TAKEN FROM FIGURE __ IN THE REPORT BY NOVATERRA ENVIRONMENTAL LTD. (MONTH DAY, 2016) TITLED: HYDROGEOLOGICAL LEVEL 1 AND LEVEL 2 ASSESSMENTS, PROPOSED MAES PIT.

6. REFERENCE WAS ALSO MADE TO MAPPING FROM THE COUNTY OF MIDDLESEX WEBSITE. ZONING INFORMATION WAS OBTAINED FROM THE WEBSITES OF THE MUNICIPALITY OF MIDDLESEX CENTRE AND THE MUNICIPALITY OF STRATHROY-CARADOC.

7. SEE DRAWING 3 OF 3, PROGRESSIVE REHABILITATION AND FINAL REHABILITATION PLANS FOR CROSS-SECTIONS A-A' & B-B'.

JOHNSTON BROTHERS (BOTHWELL) LIMITED
21220 JOHNSTON LINE, RR1, WARDSVILLE, ONTARIO, N0L 2N0
MAES PIT
PART LOTS 1 & 2, CONCESSION 2
TOWNSHIP OF MIDDLESEX CENTRE
(FORMERLY THE TOWNSHIP OF LOBO)
COUNTY OF MIDDLESEX

EXISTING FEATURES
DRAWING 1 of 4

SCALE 1:2000
50 0 50 100 150

No.	AMENDMENT	DATE

W.L. BRADSHAW

September 26, 2016

Novaterra
ENVIRONMENTAL

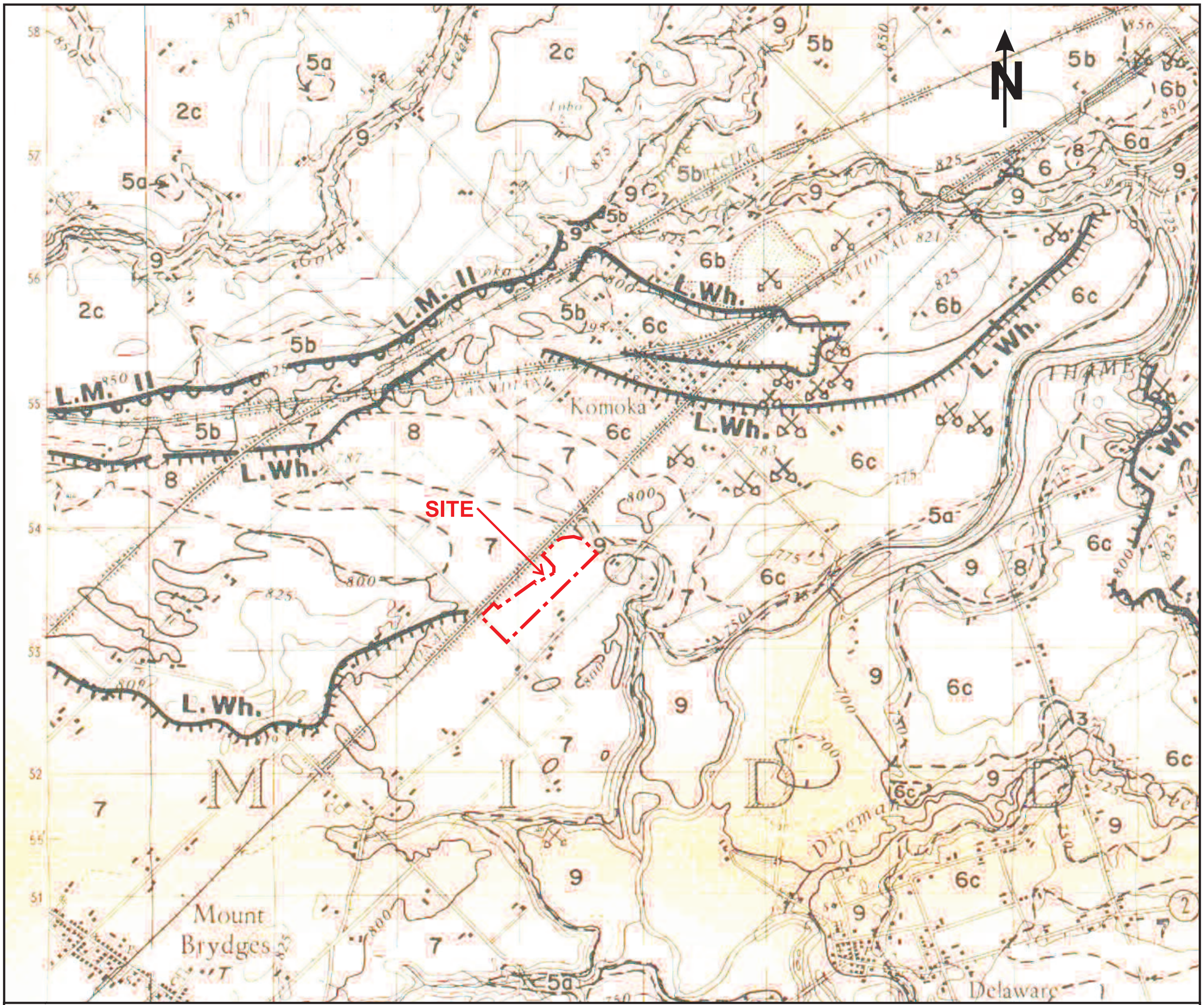
EXISTING FEATURES

Part Lots 1 and 2, Concession 2, Township of Middlesex Centre (formerly Township of Lobo), Middlesex County

Figure 2

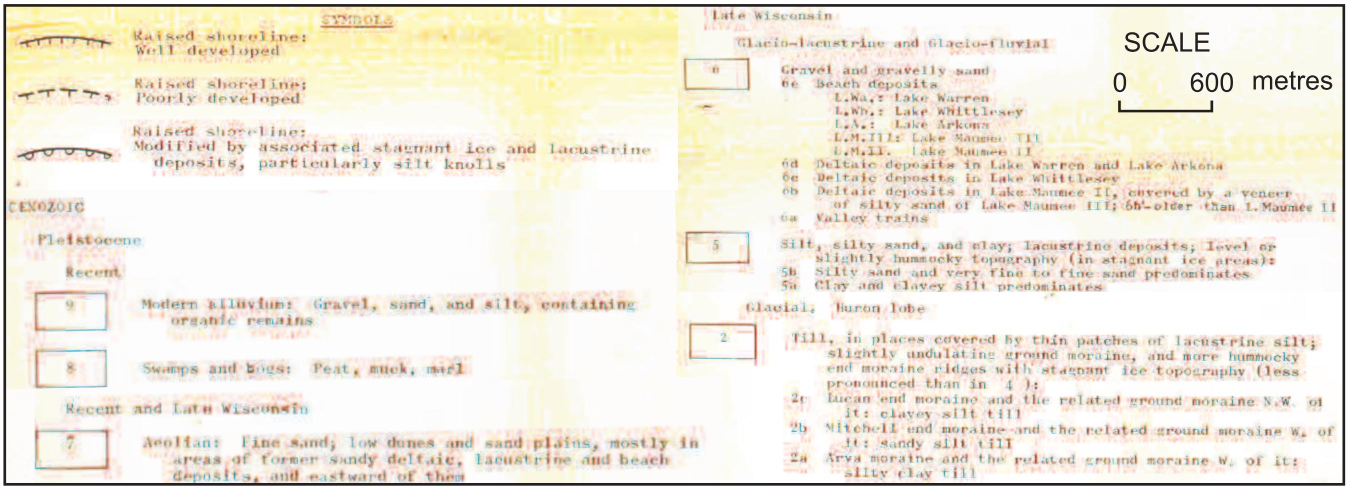
Maes Pit
Johnston Bros. (Bothwell) Ltd.

March 20, 2017



LEGEND

After Dreimanis, 1964



SYMBOLS

Raised shoreline:
Well developed

Raised shoreline:
Poorly developed

Raised shoreline:
Modified by associated stagnant ice and lacustrine deposits, particularly silt knolls

CENOZOIC

Pleistocene

Recent

9	Modern alluvium: Gravel, sand, and silt, containing organic remains
8	Swamps and bogs: Peat, muck, marl

Recent and Late Wisconsin

7	Aeolian: Fine sand; low dunes and sand plains, mostly in areas of former sandy deltaic, lacustrine and beach deposits, and eastward of them

Late Wisconsin

Glacio-lacustrine and Glacio-fluvial

6	Gravel and gravelly sand

6e Beach deposits
L.Wa.: Lake Warren
L.Wh.: Lake Whittlesey
L.A.: Lake Arkona
L.M.III: Lake Maumee III
L.M.II. Lake Maumee II
6d Deltaic deposits in Lake Warren and Lake Arkona
6c Deltaic deposits in Lake Whittlesey
6b Deltaic deposits in Lake Maumee II, covered by a veneer of silty sand of Lake Maumee III; 6b'-older than L.Maumee II
6a Valley trains

5	Silt, silty sand, and clay; lacustrine deposits; level or slightly hummocky topography (in stagnant ice areas):

5b Silty sand and very fine to fine sand predominates
5a Clay and clayey silt predominates

Glacial, Huron lobe

2	Till, in places covered by thin patches of lacustrine silt; slightly undulating ground moraine, and more hummocky end moraine ridges with stagnant ice topography (less pronounced than in 4):

2c Lucan end moraine and the related ground moraine N.W. of it: clayey silt till
2b Mitchell end moraine and the related ground moraine W. of it: sandy silt till
2a Arva moraine and the related ground moraine W. of it: silty clay till

SCALE
0 600 metres

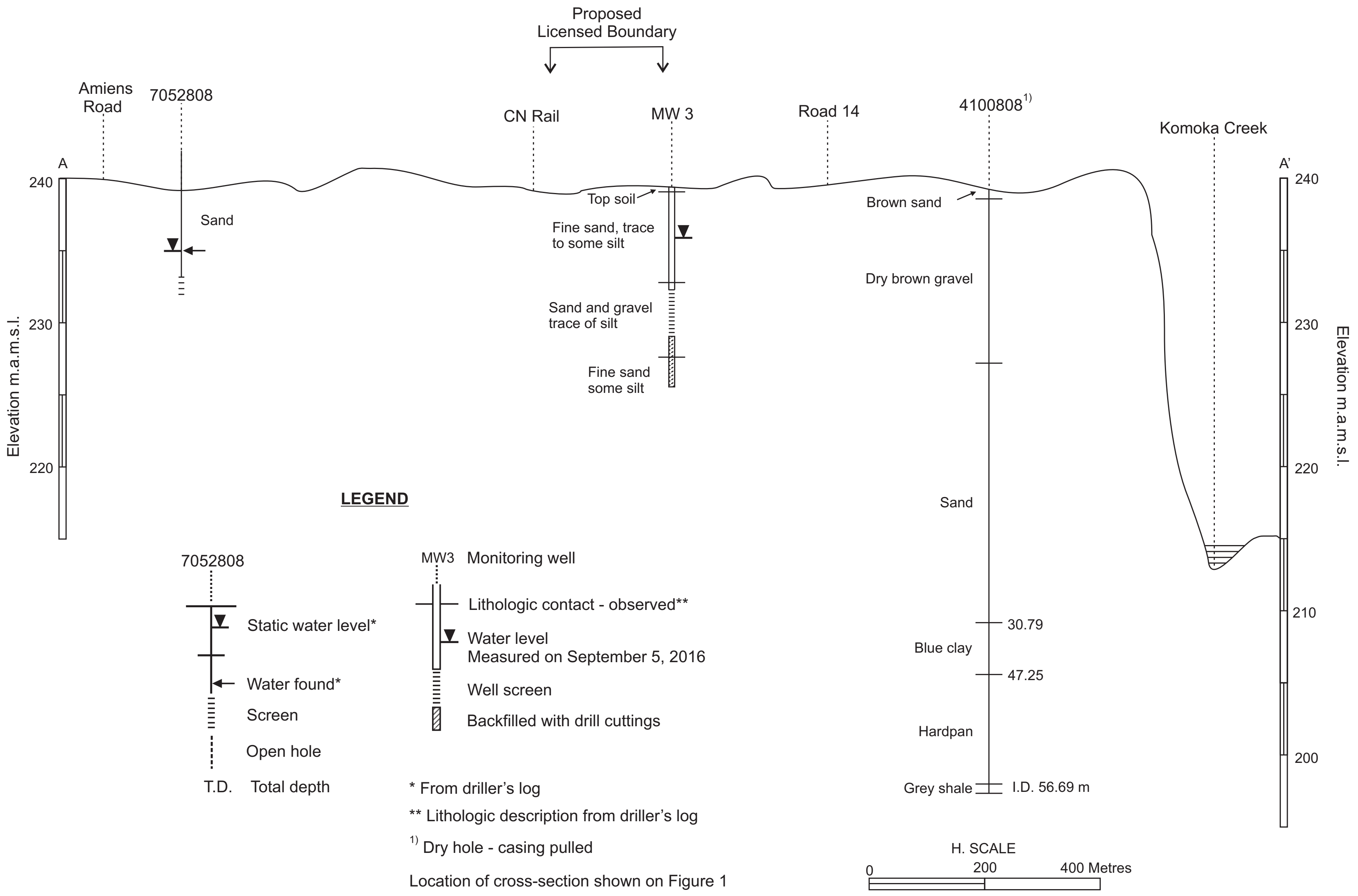
QUATERNARY GEOLOGY MAP

Part Lots 1 and 2, Concessions 2, (Formerly Lobo Township)
Middlesex Centre, Middlesex County

Figure 3

Maes Pit
Johnston Bros. (Bothwell) Ltd.

March 20, 2017



* From driller's log

** Lithologic description from driller's log

1) Dry hole - casing pulled

Location of cross-section shown on Figure 1

Novaterra
ENVIRONMENTAL

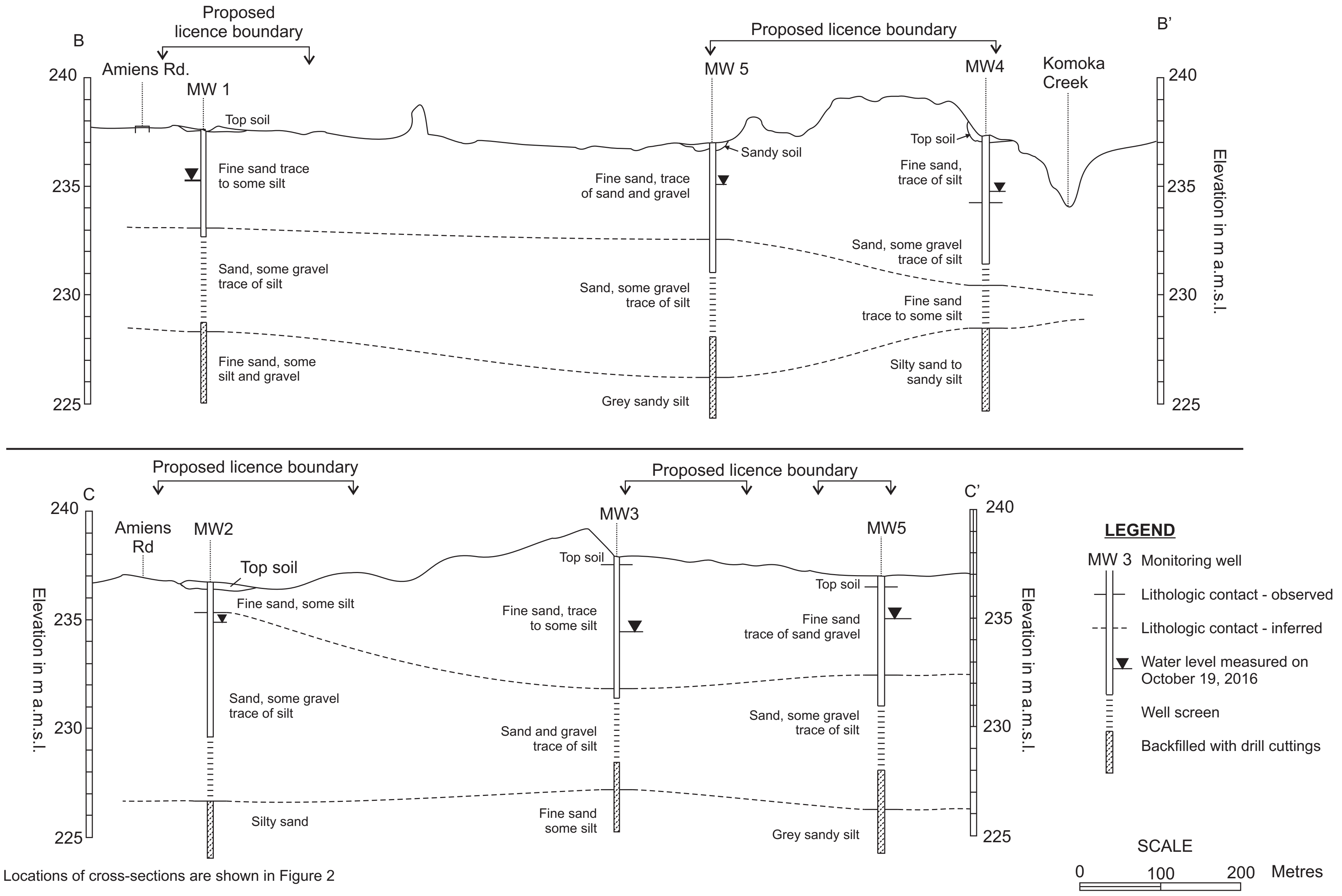
REGIONAL CROSS-SECTION A-A'

Part Lots 1 and 2, Concession 2, (Formerly Lobo Township), Middlesex Centre, Middlesex County

Figure 4

Maes Pit
Johnston Bros. (Bothwell) Ltd.

March 20, 2017



Locations of cross-sections are shown in Figure 2

Novaterra
ENVIRONMENTAL

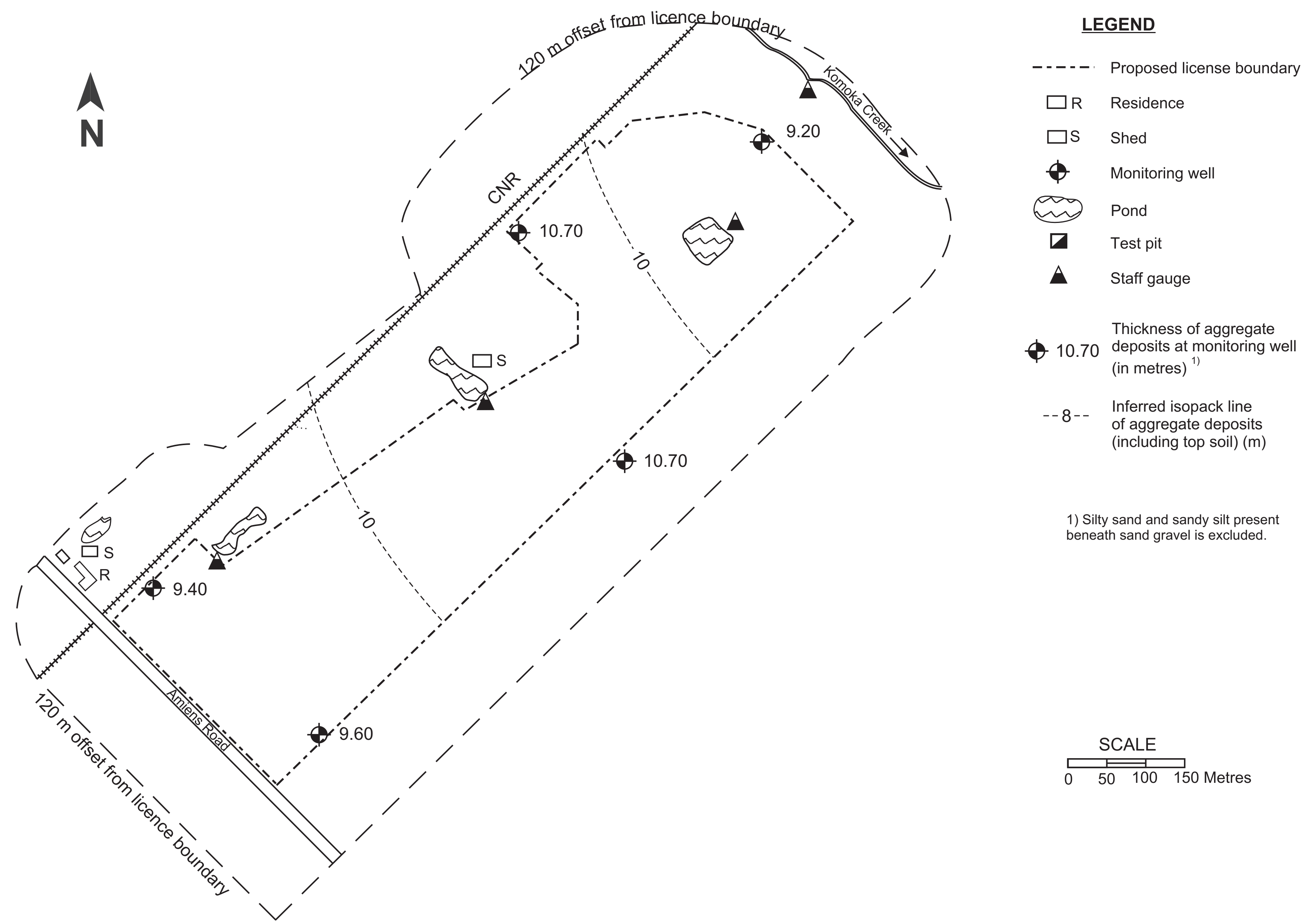
LOCAL CROSS SECTIONS B-B' AND C-C'

Part Lots 1 and 2, Concession 2, Township of Middlesex Centre (formerly Township of Lobo), Middlesex County

Figure 5

Maes Pit
Johnston Bros. (Bothwell) Ltd.

November 19, 2016



Base map modified after Bradshaw (2016)

Novaterra
ENVIRONMENTAL

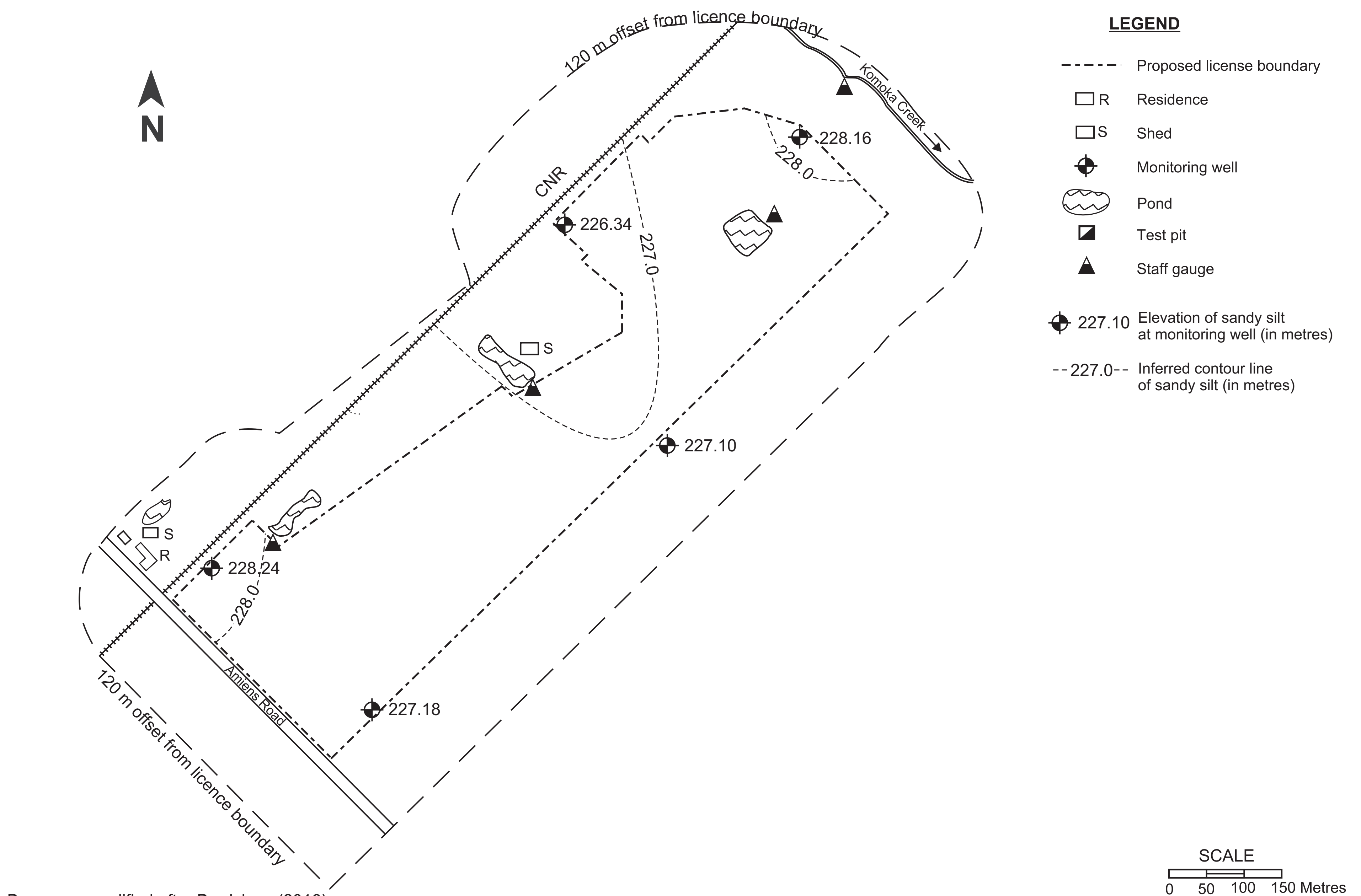
THICKNESS OF SAND AND GRAVEL

Part Lots 1 and 2, Concession 2, Township of Middlesex Centre (formerly Township of Lobo), Middlesex County

Figure 6

Maes Pit
Johnston Bros. (Bothwell) Ltd.

