REPORT

North Dundas Drinking Water Supply System Capacity Expansion Aquifer Testing Program

Township of North Dundas Municipal Class Environmental Assessment for the North Dundas Drinking Water Supply System Capacity Expansion

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1.0 PROJECT DESCRIPTION

Golder Associates Ltd. (Golder) was retained by J.L. Richards & Associates Limited (JLR) on behalf of the Township of North Dundas (Township) to provide consulting engineering services for the Municipal Environmental Assessment (Class EA) of the North Dundas Drinking Water Supply System Capacity Expansion. The Class EA is being undertaken to provide a solution to address water supply capacity for both residential and industrial use for the future 20-year projection period and provide water supply system reliability over the 20-year future projection period for the Village of Winchester (Winchester) and the Village of Chesterville (Chesterville) in the Township of North Dundas.

As part of the study, Golder carried out a hydrogeological investigation to assess the capacity of the overburden aquifer at a property identified as a potential site (the site) for a proposed new communal water supply well. A test well was drilled and hydraulically tested to determine if the aquifer yield available at the proposed location would be sufficient to be included as a part of the solution to address the required water supply capacity shortage identified during the Class EA process. This investigation was carried out between October and November 2021 as a component of the ongoing Class EA.

This technical report was prepared to present the results of the aquifer testing program. A geotechnical investigation was also carried out as part of the assessment and the results are presented in Appendix A.

2.0 SITE DESCRIPTION

The site is located on Lot 14, Concession 9 in the Geographic Township of Winchester, Township of North Dundas, approximately 7 kilometres northeast of Winchester and consists of a partially developed licensed aggregate pit. A small water table pond is located within the site. Agriculture operations are found to the immediate north, west, south and east of the site. A private residence is located north of the site, about 250 metres from the test well location on Lafleur Road. A site plan is shown on Figure 1.

3.0 HYDROGEOLOGIC SETTING

3.1 Surficial Geology

The area between Winchester and north of the site is located within the physiographic region of the Winchester Clay Plain (Chapman and Putnam 1984) which is characterized by flat to gently sloping topography and imperfect to poorly drained soils. The surficial geology of the area consists of recently deposited materials of glacial, glaciofluvial and marine origins (refer to Figure 2). Spatially the most dominant units consist of glacial till and marine clays, with a thickness ranging between a few metres to 20 metres. The glacial till in the area tends to be stony and sandy and is generally characterized as silty sands.

The Morewood Esker is an extensive north-south linear feature that is some 7.5 kilometers long by approximately 250 metres wide at the surface (average subsurface width is ~800 metres) and the southern end of the esker feature is mappable from about 1.2 kilometres south of the site (Figure 2). The esker material consists of a highly conductive, 100 to 200 metre wide, esker core of well sorted sand and gravel, cobbles and gravel and sandy gravel. The core is flanked by finer soils, grading from sands to silts and clays. The esker is entrenched into the glacial till and its base is generally at or near the underlying bedrock surface; it is frequently overlain by marine clays at the margins. The signature of the esker core is delineated in places by a small topographic ridge reworked by nearshore processes (former beach). Elsewhere the presence of the esker core is only inferred and may be discontinuous in places.

3.2 Bedrock Geology

The vicinity of the site is underlain by sedimentary bedrock of the Middle to Lower Ordovician Period that dips eastwards along a major synclinal structure (Wilson (1968) in Charon 1978). The sequence of sedimentary rocks underlying the majority of the study area (from youngest/shallowest to oldest/deepest) have been interpreted to consist of the Bobcaygeon Formation (limestone), Gull River Formation (interbedded silty dolostone and limestone), Rockcliffe Formation (interbedded sandstone, shaley limestone and shale) and Oxford Formation (dolostone; Williams 1991). Bedrock in the general site vicinity is encountered at depths ranging from 0 to 20 metres below ground surface. Bedrock outcrops are limited although several occur along escarpments north of Winchester and Morewood.

3.3 Bedrock Aquifers

Groundwater flow in the bedrock aquifers is controlled by and occurs along and through fractures and bedding plane features (secondary porosity). It has been hypothesized that the contact zone between the upper weathered bedrock surface and the overburden materials (basal till) have an enhanced permeability and thus have a higher hydraulic conductivity than the lower, more massive bedrock.

The Gull River Formation, the predominant bedrock in the area studied, is regionally known to have low transmissivities and potable quality at a regional scale. Yields are usually adequate for private individual well supplies but are not adequate for municipal communal water supply.

The lower formations in the stratigraphic sequence (i.e., Oxford Formation and the underlying Nepean Formation) are regionally known to produce higher well yields. The bedrock municipal wells of Winchester (No. 1, 5 and 6) are completed in these deeper bedrock aquifers. The bedrock aquifers are largely overlain by several metres of low permeability clays and silts that act as an aquitard by storing water and transmitting it slowly to the aquifer. Therefore, the bedrock aquifers in the area studied are considered mostly to be confined/semi-confined.