November 1, 2016



Base map modified after Bradshaw (2016)

Novaterra
ENVIRONMENTAL

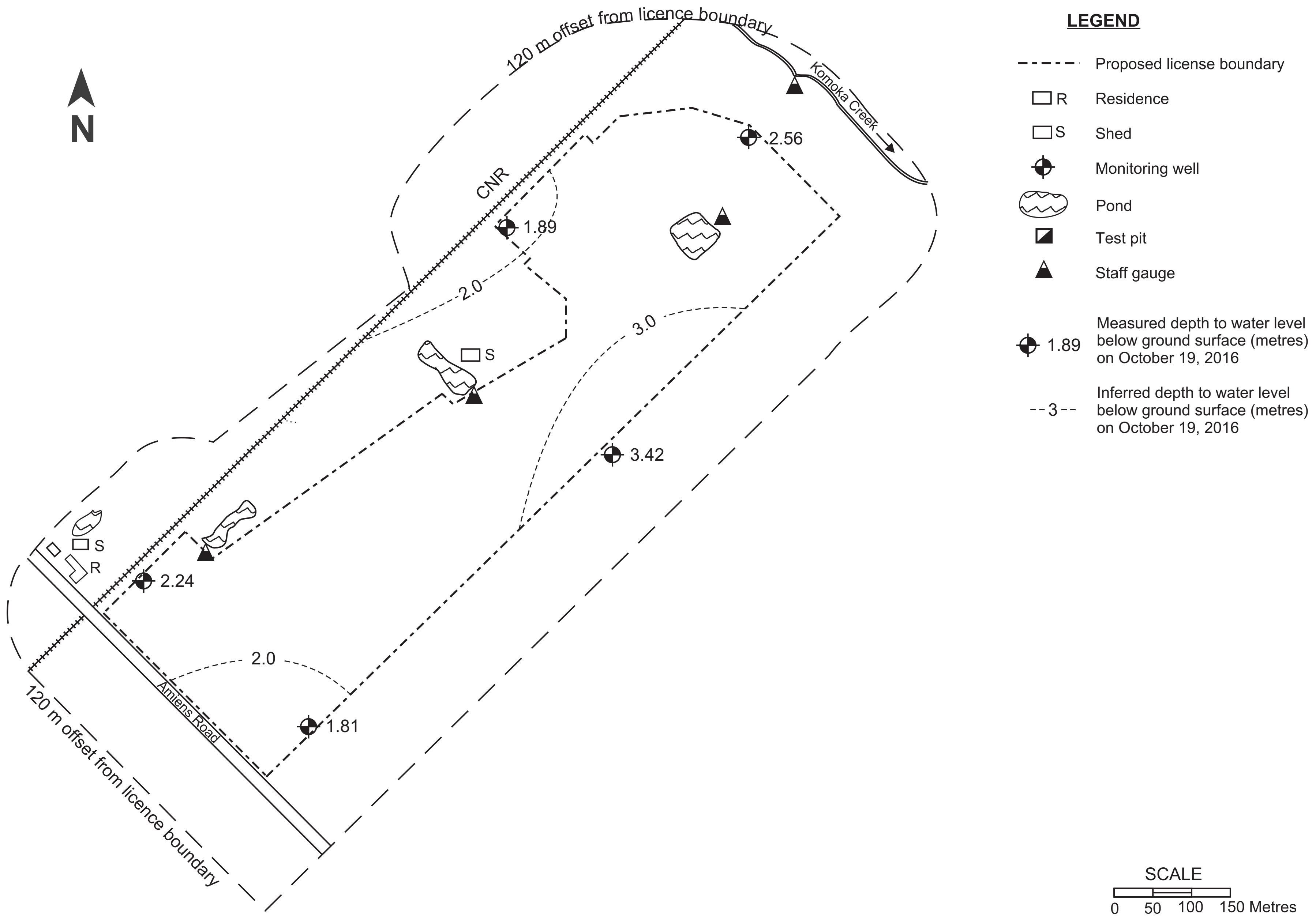
SURFACE ELEVATION OF SANDY SILT AND SILTY SAND

Part Lots 1 and 2, Concession 2, Township of Middlesex Centre (formerly Township of Lobo), Middlesex County

Figure 7

Maes Pit
Johnston Bros. (Bothwell) Ltd.

November 1, 2016



Base map modified after Bradshaw (2016)

Novaterra
ENVIRONMENTAL

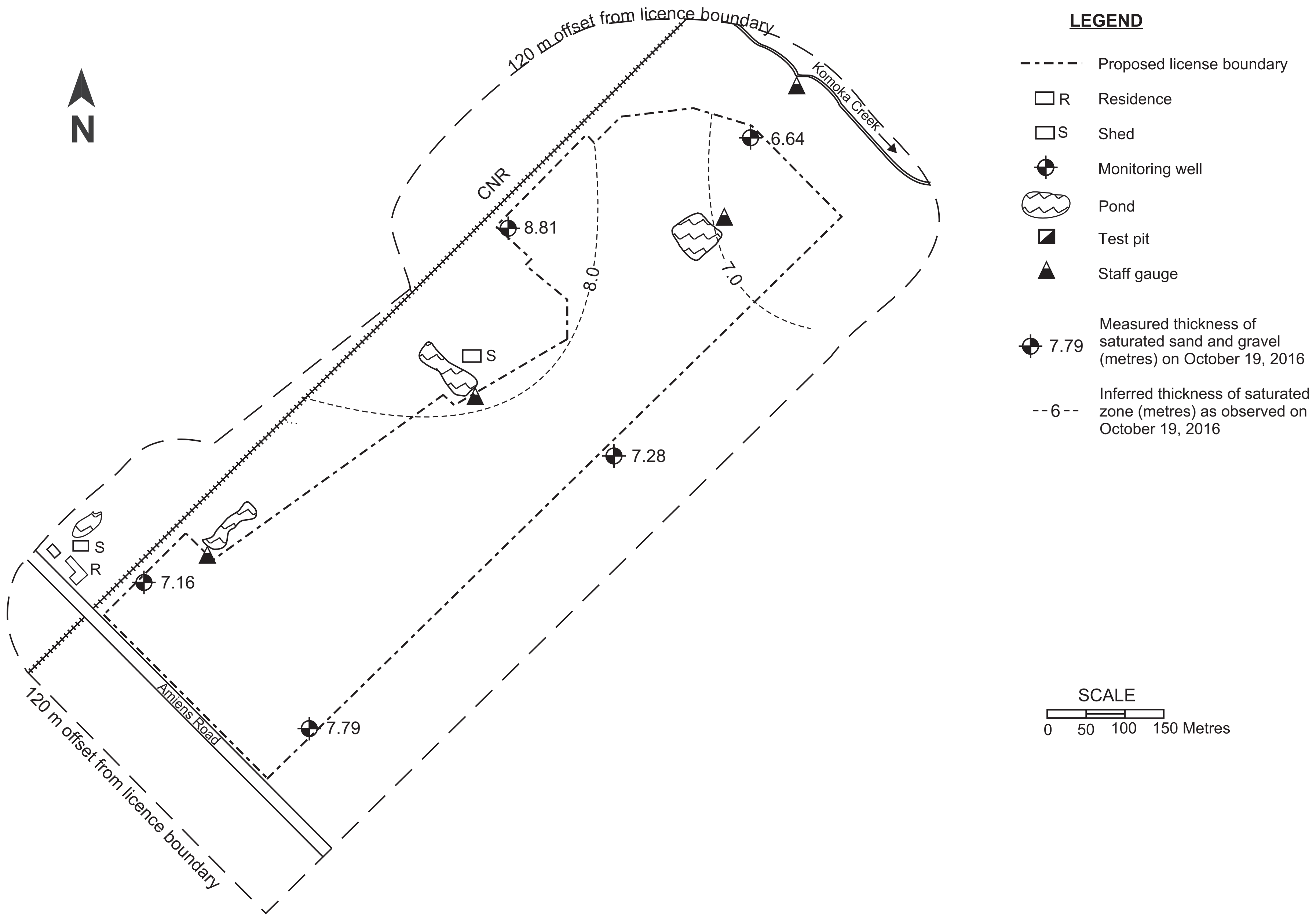
INFERRED DEPTH TO GROUNDWATER BELOW GROUND SURFACE

Part Lots 1 and 2, Concession 2, Township of Middlesex Centre (formerly Township of Lobo), Middlesex County

Figure 8

Maes Pit
Johnston Bros. (Bothwell) Ltd.

November 1, 2016



Base map modified after Bradshaw (2016)

Novaterra
ENVIRONMENTAL

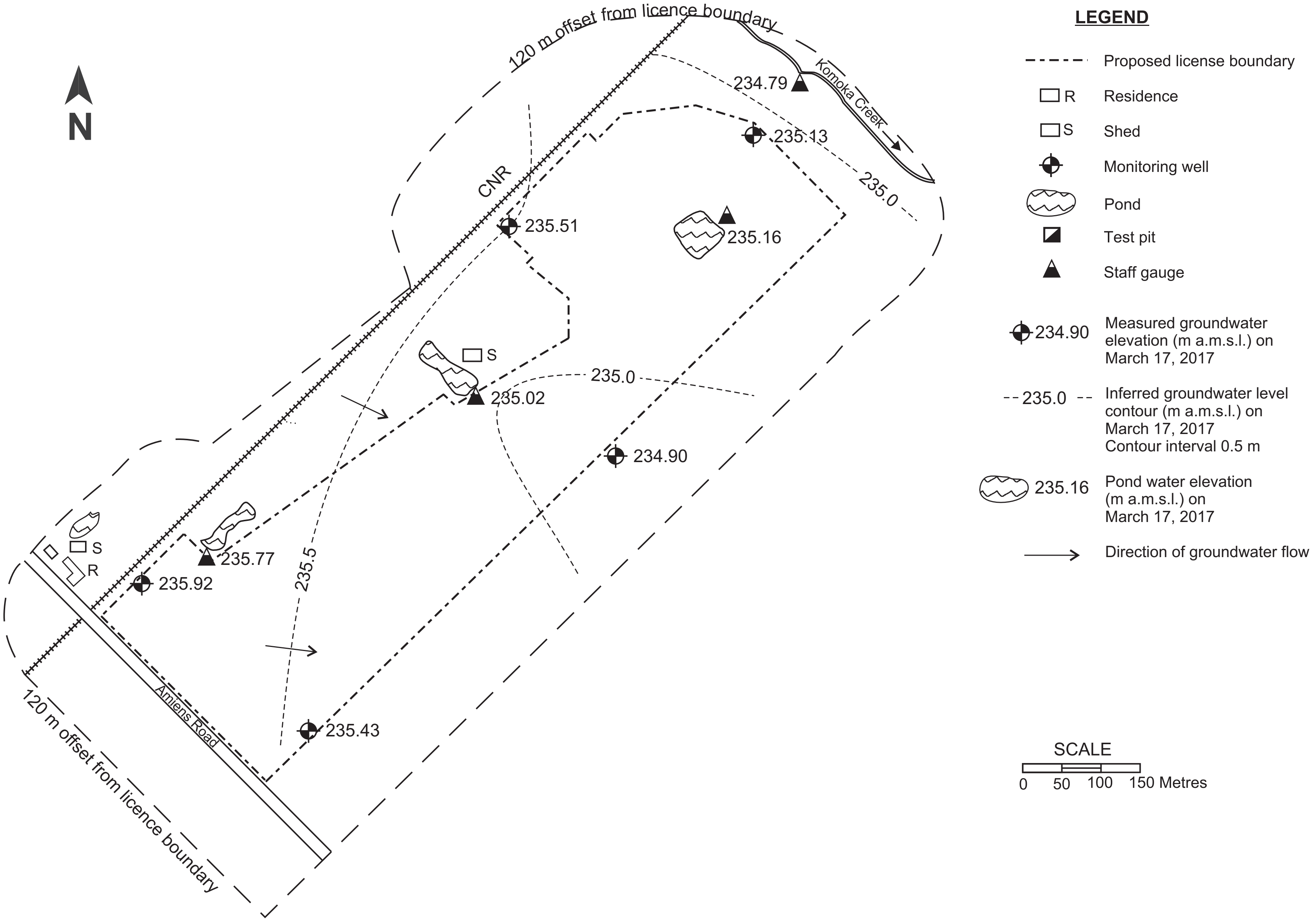
THICKNESS OF SATURATED SAND AND GRAVEL

Part Lots 1 and 2, Concession 2, Township of Middlesex Centre (formerly Township of Lobo), Middlesex County

Figure 9

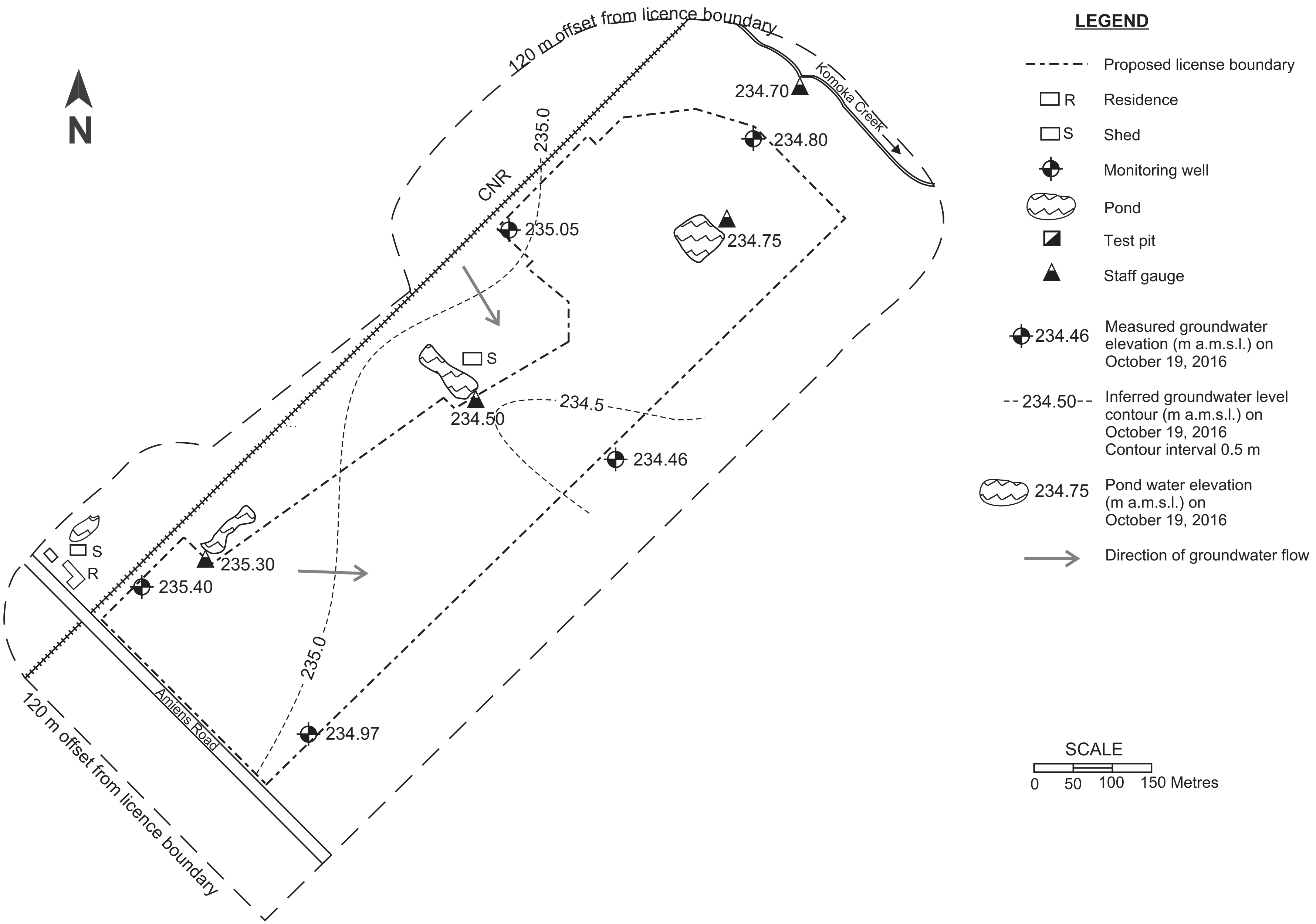
Maes Pit
Johnston Bros. (Bothwell) Ltd.

November 1, 2016



Base map modified after Bradshaw (2016)

Novaterra ENVIRONMENTAL	INFERRED HIGH GROUNDWATER TABLE CONFIGURATION (MARCH, 2017)	Figure 10
	Part Lots 1 and 2, Concession 2, Township of Middlesex Centre (formerly Township of Lobo), Middlesex County	Maes Plt Johnston Bros. (Bothwell) Ltd.
		March 20, 2017



Base map modified after Bradshaw (2016)

Novaterra
ENVIRONMENTAL

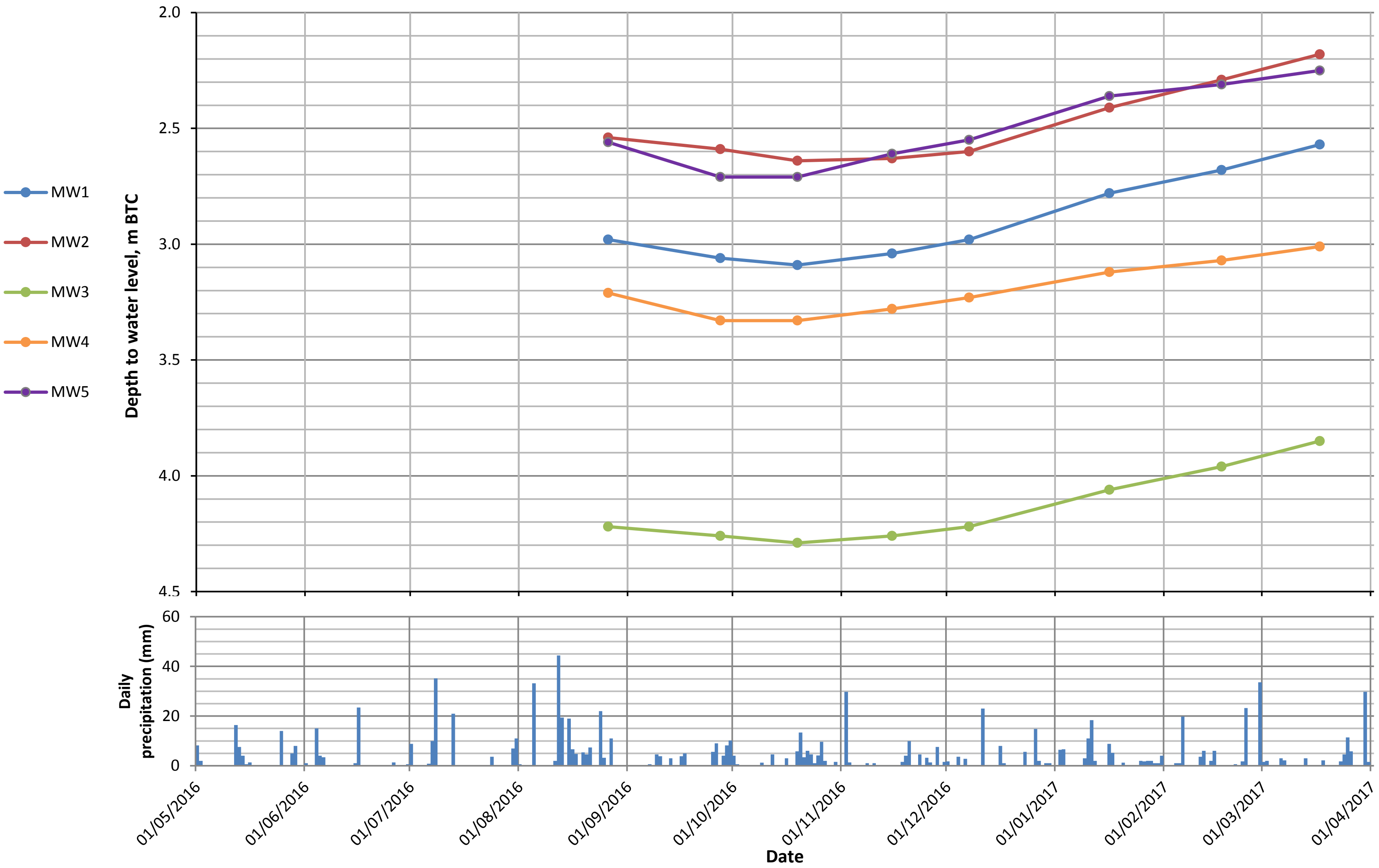
INFERRED LOW GROUNDWATER TABLE CONFIGURATION (OCTOBER, 2016)

Part Lots 1 and 2, Concession 2, Township of Middlesex Centre (formerly Township of Lobo), Middlesex County

Figure 11

Maes Pit
Johnston Bros. (Bothwell) Ltd.

November 1, 2016



* Precipitation data obtained from Strathroy climate station (http://www.climate.weather.gc.ca)

Novaterra
ENVIRONMENTAL

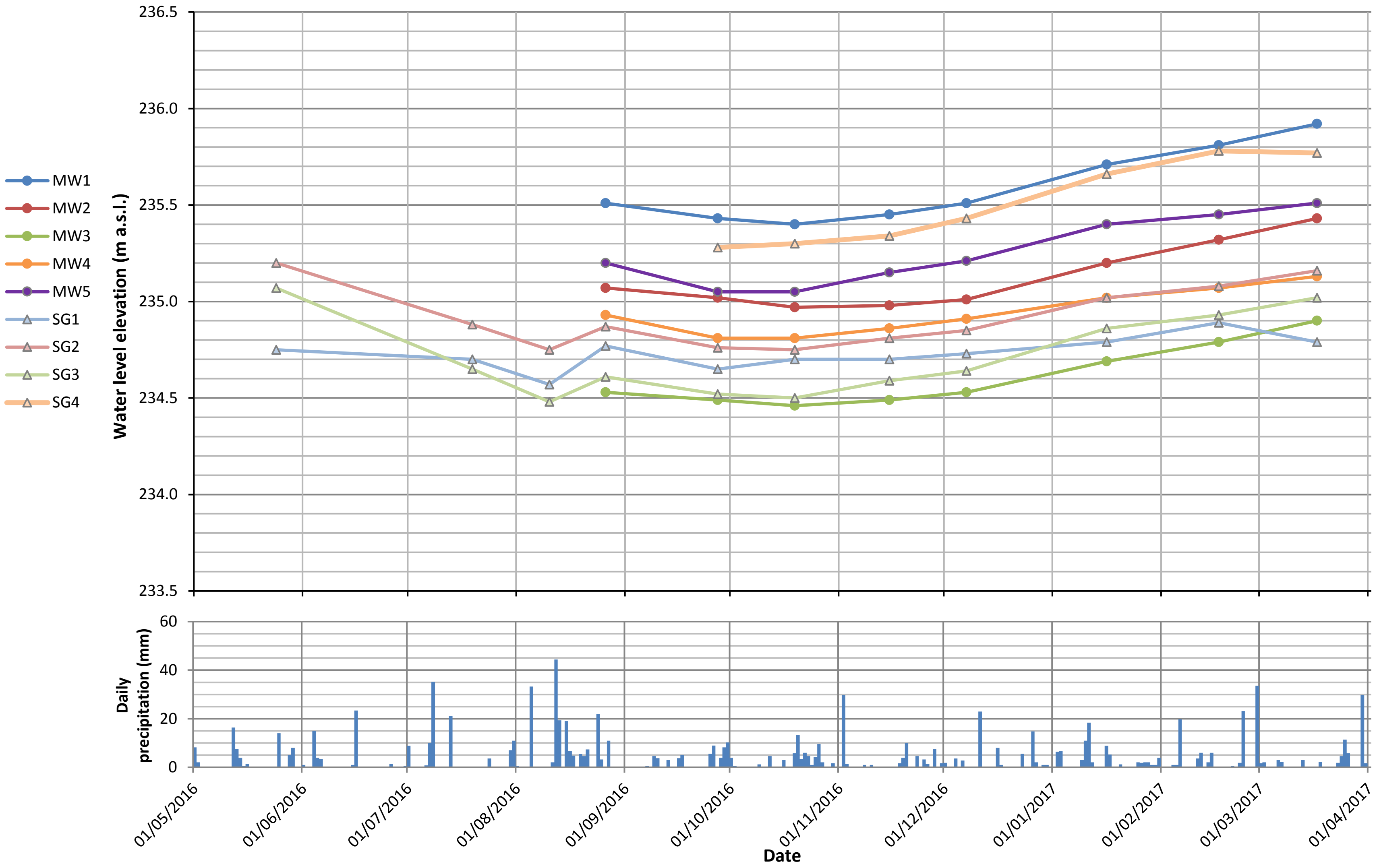
DEPTH TO GROUNDWATER HYDROGRAPHS AND PRECIPITATION

Part Lots 1 and 2, Concession 2, Township of Middlesex Centre
(formerly Township of Lobo), Middlesex County

Figure 12

Maes Pit
Johnston Bros. (Bothwell) Ltd.

March 20, 2017



Novaterra
ENVIRONMENTAL

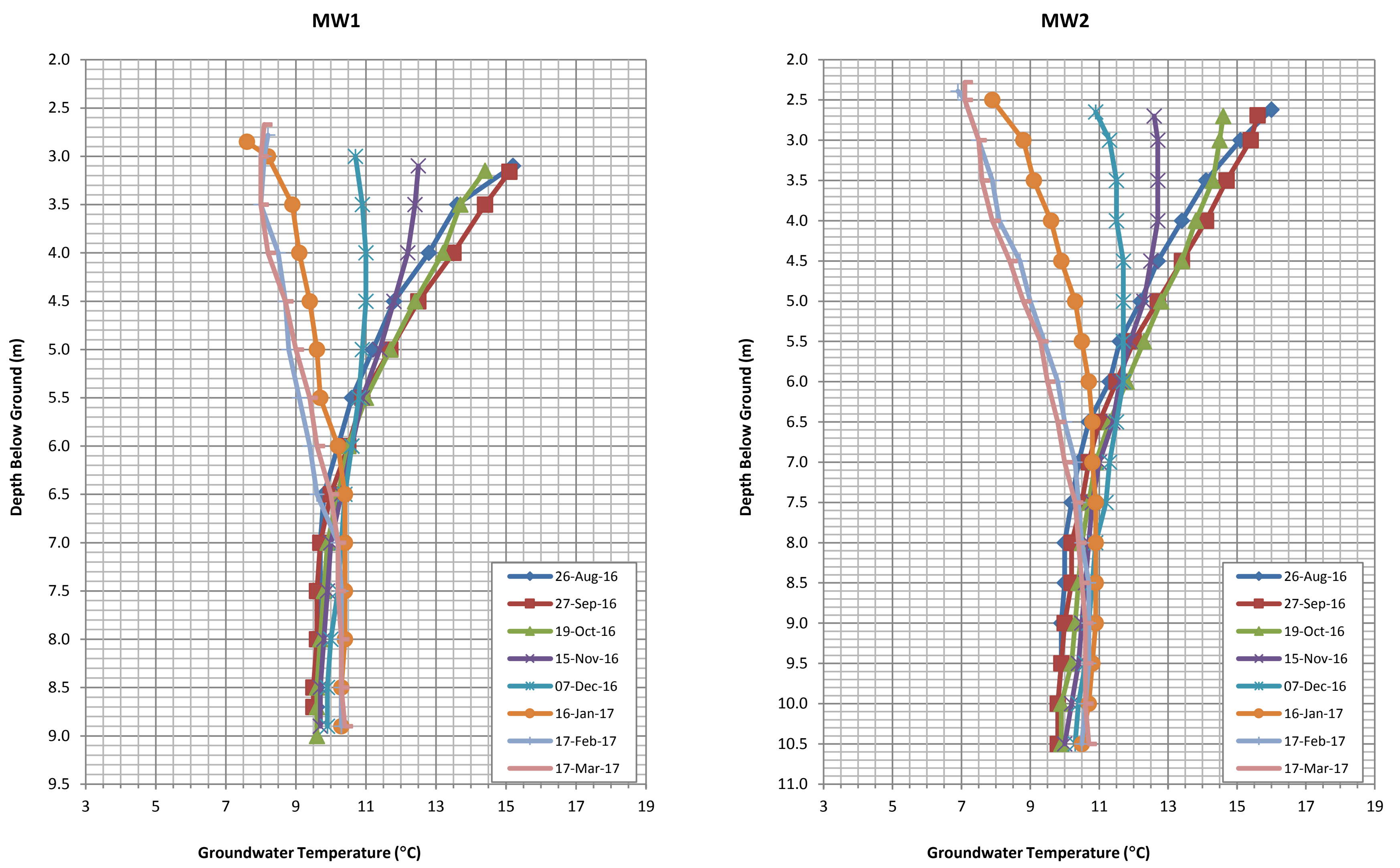
WATER LEVEL ELEVATION HYDROGRAPHS AND PRECIPITATION

Part Lots 1 and 2, Concession 2, Township of Middlesex Centre
(formerly Township of Lobo), Middlesex County

Figure 13

Maes Pit
Johnston Bros. (Bothwell) Ltd.

March 20, 2017



GROUNDWATER TEMPERATURE PROFILES FOR MW1 AND MW2

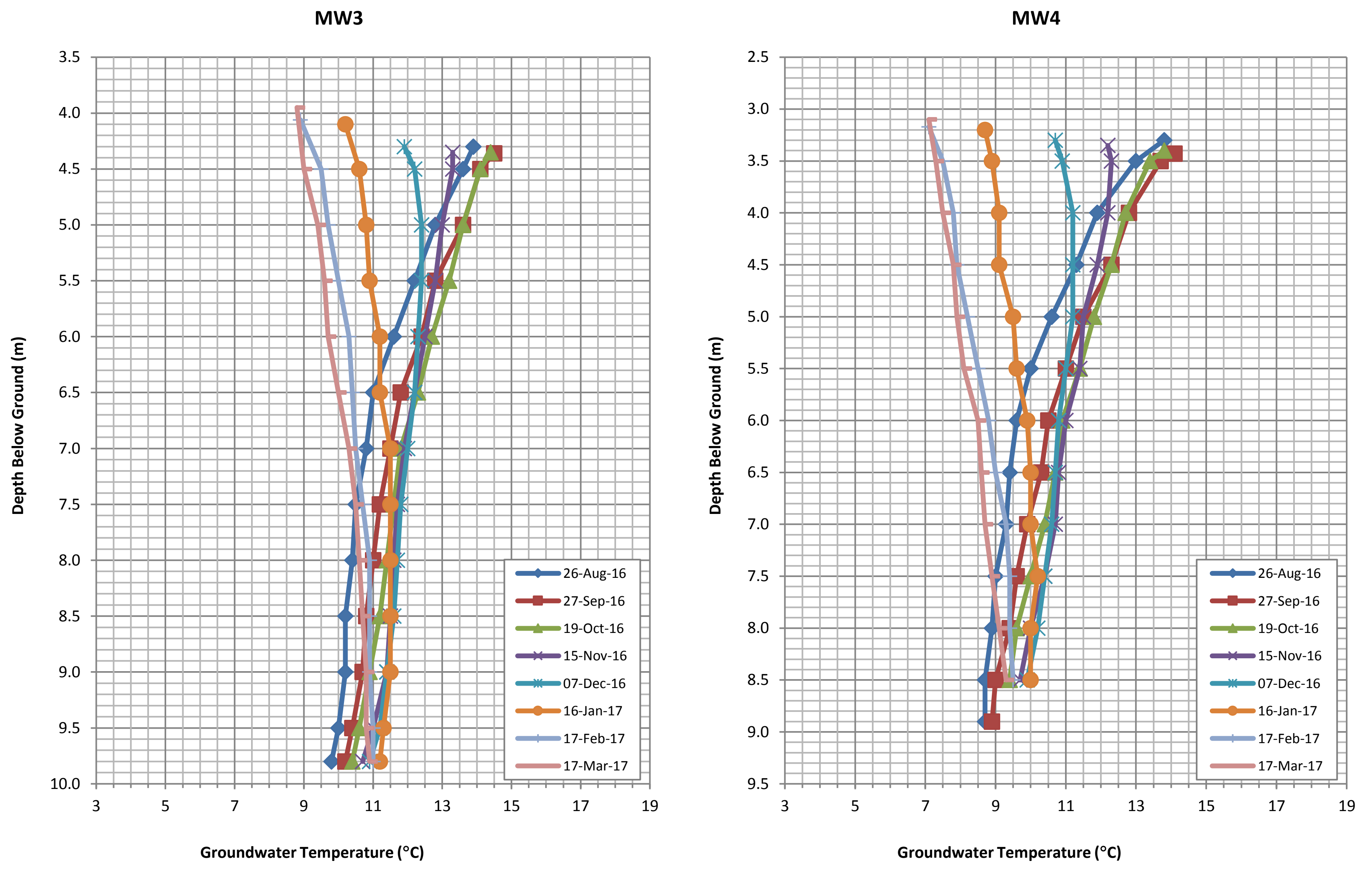
Part Lots 1 and 2, Concession 2, Township of Middlesex Centre
(formerly Township of Lobo), Middlesex County

Figure 14

Maes Pit
Johnston Bros. (Bothwell) Ltd.

March 20, 2017

Novaterra
ENVIRONMENTAL



Novaterra
ENVIRONMENTAL

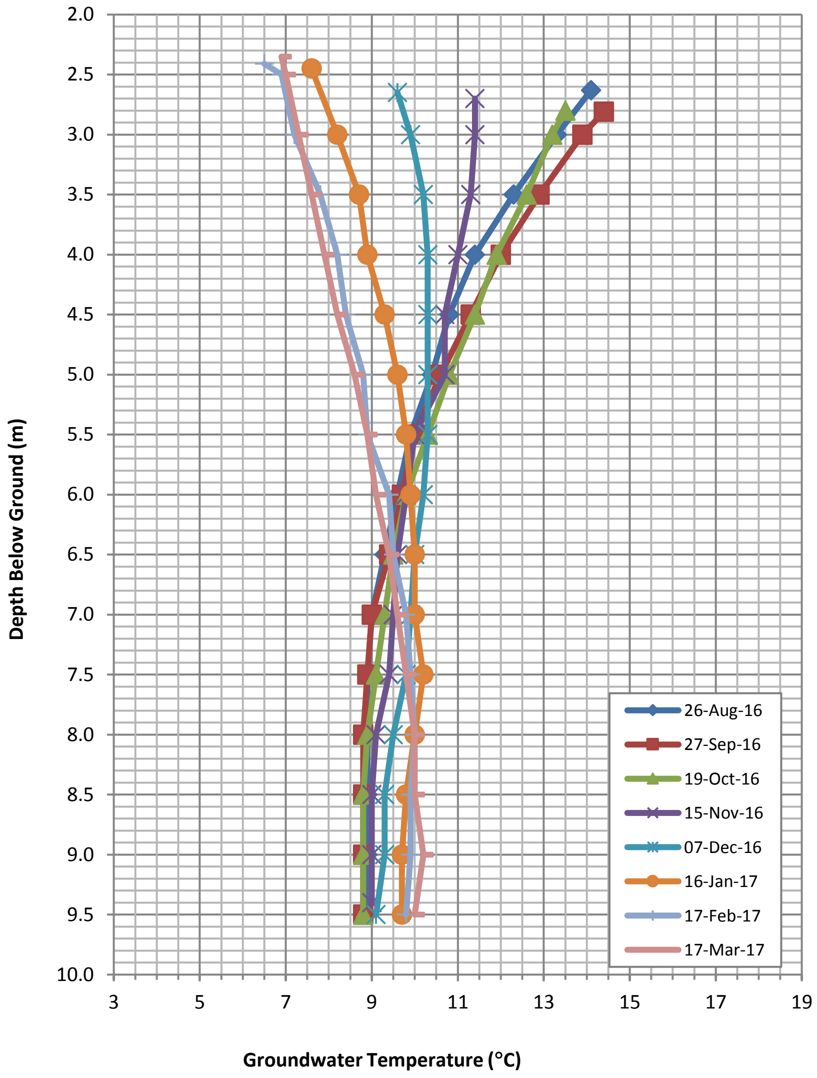
GROUNDWATER TEMPERATURE PROFILES FOR MW3 AND MW4

Part Lots 1 and 2, Concession 2, Township of Middlesex Centre
(formerly Township of Lobo), Middlesex County

Figure 15

Maes Pit
Johnston Bros. (Bothwell) Ltd.

March 20, 2017



Novaterra
ENVIRONMENTAL

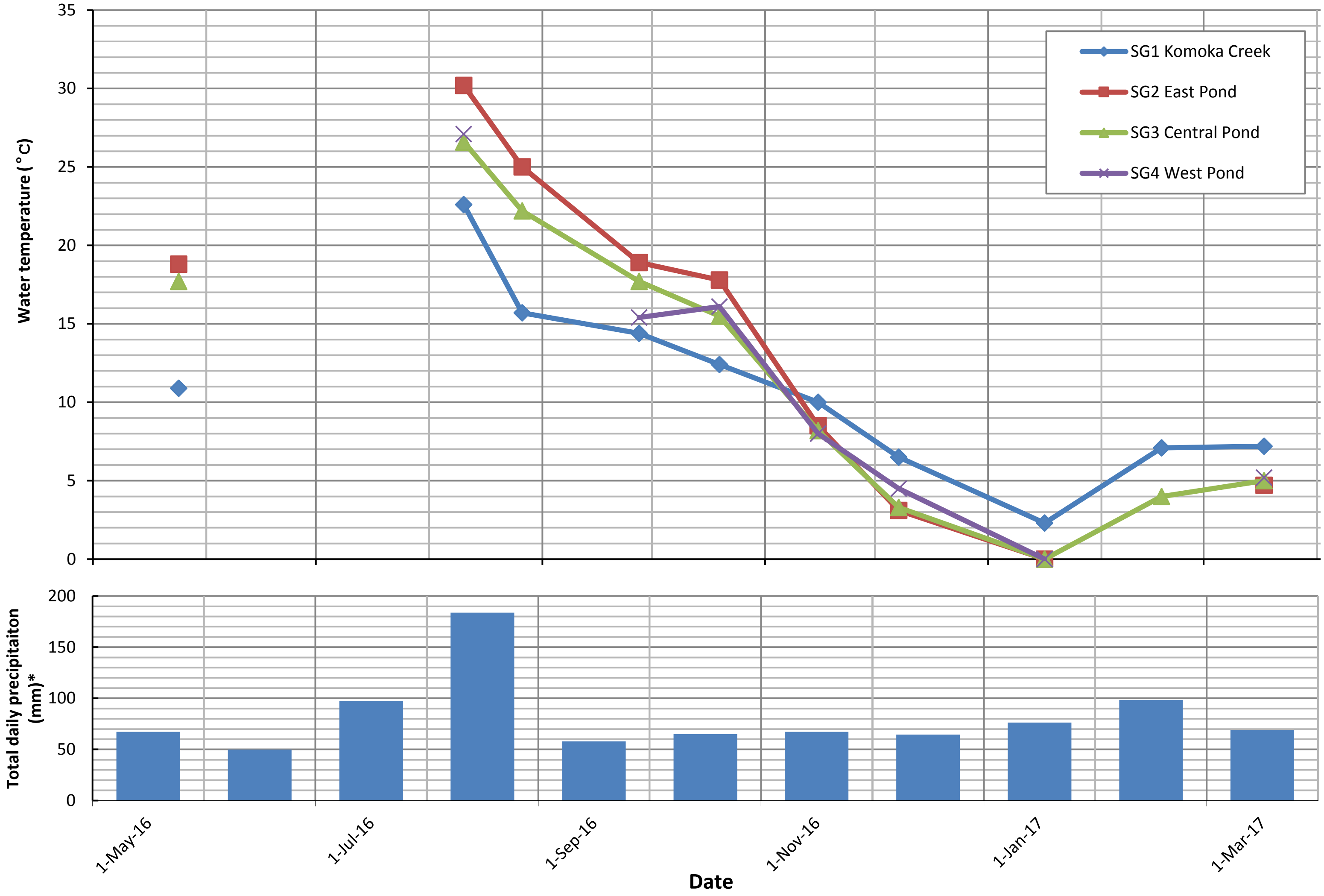
GROUNDWATER TEMPERATURE PROFILES FOR MW5

Part Lots 1 and 2, Concession 2, Township of Middlesex Centre
(formerly Township of Lobo), Middlesex County

Figure 16

Maes Pit
Johnston Bros. (Bothwell) Ltd.

March 20, 2017



* Precipitation data obtained from Strathroy climate station (http://www.climate.weather.gc.ca)

Novaterra
ENVIRONMENTAL

WATER TEMPERATURE IN KOMOKA CREEK AND ONSITE PONDS AT MAES PIT

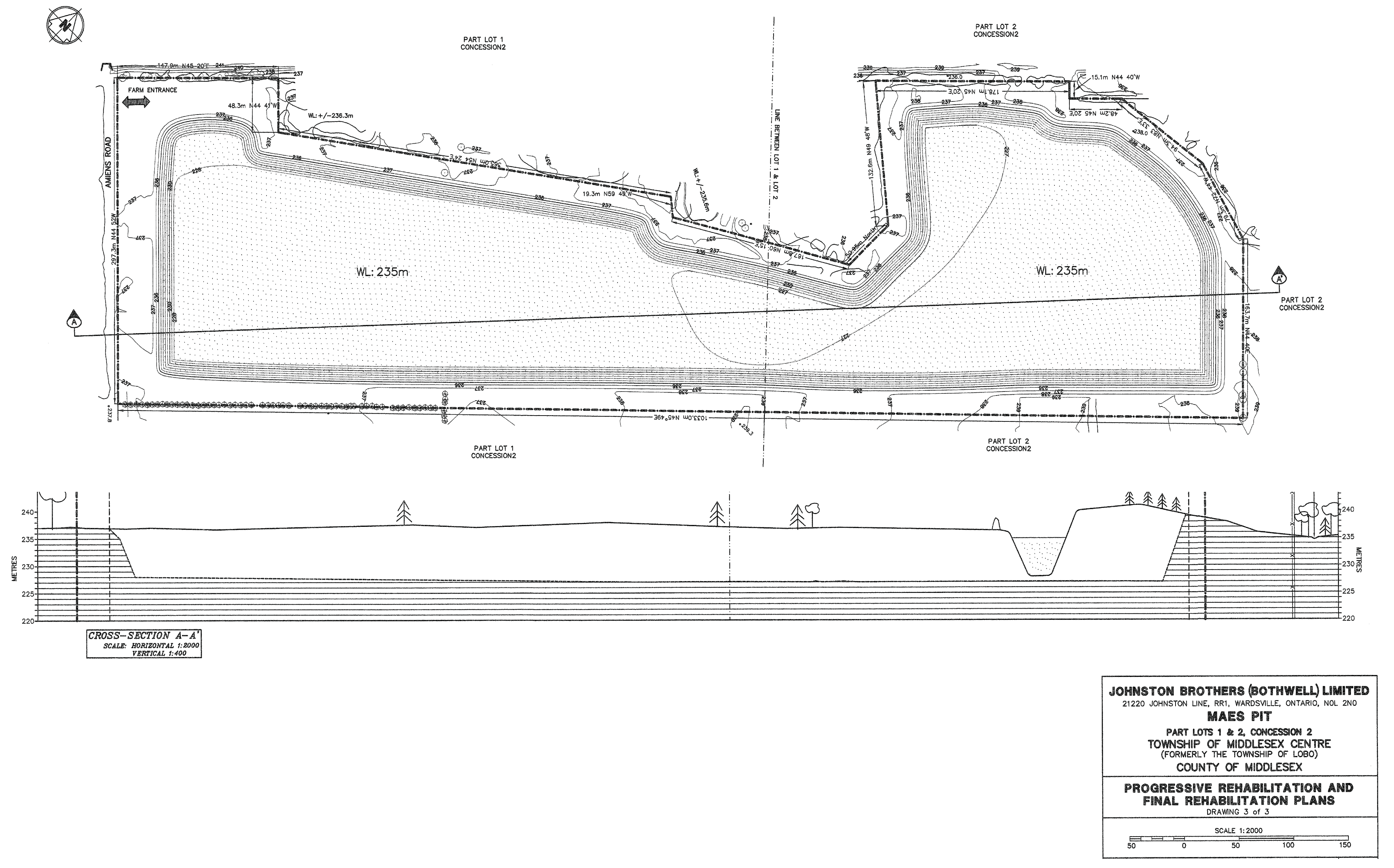
Part Lots 1 and 2, Concession 2, Township of Middlesex Centre
(formerly Township of Lobo), Middlesex County

Figure 17

Maes Pit

Johnston Bros. (Bothwell) Ltd.

March 7, 2017



Adapted from Drawing 3 of 3 in Bradshaw (2016)

Novaterra ENVIRONMENTAL

FINAL REHABILITATION PLAN

Part Lots 1 and 2, Concession 2, Township of Middlesex Centre (formerly Township of Lobo), Middlesex County

Figure 18

Maes Pit
Johnston Bros. (Bothwell) Ltd.

May 8, 2017

TABLES

Tables 1 to 7 inclusive

Table 1. Summary of Information on Local Domestic Wells Obtained During Door-to-Door Survey in the vicinity of Maes pit.

Location: Part Lots 1 and 2 Concession 2, Municipality of Middlesex Centre (formerly Lobo Township) Middlesex County;
Date of survey: October 29, 2016 Surveyed by: Blagy Novakovic

Location*) Glendon Dr.	Well designation-assigned *)	MOECC water well record number	Type of well; Date complete	Well diameter O.D. (cm)	Casing above ground (m)	Well depth (m) 2)	Depth to water level top casing (m) 3)	Well use; geology (m); and comments
9548 Glendon Dr.	1	Not available	Sand point	N/A	N/A	N/A	N/A	Sand point; depth unknown
9584 Glendon Dr.	2	Not available	Sand point	N/A	N/A	N/A	N/A	Sand point; depth unknown
9598 Glendon Dr.	3	Not available	Sand point	N/A	N/A	N/A	N/A	No answer at the door on 3 dates
9694 Glendon Dr.	4	Not available	Sand point	N/A	Well pit	N/A	N/A	Sand point in well pit. Pump located in basement
9678 Glendon Dr.	5	Not available	Sand point	N/A	N/A	N/A	N/A	Sand point
9682 Glendon Dr.	6	Not available	Bored well	108	0.30	11	n/m	Bored well heavy concrete at the top
9692 Glendon Dr.	7	Not available	Sand point	N/A	N/A	N/A	N/A	Sand point in the basement
22964 Amiens Rd.	8	Not available	Sand point	N/A	N/A	N/A	N/A	Sand point in the basement; never short of water
9449 Glendon Dr.	9	Not available	Unknown	N/A	N/A	N/A	N/A	No answer at the door on 3 dates
9507 Glendon Dr.	10	Not available	Sand point	N/A	N/A	29.15	N/A	Sand point
9561 Glendon Dr.	11	Not available	unknown	N/A	N/A	N/A	N/A	No answer at the door
9573 Glendon Dr.	12	Not available	Sand point	N/A	N/A	7.6 to 10.7	N/A	Sand point; same resident for 22 years; no problem with water
9607 Glendon Dr.	13	Not available	Sand point	N/A	N/A	7.6	N/A	Sand point in the basement; deepened from 5.5 m
9629 Glendon Dr.	14	Not available	Sand point	N/A	N/A	4.5	N/A	Sand point at the back of house
9637 Glendon Dr.	15	Not available	Sand point	N/A	N/A	6.1	N/A	Sand point in basement

1) Well location is indicated in Figures 1; 2) According to well owner; 3) Unable to measure; n/m – Not measured; N/A – Not available.
NOTE: In cases of sand points, most of identified wells are buried and access to well head not possible.

Table 2. Wells construction data and depths to water levels in monitoring wells, Komoka Creek, and ponds at Maes Pit.

Monitoring station*)	Elevation, m a.s.l.		Well construction data 1)							Depth to water level BTC				
	Ground	Top of well casing	Original well depth (m)	Casing stick-up (m)	Well diameter (cm)	Screen interval below ground (m)	Gravel pack	Bentonite seal inter.	Screen slot number	24-May-16	19-Jul-16	10-Aug-16	26-Aug-16*)	27-Sep-16
MW1	237.64	238.49	12.70	0.85	5	6.0 - 9.0	5.2 – 9.0	1.0 – 1.4	10	n/i	n/i	n/i	2.98	3.06
MW2	236.78	237.61	12.70	0.83	5	7.0 - 10.0	5.9 – 10.0	1.0 -2.4	10	n/i	n/i	n/i	2.54	2.59
MW3	237.36	238.75	12.70	0.87	5	6.5 - 9.5	5.8 – 10.1	4.5 – 5.7	10	n/i	n/i	n/i	4.22	4.26
MW4	236.36	238.14	12.70	0.78	5	6.0 - 9.0	5.7 – 9.0	1.0 – 2.4	10	n/i	n/i	n/i	3.21	3.33
MW5	235.53	237.76	12.70	0.82	5	6.0 - 9.0	6.0 – 9.0	0.6 – 2.7	10	n/i	n/i	n/i	2.56	2.71
SG1 2) Komoka Creek	N/A	235.53	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.78	0.830	0.96	0.76	0.88
SG2 2) East (Pit) Pond	N/A	235.72	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.52	0.840	0.97	0.85	0.96
SG3 2) Central Pond	N/A	235.70	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.63	1.050	1.22	1.09	1.18
SG4 2) West pond	N/A	235.77	N/A	N/A	N/A	N/A	N/A	N/A	N/A	n/i	n/i	n/i	n/i	0.49

*) Monitoring wells were constructed on Aug. 22, 23 and 24, 2016 and developed on Aug. 25, 2016; 1) Based on Englobe (2017) borehole log data;

2) Measurement below top of staff gauge for surface water bodies.