A review of the water level information within the Ministry of Environment, Conservation and Parks (MECP) Water Well Information System (WWIS) indicates that, on a regional scale, flow in the bedrock is from southwest to northeast. On a more local scale, groundwater flow in the bedrock is generally towards the rivers that exist within the area (East Castor River and South Nation River). Recharge to the bedrock aquifers likely occurs where the bedrock outcrops, where the overburden is thin, or in areas where relatively permeable sediments are in contact with the bedrock. The main recharge areas are expected to be in areas of topographic highs. Some recharge occurs from storage in the overlying aquitard. Recharge through the aquitard may occur in areas of local topographic lows where depression-focused recharge may occur.

3.4 Overburden Aquifers

As discussed in Section 3.1, the overburden in the area studied is mainly comprised of marine clay and glacial till. The hydraulic conductivity of the clay is very low, and water is transmitted very slowly through the matrix of the clay. The clay is considered an aquitard and not suitable for the development of a high yield water supply.
Even though the glacial till has a higher hydraulic conductivity than the marine clays, it is perhaps only capable of providing adequate well yields for a higher yield water supply in very localized areas. These high producing areas, if present, would have to be identified by chance. The lower portion of the till (basal till) is known to contain coarse-grained sediments, which can have relatively high hydraulic conductivities and at selected locations high producing areas for communal water supply systems in the basal till/upper bedrock contact zone have been identified. These high producing areas would again have to be identified by chance. This unit could be targeted by wells that also penetrate other formations (i.e., glaciofluvial or bedrock) to potentially increase well yields.

The coarse grained glaciofluvial deposits within the Morewood Esker (~7 kilometres northeast of Winchester), and the Maple Ridge Esker (~4.5 kilometres east of Winchester), and potentially the Loughlin Ridge (~11 kilometres west of Winchester) form excellent local aquifers. Wells constructed within these deposits typically have high yields of potable water. The Morewood Esker, the Maple Ridge Esker and the Loughlin Ridge are principally unconfined, but confined conditions persist where the marine clays overly the coarse-grained materials on the margins of the deposits, or where the deposits are entirely buried (if present). The aquifers are recharged by infiltrating precipitation (diffuse) and by the surface ponds created by gravel extraction operations (local) below the water table. The majority of recharge will occur where the coarse granular central core and sandy flanks of the eskers are exposed at the surface. The permeable material that comprises the core of the eskers is underlain by less permeable till and/or bedrock. Previous hydrogeological evaluations completed for the wellfield in the Morewood Esker (Golder, 2003a; Golder and Sauriol, 2005) and the Maple Ridge Esker (Golder, 2003b), indicate that it is likely that the two eskers have some component of inflow from an adjacent source such as underlying bedrock zones, although this has not been conclusively determined.

4.0 SITE SPECIFIC HYDROGEOLOGICAL CONDITIONS

The hydrogeology of the site was investigated through the drilling and installation of a total of seven boreholes instrumented with monitoring wells completed by Golder in 1992 and 2021. During the investigations, boreholes were put down at the approximate locations shown on Figure 1 as described below. Borehole logs and grain size distribution curves from the previous and current investigations are included in Appendices B and C, respectively.

- Six boreholes (numbered OW-1 through OW-6) were advanced between March 1 and 20, 1992 as part of the 1992 Groundwater Supply Investigation on the St. Pierre Property (Golder 1992). Boreholes OW-1 through OW-4 were located within the central core of the esker, while OW-5 and OW-6 were located within the flanks of the esker.
- One borehole (number BH21-01) was advanced on October 4, 2021 as part of the current geotechnical investigation (Golder 2021).

Based on the available information, the subsurface conditions at the site consist of coarse granular deposits underlain by glacial till, which in turn is underlain by bedrock. Deposits of sand and gravel to fine to coarse gravel were encountered in OW-1, OW-2, OW-4 and BH21-01 to a depth of up to 11 metres. Away from the central core of the aquifer, the deposit grades into fine to medium sand and silty sand between approximately 11 metres (OW-5) and 15 metres (OW-6) depth. Glacial till comprised of grey sandy silt with gravel and trace clay was proven at boreholes OW-1 through OW-6, where its thickness ranged between 0.9 metres to 3.8 metres. Auger refusal was encountered between 12.7 and 13.7 metres depth. As shown in Figure 3, the site is interpreted to be underlain by bedrock comprised of the Gull River Formation (interbedded silty dolostone and limestone).

Monitoring wells were sealed into boreholes OW-1 through OW-6 and BH21-01 to allow for hydraulic response testing and measurement of groundwater levels as part of the 1992 or 2021 aquifer testing programs. The resulting groundwater levels and aquifer parameters are summarized in Table 1.

Table 1: Groundwater Levels and Aquifer Parameters

Location	Geological Unit	Ground Surface Elevation (masl)	Measurement Date	Water Level Depth (mbgs)	Water Level Elevation (masl)	Aquifer Parameter(s)
OW-1[1]	Gravel	76.98	1-Apr-92	1.37	75.61	T = 1,000 m^2/day S = 0.1
OW-2[1]	Sandy Gravel	76.48	1-Apr-92	0.88	75.60	
OW-3[1]	Sand	77.04	1-Apr-92	1.43	75.61	-
OW-4[1]	Gravel	76.36	1-Apr-92	0.76	75.60	-
OW-5[1]	Sand	78.31	1-Apr-92	2.72	75.59	-
OW-6[1]	Sand to Silty Sand	80.72	1-Apr-92	5.29	75.43	-
BH21-01[2]	Gravel and Sand to Sandy Gravel	76.04	12-Nov-21	0.86	75.18	K = 8 x 10^{-4} m/s

Notes:

masl - metres above sea level, mbgs - metres below ground surface, K - hydraulic conductivity, T - transmissivity; S - storativity

[1] OW-1 through OW-6 data from aquifer testing program (Golder 1992).

[2] BH21-01 data from current investigation.

It is noted that groundwater levels are expected to fluctuate seasonally. Higher groundwater levels are expected during wet periods of the year such as spring. As shown in Table 1, the groundwater table is relatively flat and subject to topographic influences; groundwater flow direction is interpreted to be towards the southwest (Golder 1992).

5.0 METHODOLOGY

5.1 Construction of Monitoring Well BH21-01

Borehole 21-01 was drilled on October 4, 2021 at the approximate location shown on Figure 1. The borehole was advanced using a track-mounted hollow stem auger rig supplied and operated by CCC Geotechnical and Environmental Drilling of Ottawa, Ontario. The borehole was advanced to a depth of about 9.8 metres below the existing ground surface (bgs).

Borehole 20-01 was instrumented with a 32 millimetre (mm) diameter monitoring well screened within gravel and sand to sandy gravel materials from about 7.6 to 9.1 metres bgs to allow for hydraulic conductivity testing and subsequent measurement of the groundwater level. Golder personnel developed the monitoring well following completion of the installation by purging 120 Litres (17 well volumes) using conventional purging methods.

5.2 Construction of Test Well TW21-01

Test well TW21-01 was constructed by J.R. Drilling using mud rotary drilling techniques from October 25 to 29, 2021. The 300 mm diameter borehole was drilled to a total depth of 9.14 metres bgs. The 150 mm diameter well test well was built inside of the borehole. The test well was equipped with a steel well casing through the upper sandy gravel and gravel to a depth of approximately 7.32 metres bgs. Below this depth the test well was equipped with a 140 mm diameter stainless steel well screen (40 slot size) to a depth of approximately 8.84 metres bgs. The borehole annulus was backfilled with filter pack (No. 3 silica sand) from 6.07 metres bgs to 8.84 metres bgs. The annulus was sealed from 6.07 metres bgs to ground surface with bentonite. The borehole log and water well record for TW21-01 are found in Appendix B. TW21-01 was developed by using the water well rig to blow air through the screen until the discharge was clear with trace sediments (approximately 30 minutes).

5.3 Hydraulic Conductivity Testing Program

In situ hydraulic testing (rising and falling slug tests) was carried out in the monitoring well installed in borehole 20-01 to estimate the hydraulic conductivity of the screened gravel to silty sand and gravel materials. The hydraulic conductivity was calculated using the Springer-Gelhar (1991) method. The test results indicate an estimated hydraulic conductivity value of 8 x 10^{-4} metres per second (m/s). The detailed results of the testing are provided in Appendix A and summarized in Table 1.

5.4 Aquifer Testing Program

Prior to commencement of the constant rate pumping test, a preliminary step test was carried out at TW21-01. On November 2, 2021, TW21-01 was pumped for a series of short steps at increasing pumping rates (227, 322 and 334 Litres per minute; L/min). However, the well could not be pumped at the expected testing rate due to inefficiency of the well.

Test well TW21-01 underwent additional development on November 8, 2021 using an air compressor and a perforated airline to increase the well yield. The airline was lowered to the bottom of the well, and compressed air was introduced into the well for 30 minutes. The airline was then raised by 0.3 metres and the compressed air continued for another 30 minutes after which the process was repeated until all of the 1.52 metre screen was developed (at 0.3 metre intervals). A second step test was completed on November 8, 2021 after the additional development. The second step test determined that the additional development of the well had increased its efficiency and that the test well could sustain a higher constant pumping rate for the longer duration test.

The maximum pumping rate for the constant rate test was limited to 400 L/min by the Permit to Take Water that was previously obtained for the site. Groundwater was pumped from TW21-01 using a 342 L/min (90 US gallon per minute) 5 horsepower submersible pump supplied by J.R. Drilling. The pump was able to operate above its rated capacity due to the limited head above the pump at TW21-01.