BTC – Below top of casing; N/A - not applicable; n/i – Not installed; n/m – Not measured; a.s.l. – Above sea level.

Table 2. Cont'd.

Monitoring station	**Date and depth to water level BTC**					
	19-Oct-16	15-Nov-16	7-Dec-16	16-Jan-17	17-Feb-17	17-Mar-17
MW1	3.09	3.04	2.98	2.78	2.68	2.57
MW2	2.64	2.63	2.60	2.41	2.29	2.18
MW3	4.29	4.26	4.22	4.06	3.96	3.85
MW4	3.33	3.28	3.23	3.12	3.07	3.01
MW5	2.71	2.61	2.55	2.36	2.31	2.25
SG1 2) Komoka Creek	0.83	0.83	0.80	0.74	0.64	0.74
SG2 2) East (Pit) Pond	0.97	0.91	0.87	0.70	0.64	0.56
SG3 2) Central Pond	1.20	1.11	1.06	0.84	0.77	0.68
SG4 West pond	0.47	0.43	0.34	0.11	-0.01	0.00

2) Measurement below top of staff gauge for surface water bodies.

BTC – Below top of casing; N/A – Not applicable;

Table 3. Water level elevations in monitoring wells, Komoka Creek, and ponds at Maes Pit.

Monitoring station [1]	Elevation, m a.s.l.		Date and water level elevation, m a.m.s.l.										
	Ground	Top of well casing	24-May-16	19-Jul-16	10-Aug-16	26-Aug-16	27-Sept-16	19-Oct-16	15-Nov-16	7-Dec-16	16-Jan-17	17-Feb-17	17-Mar-17
MW1	237.64	238.49	N/I	N/I	N/I	235.51[1]	235.43	235.40	235.45	235.51	235.71	235.81	235.92
MW2	236.78	237.61	N/I	N/I	N/I	235.07	235.02	234.97	234.98	235.01	235.20	235.32	235.43
MW3	237.36	238.75	N/I	N/I	N/I	234.53	234.49	234.46	234.49	234.53	234.69	234.79	234.90
MW4	236.36	238.14	N/I	N/I	N/I	234.93	234.81	234.80	234.86	234.91	235.02	235.07	235.13
MW5	235.53	237.76	N/I	N/I	N/I	235.20	235.05	235.05	235.15	235.21	235.40	235.45	235.51
SG1 Komoka Creek	N/A	235.53	234.75	234.70	234.57	234.77	234.63	234.70	234.70	234.73	234.79	234.89	234.79
SG2 East (Pit) Pond	N/A	235.72	235.20	234.88	234.75	234.87	234.76	234.75	234.81	234.85	235.02	235.08	235.16
SG3 Central Pond	N/A	235.73	235.07	234.65	234.48	234.87	234.76	234.75	234.59	234.64	234.86	234.93	235.02
SG4 West Pond	N/A	235.77	N/I	N/I	N/I	N/I	234.98	235.30	235.34	235.43	235.66	235.78	235.77

[1] Monitoring wells were installed on August 22, 23 and 24, 2016; m a.s.l. – metres above mean sea level;
N/A - not applicable; N/I – Not installed; n/m – Not measured;

Table 4. Geological and hydrogeological data at monitoring wells and test pits at Maes Pit used to construct five figures in the hydrogeological report *).

Well and test pit designation	Well, test pit elevation, m a.m.s.l.		Water level (m) October 19, 2016		Water level elevation, m a.m.s.l. on October 19, 2016	Depth to bottom of sand and gravel 2) (m)	Thickness of unsaturated sand and gravel 3) on Oct. 19, 2016	Elevation of sandy silt 4) m a.m.s.l.	Thickness of saturated sand and gravel 2) (m) on October 19, 2016
	Ground	Top of casing 1)	Top of casing 1)	Ground					
MW1	237.64	238.49	3.09	2.24	235.40	9.40	2.24	228.24	7.16
MW2	236.78	237.61	2.64	1.81	234.97	9.60	1.81	227.18	7.79
MW3	237.88	238.75	4.29	3.42	234.46	10.70	3.42	227.10	7.28
MW4	237.36	238.14	3.33	2.56	234.80	9.20	2.56	228.16	6.64
MW5	236.94	237.76	2.71	1.89	235.05	10.70	1.89	226.24	8.81
SG1 Komoka Creek	N/A	235.53	0.83	N/A	234.70	N/A	N/A	N/Av	N/A
SG2 East (Pit) Pond	N/A	235.72	0.97	N/A	234.75	N/A	N/A	N/Av	N/A
SG3 Central pond	N/A	233.736	1.20	N/A	234.75	N/A	N/A	N/Av	N/A
SG4 West pond	N/A	235.77	0.47	N/A	235.50	N/A	N/A	N/Av	N/A
TP1	N/Av	N/A	N/A	N/A	N/A	G 4.9	N/A	N/Av	N/A
TP2	N/Av	N/A	N/A	N/A	N/A	G 4.0	N/A	N/Av	N/A
TP3	N/Av	N/A	N/A	N/A	N/A	G 3.0	N/A	N/Av	N/A
TP4	N/Av	N/A	N/A	N/A	N/A	G 3.7	N/A	N/Av	N/A
TP5	N/Av	N/A	N/A	N/A	N/A	G 4.1	N/A	N/Av	N/A
TP6	N/Av	N/A	N/A	N/A	N/A	G 3.7	N/A	N/Av	N/A
TP7	N/Av	N/A	N/A	N/A	N/A	G 3.3	N/A	N/Av	N/A

*) Figures 4; 5; 6; 7, 8, and 9; 1) Top of staff gauge for surface water bodies; 2) Excludes silty sand or sandy silt at the bottom; 3) Includes top soil up to 0.40 m;
4) Top of silty sand at the bottom; MW – designates monitoring well; TP – designates test pit; SG – designates staff gauge;
N/A – Not applicable; N/Av – Not available; G – greater than; L – lower than;

Table 5. Groundwater Temperature Profiles in Monitoring Wells at Maes Pit.

Monitoring Station	26-Aug-16		27-Sep-16		19-Oct-16		15-Nov-16		7-Dec-16		16-Jan-17		17-Feb-17		17-Mar-17	
	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)
MW1	2.98		3.06		3.09		3.04		2.98		2.78		2.68		2.57	
	3.10	15.2	3.16	15.1	3.15	14.4	3.10	12.5	3.00	10.7	2.85	7.6	2.78	8.2	2.67	8.1
	3.50	13.6	3.50	14.4	3.50	13.7	3.50	12.4	3.50	10.9	3.00	8.2	3.00	8.1	3.00	8.0
	4.00	12.8	4.00	13.5	4.00	13.2	4.00	12.2	4.00	11.0	3.5	8.9	3.5	8.0	3.50	8.0
	4.50	11.8	4.50	12.5	4.50	12.4	4.50	11.8	4.50	11.0	4.0	9.1	4.0	8.5	4.00	8.2
	5.00	11.2	5.00	11.7	5.00	11.7	5.00	11.4	5.00	10.9	4.5	9.4	4.5	8.7	4.50	8.7
	5.50	10.6	5.50	10.9	5.50	11.0	5.50	10.9	5.50	10.8	5.0	9.6	5.0	8.8	5.00	9.0
	6.00	10.2	6.00	10.5	6.00	10.5	6.00	10.6	6.00	10.6	5.5	9.7	5.5	9.1	5.50	9.4
	6.50	9.8	6.50	10.0	6.50	10.2	6.50	10.3	6.50	10.4	6.0	10.2	6.0	9.4	6.00	9.6
	7.00	9.7	7.00	9.7	7.00	9.9	7.00	10.0	7.00	10.3	6.5	10.4	6.5	9.6	6.50	10.0
	7.50	9.7	7.50	9.6	7.50	9.8	7.50	9.9	7.50	10.2	7.0	10.4	7.0	10.2	7.00	10.2
	8.00	9.6	8.00	9.6	8.00	9.7	8.00	9.8	8.00	10.0	7.5	10.4	7.5	10.3	7.50	10.2
	8.50	9.6	8.50	9.5	8.50	9.6	8.50	9.7	8.50	9.9	8.0	10.4	8.0	10.3	8.00	10.3
	8.70	9.6	8.70	9.5	8.70	9.6	8.90	9.7	8.90	9.9	8.5	10.3	8.5	10.3	8.50	10.3
					9.00	9.6					8.9	10.3	8.9	10.3	8.90	10.4
MW2	2.54		2.59		2.64		2.63		2.6		2.41		2.29		2.18	
	2.62	16.0	2.69	15.6	2.70	14.6	2.70	12.6	2.65	10.9	2.50	7.9	2.39	6.9	2.28	7.1
	3.00	15.1	3.00	15.4	3.00	14.5	3.00	12.7	3.00	11.3	3.0	8.8	2.50	7.1	2.50	7.1
	3.50	14.1	3.50	14.7	3.50	14.3	3.50	12.7	3.50	11.5	3.5	9.10	3.0	7.5	3.00	7.5
	4.00	13.4	4.00	14.1	4.00	13.8	4.00	12.7	4.00	11.5	4.0	9.6	3.5	7.9	3.50	7.6
	4.50	12.7	4.50	13.4	4.50	13.4	4.50	12.5	4.50	11.7	4.5	9.9	4.0	8.1	4.00	7.9
	5.00	12.2	5.00	12.7	5.00	12.8	5.00	12.3	5.00	11.7	5.0	10.3	4.5	8.7	4.50	8.4
	5.50	11.6	5.50	12.0	5.50	12.3	5.50	11.9	5.50	11.7	5.5	10.5	5.0	9.0	5.00	8.8
	6.00	11.3	6.00	11.5	6.00	11.8	6.00	11.6	6.00	11.7	6.0	10.7	5.5	9.4	5.50	9.3
	6.50	10.7	6.50	11.0	6.50	11.3	6.50	11.4	6.50	11.5	6.5	10.8	6.0	9.8	6.00	9.5
	7.00	10.4	7.00	10.7	7.00	10.9	7.00	11.0	7.00	11.3	7.0	10.8	6.5	10.0	6.50	9.8
	7.50	10.2	7.50	10.5	7.50	10.7	7.50	10.8	7.50	11.2	7.5	10.9	7.0	10.3	7.00	10.0
	8.00	10.0	8.00	10.2	8.00	10.5	8.00	10.7	8.00	10.9	8.0	10.9	7.5	10.4	7.50	10.3
	8.50	10.0	8.50	10.2	8.50	10.4	8.50	10.6	8.50	10.8	8.5	10.9	8.0	10.5	8.00	10.4
	9.00	9.9	9.00	10.0	9.00	10.3	9.00	10.5	9.00	10.7	9.0	10.9	8.5	10.7	8.50	10.5
	9.50	9.9	9.50	9.9	9.50	10.2	9.50	10.4	9.50	10.6	9.5	10.8	9.0	10.7	9.00	10.6
	10.0	9.8	10.0	9.8	10.0	9.9	10.0	10.2	10.0	10.4	10.0	10.7	9.5	10.7	9.50	10.6
	10.5	9.8	10.5	9.8	10.5	9.9	10.5	10.0	10.5	10.3	10.5	10.5	10.0	10.6	10.00	10.6
													10.5	10.5	10.50	10.7

BTC - Below top of casing; * - First reading represents water level;

Table 5. Cont'd.

Monitoring Station	26-Aug-16		27-Sep-16		19-Oct-16		15-Nov-16		7-Dec-16		16-Jan-17		17-Feb-17		17-Mar-17	
	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)
MW3	4.22		4.26		4.29		4.26		4.22		4.06		3.96		3.85	
	4.30	13.9	4.36	14.5	4.35	14.4	4.35	13.3	4.30	11.9	4.10	10.2	4.06	8.9	3.95	8.8
	4.50	13.6	4.50	14.1	4.50	14.1	4.50	13.3	4.50	12.2	4.5	10.6	4.5	9.5	4.50	9.0
	5.00	12.8	5.00	13.6	5.00	13.6	5.00	13.0	5.00	12.4	5.0	10.8	5.0	9.7	5.00	9.4
	5.50	12.2	5.50	12.8	5.50	13.2	5.50	12.8	5.50	12.4	5.5	10.9	5.5	10.0	5.50	9.6
	6.00	11.6	6.00	12.4	6.00	12.7	6.00	12.5	6.00	12.3	6.0	11.2	6.0	10.3	6.00	9.7
	6.50	11.0	6.50	11.8	6.50	12.3	6.50	12.2	6.50	12.2	6.5	11.2	6.5	10.4	6.50	10.0
	7.00	10.8	7.00	11.5	7.00	11.8	7.00	11.9	7.00	12.0	7.0	11.5	7.0	10.5	7.00	10.3
	7.50	10.5	7.50	11.2	7.50	11.6	7.50	11.7	7.50	11.8	7.5	11.5	7.5	10.7	7.50	10.5
	8.00	10.4	8.00	11.0	8.00	11.4	8.00	11.6	8.00	11.7	8.0	11.5	8.0	10.9	8.00	10.6
	8.50	10.2	8.50	10.8	8.50	11.2	8.50	11.5	8.50	11.6	8.5	11.5	8.5	10.9	8.50	10.7
	9.00	10.2	9.00	10.7	9.00	10.9	9.00	11.4	9.00	11.4	9.0	11.5	9.0	10.9	9.00	10.8
	9.50	10.0	9.50	10.4	9.50	10.6	9.50	11.0	9.50	11.2	9.5	11.3	9.5	11.0	9.50	10.8
	9.8	9.8	9.80	10.2	9.80	10.4	9.80	10.7	9.80	10.9	9.8	11.2	9.8	11.0	9.80	10.9
MW4	3.21		3.33		3.33		3.28		3.23		3.12		3.07		3.01	
	3.30	13.8	3.43	14.1	3.40	13.8	3.35	12.2	3.30	10.7	3.20	8.7	3.17	7.1	3.10	7.1
	3.50	13.0	3.50	13.7	3.50	13.4	3.50	12.3	3.50	10.9	3.50	8.9	3.5	7.5	3.50	7.3
	4.00	11.9	4.00	12.8	4.00	12.7	4.00	12.2	4.00	11.2	4.0	9.1	4.0	7.8	4.00	7.5
	4.50	11.3	4.50	12.3	4.50	12.3	4.50	11.9	4.50	11.2	4.5	9.1	4.5	7.9	4.50	7.8
	5.00	10.6	5.00	11.5	5.00	11.8	5.00	11.5	5.00	11.2	5.0	9.5	5.0	8.2	5.00	7.9
	5.50	10.0	5.50	11.0	5.50	11.4	5.50	11.4	5.50	11.0	5.5	9.6	5.5	8.5	5.50	8.1
	6.00	9.6	6.00	10.5	6.00	10.9	6.00	11.0	6.00	10.8	6.0	9.9	6.0	8.8	6.00	8.5
	6.50	9.4	6.50	10.3	6.50	10.7	6.50	10.8	6.50	10.7	6.5	10.0	6.5	9.0	6.50	8.6
	7.00	9.3	7.00	9.9	7.00	10.4	7.00	10.7	7.00	10.6	7.0	10.0	7.0	9.3	7.00	8.7
	7.50	9.0	7.50	9.6	7.50	10.0	7.50	10.4	7.50	10.4	7.5	10.2	7.5	9.4	7.50	8.9
	8.00	8.9	8.00	9.4	8.00	9.6	8.00	10.0	8.00	10.2	8.0	10.0	8.0	9.4	8.00	9.1
	8.50	8.7	8.50	9.0	8.50	9.4	8.50	9.7	8.50	9.9	8.5	10.0	8.5	9.5	8.50	9.3
	8.90	8.7	8.90	8.9												

BTC* - Below top of casing;

Table 5. Cont'd.

Monitoring Station	26-Aug-16		27-Sep-16		19-Oct-16		15-Nov-16		7-Dec-16		16-Jan-17		17-Feb-17		17-Mar-17	
	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)	depth BTC* (m)	temp (°C)
MW5	2.56		2.71		2.71		2.61		2.55		2.36		2.31		2.25	
	2.63	14.1	2.81	14.4	2.80	13.5	2.70	11.4	2.65	9.6	2.45	7.6	2.41	6.5	2.35	6.9
	3.00	13.3	3.00	13.9	3.00	13.2	3.00	11.4	3.00	9.9	3.0	8.2	2.50	6.9	2.50	7.0
	3.50	12.3	3.50	12.9	3.50	12.6	3.50	11.3	3.50	10.2	3.5	8.7	3.0	7.2	3.00	7.3
	4.00	11.4	4.00	12.0	4.00	11.9	4.00	11.0	4.00	10.3	4.0	8.9	3.5	7.8	3.50	7.6
	4.50	10.8	4.50	11.3	4.50	11.4	4.50	10.7	4.50	10.3	4.5	9.3	4.0	8.2	4.00	7.9
	5.00	10.4	5.00	10.6	5.00	10.8	5.00	10.7	5.00	10.3	5.0	9.6	4.5	8.4	4.50	8.2
	5.50	9.9	5.50	10.0	5.50	10.3	5.50	10.0	5.50	10.3	5.5	9.8	5.0	8.8	5.00	8.6
	6.00	9.6	6.00	9.7	6.00	9.8	6.00	9.8	6.00	10.2	6.0	9.9	5.5	8.9	5.50	8.9
	6.50	9.3	6.50	9.4	6.50	9.5	6.50	9.6	6.50	10.0	6.5	10.0	6.0	9.4	6.00	9.1
	7.00	9.0	7.00	9.0	7.00	9.3	7.00	9.5	7.00	9.9	7.0	10.0	6.5	9.5	6.50	9.4
	7.50	8.9	7.50	8.9	7.50	9.1	7.50	9.4	7.50	9.8	7.5	10.2	7.0	9.8	7.00	9.6
	8.00	8.9	8.00	8.8	8.00	8.9	8.00	9.1	8.00	9.5	8.0	10.0	7.5	9.9	7.50	9.8
	8.50	8.9	8.50	8.8	8.50	8.8	8.50	9.0	8.50	9.3	8.5	9.8	8.0	10.0	8.00	10.0
	9.00	8.9	9.00	8.8	9.00	8.8	9.00	9.0	9.00	9.3	9.0	9.7	8.5	9.9	8.50	10.0
	9.50	8.9	9.50	8.8	9.50	8.8	9.40	9.0	9.50	9.1	9.5	9.7	9.0	9.9	9.00	10.2
													9.5	9.8	9.50	10.0

BTC* - Below top of casing;

Table 6. Water level and temperature measurements in surface water bodies at Maes Pit.

Date	SG1 (Komoka Creek)		SG2 (East - Pit Pond)		SG3 (Central Pond)		SG4 (West Pond)	
	Water level (m BTC)	Temp. (°C)	Water level (m BTC)	Temp. (°C)	Water level (m BTC)	Temp. (°C)	Water level (m BTC)	Temp. (°C)
24-May-16	234.75	10.9	235.20	18.8	235.07	17.7	n/m	n/m
19-Jul-16	234.70	n/m	234.88	n/m	234.65	n/m	n/m	n/m
10-Aug-16	234.57	22.6	234.75	30.2	234.48	26.6	n/m	27.1
26-Aug-16	234.77	15.7	234.87	25.0	234.61	22.2	n/m	n/m
27-Sep-16	234.65	14.4	234.76	18.9	234.52	17.7	235.28	15.4
19-Oct-16	234.7	12.4	234.75	17.8	234.5	15.5	235.30	16.1
15-Nov-16	234.7	10	234.81	8.5	234.59	8.2	235.34	8
7-Dec-16	234.73	6.5	234.85	3.1	234.64	3.3	235.43	4.5
16-Jan-17	234.79	2.3	235.02	Fr	234.86	Fr	235.66	Fr
17-Feb-17	234.89	7.1	235.08	n/m	234.93	4	235.78	n/m

n/m – Not measured; Fr – Frozen;

Table 7. Results of groundwater quality analyses in MW2, MW3, and MW5 at Maes Pit.

Parameter	**Units**	**MDL**	**Regulation**	**Sample**		
				Monitoring Well, MW2 1647201-01	**Monitoring Well, MW3 1647201-02**	**Monitoring Well, MW5 1647201-03**
Sample Date (m/d/y)			**Ontario Drinking Water Standards**	**11/15/2016 02:20 PM**	**11/15/2016 02:55 PM**	**11/15/2016 04:00 PM**
General Inorganics						
Alkalinity, total	mg/L	5	500 mg/L	215	115	252
Hardness	mg/L			261	113	270
pH	pH Units	0.1		7.7	7.6	7.5
Anions						
Chloride	mg/L	1	250 mg/L	35	15	22
Fluoride	mg/L	0.1	1.5 mg/L	ND (0.1)	0.5	ND (0.1)
Nitrate as N	mg/L	0.1	10 mg/L	2.9	0.3	0.1
Nitrite as N	mg/L	0.05	1 mg/L	0.46	ND (0.05)	ND (0.05)
Phosphate as P	mg/L	0.2		ND (0.2)	ND (0.2)	ND (0.2)
Sulphate	mg/L	1	500 mg/L	52	33	63
Metals						
Aluminum	ug/L	10	100 ug/L	13	39	ND (10)
Antimony	ug/L	1	6 ug/L	1	1	ND (1)
Arsenic	ug/L	10	25 ug/L	ND (10)	ND (10)	ND (10)
Barium	ug/L	10	1000 ug/L	69	36	68
Beryllium	ug/L	1		ND (1)	ND (1)	ND (1)
Bismuth	ug/L	5		ND (5)	ND (5)	ND (5)
Boron	ug/L	50	5000 ug/L	ND (50)	ND (50)	ND (50)
Cadmium	ug/L	1	5 ug/L	ND (1)	ND (1)	ND (1)
Calcium	ug/L	200		75900	33200	83800
Chromium	ug/L	50	50 ug/L	ND (50)	ND (50)	ND (50)
Cobalt	ug/L	1		ND (1)	ND (1)	ND (1)
Copper	ug/L	5	1000 ug/L	99	73	179
Iron	ug/L	200	300 ug/L	ND (200)	ND (200)	ND (200)
Lead	ug/L	1	10 ug/L	2	ND (1)	ND (1)
Magnesium	ug/L	200		17400	7200	14700
Manganese	ug/L	50	50 ug/L	ND (50)	ND (50)	274
Molybdenum	ug/L	5		ND (5)	ND (5)	ND (5)
Nickel	ug/L	5		ND (5)	ND (5)	ND (5)
Potassium	ug/L	200		1510	1680	1300
Selenium	ug/L	5	10 ug/L	ND (5)	ND (5)	ND (5)
Silver	ug/L	1		ND (1)	ND (1)	ND (1)
Sodium	ug/L	200	200000 ug/L	8460	12100	8240
Strontium	ug/L	50		143	124	152
Thallium	ug/L	1		ND (1)	ND (1)	ND (1)
Tin	ug/L	10		ND (10)	ND (10)	ND (10)
Titanium	ug/L	10		ND (10)	ND (10)	ND (10)
Uranium	ug/L	5	20 ug/L	ND (5)	ND (5)	ND (5)
Vanadium	ug/L	1		ND (1)	ND (1)	ND (1)
Zinc	ug/L	20	5000 ug/L	60	56	68

Parameter	**Units**	**MDL**	**Regulation**	**Sample**		
				Monitoring Well, MW2 1647201-01	**Monitoring Well, MW3 1647201-02**	**Monitoring Well, MW5 1647201-03**
Sample Date (m/d/y)			**Ontario Drinking Water Standards**	**11/15/2016 02:20 PM**	**11/15/2016 02:55 PM**	**11/15/2016 04:00 PM**
Volatiles						
Benzene	ug/L	0.5	5 ug/L	ND (0.5)	ND (0.5)	ND (0.5)
Ethylbenzene	ug/L	0.5	2.4 ug/L	ND (0.5)	ND (0.5)	ND (0.5)
Toluene	ug/L	0.5	24 ug/L	ND (0.5)	ND (0.5)	ND (0.5)
m/p-Xylene	ug/L	0.5		ND (0.5)	ND (0.5)	ND (0.5)
o-Xylene	ug/L	0.5		ND (0.5)	ND (0.5)	ND (0.5)
Xylenes, total	ug/L	0.5	300 ug/L	ND (0.5)	ND (0.5)	ND (0.5)

Date sampled: November 15, 2016. (*) Analysed by Paracel Laboratories Ltd.