A 24-hour pumping test was completed on TW21-01 with a subsequent recovery period of approximately 24 hours. The well was pumped at a constant rate of approximately 400 L/min for the duration of the test. The constant pumping rate was maintained with a flow control valve and monitored using a flow meter. The discharge from the pumping test was directed through a flexible 75 mm diameter hose to a low-lying area located approximately 90 metres west of the pumping well (refer to Figure 1).

During the pumping test, water levels were monitored in the pumping well (TW21-01) and in the available on-site wells (St. Pierre well and BH21-01) to observe aquifer response to the pumping test. The St. Pierre Well is an existing 200 mm diameter well that was installed in 1988. The well apparently consists of an open-ended pipe (without a well screen or slots in the pipe) completed to a depth of about 9 metres bgs. The St. Pierre well was previously hydraulically tested by Golder in 1992. A staff gauge (SG-1) was installed in the nearby water table pond that is located south of the pumping well. The pond was created after materials were excavated below the water table. For approximately 7 days prior to the start of the pumping test, water levels were collected using pressure transducers installed in BH21-01 and the pond (SG-1) to establish background static water levels. The locations of the existing on-site wells, staff gauge and boreholes installed as part of the previous investigation are shown on Figure 1. Details for the pumping well and water level monitoring network are summarized in Table 2.

Table 2: Summary of Test Well and Observation Wells

Location	Ground Surface (masl)	Radial Distance from Pumping Well (m)	Top of Interval (mbgs)	Bottom of Interval (mbgs)	Screened Unit
TW21-01	76.34	-	7.32	8.84	Gravel
St. Pierre Well	[1]	14.0[2]	[3]	9.00	Sandy Gravel
BH21-01	76.04	16.1	7.62	9.15	Gravel and Sand to Sandy Gravel
SG-1	74.90[4]	54.0	-	-	-

Notes:

[1] St. Pierre well is located inside a pump house. Geodetic elevation data unavailable.

[2] Approximate radial distance interpreted from Google Earth coordinates.

[3] St. Pierre Well reportedly installed as an open-ended pipe (no slots) in sand and gravel.

[4] Bottom of the pond at the location of the staked staff gauge.

Water levels were monitored in the test well, observation wells and at the nearby water table pond during the pumping period and recovery period after the pump was shut off. Water levels were measured at TW21-01, BH21-01, St. Pierre Well and SG-1 continuously using pressure transducers at pre-set intervals (30 seconds in the pumping well and 5 minutes at the observation monitors) during the pumping test as well as the recovery period. Manual water level measurements were also taken frequently in each of the wells and the staff gauge during the pumping and recovery periods.

Groundwater samples were collected from the pumping well after 1 and 24 hours of pumping to assess any changes to groundwater quality as a result of pumping. Groundwater samples were analyzed for a select set of parameters. The analysis of the water samples was completed by Eurofins Environment Test Canada located in Ottawa, Ontario.

6.0 RESULTS

6.1 Aquifer Testing Program

A 24-hour pumping test was conducted at TW21-01 at a rate of approximately 400 L/min (6.8 L/s) on November 10 and November 11, 2021. Water levels during the pumping and recovery periods were monitored at the test well (TW21-01), St. Pierre Well, BH21-01 and SG-1. Figure 4 presents the drawdown measured in the test well, observation wells and the staff gauge installed in the on-Site pond during the 24-hour constant rate pumping test. Figure 5 presents the drawdown measured in the observation wells and pond. The response to the pumping measured at TW21-01 indicates that the well is located in an unconfined aquifer based on the characteristic "S" shaped curve. The early and late time drawdown data follows the Theis (1935) response, where water is being released from storage due to compression of the formation and expansion of the water (early time), followed by delayed gravity drainage and a return Theis curve response following the cessation of the contribution of water from delayed drainage.

A maximum of 3.29 metres of drawdown was measured in the test well at the end of the pumping period. The water level recovered rapidly after the pump was shut down, with 99% of the drawdown recovered within 1 minute. Table 3 below summarizes the maximum drawdown observed in the test well and in the monitoring network during the 24-hour pumping period.

Table 3 Summary of Water Levels and Drawdown During TW21-01 Pumping Test

Location	Ground Surface (masl)	Screen Interval (mbgs)	Radial Distance From Pumping Well (m)	Water Level Prior to Start of Test (mbgs)	Water Level Elevation (masl)	Maximum Observed Drawdown (m)	Time of Maximum Drawdown (min)
TW21-01	76.34	7.32– 8.84	-	1.19	75.15	3.29	1,441
St. Pierre Well	[1]	[3]	14.0[2]	1.61	-	0.05	1,080
BH21-01	76.04	7.62 – 9.15	16.1	0.88	75.16	0.04	1,178
SG-1	74.90[4]	-	54.0	-	75.18	0.03	1,205

Notes:

masl - metres above sea level, mbgs - metres below ground surface m - metres; min - minutes since start of pumping

[1] St. Pierre well located inside pump house, Geodetic elevation data unavailable.

[2] St. Pierre Well reportedly installed as an open-ended pipe (no slots) in sand and gravel.

[3] Approximate radial distance interpreted from Google Earth coordinates.

[4] Bottom of the pond at the location of the staked staff gauge.

As shown in Table *3* and Figure 5, the maximum drawdown observed in the observation wells and staff gauge occurred between 1,080 and 1,205 minutes after the start of pumping. The recovery period observed at these locations towards the end of the pumping test may possibly be related to potential recharge from the discharge as no precipitation event occurred during the pumping period.

For approximately 7 days prior to the start of the pumping test, water levels were collected using pressure transducers installed in BH21-01 and the pond (SG-1) to establish background static water levels. Figure 6 shows the water level elevations at BH21-01 and SG-1 between October 28 and November 12, 2021, which includes periods of little to no pumping between October 28 and November 2, 2021 and the 24-hour pumping and recovery period between November 10 and 12, 2021. A slight increasing trend was observed at BH21-01 and SG-1 during periods of no pumping (baseline). It is noted that water levels at BH21-01 and SG-1 are subject to small variations throughout the day that may be related to barometric changes and the possible influence from the intermittent pumping of Winchester Well #7 (refer to Figures 5 and 6). Based on the available baseline water level data, the water level trends observed at BH21-01, the St. Pierre Well and SG-1 during the pumping test are interpreted to be the response of the aquifer to the pumping.

6.1.1 Aquifer Parameters

The drawdown data was analyzed using the Cooper-Jacob (1946) method. Table 4 provides estimates of transmissivity and storativity obtained from the TW21-01 pumping test. The pumping test analysis plots are provided in Appendix D.

Table 4: TW21-01 - Estimates of Transmissivity and Storativity of the Morewood Esker

Well ID	Solution Method	Transmissivity (m²/day)	Storativity
BH21-01	Cooper Jacob (1946) – 80-216 min	6,042	0.59
	Cooper Jacob (1946) – 288-1,178 min	4,402	0.60

The transmissivity of the aquifer was estimated to range from 4,402 m²/day to 6,042 m²/day and the storativity was estimated to range from 0.59 to 0.60.

A 12-hour pumping test at St. Pierre Well was previously completed at the Site by Golder in 1992 (Golder 1992) at a pumping rate of 1,514 L/min (25.2 L/s), which estimated a transmissivity of 5,405 and 11,850 m²/day and a storativity between 0.01 and 0.27. The aquifer parameters estimated from the pumping test completed at TW21-01 are comparable to the previously estimated values.

Golder also performed a 30-day pumping test at Winchester Well No. 7a in 1995 (Golder 1995) at a pumping rate of 1,476 L/min (24.6 L/s), which estimated the transmissivity of the Morewood Esker to be 1,100 m^2/day and a storativity between 0.02 to 0.32. The hydraulic conductivity of the formation was calculated to be 8×10^{-3} m/s.

The transmissivity values (4,750 to 11,850 m^2/day) estimated from the two aquifer testing programs completed at the on-site overburden aquifer in 1992 and 2021 by Golder are not considered completely representative, since the relatively short pumping test does not reflect any boundary conditions. Due to the geometry of the esker deposit, the boundary conditions would likely be observed during a longer duration pumping period.

6.1.2 Well Efficiency

Throughout the pumping test, the observed drawdown at TW21-01 was higher than would be expected given the drawdown observed in the nearby monitoring wells and based on the results of previous hydraulic testing of the St. Pierre Well in 1992. The efficiency of TW21-01 was estimated from the Cooper-Jacob (1946) distance-drawdown plot presented in Figure 7. The theoretical drawdown produced by the pumped well was extrapolated from the plot of the drawdown produced at monitoring wells BH21-01 and St. Pierre Well and evaluated at the radius corresponding to the outside surface of the gravel pack (radius = 0.305 metres). The drawdown at TW21-01, St. Pierre Well and BH21-01 were corrected using the Jacob correction for an unconfined condition (Jacob 1944), since the drawdown produced within the vicinity of TW21-01 was significant (3.29 metres) compared to the saturated thickness of the aquifer (9 metres).

The well efficiency value obtained using this method was 18%. The low efficiency is potentially attributed to issues that include the limited development of the filter pack (to remove the drilling mud), and small size of the screen slot and sand pack relative to the natural aquifer used for the construction of the test well. Selection of the screen and sand pack were affected by the availability of the well construction supplies at the time of drilling. Results show that with 100% efficiency, drawdown in TW21-01 would be approximately 0.49 metres and smaller than the corrected drawdown (2.68 metres). Improved efficiency of TW21-01 could result in both a lower magnitude of drawdown and a reduction in the rate of drawdown.