MDL –Method Detection Limit ND – Not Detected

APPENDIX A

Figure 6 – Vegetation Communities from Natural Environment Report
(Biologic, 2017)

Figure 6: Vegetation Communities

(2016 Google Air Photo)

Ecological Land Classifications

Polygon	Area (ha)	ELC Code	Description
Anthropogenic Communities			
A1	–	–	Agricultural Fields (corn and beans) with 0.53ha East Pond
A2	3.4	–	Horse Pasture
H1	–	–	Hedgerow - Spruce
H2	–	–	Hedgerow - Willow
Cultural Communities			
1	1.5	CUT1	Mineral Cultural Thicket Ecosite with FOD Deciduous Forest inclusion (0.48ha) with the 0.22ha West Pond
4	1.6	CUP3	Coniferous Plantation - White and Blue Spruce
5	1.2	CU	Cultural Community consisting of a cultural thicket (CUT), woodland (CUW), plantation (CUP) and the 0.18ha Central Pond
Wetland Communities			
2	3.5	SWD3-3	Swamp Maple Mineral Deciduous Swamp Type
3	3.4	SWD7	Birch-Poplar Organic Deciduous Swamp Type

0 1,000
Scale 1:50,000
Key Plan

Legend:

🟦	Komoka Creek
🟦	Farm Irrigation Pond
🟧	Farm Lane

*BioLogic created ELC label
Print on 11X17, Landscape Orientation
0 100
Scale 1:5000
May 2017

BioLogic
AQUATIC AND TERRESTRIAL ECOSYSTEM PLANNERS

APPENDIX B

Borehole and Instrumentation Logs

Englobe

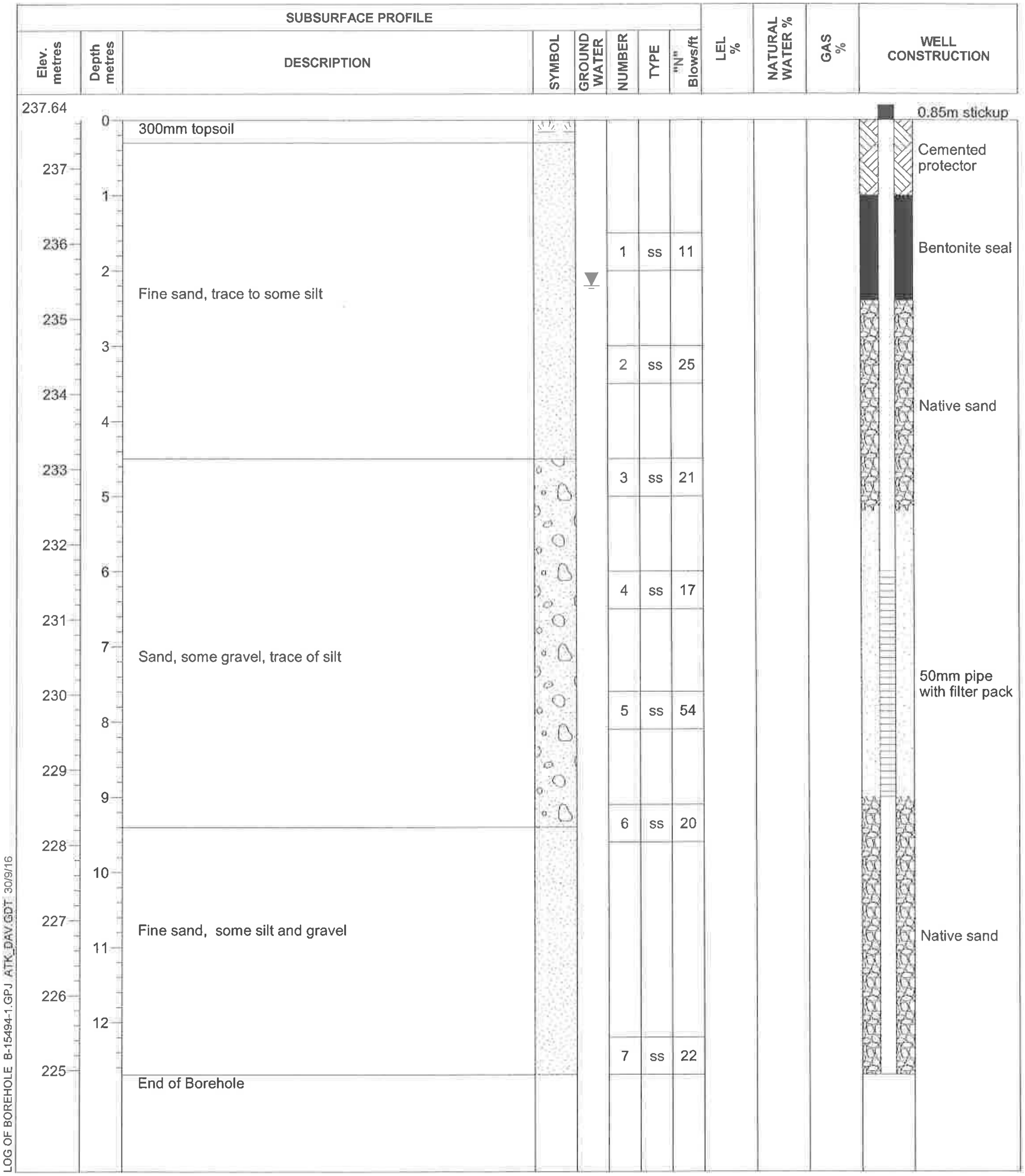
CONSULTING SOILS AND MATERIALS ENGINEERS

12 - 60 Meg Drive, London, ON, N6E 3T6
Phone: 519-685-6400 Fax: 519-685-0943

LOG OF BOREHOLE NO. MW01-16

REF. NO.: B-15494-1
CLIENT: Johnston Brothers (Bothwell) Ltd.
PROJECT: Geotechnical Investigation
LOCATION: Part of Lots 1,2,3, Concession 2, Lobo Twp
DATUM ELEVATION: Geodetic

Encl. No. 1 (Sheet 1 of 1)
DRILLING DATA: D50T
METHOD: Hollow stem
DIAMETER: 150mm
DATE: Aug 22, 2016



NUMBER	TYPE	"N" Blows/ft
1	ss	11
2	ss	25
3	ss	21
4	ss	17
5	ss	54
6	ss	20
7	ss	22

Englobe

CONSULTING SOILS AND MATERIALS ENGINEERS

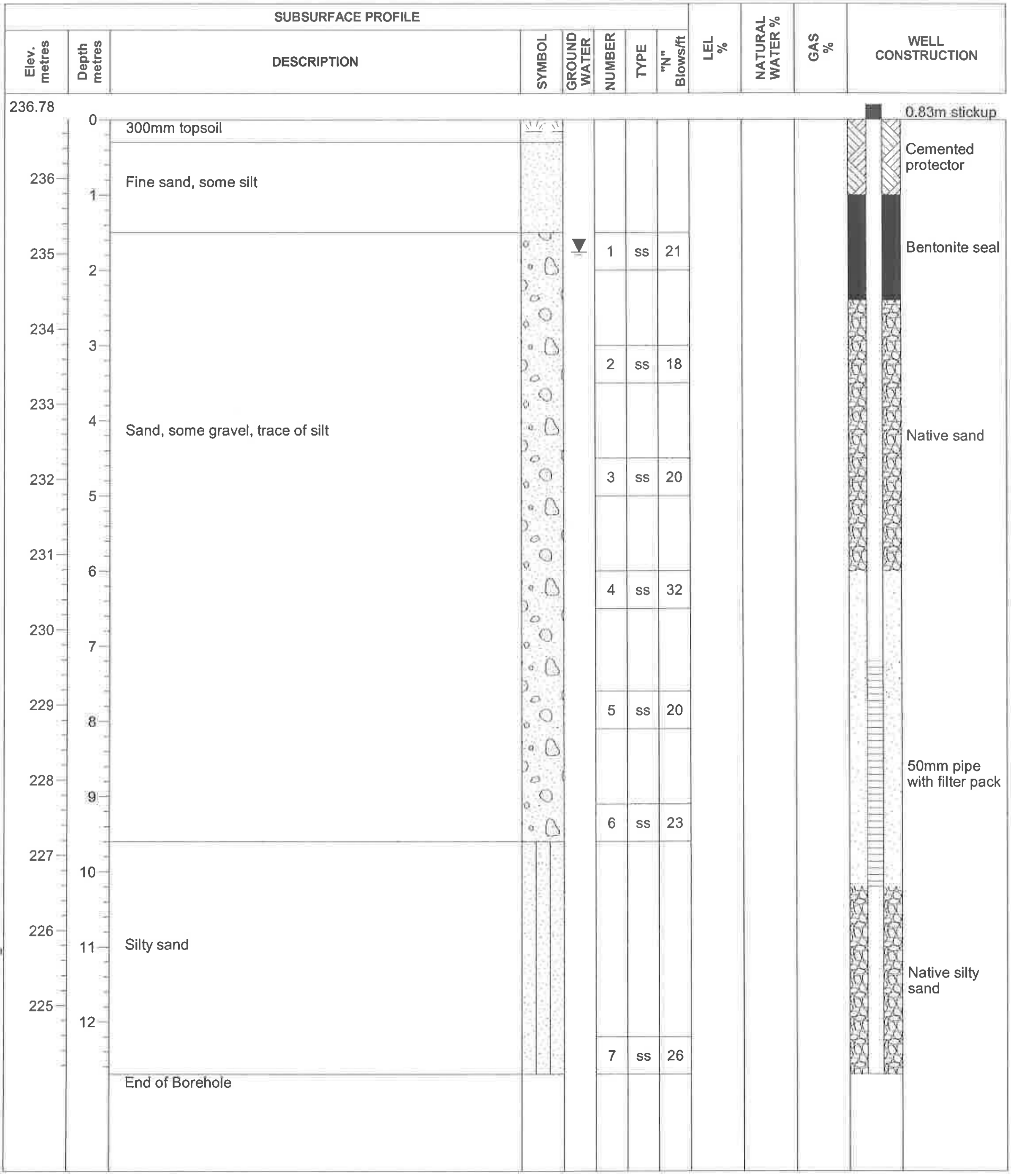
12 - 60 Meg Drive, London, ON, N6E 3T6

Phone: 519-685-6400 Fax: 519-685-0943

REF. NO.: B-15494-1
CLIENT: Johnston Brothers (Bothwell) Ltd.
PROJECT: Geotechnical Investigation
LOCATION: Part of Lots 1,2,3, Concession 2, Lobo Twp
DATUM ELEVATION: Geodetic

LOG OF BOREHOLE NO. MW02-16

Encl. No. 2 (Sheet 1 of 1)
DRILLING DATA: D50T
METHOD: Hollow stem
DIAMETER: 150mm
DATE: Aug 24, 2016

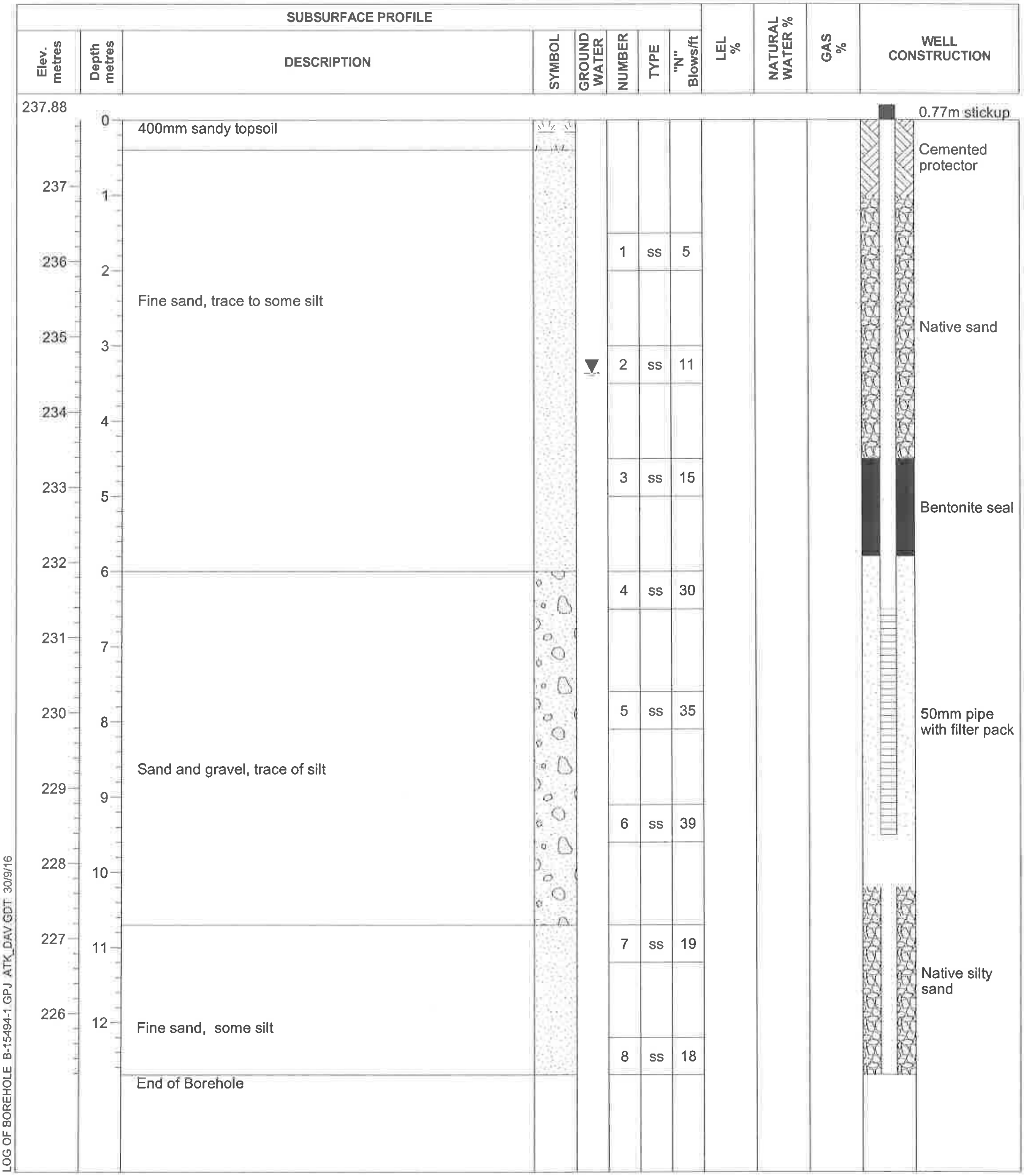


DESCRIPTION	NUMBER	TYPE	"N" Blows/ft
300mm topsoil			
Fine sand, some silt			
Sand, some gravel, trace of silt	1	ss	21
	2	ss	18
	3	ss	20
	4	ss	32
	5	ss	20
	6	ss	23
Silty sand	7	ss	26
End of Borehole			

REF. NO.: B-15494-1
CLIENT: Johnston Brothers (Bothwell) Ltd.
PROJECT: Geotechnical Investigation
LOCATION: Part of Lots 1,2,3, Concession 2, Lobo Twp
DATUM ELEVATION: Geodetic

LOG OF BOREHOLE NO.
MW03-16

Encl. No. 3 (Sheet 1 of 1)
DRILLING DATA: D50T
METHOD: Hollow stem
DIAMETER: 150mm
DATE: Aug 22, 2016



400mm sandy topsoil

Fine sand, trace to some silt

Sand and gravel, trace of silt

Fine sand, some silt

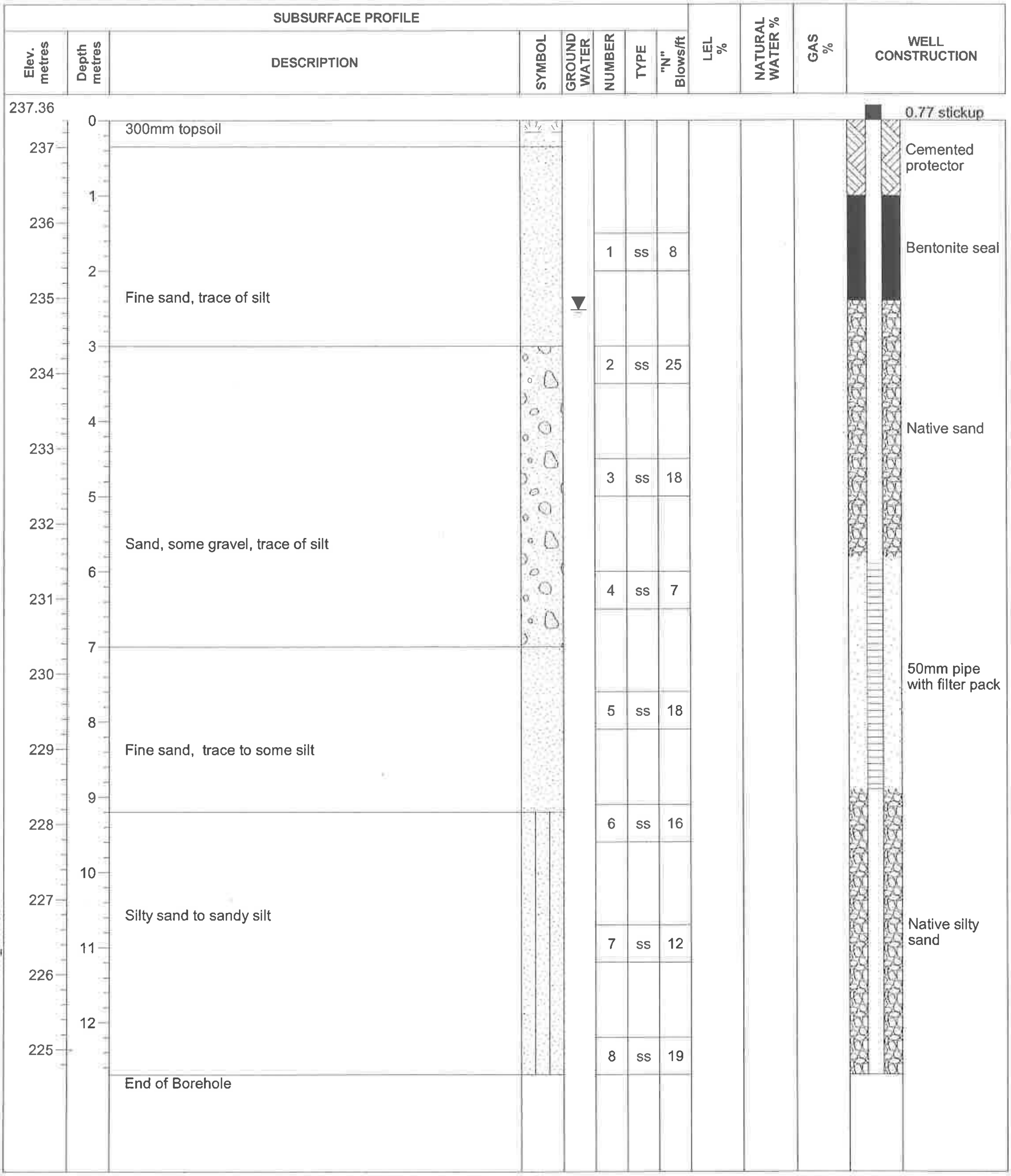
End of Borehole

NUMBER	TYPE	"N" Blows/ft
1	ss	5
2	ss	11
3	ss	15
4	ss	30
5	ss	35
6	ss	39
7	ss	19
8	ss	18

Englobe
CONSULTING SOILS AND MATERIALS ENGINEERS
12 - 60 Meg Drive, London, ON, N6E 3T6 **Phone: 519-685-6400 Fax: 519-685-0943**

REF. NO.: B-15494-1
LOG OF BOREHOLE NO.
MW04-16
CLIENT: Johnston Brothers (Bothwell) Ltd.
PROJECT: Geotechnical Investigation
LOCATION: Part of Lots 1,2,3, Concession 2, Lobo Twp
DATUM ELEVATION: Geodetic

Encl. No. 4 (Sheet 1 of 1)
DRILLING DATA: D50T
METHOD: Hollow stem
DIAMETER: 150mm
DATE: Aug 23, 2016



DESCRIPTION
300mm topsoil
Fine sand, trace of silt
Sand, some gravel, trace of silt
Fine sand, trace to some silt
Silty sand to sandy silt
End of Borehole

NUMBER	TYPE	"N" Blows/ft
1	ss	8
2	ss	25
3	ss	18
4	ss	7
5	ss	18
6	ss	16
7	ss	12
8	ss	19

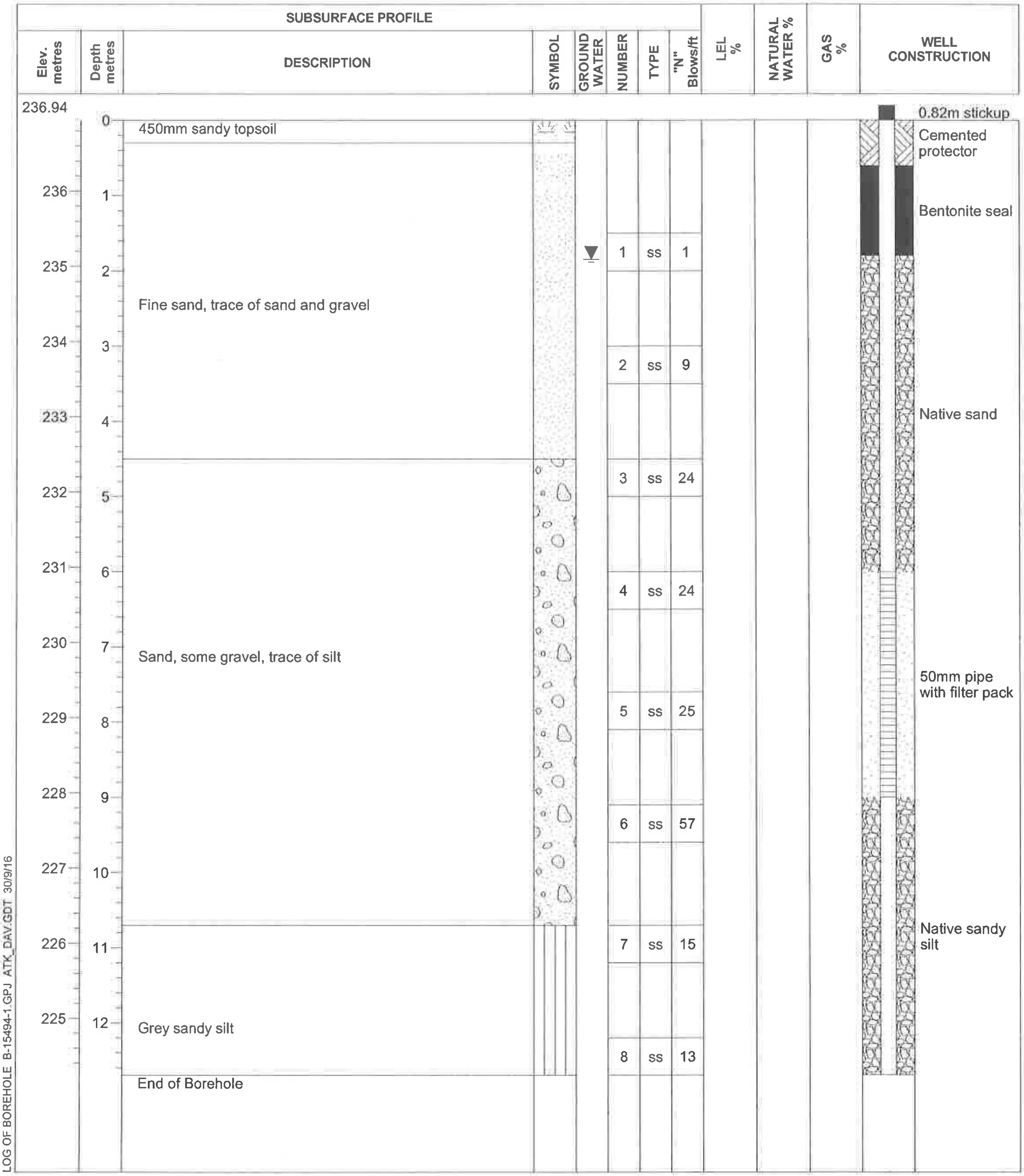
Englobe
CONSULTING SOILS AND MATERIALS ENGINEERS
12 - 60 Meg Drive, London, ON, N6E 3T6 **Phone: 519-685-6400 Fax: 519-685-0943**

REF. NO.: B-15494-1
CLIENT: Johnston Brothers (Bothwell) Ltd.
PROJECT: Geotechnical Investigation
LOCATION: Part of Lots 1,2,3, Concession 2, Lobo Twp
DATUM ELEVATION: Geodetic

LOG OF BOREHOLE NO.