6.2 Aquifer Yield

One of the primary objectives of this investigation was to assess the water supply potential of the overburden aquifer in the vicinity of the St. Pierre property. This assessment was carried out utilizing the results obtained from the 24-hour pumping test and based on the productivity of other high capacity wells (Winchester and Chesterville) also completed in similar deposits.

The period of the pumping test was not long enough to warrant firm long-term predictions on the safe aquifer yield and the efficiency of the well and limitations of the PTTW prevented using a higher pumping rate. However, it is possible to calculate the theoretical pumping rate (Driscoll, 1986) for a given drawdown in the pumping well based on the aquifer parameters estimated from the testing in the current investigation and other nearby wells constructed in the same esker. For example, assuming a 305 mm diameter pumping well, and a transmissivity of 1,000 m^2/d and a storativity of 0.3 and a theoretical drawdown of 4 metres, one could estimate a potential flow rate of 30 L/s. This is assuming a well with an efficiency of 100% and, as such, a properly designed and constructed production well is required. It is emphasized that a long-term pumping test (72 hours or more) would provide a better indication of the safe yield of the aquifer.

Elsewhere, the potential of the overburden aquifer to supply large volumes of groundwater is demonstrated by the existing high-capacity wells that serve Winchester and Chesterville. The well field at Winchester Well #7 accesses a groundwater supply located in the Morewood Esker approximately 950 metres to the northeast of the test well site. There are three wells located at the site (7a, 7b and 7c). Golder performed a 30-day pumping test at Winchester Well No. 7a in 1995 (Golder, 1995) at a pumping rate of 2,127 m³/day (24.6 L/s), which estimated the transmissivity of the overburden aquifer to be 1,100 m²/day with a storage coefficient between 0.02 to 0.32. Drawdowns in excess of one metre were limited to a zone of about 130 metres from the test well. The point of zero drawdown was estimated to be located 3,500 metres from the test well. The study concluded that the safe yield of the aquifer would range from 2,252 to 2,380 m³/day (26.1 to 27.5 L/s).

After Winchester Wells No. 7b and Well 7c were added, the well field was operated at a daily taking of approximately 1,944 m³/day (22.5 L/s). In 2003, a hydrogeological study concluded that the capacity of Winchester Well Field No. 7 could be increased to 2,169 m³/day (25.1 L/s) without adversely affecting the Morewood Esker over a twenty-year period (Golder 2003a).

Chesterville Wells No. 5 and 6 also derive water supply from a glaciofluvial outwash complex about 5.5 kilometres south of the test well site. It has not been proven whether this deposit is or is not a southern extension of the Morewood Esker; however, the test drilling program conducted by Golder Associates in 1990 between the St. Pierre pit and Boyne Road (north of Maple Ridge) only rarely encountered coarse granular deposits within/beneath fine sand, silty clay and till materials.

A 72-hour pumping test was performed on Chesterville Well No. 5 in 1989; the transmissivity of the overburden aquifer in the area of the well was estimated to be between 1,000 and 2,000 m²/day. The storativity of the aquifer sediments was estimated to be 0.005. it was concluded that the well could produce up to 22.7 L/s, and that the water quality was good.

In 2003, Golder conducted a 72-hour pumping test at a pumping rate of 30.3 L/s at Chesterville Well No. 6 (Golder, 2003b). The transmissivity of the overburden aquifer was estimated to be 1,300 m²/day and the specific yield was 0.045. The final measured drawdown at the pumping well was 2.13 metres and the calculated well efficiency was 97%. During the testing, only minor interference from pumping at Chesterville Well No. 5 was observed in Chesterville Well No. 6. The long-term capacity of Chesterville Well No. 6 was conservatively evaluated at 2,290 m³/day (26.5 L/s).

In 2005, a 30-day pumping test was completed at Chesterville Wells No. 5 and 6 to gain a better understanding of the long-term yield of the aquifer (Golder, 2005). During the test, Chesterville Wells No. 5 and 6 were simultaneously pumped at rates of 17 to 20 L/s and 29.3 L/s, respectively, for the initial 25 days, and then at rates of 16.5 and 22.7 L/s, respectively, until the end of the test. Based on the results of the test, it was concluded that the yield of Chesterville Well No. 6 was at least 2,592 m³/day (30 L/s), and the long-term aquifer yield is at least 3,456 m³/day (40 L/s). Also, a yield of 4,320 m³/day (50 L/s) may be sustainable for several weeks.

The pumping test completed at the St. Pierre Well in 1992 determined that the water table aquifer is easily capable of delivering in excess of 30.7 L/s over short periods with minimal drawdown. These historical results combined with the results of the current investigation and testing program indicate that a properly designed and constructed production well located within the Morewood Esker core at the site should be constructed and is expected to likely be capable of supplying 20 to 30 L/s. This test well would be intended to subsequently become the municipal supply well. A long-term pumping test (72 hour minimum, preferably longer) should then be undertaken to estimate the sustained yield of the aquifer. This testing will also provide more representative values for aquifer transmissivity and storativity.