MW05-16

Encl. No. 5 (Sheet 1 of 1)
DRILLING DATA: D50T
METHOD: Hollow stem
DIAMETER: 150mm
DATE: Aug 23, 2016



Elev. metres	Depth metres	DESCRIPTION	SYMBOL	GROUND WATER	NUMBER	TYPE	"N" Blows/ft	LEL %	NATURAL WATER %	GAS %	WELL CONSTRUCTION
236.94	0	450mm sandy topsoil									0.82m stickup Cemented protector
		Fine sand, trace of sand and gravel		▼	1	ss	1				Bentonite seal
					2	ss	9				Native sand
		Sand, some gravel, trace of silt			3	ss	24				
					4	ss	24				
					5	ss	25				50mm pipe with filter pack
					6	ss	57				
		Grey sandy silt			7	ss	15				Native sandy silt
					8	ss	13				
		End of Borehole									

LOG OF BOREHOLE B-15494-1.GPJ ATK_DAV.GDT 30/9/16

APPENDIX C

Water Well Records Printout from MOECC Files

Water well record printout from water well records on file with MOECC

Printout generated on 13/08/2016

Obtained from WWIS database, v2.05 updated January 20, 2016

Project: Maes Pit

Location: .

Search Criteria Easting (m): 463197 Northing (m): 4753700 Radius (m): 1000

Water Well Record No.	Audit No. (Well Tag)	Township Concession (Lot)	UTM Zone Easting Northing	Casing diameter (cm)	Date Work Completed	Water Found (m)	Pumping Test STAT / PUMP RATE / HR:MIN	Water Use	Screen depth interval (m)	Depth to which formation was penetrated (m)
7109380	Z80181 (A034374)	LOBO TOWNSHIP CON 02 (001)	17 462453 4753989	15.9 13	30/09/2007	FR 4.3	3.3 / 3.6 90.9 / 1:	DO	7.62-10.06	BLCK LOAM SAND LOAM 0.3, BRWN SAND SILT DRTY 1.83, GREY SAND SILT DRTY 2.44, BRWN SAND CLN 3.66, GREY CLAY SILT SAND 4.27, GREY FSND CSND 10.06, GREY GRVL SAND CLAY 11.28
7052808	Z67358 (A060621)	LOBO TOWNSHIP ()	17 462488 4753821	1.2	03/10/2007	FR 14	14 / 7 / 1:0	IR	Casing to 21	SAND 24.5
4113244	106739 ()	LOBO TOWNSHIP CON 02 (002)	17 463896 4753965	91.4	30/06/1994	FR 7.6	7.6 / 9.1 227.3 / 2:0	DO	3.05-12.19	BLCK LOAM LOOS 0.3, REDD FSND LOOS 3.35, GREY FSND LOOS 7.62, BRWN CSND 7.92, GREY CSND GRVL 11.28
4112959	114721 ()	LOBO TOWNSHIP CON 02 (002)	17 463253 4754212	12.7	05/10/1993	SA 1.8	1.8 / 4.9 54.6 / 2:0	DO	8.84-9.75	LOAM 0.61, BRWN CLAY 0.91, GREY SAND 2.74, GREY SAND CGVL 8.23, GREY CSND 9.75, GREY CLAY SAND 12.8
4112864	106879 ()	LOBO TOWNSHIP CON 02 (001)	17 462466 4754288	10.2 10.2 12.7	05/01/1993	FR 11.6	3.4 / 4.9 77.3 / 1:0	DO	11.58-12.5	BRWN SAND PCKD 6.1, BRWN SAND GRVL 10.36, BRWN CLAY GRVL SAND 11.58, BRWN SAND LOOS 12.8, GREY CLAY GRVL 16.76, GREY CLAY DNSE 36.58, GREY CLAY STNS DNSE 39.62, GREY CLAY GRVL 44.5, GREY CLAY GRVL 49.68
4106751	()	LOBO TOWNSHIP CON 02 (002)	17 462734 4754576	12.7	16/05/1974	FR 10.7	6.7 / 9.1 36.4 / 3:0	ST DO	14.33-15.24	BRWN LOAM 4.88, BLUE CLAY SILT 10.67, BRWN SAND 12.19, GREY SAND 15.54
4100803	()	LOBO TOWNSHIP CON 01 (002)	17 463773 4753403	15.2 15.2	24/10/1958				Casing to 56.69	BRWN MSND 10.36, GRVL 12.19, MSND 30.78, BLUE CLAY 47.24, HPAN 56.39, GREY SHLE 56.69

Notes on columns:

Column 1. Water well record number of the well, as shown on MOECC files.
Column 2. Audit Number and Well Tag in brackets as given on MOECC files; Well Tag number available for wells drilled in 2003 or later.
Column 3. Geographic Township, Concession, and Lot in brackets.
Column 4. UTM Zone, Easting, and Northing (Datum is NAD83). Cannot be field verified unless Well Tag is affixed to well casing which can be cross-referenced.
Column 5. Casing diameter, in centimetres.
Column 6. Date work completed (construction, alteration, abandonment etc.).
Column 7. Depth water found (metres) and water type - see Table 4 for meaning of code.
Column 8. Results of pumping test performed at time of well construction. STAT is static level before test (metres); PUMP is pumping level at end of test (metres); RATE is pumping rate (L/min); HR:MIN is duration of test in hours and minutes.
Column 9. Water use - see Table 3 for meaning of code.
Column 10. Depth interval of screen (metres).
Column 11. Lithology as described by well driller - see Table 1 and Table 2 for meaning of code. Units in metres.

Colour Description

Code	Description
WHIT	WHITE
GREY	GREY
BLUE	BLUE
GREN	GREEN
YLLW	YELLOW
BRWN	BROWN
REDD	RED
BLCK	BLACK
BLGY	BLUE-GREY

Material Description

Code	Description
BLDR	BOULDERS
BSLT	BASALT
CGRD	COARSE-GRAINED
CGVL	COARSE GRAVEL
CHRT	CHERT
CLAY	CLAY
CLN	CLEAN
CLYY	CLAYEY
CMTD	CEMENTED
CONG	CONGLOMERATE
CRYS	CRYSTALLINE
CSND	COARSE SAND
DKCL	DARK-COLOURED
DLMT	DOLOMITE
DNSE	DENSE
DRTY	DIRTY
DRY	DRY
FCRD	FRACTURED
FGRD	FINE-GRAINED
FGVL	FINE GRAVEL
FILL	FILL
FLDS	FELDSPAR
FLNT	FLINT
FOSS	FOSILIFEROUS
FSND	FINE SAND
GNIS	GNEISS
GRNT	GRANITE
GRSN	GREENSTONE
GRVL	GRAVEL
GRWK	GREYWACKE
GVLY	GRAVELLY
GYPS	GYPSUM
HARD	HARD
HPAN	HARDPAN
IRFM	IRON FORMATION
LIMY	LIMY
LMSN	LIMESTONE
LOAM	TOPSOIL
LOOS	LOOSE
LTCL	LIGHT-COLOURED
LYRD	LAYERED
MARL	MARL
MGRD	MEDIUM-GRAINED
MGVL	MEDIUM GRAVEL
MRBL	MARBLE
MSND	MEDIUM SAND
MUCK	MUCK
OBDN	OVERBURDEN
OTHER	OTHER
PCKD	PACKED
PEAT	PEAT
PGVL	PEA GRAVEL
PORS	POROUS
PRDG	PREVIOUSLY DUG
PRDR	PREV. DRILLED
QRTZ	QUARTZITE
QSND	QUICKSAND
QTZ	QUARTZ
ROCK	ROCK
SAND	SAND
SHLE	SHALE
SHLY	SHALY
SHRP	SHARP
SHST	SCHIST
SILT	SILT
SLTE	SLATE
SLTY	SILTY
SNDS	SANDSTONE
SNDY	SANDY
SOFT	SOFT
SPST	SOAPSTONE
STKY	STICKY
STNS	STONES
STNY	STONEY
THIK	THICK
THIN	THIN
TILL	TILL
UNKN	UNKNOWN TYPE
VERY	VERY
WBRG	WATER-BEARING
WDFR	WOOD FRAGMENTS
WTHD	WEATHERED

Water Use

Code	Description
DO	Domestic
ST	Livestock
IR	Irrigation
IN	Industrial
CO	Commerical
MN	Municipal
PS	Public
AC	Cooling And A/C
NU	Not Used
OT	Other
TH	Test Hole
DE	Dewatering
MO	Monitoring
MT	Monitoring and Test Hole

Water Type

Code	Description
FR	FRESH
SA	SALTY
SU	SULPHUR
MN	MINERIAL
UK	Not stated
GS	GAS
IR	IRON
UT	Untested
OT	Other

APPENDIX D

Calculation of Hydraulic Conductivity

APPENDIX D

CALCULATION OF HYDRAULIC CONDUCTIVITIES

In situ falling head slug tests were performed on August 25, 2016 at four onsite monitoring wells: MW1, MW3, MW4, and MW5. The purpose of the slug tests was to estimate hydraulic conductivity of the overburden deposits at the Site.

Physical characteristics of each tested well and relevant aquifer properties are summarized in Table D1, below.

Table D1. Physical characteristics of monitoring wells and the aquifer.

Borehole ID	Ground surface elevation	Depth, m BGS						25-Aug-16	
		Stickup	Top of screen	Bottom of screen	Aquifer top	Aquifer bottom	Bottom of borehole	Water level BTC	Water level BGS
MW1	237.64	0.85	6.0	9.0	0	> 12.7	12.7	2.98	2.13
MW3	237.88	0.77	6.6	9.6	0	> 12.7	12.7	4.22	3.45
MW4	237.36	0.77	5.8	8.8	0	> 12.7	12.7	3.21	2.44
MW5	236.94	0.82	6.0	9.0	0	> 12.7	12.7	2.56	1.74

BGS – Below ground surface; BTC – Below top of casing.

All four monitoring wells have the same diameter and well screen length, but have slightly different screen depths. There are also screened in the same material: sand, some gravel, trace silt. Notably, none of the wells intercepted aquitard material such as clay or till, therefore the thickness of the aquifer is unknown. All four wells are partially penetrating the aquifer, which is an unconfined overburden aquifer.

For each slug test, a data logging pressure transducer was installed at the bottom of each well prior to the test, and set to record water level at one-second intervals. The results of the slug test are illustrated on Figure D1, on the following page.

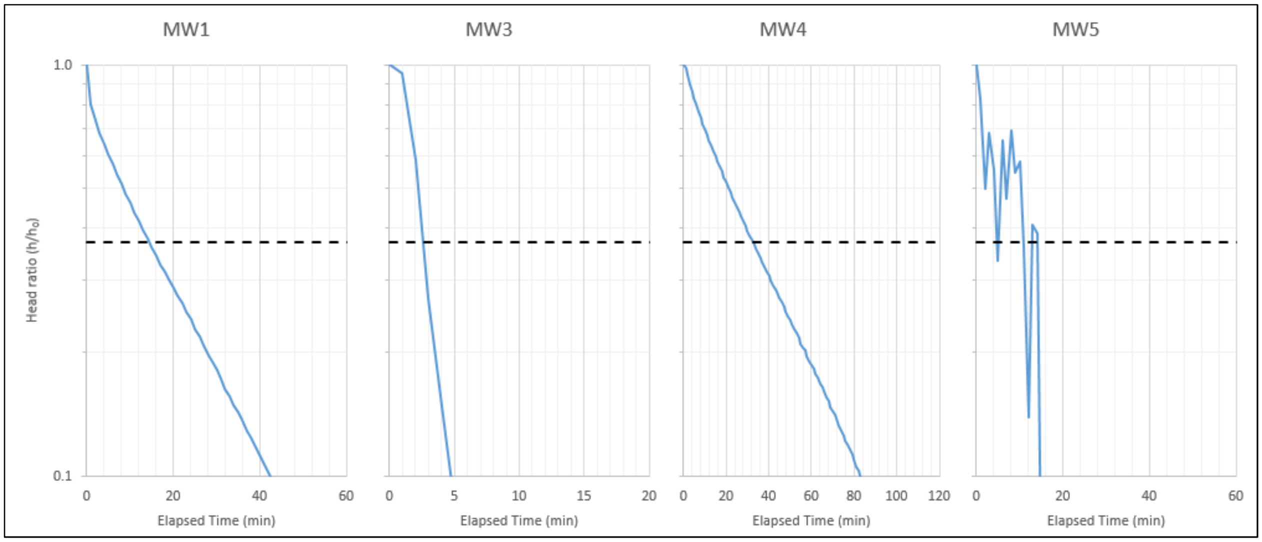
The information collected from the slug tests was then applied to the Hvorslev (1951) method to calculate the approximate hydraulic conductivity of the overburden deposits:

$$K = \frac{r^2 \ln(L_e / R)}{2L_e t_{37}}$$

where

K = hydraulic conductivity (cm/s)
$r = R$ = radius of well casing and well screen = 2.54 cm
L_e = length of well screen (same for all wells) = 300 cm
t_{37} = time it takes for water level to fall 37% of initial change (s)

Figure D1. Results of falling head test, with 37% line identified.



The parameter t_{37} was obtained from the graphs shown on Figure D1. For monitoring wells MW1, MW3, and MW4 it was clearly visible from the field data, but for MW5 it was not. The reason for the sporadic response of the water levels is unclear, and the test was repeated with similar results. Nevertheless, t_{37} was approximated for MW5, and the hydraulic conductivity was calculated. The results are shown in Table D2.

Table D2. Results of Hydraulic Conductivity Calculation.

Borehole ID	r (cm)	R (cm)	Le (cm)	t_{37} (s)	K (cm/s)
MW1	2.54	2.54	300	14	$3.66\text{x}10^{-3}$
MW3	2.54	2.54	300	2.5	$2.05\text{x}10^{-2}$
MW4	2.54	2.54	300	32	$1.60\text{x}10^{-3}$
MW5	2.54	2.54	300	7*	$7.33\text{x}10^{-3}$
				Average:	**$8.28\text{x}10^{-3}$**

*Estimated – inaccurate reading from field slug test

Based on the calculations, the approximate hydraulic conductivity at the Site is $8.28\text{x}10^{-3}$ cm/s. According to Freeze and Cherry (1979), this value falls within the range of hydraulic conductivities of silty sand, and clean sand.

APPENDIX E

Laboratory Certificate of Analyses

PARACEL LABORATORIES LTD.
TRUSTED. RESPONSIVE. RELIABLE.

300 - 2319 St. Laurent Blvd
Ottawa, ON, K1G 4J8
1-800-749-1947
www.paracellabs.com

Certificate of Analysis

Novaterra Environmental
39 Winship Close
London, ON N6C5M8
Attn: Blagy Novakovic

Client PO:
Project: Maes Pit
Custody: 30248

Report Date: 21-Nov-2016
Order Date: 15-Nov-2016

Order #: 1647201

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

Paracel ID	Client ID
1647201-01	Monitoring Well, MW2
1647201-02	Monitoring Well, MW3
1647201-03	Monitoring Well, MW5

Approved By: Mark Foto

Mark Foto, M.Sc.
Lab Supervisor

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Alkalinity, total to pH 4.5	EPA 310.1 - Titration to pH 4.5	17-Nov-16	17-Nov-16
Anions	EPA 300.1 - IC	18-Nov-16	18-Nov-16
BTEX by P&T GC-MS	EPA 624 - P&T GC-MS	20-Nov-16	20-Nov-16
Hardness	Hardness as CaCO3	18-Nov-16	18-Nov-16
Metals, ICP-MS	EPA 200.8 - ICP-MS	18-Nov-16	18-Nov-16
pH	EPA 150.1 - pH probe @25 °C	17-Nov-16	17-Nov-16

Certificate of Analysis
Client: Novaterra Environmental
Client PO:

Report Date: 21-Nov-2016
Order Date: 15-Nov-2016
Project Description: Maes Pit

Client ID:		Monitoring Well, MW2	Monitoring Well, MW3	Monitoring Well, MW5	-
Sample Date:		15-Nov-16	15-Nov-16	15-Nov-16	-
Sample ID:		1647201-01	1647201-02	1647201-03	-
	MDL/Units	Water	Water	Water	-
General Inorganics					
Alkalinity, total	5 mg/L	215	115	252	-
Hardness	mg/L	261	113	270	-
pH	0.1 pH Units	7.7	7.6	7.5	-
Anions					
Chloride	1 mg/L	35	15	22	-
Fluoride	0.1 mg/L	<0.1	0.5	<0.1	-
Nitrate as N	0.1 mg/L	2.9	0.3	0.1	-
Nitrite as N	0.05 mg/L	0.46	<0.05	<0.05	-
Phosphate as P	0.2 mg/L	<0.2	<0.2	<0.2	-
Sulphate	1 mg/L	52	33	63	-
Metals					
Aluminum	10 ug/L	13	39	<10	-
Antimony	1 ug/L	1	1	<1	-
Arsenic	10 ug/L	<10	<10	<10	-
Barium	10 ug/L	69	36	68	-
Beryllium	1 ug/L	<1	<1	<1	-
Bismuth	5 ug/L	<5	<5	<5	-
Boron	50 ug/L	<50	<50	<50	-
Cadmium	1 ug/L	<1	<1	<1	-
Calcium	200 ug/L	75900	33200	83800	-
Chromium	50 ug/L	<50	<50	<50	-
Cobalt	1 ug/L	<1	<1	<1	-
Copper	5 ug/L	99	73	179	-
Iron	200 ug/L	<200	<200	<200	-
Lead	1 ug/L	2	<1	<1	-
Magnesium	200 ug/L	17400	7200	14700	-
Manganese	50 ug/L	<50	<50	274	-
Molybdenum	5 ug/L	<5	<5	<5	-
Nickel	5 ug/L	<5	<5	<5	-
Potassium	200 ug/L	1510	1680	1300	-
Selenium	5 ug/L	<5	<5	<5	-
Silver	1 ug/L	<1	<1	<1	-
Sodium	200 ug/L	8460	12100	8240	-
Strontium	50 ug/L	143	124	152	-
Thallium	1 ug/L	<1	<1	<1	-

Certificate of Analysis

Client: Novaterra Environmental

Client PO:

Report Date: 21-Nov-2016

Order Date: 15-Nov-2016

Project Description: Maes Pit

Client ID:		Monitoring Well, MW2	Monitoring Well, MW3	Monitoring Well, MW5	-
Sample Date:		15-Nov-16	15-Nov-16	15-Nov-16	-
Sample ID:		1647201-01	1647201-02	1647201-03	-
	MDL/Units	Water	Water	Water	-
Tin	10 ug/L	<10	<10	<10	-
Titanium	10 ug/L	<10	<10	<10	-
Uranium	5 ug/L	<5	<5	<5	-
Vanadium	1 ug/L	<1	<1	<1	-
Zinc	20 ug/L	60	56	68	-
Volatiles					
Benzene	0.5 ug/L	<0.5	<0.5	<0.5	-
Ethylbenzene	0.5 ug/L	<0.5	<0.5	<0.5	-
Toluene	0.5 ug/L	<0.5	<0.5	<0.5	-
m,p-Xylenes	0.5 ug/L	<0.5	<0.5	<0.5	-
o-Xylene	0.5 ug/L	<0.5	<0.5	<0.5	-
Xylenes, total	0.5 ug/L	<0.5	<0.5	<0.5	-
Toluene-d8	Surrogate	101%	105%	101%	-

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	1	mg/L						
Fluoride	ND	0.1	mg/L						
Nitrate as N	ND	0.1	mg/L						
Nitrite as N	ND	0.05	mg/L						
Phosphate as P	ND	0.2	mg/L						
Sulphate	ND	1	mg/L						
General Inorganics									
Alkalinity, total	ND	5	mg/L						
Metals									
Aluminum	ND	10	ug/L						
Antimony	ND	1	ug/L						
Arsenic	ND	10	ug/L						
Barium	ND	10	ug/L						
Beryllium	ND	1	ug/L						
Bismuth	ND	5	ug/L						
Boron	ND	50	ug/L						
Cadmium	ND	1	ug/L						
Calcium	ND	200	ug/L						
Chromium	ND	50	ug/L						
Cobalt	ND	1	ug/L						
Copper	ND	5	ug/L						
Iron	ND	200	ug/L						
Lead	ND	1	ug/L						
Magnesium	ND	200	ug/L						
Manganese	ND	50	ug/L						
Molybdenum	ND	5	ug/L						
Nickel	ND	5	ug/L						
Potassium	ND	200	ug/L						
Selenium	ND	5	ug/L						
Silver	ND	1	ug/L						
Sodium	ND	200	ug/L						
Strontium	ND	50	ug/L						
Thallium	ND	1	ug/L						
Tin	ND	10	ug/L						
Titanium	ND	10	ug/L						
Uranium	ND	5	ug/L						
Vanadium	ND	1	ug/L						
Zinc	ND	20	ug/L						
Volatiles									
Benzene	ND	0.5	ug/L						
Ethylbenzene	ND	0.5	ug/L						
Toluene	ND	0.5	ug/L						
m,p-Xylenes	ND	0.5	ug/L						
o-Xylene	ND	0.5	ug/L						
Xylenes, total	ND	0.5	ug/L						
Surrogate: Toluene-d8	*81.1*		*ug/L*		*101*	*50-140*			

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	1.96	1	mg/L	1.91			2.7	10	
Fluoride	0.53	0.1	mg/L	0.49			6.6	10	
Nitrate as N	ND	0.1	mg/L	ND			0.0	20	
Nitrite as N	ND	0.05	mg/L	ND				20	
Phosphate as P	ND	0.2	mg/L	ND				20	
Sulphate	10.9	1	mg/L	10.8			0.9	10	
General Inorganics									
Alkalinity, total	214	5	mg/L	215			0.7	14	
pH	7.7	0.1	pH Units	7.7			0.7	10	
Metals									
Aluminum	13.6	10	ug/L	13.2			3.3	20	
Antimony	2.0	1	ug/L	1.3			45.2	20	QR-01
Arsenic	ND	10	ug/L	ND			0.0	20	
Barium	70.1	10	ug/L	68.6			2.2	20	
Beryllium	ND	1	ug/L	ND			0.0	20	
Bismuth	ND	5	ug/L	ND			0.0	20	
Boron	ND	50	ug/L	ND			0.0	20	
Cadmium	ND	1	ug/L	ND			0.0	20	
Calcium	77900	200	ug/L	75900			2.6	20	
Chromium	ND	50	ug/L	ND			0.0	20	
Cobalt	ND	1	ug/L	ND			0.0	20	
Copper	99.5	5	ug/L	98.7			0.9	20	
Iron	ND	200	ug/L	ND			0.0	20	
Lead	1.8	1	ug/L	1.5			12.7	20	
Magnesium	18000	200	ug/L	17400			3.2	20	
Manganese	ND	50	ug/L	ND			0.0	20	
Molybdenum	ND	5	ug/L	ND			0.0	20	
Nickel	ND	5	ug/L	ND			0.0	20	
Potassium	1560	200	ug/L	1510			3.9	20	
Selenium	5.7	5	ug/L	ND			0.0	20	
Silver	ND	1	ug/L	ND			0.0	20	
Sodium	10300	200	ug/L	8460			20.0	20	
Strontium	145	50	ug/L	143			1.3	20	
Thallium	ND	1	ug/L	ND			0.0	20	
Tin	ND	10	ug/L	ND			0.0	20	
Titanium	ND	10	ug/L	ND			0.0	20	
Uranium	ND	5	ug/L	ND			0.0	20	
Vanadium	ND	1	ug/L	ND			0.0	20	
Zinc	60.5	20	ug/L	59.5			1.6	20	
Volatiles									
Benzene	ND	0.5	ug/L	ND				30	
Ethylbenzene	ND	0.5	ug/L	ND				30	
Toluene	ND	0.5	ug/L	ND				30	
m,p-Xylenes	ND	0.5	ug/L	ND				30	
o-Xylene	ND	0.5	ug/L	ND				30	
Surrogate: Toluene-d8	*81.7*		*ug/L*		*102*	*50-140*			

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	11.3	1	mg/L	1.91	93.6	78-112			
Fluoride	1.42	0.1	mg/L	0.49	92.5	73-113			
Nitrate as N	0.99	0.1	mg/L	ND	99.3	81-112			
Nitrite as N	1.02	0.05	mg/L	ND	102	76-117			
Phosphate as P	4.92	0.2	mg/L	ND	98.4	72-131			
Sulphate	21.1	1	mg/L	10.8	102	75-111			
Metals									
Aluminum	56.0		ug/L	ND	109	80-120			
Antimony	50.7		ug/L	ND	101	80-120			
Arsenic	53.5		ug/L	ND	107	80-120			
Barium	60.8		ug/L	ND	108	80-120			
Beryllium	48.5		ug/L	ND	96.9	80-120			
Bismuth	49.9		ug/L	ND	99.7	80-120			
Boron	50.1		ug/L	ND	94.2	80-120			
Cadmium	49.7		ug/L	ND	99.5	80-120			
Calcium	8800		ug/L	7590	121	80-120			QM-07
Chromium	53.0		ug/L	ND	106	80-120			
Cobalt	51.8		ug/L	ND	103	80-120			
Copper	59.6		ug/L	9.9	99.5	80-120			
Iron	1020		ug/L	ND	102	80-120			
Lead	48.8		ug/L	ND	97.4	80-120			
Magnesium	2820		ug/L	1740	108	80-120			
Manganese	54.0		ug/L	ND	107	80-120			
Molybdenum	50.7		ug/L	ND	101	80-120			
Nickel	49.9		ug/L	ND	99.7	80-120			
Potassium	1210		ug/L	ND	106	80-120			
Selenium	52.5		ug/L	ND	104	80-120			
Silver	49.8		ug/L	ND	99.5	80-120			
Sodium	1970		ug/L	846	112	80-120			
Strontium	66.3		ug/L	ND	104	80-120			
Thallium	49.8		ug/L	ND	99.7	80-120			
Tin	50.2		ug/L	ND	99.9	80-120			
Titanium	52.3		ug/L	ND	105	80-120			
Uranium	52.1		ug/L	ND	104	80-120			
Vanadium	54.0		ug/L	ND	108	80-120			
Zinc	57.5		ug/L	ND	103	80-120			
Volatiles									
Benzene	32.4	0.5	ug/L	ND	81.1	50-140			
Ethylbenzene	37.6	0.5	ug/L	ND	93.9	50-140			
Toluene	35.0	0.5	ug/L	ND	87.4	50-140			
m,p-Xylenes	73.7	0.5	ug/L	ND	92.2	50-140			
o-Xylene	37.3	0.5	ug/L	ND	93.2	50-140			
Surrogate: Toluene-d8	*73.8*		*ug/L*		*92.3*	*50-140*			

Qualifier Notes:

Login Qualifiers :

Sample - Filtered and preserved by Paracel upon receipt at the laboratory - Metals

Applies to samples: Monitoring Well, MW2, Monitoring Well, MW3, Monitoring Well, MW5

Sample - Not field filtered - Metals, subsample for unpreserved from gereral bottle

Applies to samples: Monitoring Well, MW2, Monitoring Well, MW3, Monitoring Well, MW5

QC Qualifiers :

QM-07 :	The spike recovery was outside acceptance limits for the MS and/or MSD. The batch was accepted based on other acceptable QC.
QR-01 :	Duplicate RPD is high, however, the sample result is less than 10x the MDL.
QS-02 :	Spike level outside of control limits. Analysis batch accepted based on other QC included in the batch.