6.3 Water Quality Sampling

Groundwater samples were regularly tested in the field for conductivity, pH, temperature and hydrogen sulphide. Water quality samples were collected after 1 hour of pumping on November 10, 2021 and towards the end of the pumping test on November 11, 2021 (24 hours) and submitted to a laboratory for analysis of a suite of groundwater parameters commonly used to evaluate drinking water quality, as summarized in Table 5.

Table 5: Summary of Water Quality Testing

Date and Time	Minutes (hours) since Start of Pumping	Sample and Analysis Type
10/11/2021 13:05	60 (1)	Subdivision package
11/11/2021 11:55	1430 (24)	Subdivision package

The analytical results of the groundwater samples collected from the test well are summarized in the attached Table 6 and are compared to the Ontario Drinking Water Quality Standards ("ODWQS", MOE 2003) to assess the suitability of the water as a potable water source. The ODWQS defines the following types of standards, objectives and guidelines:

- Maximum Allowable Concentration (MAC) – established for parameters that, when present above certain concentration, have known or suspected adverse health effects;
- Aesthetic Objective (AO) – established for parameters that may impair the taste, colour or colour of water, or that may interfere with good water control practices; and,
- Operational Guidelines (OG) – established for parameters that, if not controlled, may negatively affect the efficient and effective treatment, disinfection and distribution of the water.

The analytical results indicate the water generally meets the applicable standards, objectives and guidelines. Laboratory certificates of analysis are found in Appendix E.

The AO for manganese and colour were exceeded in all samples. The groundwater quality samples collected were odourless, sediment free, clear and light beige in colour. The manganese and colour exceedance is considered to be a naturally occurring condition of the aquifer. The occurrence of manganese in groundwater can lead to discoloration and taste issues. Water treatment will need to consider these levels.

The OG for hardness was exceeded in all samples, which is normal for calcium-bicarbonate type aquifers; the OG was also exceeded for organic nitrogen. The ODWQS technical support document (MOE, 2006) states that:

> *"Organic nitrogen is calculated by the difference between the total Kjeldahl nitrogen and the ammonia nitrogen. High levels may be caused by septic tank or sewage effluent contamination. This form of contamination is often associated with some types of chloride-worsened taste problems. Organic nitrogen at levels above 0.15 mg/L would typically be associated with dissolved organic carbon (DOC) contribution of 0.6 mg/L. Organic nitrogen compounds frequently contain amine groups which can react with chlorine and severely reduce its disinfection power. Certain chlorinated organic nitrogen compounds may be responsible for flavour problems that are associated with chlorophenol. Taste and odour problems are common with organic nitrogen levels greater than 0.15 mg/L."*

In this case, given the isolated hydrogeologic setting, the organic nitrogen in the aquifer is considered to be from a naturally occurring condition of the aquifer. Water treatment will need to consider these levels.

The MAC was exceeded for total coliforms in the final sample collected towards the end of the pumping test. The source of the total coliforms is unknown but may be related to groundwater under the influence of the nearby pond, which is subject to potential water quality contamination from local and nearby migratory bird species. It is noted that if this site is developed for a communal water supply, the pond can be easily infilled with soil. There are also multiple treatment options available for coliforms.

Overall, the results of the parameters tested indicate the quality of the water produced by TW21-01 is good and suitable for use as a potable water source with some treatment required.

It is understood that the water pumped from the new well location would be mixed with water from Winchester Well #7 in the transmission main to Winchester, and then with the water from the Town's other supply wells in the water tower prior to distribution. Ultimately it is the quality of this mixed water supply that is most relevant for determining treatment requirements for the new well.

Water quality results from the 2021 aquifer testing program completed at TW21-01 were compared to the 1992 results from the St. Pierre Well and are presented in Table 6. The St. Pierre Well water quality met the ODWQS for the parameters tested with the exception of hardness that exceeded the operational guideline in all samples collected. The water quality data from TW21-01 are similar to the available historical water quality data from the St. Pierre Well; however concentrations of a majority of parameters are elevated in TW21-01 and in some instances exceeded the ODWQS (i.e., colour, total coliform, manganese and organic nitrogen as previously discussed).