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

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

PARACEL
LABORATORIES LTD.

TRUSTED .
RESPONSIVE .
RELIABLE .

Head Office
300-2319 St. Laurent Blvd.
Ottawa, Ontario K1G 4J8
p: 1-800-749-1947
e: paracel@paracellabs.com
www.paracellabs.com

Chain of Custody
(Lab Use Only)
№ 30248

Page 1 of 1

Client Name: Novaterre Environmental Ltd

Contact Name: Blagy Novakovic

Address: 39 Winship Close
London, ON N6C 5M8

Telephone: (519) 690-1796

Project Reference: Maes pit

Quote # 16-751

PO #

Email Address: Novaterra@sympatico. ca

Turnaround Time:
☐ 1 Day ☐ 3 Day
☐ 2 Day ☒ Regular
Date Required:

Criteria: ☐ O. Reg. 153/04 (As Amended) Table __ ☐ RSC Filing ☐ O. Reg. 558/00 ☐ PWQO ☐ CCME ☐ SUB (Storm) ☐ SUB (Sanitary) Municipality: ______ ☒ Other: ______

Matrix Type: S (Soil/Sed.) **GW** (Ground Water) **SW** (Surface Water) **SS** (Storm/Sanitary Sewer) **P** (Paint) **A** (Air) **O** (Other)

Paracel Order Number: 1647201

	Sample ID/Location Name	Matrix	Air Volume	# of Containers	**Sample Taken** Date	**Sample Taken** Time	**Required Analyses** pH, Alkal, hardness	major cations anions	metal scan	BTEX							
①	Monitoring Well, MW2.	GW		4	15 Nov '16	14:00	✓	✓	✓	✓							
②	Monitoring well MW3	GW		↓	15 Nov. '16	14:55	✓	✓	✓	✓							
③	Monitoring well MW5	GW		↓	15 Nov. 16	16:00	✓	✓	✓	✓							
4																	
5																	
6																	
7																	
8																	
9																	
10																	

Comments: Metals not field filtered, ~~subsamsan~~ subsample from general bottle and filter and preserve in lab as per Elizabeth -RS

Method of Delivery: walk in

Relinquished By (Sign): BNovakovic

Relinquished By (Print): BLAGY NOVAKOVIC

Date/Time: 15 November, 2016

Received by Driver/Depot:

Date/Time: 11 15 16 16:57

Temperature: 11.4 °C

Received at Lab: SUNEEPORN DOKMAI

Date/Time: NOV 17, 2016 10.37

Temperature: 5.3 °C

Verified By:

Date/Time: NOV 17/16 11:30

pH Verified ☑ By:

Chain of Custody (Blank) - Rev 0.4 Feb 2016

APPENDIX F

Water Budget and Calculation of Potential Impact on Water Resources

APPENDIX F

WATER BUDGET AND CALCULATIONS OF POTENTIAL IMPACT ON WATER RESOURCES

F.1 Potential Changes in Water Balance

The methods for calculating groundwater recharge involve the use of a climatic water budget and applying it to the area proposed for proposed sand and gravel extraction. A method developed by the Ministry of the Environment and Energy was used (MOEE, 1995).

First, the water balance for existing site conditions (Drawing 1 of 3 from Bradshaw, 2016) is determined, then it is compared to the water balance of the site after rehabilitation (Drawing 3 of 3 from Bradshaw, 2016).

The following data were taken from the Upper Thames River Conservation Authority (UTRCA) Assessment Report prepared by Thames-Sydenham and Region (2010). For the Thames River Between Forks and Dutton Subwatershed, the following data were given in the report:

Table F1. Actual site water budget for existing conditions.

Parameter	Value	Source
Yearly precipitation	954	Table 21 in Thames-Sydenham and Region Tier 1 Water Budget, Version 1.0 (2010)
Evapotranspiration	550	Table 23 in Thames-Sydenham and Region Tier 1 Water Budget, Version 1.0 (2010)
Actual water balance	440	Using method shown in Section 4.5, Table 1, of MOEE (1995)

The following infiltration factors were used for current/existing site conditions:

Table F2. Infiltration factors for existing conditions[1)]

Parameter	Value	Description
Topography	0.2	Rolling land, average slope of 2.8 m to 3.8 m per km
Soil	0.4	Open sandy loam
Cover	0.1	Cultivated lands
TOTAL	0.7	Estimated total infiltration factor

[1)] Note: Taken from (Table 2 in Section 4.5 of MOEE, 1995)

Infiltration at the site is calculated by multiplying the actual water balance with the infiltration factor (440 mm x 0.7 = 308 mm). Therefore, the amount of infiltration is 308 mm, and the remaining amount, 132 mm, is runoff.

It is proposed to have one pond with a maximum size of approximately 17.6 ha as the final land use. Therefore, lake evaporation would replace evapotranspiration. According to Environment Canada Climate Normals from 1981 to 2010, average value of lake evaporation measured at the Delhi Climate Station is 634.5 mm (Environment Canada, 2015). Subtracting this value from the average annual precipitation gives 319.5 mm, which is the amount of precipitation that will remain in the pond. In a crude sense, we can consider this as groundwater recharge or infiltration because it will not be possible for this water to leave the pond area as runoff.

The Table F3 provides a comparison of the water budget for current site conditions and rehabilitated conditions.

Table F3. Comparison of water budget at Maes Pit before and after gravel extraction.

Parameter	Current conditions (mm)	Rehabilitated conditions (mm)	Change (mm)
Precipitation	954	954	0
Evapotranspiration	550	n/a	n/a
Evaporation (from pond)	n/a	634.5	n/a
Groundwater recharge or infiltration	308	319.5 (pond)	+11.5
Runoff	132	0	0 (-132)

In a stricter sense of water budget, there is a gain of groundwater recharge of 11.5 mm, when compared to existing conditions (319.5 mm – 308 mm = 11.5 mm). However, the overall water budget is expected to decrease by 120.5 mm because more water is being lost due to direct evaporation from the pond, and there would be no runoff in the area of the pond (11.5 mm – 132 mm = - 120.5 mm).

F.2 Potential for Water Level Lowering Due to Removal of Aggregate

F.2.1 Background

The removal of sand and gravel from the proposed extraction area theoretically has a potential to create a cone of depression around the pond. As excavation proceeds in the proposed extraction area, the size of the pond and volume of water stored will proportionally increase. The effects of daily extraction on the water table are presented in this section.

When a given volume of aquifer material (sand and gravel plus pore water) is removed, most of the water in the excavator bucket drains back into the pond. Additionally, the removed sand and gravel is placed near the pond so that the remaining water drains back into the pond. A volume of water equal to the volume of excavated sand and gravel flows from the existing pond, and groundwater, into the void created by sand and gravel removal.

The overall water level drops slightly as the void space is filled. The effect of this marginal drawdown can instantly be observed at the pond edge. The temporary hydraulic gradient across the pond edge increases in proportion to the drawdown, and flow from the adjacent aquifer into the pond increases.

The aquifer material captured in each bucket consists of saturated sand and gravel. Assuming a porosity of the granular material of 0.35, the volume of aquifer solids removed in a 1 m^3 scoop is 0.65 m^3. When an excavated pond is small, the change in volume caused by the removal of granular material has the greatest effect on the water level in the pond. As pond size increases, there is more water available in relation to the extraction of one bucket of material, so the effects of extraction become increasingly subdued.

The following calculation show the maximum possible drawdown created around the pond at its smallest and largest extents under conservative and most adverse conditions. These conservative conditions are based on assumptions which overestimate factors which could cause drawdown in the pond.

A volume of water required to replace solid extracted volume was calculated by using a daily tonnage of 3,000 tonnes. This value is representative of the average amount of granular material that can be removed with a drag line excavator in a 10-hour work day (300 tonnes/hour). Because a drag lines are expensive to run, they will typically only be on site for a 2 or 3 week period, operating 10 hours a day, which means that the daily tonnage of 3,000 tonnes is the maximum amount of aggregate that will be removed in a single day.

Typically, the material removed with the drag line will be piled along the shoreline so that water present in the aggregate will drain back into the pond because wet material is heavy and undesirable to customers.

Based on the above-mentioned tonnage, the volume of water required to replace the extracted materials is calculated as follows:

The input parameters:

Maximum daily tonnage = 3,000 tonnes/day
Density of aggregate = 1766 kg/ m^3 (MNDM, 1991)
Porosity = 0.35
Solids ratio = 0.65

Calculated volume of sand and gravel being excavated per day:

$$V_w = \left(\frac{3{,}000{,}000\ kg/day}{1{,}766\ kg/m^3}\right) \times 0.65$$
$$V_w = 1{,}104\ m^3/day$$

This is the approximate volume of water that will need to flow into the excavated area to replace the sand and gravel.

F.2.2 Scenario A: Early Phase of Extraction

The potential effect on water table is considered to be the greatest when the pond is small in size. We will assume the pond size to be 1 hectare, and the average thickness of saturated sand and gravel to be 9 m (Drawing 3 of 3 in Bradshaw, 2016). The banks of the pond area assumed to be vertical for simplicity. At this stage, the maximum volume of water in the pond is given by:

$$V_1 = A \times b \ \ (assuming\ vertical\ slope\ of\ the\ pond\ banks)$$
$$V_1 = 10{,}000\ m^2 \times 9\ m$$
$$V_1 = 90{,}000\ m^3$$

Where,
A = area of the pond
b = depth of the pond

The maximum daily drawdown caused by the removal of aggregate was calculated as follows:

$$dd_{(1)} = h_o - [V_1 - V_w]/A$$
$$dd_{(1)} = 9\ m - [90{,}000\ m^3 - 1{,}104\ m^3/day]/10{,}000\ m^2$$
$$dd_{(1)} = 0.1104\ m$$

Where,
$dd_{(1)}$ = Reduction of hydraulic head in pond, (m)
h_o = Initial head in pond, (m)
V_1 = volume of water in the pond, (m^3)
V_w = The effective calculated pumping rate, (m^3/day)
A = Area of the pond (m^2)

Given the size of the pond of 1 hectare, and assuming no water level recovery during the daily extraction, the calculated drawdown would be 0.1104 m at the end of 10-hour extraction day. In reality, water level will recover over the remaining 14 hours of day because there is a constant groundwater flux from the upgradient area of the adjacent land which flows into the Site. So, the drawdown caused by removal of the solid phase of the aquifer will be replenished quickly even before the next extraction day begins.

F.2.3 Scenario B: Near Completion of Extraction

As the extraction of sand and gravel progresses, the size of the proposed pond would increase past 10.02 ha, and the pond depth is assumed to be an average of 9 m (Drawing 3 of 3 in Bradshaw, 2016). At this stage, the maximum volume of water in the pond is given by:

$$V_2 = A \times b \ \ (assuming\ vertical\ slope\ of\ the\ pond\ banks)$$
$$V_2 = 100{,}200\ m^2 \times 9\ m$$
$$V_2 = 901{,}800\ m^3$$

The drawdown caused by the removal of aggregate below water table was calculated to be:

$$dd_{(2)} = h_o - [V_2 - V_w]/A$$
$$dd_{(2)} = 9\ m - [901{,}800\ m^3 - 1{,}104\ m^3/day]/100{,}200\ m^2$$
$$dd_{(2)} = 0.0111\ m$$

Given the pond size of 10.02 ha, and assuming no water level recovery during the daily extraction, the calculated drawdown would be 0.0111 m at the end of a 10-hour extraction day. In reality, water level will recover over the remaining 14 hours of day because there is a constant groundwater flux from the upgradient area of the adjacent land which flows into the Site. So, the drawdown caused by removal of the solid phase of the aquifer will be replenished quickly even before next extraction day begins.

As the size of the future pond increases to its final size, the effects of the temporary lowering would become negligible.

APPENDIX G

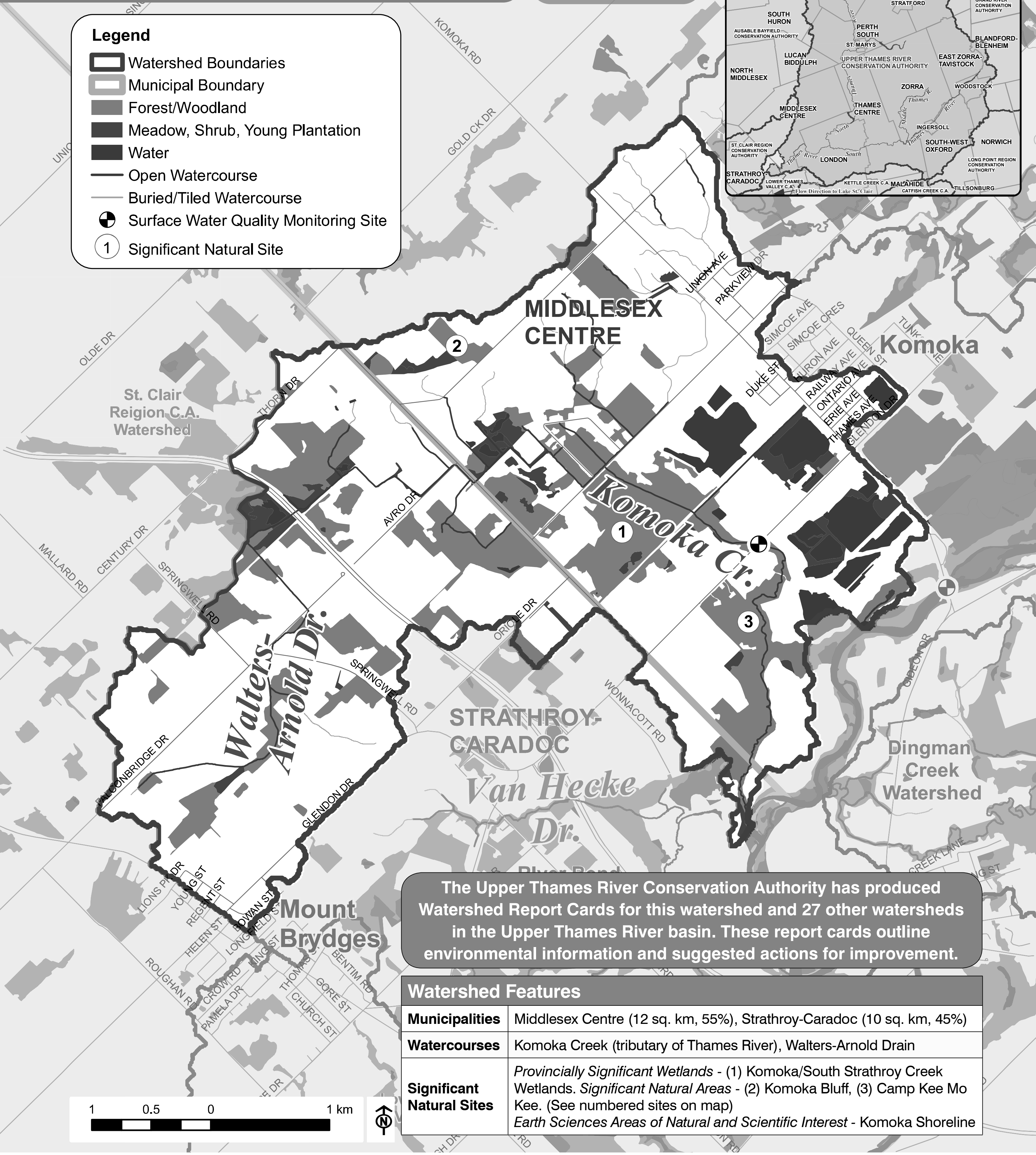
Komoka Creek 2012 Watershed Report Card

KOMOKA CREEK

2012 Watershed Report Card

GRADES

Surface Water Quality
C - STEADY
Forest Conditions
C - STEADY



The Upper Thames River Conservation Authority has produced Watershed Report Cards for this watershed and 27 other watersheds in the Upper Thames River basin. These report cards outline environmental information and suggested actions for improvement.

Watershed Features

Municipalities	Middlesex Centre (12 sq. km, 55%), Strathroy-Caradoc (10 sq. km, 45%)
Watercourses	Komoka Creek (tributary of Thames River), Walters-Arnold Drain
Significant Natural Sites	*Provincially Significant Wetlands* - (1) Komoka/South Strathroy Creek Wetlands. *Significant Natural Areas* - (2) Komoka Bluff, (3) Camp Kee Mo Kee. (See numbered sites on map) *Earth Sciences Areas of Natural and Scientific Interest* - Komoka Shoreline

WATERSHED FEATURES

<table>
<tr><td>Area</td><td>2140 ha (21 sq. km), 1% of Upper Thames River watershed</td></tr>
<tr><td>Land Use</td><td>64% agriculture, 22% natural vegetation, 6% urban, 4% aggregates, 5% water</td></tr>
<tr><td>Population</td><td>1,460 in 2011, an increase from 1,180 in 2006. 1,420 in 1996.</td></tr>
<tr><td>Soil Type</td><td>63% loamy fine sand, 12% not mapped (urban), 8% silty loam, 6% coarse sand, 5% silt clay loam, 4% organic, 2% bottomland</td></tr>
<tr><td>Physiography</td><td>89% sand plain, 6% till moraine, 4% spillway, 1% water</td></tr>
<tr><td>Soil Erosion / Delivery</td><td>4% highly erodible (lands that could potentially contribute >7 tonnes/ha of soil to a watercourse/yr). The average for the Upper Thames River watershed is 9%.</td></tr>
<tr><td>Stream Flow</td><td>There is no flow monitoring station on Komoka Creek.</td></tr>
<tr><td>Tiling & Drainage</td><td>94% no tiling, 6% urban drainage, 0% randomly field tiled, 0% systematically field tiled</td></tr>
<tr><td>Watercourse Characteristics</td><td>Total length: 32 km of watercourse
Watercourse type: 46% channelized, 27% natural, 27% buried
Flow type: 49% permanent, 27% buried, 24% intermittent
Temperature: 61% unconfirmed, 21% cool/coldwater, 18% warmwater</td></tr>
<tr><td>Dams & Barriers</td><td>No dams or barriers are reported in this watershed.</td></tr>
<tr><td>Sewage Treatment</td><td>There are no sewage treatment plants discharging into Komoka Creek. Properties in Komoka are serviced by the Komoka Wastewater Treatment Plant which discharges treated effluent into the Thames River. Rural residences in the watershed are serviced by private septic systems.</td></tr>
<tr><td>Spills</td><td>1 spill reported from 2006-2011, 0 spills from 2001-2005, 0 spills from 1988-2000</td></tr>
<tr><td>% Vegetation Cover Types</td><td>Total vegetation cover: 501 ha (23.2% of the Komoka Creek watershed)
Forest cover types: 76% deciduous, 3% mixed, 5% coniferous/plantation
Other cover types: 11% meadow, 3% shrubland, 2% hedgerow</td></tr>
<tr><td>Wetland Cover</td><td>13.3% (285 ha) of the watershed is in wetland cover. Wetlands make up 57% of the natural vegetation cover.</td></tr>
<tr><td>Woodlot or Patch Size</td><td>
<table>
<tr><th>Size Category</th><th>Number of Woodlots</th><th>Average Size (ha)</th><th>Total Woodland Area (ha)</th><th>% of Woodland Area</th><th>Largest Woodlot (ha)</th></tr>
<tr><td>Small (<10 ha)</td><td>34</td><td>3</td><td>106</td><td>25</td><td>71</td></tr>
<tr><td>Medium (10-30 ha)</td><td>7</td><td>14</td><td>97</td><td>23</td><td></td></tr>
<tr><td>Large (>30 ha)</td><td>4</td><td>54</td><td>214</td><td>51</td><td></td></tr>
</table>
</td></tr>
<tr><td>Fisheries Resources</td><td>21 fish species have been recorded. Gamefish include Largemouth Bass, Northern Pike, and Brown and Rainbow Trout. No freshwater mussels documented, but more sampling is needed.</td></tr>
<tr><td>Species at Risk</td><td><i>Birds</i> – Hooded Warbler, Louisiana Waterthrush, Yellow-breasted Chat. <i>Fish</i> – Eastern Sand Darter. <i>Plants</i> – Crooked-stem Aster, Eastern Flowering Dogwood, Tuberous Indian-plantain, Willowleaf Aster. <i>Reptiles</i> – Blanding’s Turtle, Snapping Turtle.</td></tr>
</table>

WEATHER & WATER HIGHS & LOWS

Some extreme weather patterns were experienced from 2006 to 2011. A major summer drought in 2007 affected some well supplies and dried out some smaller watercourses. Conversely, there were three significant flood events caused by rain and snowmelt in April and December 2008 and February 2009. In 2011, a very wet year, the UTRCA issued over 30 Flood Bulletins. With changing climate patterns, the Great Lakes area is expected to see more extremes in precipitation and temperature.

GRADE:
C
STEADY

SURFACE WATER QUALITY

Surface water quality has remained steady in Komoka Creek since 2005 and scores an overall grade of C (see table below). A water quality monitoring station was added to Komoka Creek at Glendon Drive (see cover map) in 2002.

Phosphorus levels have remained steady at the provincial guideline level and are lower than most of the other 27 watersheds of the Upper Thames River. The *E. coli* bacteria grade has changed from a D to a C, but levels have remained fairly steady and indicate the presence of some sources of human/animal waste.

Nitrate levels (sources include fertilizer, waste) have improved since 2005 and are lower than the aquatic life guideline. Metals such as lead, copper and zinc are below provincial guidelines.

Komoka Creek has good riparian cover throughout much of the watershed and, in the lower reaches, excellent natural stream habitat and groundwater inputs. Benthic scores were steady and near the Upper Thames average, but lower than expected based on these physical conditions.

Indicators	Komoka Creek			Upper Thames 2006-2010	Provincial Guideline	Indicator Description
	1996-2000	2001-2005	2006-2010			
Phosphorus (mg/l) *	No data	0.032 C	**0.032 C Steady**	0.091 D	0.030 B (Aquatic Life)	Phosphorus is found in products such as soap, detergent and fertilizer as well as waste, and contributes to excess algae and low oxygen in streams and lakes.
Bacteria (*E. coli*/ 100 ml) **	No data	304 D	**288 C Steady**	249 C	100 B (Recreation)	*E. coli* is a fecal coliform bacteria found in human and animal (livestock/wildlife/pets) waste and, in water, indicates fecal contamination. *E. coli* is a strong indicator for the potential to have other disease-causing organisms in the water.
Benthic Score (FBI)	6.07 D	6.26 D	**6.03 D Steady**	6.04 D	<5.00 B (Target Only)	Benthic organisms (aquatic invertebrates that live in stream sediments) are good indicators of water quality and stream health. The Family Biotic Index (FBI) scores each taxa according to its pollution tolerance.

* 75th percentile, MOE Provincial Water Quality Monitoring Network data. ** Geometric mean, Health Unit data. Province-wide Grading System used (see page 6).

GRADE:
C
STEADY

FOREST CONDITIONS

The three forest conditions indicators score a C, F and B (see table below), producing an overall grade of C.

The percent forest cover (19.5%) is higher than the average for the Upper Thames watershed, but the small size of this watershed skews comparisons with other watersheds somewhat. The target for southern Ontario is 30% forest cover. Meadows and other habitat types add another 3.7% for a total of 23.2% natural cover.

The percent forest interior (2.3%) is low, but higher than the Upper Thames watershed average. There are some, but not enough, large woodlots to provide habitat for area sensitive birds such as Scarlet Tanager and Ovenbird. The target for southern Ontario is 10% forest interior.

The percent riparian zone forested (44%) is close to the target of 50%. Additional riparian areas are in permanent meadows (11.3%) for a total of 55.3% riparian zone vegetated.

The decline in forest cover and interior between the 2007 and 2012 report cards is largely a reflection of more accurate mapping, but incremental forest loss still occurs.

Indicators	Komoka Creek		Upper Thames 2012*	S. Ont. Target **	Indicator Description
	2007*	2012*			
% Forest Cover	21.1 C	**19.5 C**	11.3 D	30.0 B	Percent forest cover is the percentage of the watershed that is forested or wooded. Forest cover includes upland and wetland forest types.
% Forest Interior	3.2 D	**2.3 F**	1.4 F	10.0 B	Percent forest interior is the percentage of the watershed that is forest interior. Forest interior is the protected core area 100 m inside a woodlot that some bird species require to nest successfully. The outer 100 m is considered 'edge' habitat and is prone to high predation, wind damage and alien species invasion.
% Riparian Zone Forested	No Data	**44.0 B**	31.4 C	50.0 B	Percent riparian zone forested is a measure of the amount of forest cover within a 30 m riparian/buffer zone adjacent to all open watercourses. Riparian habitats support high numbers of wildlife species and provide an array of ecological functions.

* 2007 report card data based on 2000 air photo; 2012 report card data based on 2006 air photo.

** Targets for southern Ontario based on Environment Canada (2004) and Conservation Ontario (2011).

GROUNDWATER

Municipal Water Supply

Since 2010, Komoka and Mount Brydges no longer use groundwater from municipal wells. A pipeline supplies water from Lake Huron through the Lake Huron Primary Water Supply System.

Private Wells

There are 242 private wells on record in the Komoka Creek watershed, the majority drawing groundwater from overburden aquifers rather than bedrock. Properly constructed deep wells have a lower risk of contamination from the surface than shallow wells. The highest risk to any well is from contaminants and activities closest to the well. The safety, testing and treatment of a private well are the responsibility of the well owner.

Groundwater Monitoring

The Provincial Groundwater Monitoring Network has shown groundwater levels generally decline from May to October, and increase from fall to spring with the largest increase in March (up to 1.5 m change). Groundwater levels were lowest in 2007 (drought year), and highest in 2009 and 2011. About 60-70% of local streamflow/baseflow is from groundwater discharging into streams.

Drinking Water Source Protection

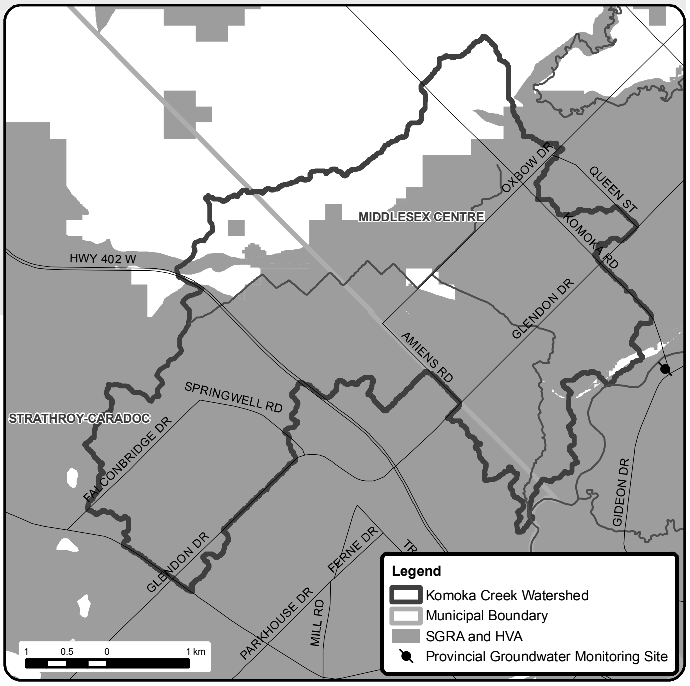
A process is underway to better protect sources of municipal drinking water in the region (www.sourcewaterprotection.on.ca). Much information on groundwater resources has been compiled. A Source Protection Plan will be completed in 2012.

On The Map

Significant Groundwater Recharge Areas (SGRA) - Areas where a relatively large volume of water makes its way from the ground's surface to recharge, or replenish, an aquifer. A recharge area is considered significant when it helps maintain the water level in an aquifer that supplies a community with drinking water.

Highly Vulnerable Aquifers (HVA) - Groundwater movement is typically slow (measured in cm/hr), but in HVA there are relatively faster pathways from the ground's surface down to an aquifer, making the aquifer more vulnerable to contamination.

Protection of these areas is very important for the protection of local groundwater as a source of drinking water.

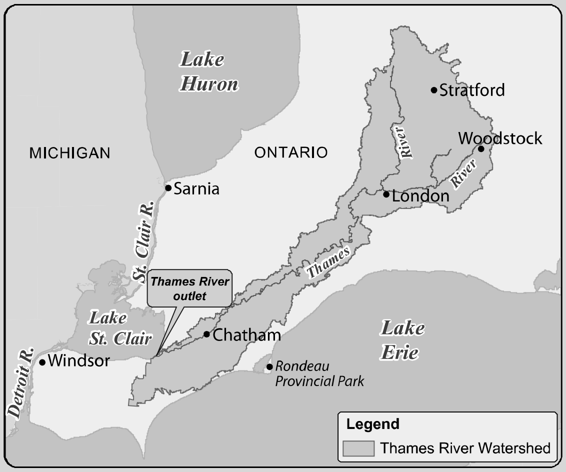


Great Lakes Connection

The Komoka Creek watershed is in the Thames watershed, which is part of the Lake Erie watershed. Water from Komoka Creek enters the Thames River downstream of London, and takes 4-10 days to flow through Chatham and reach Lake St. Clair. About two weeks later, it reaches Lake Erie.

Lake Erie provides drinking water and recreation for millions of people. However, major algae blooms from excess phosphorus are a critical issue for this lake, and the Thames River contributes 30% of the phosphorus that is coming from Ontario. A recent Canada-US Nutrient Management Strategy calls for reducing phosphorus from land use activities in watersheds including the Thames.

Fish Connections: A Rainbow Trout tagged in March 2010 in a London-area Thames tributary was caught 4 months later in Lake Erie near Rondeau Provincial Park. The study findings indicate that the fish migrate annually from deeper, colder sections of Lake Erie, through the Detroit River and Lake St. Clair, to spawn in Upper Thames River tributaries.



LOCAL ACTIONS FOR IMPROVEMENT

Individuals, groups, businesses, municipalities and agencies each have a role in improving the health of the watershed through the following actions. For more information on agencies that can help, contact the UTRCA (see last page).

A number of the local actions listed below are also identified in the following reports:

- Upper Thames River Source Protection Area Amended Proposed Assessment Report (August 2011)
- Comprehensive Review of Settlement Area Designations in the Middlesex Centre Official Plan (Middlesex Centre, 2011)
- Middlesex Natural Heritage Study (UTRCA, 2003)
- Komoka Community Surface Water Plan (Aquafor Beach, 1999)

Surface Water and Groundwater

- Protect and establish buffers (native trees, grasses) along watercourses for shade and to filter pollutants.
- Protect and enhance coldwater streams.
- Use drain maintenance methods that protect aquatic habitat (e.g., spot or bottom cleanouts).
- Ensure protection of water quality in old gravel pit ponds. These deep ponds are a direct connection to groundwater in the area.
- Repair or replace faulty septic systems and ensure proper maintenance of the systems.
- Implement agricultural Best Management Practices in manure storage and spreading, soil conservation, fertilizer and pesticide storage and application, fuel storage, and restricting livestock access to watercourses.
- Complete and follow Environmental Farm Plans and Nutrient Management Plans (www.omafra.gov.on.ca).
- Utilize grants and expertise from the Clean Water Program (www.cleanwaterprogram.ca).
- Specific to Komoka and Mt. Brydges, the following actions should be continued:
  - For new development, implement urban stormwater planning using Low Impact Development, stormwater Best Management Practices, subwatershed studies, catchment area planning, and erosion control.
  - For existing development, implement pollution prevention and control planning for all aspects of stormwater runoff including combined storm-sewer overflows.
  - Continue to upgrade sewer systems where risk of contamination is greatest (e.g., extend sanitary sewers to urban properties on septic systems).
  - Minimize use of fertilizers, adhere to Ontario's Cosmetic Pesticide Ban (effective 2009) and utilize the municipal hazardous waste disposal program.

Good streamside cover along Komoka Creek improves water quality.

Drinking Water

- Decommission abandoned wells according to Ministry of the Environment standards.
- Homeowners with wells should understand the condition of their well and risks to their water supply (www.wellwise.ca).
- Sample private wells each spring and fall (available through the Health Unit).
- Keep contaminants (e.g., fuel, pesticides, manure/waste) away from your well area.
- To protect municipal drinking water sources, implement Source Protection Plan policies.

Forests

- Connect the existing river-side woodlands and meadows with additional plantings to create a continuous wildlife corridor along Komoka Creek and its tributaries.
- Increase natural vegetation cover in urban areas by naturalizing manicured open spaces, residential and industrial areas, and school yards, and through urban planning and design.
- For tree planting and naturalization projects, create a more natural and diverse habitat by using a variety of native plant species that are better adapted to the local climate, pests, etc. Tree planting assistance and grants are available from the UTRCA (see information below).
- Conserve woodlands, wetlands and other natural areas through Official Plan designations, landowner incentives and education, tree cutting bylaw enforcement, etc.
- Connect woodlots by planting shelterbelts, windbreaks and buffers along fields and watercourses, which will also protect against soil erosion and improve water quality. Older, denser windbreaks should be thinned.
- Naturalize retired aggregate pits to create unique habitats and protect water quality.
- Increase forest interior by making woodlots larger and rounder (e.g., plant native trees and shrubs along the edges or allow the edges to naturalize on their own).
- Landowners wishing to selectively log their woodlots should use Good Forestry Practices (i.e., Basal Area Guidelines, not Diameter Limit Harvesting) and hire a Certified Tree Marker to mark the woodlot and oversee harvesting.

HIGHLIGHTS OF PROGRESS SINCE 2006

The Komoka Creek watershed is benefiting from many conservation efforts that continue to be implemented by individuals, groups, businesses, agencies and municipalities on private and public lands. Some examples follow.

- Watershed landowners completed 5 Clean Water Program (CWP) projects including fragile land retirement and livestock access restriction. The CWP was initiated in 2001 as a partnership between local municipalities to fund environmental projects (www.cleanwaterprogram.ca).
- The Thames River Anglers have been actively rehabilitating stream habitat and assisting with environmentally friendly drain maintenance, and they operate a trout hatchery for educational purposes. They have initiated a tagging study to monitor Rainbow Trout returning to Komoka Creek to spawn annually (www. anglers.org). A fish tagged in March 2010 was caught 4 months later in Lake Erie near Erieau, indicating that annual spawning migrations occur from the deeper, colder sections of Lake Erie, through the Detroit River, Lake St. Clair and the lower Thames River to Komoka Creek, a distance of over 300 km.
- Over 6000 trees were planted at four properties under the UTRCA's Private Land Reforestation Program with grants through Trees Ontario and the CWP. Through the UTRCA's Communities for Nature program, 50 trees were planted at Camp Kee Mo Kee with community members.
- Four Ducks Unlimited projects were completed in partnership with landowners looking to restore, conserve, protect and enhance wetland habitat and associated upland habitats on their land. Projects include wildlife ponds, wood duck next boxes, and establishment of upland nesting cover (www.du.ca).

A tagging study has shown that Rainbow Trout travel from Lake Erie to spawn in Komoka Creek.

Ontario-wide Report Cards

Conservation Authorities produce report cards for their watersheds every five years to track changes, using a standardized grading system (conservation-ontario.on.ca). Grades vary across the province, reflecting the range of physical characteristics and human activities. The UTRCA report cards and supporting information are available in a report titled *2012 Upper Thames River Watershed Report Cards* (thamesriver.on.ca).

For more information, contact:
Upper Thames River Conservation Authority
1424 Clarke Road, London, Ontario, Canada N5V 5B9
519-451-2800 infoline@thamesriver.on.ca
www.thamesriver.on.ca

UPPER THAMES RIVER
CONSERVATION AUTHORITY

The Thames,
A Canadian
Heritage River

APPENDIX H

Resumes

CIRRICULUM VITAE

Mr. Blagy (Blagoje) Novakovic, M. Sc. P. Eng.

39 Winship Close,
London, Ontario N6C 5M8

E-mail: novaterra@sympatico.ca

Tel.:(519) 690-1796
Fax: (519) 690-0756

Principal and Senior Hydrogeologist of Novaterra Environmental Ltd.

- Retired on December 31, 2001 from the Ontario Ministry of the Environment after 27 years
- Established consulting firm Novaterra Environmental Ltd. which was incorporated on January 9, 2002.
- Mr. B. Novakovic is the President of Novaterra Environmental Ltd. The firm is carrying out consulting work in the fields of hydrogeology and geological engineering.

EDUCATION

University of Waterloo, Waterloo, Ontario, Canada
Master of Sciences in Hydrogeology, 1973
Department of Earth Sciences

University of Belgrade, Belgrade, Yugoslavia
Bachelor of Science in Geological Engineering, 1963
Faculty of Mining and Geological Engineering

WORK EXPERIENCE

NOVATERRA ENVIRONMENTAL LTD., London, Ontario

Principal and Senior Hydrogeologist, January 2002 - Present

Member of Peer Review Committee, 2006 to 2014

- Upper Thames River Conservative Authority.
- Essex and Region Conservation Authority.
- The Committee provides critical technical review of the different stages of the technical reports prepared according to Provincial “Source Water Protection” program.

Ontario Municipal Board Hearing as an expert witness, 2008

- Relating to the proposed commercial plaza development and the protection of municipal wells in the Police Village of Dorchester, Middlesex County.

Hydrogeological Site Assessment and Technical Report Preparation Relating to Applications for Pits and Quarry License

- Preparation of hydrogeological assessment reports (Hydrogeological Level 1 and Level 2 Study) in support of the application for pits and quarries licence to be approved under Aggregate Resources Act by Ontario Ministry of Natural Resources and Forestry (MNRF).
- Over 25 hydrogeological reports were prepared

Hydrogeological Site Assessment and Technical Report Preparation Relating to Permit to Take Water and Water Resources

- Preparation of Hydrogeological Assessment Report involving aquifer pumping tests in support of for Category 3 application for Permit to Take Water. Permit to be issued by the Ontario Ministry of the Environment and Climate Change (MOECC) under Ontario Water Resources Act (OWRA).
- Over 40 hydrogeological reports were prepared.

Hydrogeological Site Assessment and Technical Report Preparation Relating to Environmental Site Assessment and Remediation

- Hydrogeological Site Assessment and Technical Report preparation relating to Environmental Site Assessment and Remediation under the Ontario Regulation 153/04 Environmental Protection Act (EPA).

- Phase I, Phase II and Phase III were involved, and in several cases actual remediation was implemented.
- 11 reports were prepared.

Provincial and Regional Groundwater Study Reports

- Peer Review of Provincial and Regional Groundwater Study report prepared by various consultants for the Ministry of the Environment. Four geographical area reports were involved and reviewed for the Ontario Ministry of the Environment.

Groundwater Under the Direct Influence of Surface Water (GUDI) reports

- Peer Review of Groundwater Under the Direct Influence of Surface Water (GUDI) reports prepared by various consultants for the Ministry of the Environment. At least 17 hydrogeological reports of this nature were reviewed for the Ontario Ministry of the Environment.

ONTARIO MINISTRY OF THE ENVIRONMENTAL, Southwest Region, London, Ontario

Regional Hydrogeologist, June 1975 – December 2001

Carried out numerous and variety of ***investigations*** relating to groundwater quality and quantity problems caused by human activities. Besides writing numerous Ministry of the Environment (MOE) interim reports relating to the variety of projects described below, Mr. B. Novakovic wrote up to10 technical papers published in referenced journals or conferences proceedings.

Main duties and responsibilities:

- ***Groundwater contamination*** including communal and domestic wells caused by the operation of waste disposal sites, former coal tar sites, deep injection wells of industrial liquid waste, operation of municipal sewage treatment facilities (sewage lagoon system), farming operations, operation of industrial plants, application of road salt, etc.
- ***Groundwater quantity interference*** mainly caused by the operation of communal/municipal wells and well fields, irrigation wells, dewatering relating to the construction of highways, roads, municipal sewage systems, communal water supply systems, dewatering of pit and quarries, etc. Many of these investigations resulted in the production of comprehensive technical reports written and produced in order to defend MOE's position at court proceedings, at the meetings of technical experts regarding a particular subject matter, and to support corrective remedial measures to be undertaken.
- ***Undertaken pioneering work*** in municipal and communal well fields protection in Ontario (Dorchester, Strathroy, Otterville, etc.), and municipal sewage effluent treatment by rapid infiltration into the subsurface (i.e. Markdale, Lucknow, etc.).
- ***Review and assess*** the comprehensive technical reports prepared by the consultants (hydrogeologists, professional engineers, etc.) dealing with suitability assessment, proposed design and the operation of landfill sites, the proposed communal water well systems, municipal sewage effluent disposal by way of spray irrigation, rapid infiltration into the subsurface, operation and dewatering of pits and quarries, proposed deep injection wells, etc. Many of these reports included mathematical model simulation of contaminants transport, groundwater flow, pumping tests analyses. These facilities proposed to be established under the OWRA, EPA, Environmental Assessment Act (EAA).
- ***Critical review*** of the comprehensive technical reports of the former coal and oil tar sites, to ensure that the proposed remediation measures were adequate and furthermore that the cleanup measures were implemented according to the prescribed Ontario regulations and standards.
- ***Review and comments*** on the proposed municipal official plans, amendments to such plans-aspects of such documents relating to groundwater and soils.
- ***Testified*** as an expert witness for the MOE in Court Proceedings, Public Hearings held under the OWRA, EPA, Consolidated Hearing Act, Environmental Review Tribunal, etc.
- ***Interpretation and implementation*** of the relevant Ontario Regulations made under OWRA, EPA and provide advice with such interpretation to municipalities, consulting communities, general public. Worked closely on such matters with legal profession representing the Crown.

NEW BRUNSWICK DEPARTMENT OF THE ENVIRONMENT, Fredericton, New Brunswick

Resource Manager, 1973 – 1975

Main duties included:

- Carrying out groundwater contamination investigations relating to leaks from gasoline service stations, accidental spills from transport trucks, utilities vehicles, from unloading petroleum hydrocarbons from ships, etc.

- Supervised pumping tests to assess hydraulic capacities of communal water supply wells and groundwater availability, potential and extent of salt water intrusion into fresh water aquifer.
- Overseeing the establishment of the Provincial groundwater monitoring network.
- Provide advice and assisted municipalities and general public with the establishment and improvement of adequate and better quality groundwater supplies.

CANADA DEPARMENT OF THE ENVIRONMENT, Ottawa-Hull, Ontario and Quebec

Project Hydrogeologist, 1973

Worked on Joint project sponsored by the Canada Department of the Environment and the Ontario Ministry of the Environment. Work involved an assessment of deep well injection of industrial liquid waste and cavern washing brines into the subsurface formation in Lambton County, Ontario. Available data were analyzed with an aim of assessing the direction of groundwater flow and subsequently the direction and the extent of injected fluid movement in the deep subsurface formations. Reservoir capacity and the potential for trans-boundary contaminants movement were assessed. This work resulted in the publication of Technical Bulletin published by Environment Canada, of which B. Novakovic is coauthor.

DEPARTMENT OF EARTH SCIENCES, University of Waterloo, Waterloo, Ontario

Research Assistant and Graduate Student, 1970 – 1972

- Obtained M. Sc. Degree in Hydrogeology. Thesis title: The Scale of Groundwater Flow Systems in Big Creek and Big Otter Creeks Drainage Basins, Ontario.
- During the summer of 1971 worked for the Ontario Water Resources Commission
- This work resulted in the publication of: Groundwater Probability Map for Elgin County, Ontario.

FALCONBRIDGE NICKEL MINES COMPANY, Toronto, Ontario

Geological Engineer, 1968 – 1970

Carried out mineral exploration including geophysical surveys at various mining properties located at Temagami Lake, Ontario, southwestern Quebec, northern Manitoba, and at La Luz Mines, Nicaragua, a subsidiary of Falconbridge Nickel Mines.

GEOLOGICAL INSTITUTE, Sarajevo, Yugoslavia

Research Assistant, 1964 – 1968

Carried out Regional water resources studies and then hydorgeological mapping of various areas of that Province with the aim of complete assessment of groundwater resources, availability and producing hydrogeological maps at the scale of 1:25,000. Such maps included a complete assessment of water resources, regime and balance of groundwater, quality and vulnerability of groundwater to contamination for the area covered by these maps. Works also included performing long term pumping tests to define the hydraulic capacity of the identified aquifer systems in the consolidated-hard rocks and unconsolidated deposits. Groundwater outcrops such as huge karst springs were also mapped and the flow monitored by the construction of weirs, staff gauges and associated water quality monitoring were also carried out. These works resulted in publishing a comprehensive reports and associated maps depicting the finding results of such studies. Carried out geotechnical studies, including test drilling and mapping for the locations of small irrigation dams.

ASSOCIATIONS MEMBERSHIP

- Association of Professional Engineers of Ontario,
- National Water Well Association (Groundwater Scientists and Engineers Division).

PUBLICATIONS

Novakovic, B., Farvolden R.N., 1974.
Investigations of groundwater flow systems in Big Creek and Big Otter Creek Drainage Basins, Ontario. Canadian Earth Sci. Journal, Vol II, PP. 964-975.

Vandenberg A., Lawson, D. W. Charron, J.E. and Novakovic, B. 1977.
Subsurface Waste Disposal in Lambton County, Ontario – Piezometric Head in the Disposal Formation and Groundwater Chemistry of the Shallow Aquifer. Inland Waters Directorate, Water Resources Branch, Fisheries and Environment Canada, Technical Bulletin No. 90. Ottawa.

Novakovic, B., Longworth J. 1984.
Well Field Protection and Management through a Municipal Official Plan. NWWA Conference on Groundwater Management, October 29-31, 1984 Orlando, Florida. National Water Well Association.

Novakovic B., Jagger, D. 1992.
Application of hydraulic confinement concept of landfill design and operation. 1992 Conference of the Canadian National Chapter, International Association of Hydrogeologists. Modern Trend in Hydrogeology. Hamilton, Ontario May 11-13, 1992. WCGR and Env. Canada

RESUME

SASHA NOVAKOVIC, BASc, EIT

39 Winship Close
London, ON N6C 5M8

Email: sasha@novaterra-env.ca

Mobile. 519-709-5653
Office. 519-690-1796

Intermediate Hydrogeologist – Novaterra Environmental Ltd.

- Initially involved with Phase I, II, and III ESAs, currently focusing on hydrogeological assessments of aggregate extraction pits and assessments supporting PTTW applications
- Involved in over 40 projects relating to Permit to Take Water applications for groundwater takings

EDUCATION

University of Waterloo, Waterloo, Ontario Canada
Bachelor of Applied Sciences, 2013
Geological Engineering – Specialization in Water Resources

EMPLOYMENT HISTORY

Novaterra Environmental Ltd., Intermediate Hydrogeologist, *London, ON* **2001 - Present**

- Conducting elevation surveys, water level monitoring, soil and groundwater sampling, field reconnaissance and instrument installation.
- Performing pumping tests, analyzing results with AQTESOLV software, writing well assessment reports, and submitting Permit to Take Water applications to regulatory agencies
- Creating groundwater contour maps and hydrographs, and analyzing data to assess hydrogeological and hydrological conditions at proposed gravel pits.
- Writing Environment Site Assessment report and Hydrogeological Site Assessment reports
- Drafting responses to comments by regulatory agencies regarding submitted reports

Golder Associates Ltd., Geological Engineering, *Mississauga, ON* **Sept. - Dec. 2011**

- Performed field compaction tests during construction of a tailings dam in Northern Manitoba for a 3-week period
- Analyzed current and historical geologic data to generate geological cross-sections and contour maps
- Conducted laboratory experiment to test settling, moisture and beach slope of mine tailings
- Performed slope stability analysis using GeoSlope software
- Limited water budget analysis, and field investigation of water reservoir in Niagara Falls used for power generation.

Matrix Solutions Inc., Environmental Engineering Intern, *Calgary, AB* **Jan. - Apr. 2011**

- Authored Phase II ESA reports and proposals for both the Alberta and B.C. regulatory jurisdictions relating to upstream oil and gas well sites, facilities and spills
- Ensured site compliance with Alberta and B.C. soil and groundwater guidelines and standards
- Created contour maps and site diagrams, while ensuring quality control of figures and data tables included in reports

MEMBERSHIPS AND CERTIFICATIONS

- Engineer-in-Training with the Association of Professional Engineers of Ontario
- Member of the International Association of Hydrogeologists
- Certified with Class 5 Ontario Well Technicians License