7.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are provided based on the assessment results of the aquifer testing programs completed at the overburden aquifer on the site during the 1992 and 2021 water supply investigations:

- The transmissivity and storativity that was estimated from the TW21-01 pumping test for the current investigation for the aquifer is similar to previous estimates for the Morewood Esker.
- The period of the pumping test was not long enough to warrant firm long-term predictions on the safe aquifer yield, and the efficiency of the well and limitations of the PTTW prevented using a higher pumping rate. However, a potential flow rate of 30 L/s was estimated for the Morewood Esker based on the aquifer parameters estimated from the current and previous investigations for nearby wells completed within the same esker.
- Drawdown in TW21-01 (pumping well) was excessive as compared to the general drawdown imposed on the aquifer during pumping due to an inefficient well. The lower efficiency in the test well may be due to the well construction and development of the aquifer following well construction. For a production well, a review of the grain size distribution curves indicates that a filter pack of 6.3 to 9.5 mm and a no.125 slot size screen (3.175 mm opening) would be appropriate. A filter pack is recommended as it allows for a larger screen slot opening, which will reduce entrance velocities and rates of mineral precipitation.
- The pumping test completed at the St. Pierre Well in 1992 determined that the water table aquifer is easily capable of delivering in excess of 30.7 L/s over short periods with minimal drawdown. These historical results combined with the results of the current investigation indicate that a properly designed and constructed production well located at the site within the Morewood Esker core should be constructed and is expected to likely be capable of supplying 20 to 30 L/s. This test well would be intended to subsequently

become the municipal supply well. A long-term pumping test (72 hour minimum, preferably longer) should then be undertaken to estimate the sustained yield of the aquifer. This testing will also provide more representative values for aquifer transmissivity and storativity.

- Review of water quality results indicates that for the parameters analysed there were no exceedances of the respective MAC, IMAC, AO or OG, with a few exceptions. The MAC for total coliforms was exceeded in the final sample collected at the end of the 24-hour pumping period. The AO for manganese and colour, as well as the OG for hardness and organic nitrogen also exceeded the ODWQS for both samples collected throughout the duration of the pumping test. Overall, the results of the parameters tested indicate the quality of water currently produced to be good and suitable for use as a potable water source with some treatment. The design of the water treatment system expansion would incorporate the water quality results to provide adequate treatment. It is understood that the water pumped from the new well location would be mixed with water from Winchester Well #7 in the transmission main to Winchester, and then with the water from the Town's other supply wells in the water tower prior to distribution. Ultimately it is the quality of this mixed water supply that is most relevant for determining treatment requirements for the new well.
- Drawdown measured at a staff gauge installed at in the nearby water table pond indicates groundwater at TW21-01 may be under direct influence of surface water. The current pond on site should be filled in with soil materials. These materials could likely be derived from another area, above the water table, on the property. By eliminating the water table pond, the potential groundwater quality impacts arising from local and migrating bird species will be eliminated.

8.0 LIMITATIONS

This report was prepared for the exclusive use of J.L. Richards & Associates Ltd. The report, which specifically includes all tables, figures and attachments, is based on data and information collected by Golder Associates Ltd. and is based solely on the conditions of the properties at the time of the work, supplemented by historical information and data obtained by Golder Associates Ltd. as described in this report.

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The services performed, as described in this report, were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

Any use which a third party makes of this report, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder Associates Ltd. 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 findings and conclusions of this report are valid only as of the date of this report. If new information is discovered in future work, including excavations, borings, or other studies, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this report, and to provide amendments as required.

9.0 CLOSURE

We trust this report meets your current requirements. Should you have any questions concerning this report, please contact the undersigned.

Golder Associates Ltd.

LICENSED PROFESSIONAL ENGINEER
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https://golderassociates.sharepoint.com/sites/111069/project files/6 deliverables/hydrogeology/tw21-01 pumping test/final/19125451-003-r-rev0-north dundas aquifer testing program tw21-01_26jan2023.docx

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Table 6: Groundwater Analytical Results for Subdivision Characteristics

Parameter	Units	ODWQS-Health(1)	ODWQS-AO(2)	ODWQS-OG(3)	TW21-01		St. Pierre Well		
					1st Hour of Pumping Test	24th Hour of Pumping Test	1st Hour of Pumping Test	7th Hour of Pumping Test	12th Hour of Pumping Test
					2021-11-10	2021-11-11	02-Apr-92	02-Apr-92	02-Apr-92
Field Parameters									
Conductivity	uS/cm	–	–	–	633	638	–	–	–
Hydrogen Sulphide	mg/L	–	–	–	0.0	0.0	–	–	–
pH	-	–	–	8.5	7.52	7.74	–	–	–
Temperature	°C	–	15	–	10.2	9.80	–	–	–
Turbidity	NTU	–	5	–	0.63	0.75	–	–	–
Bacterial									
Total Coliforms	ct/100mL	0	–	–	0	13	0	0	0
Escherichia Coli	ct/100mL	0	–	–	0	0	–	–	–
Faecal Coliforms	ct/100mL	–	–	–	0	0	0	0	0
Faecal Streptococcus	ct/100mL	–	–	–	0	0	0	0	0
Heterotrophic Plate Count	ct/1mL	–	–	–	9	19	–	–	–
General Chemistry									
Alkalinity as CaCO3	mg/L	–	–	500	235	241	234	230	230
Ammonia Nitrogen	mg/L	–	–	–	<0.010	<0.010	<0.1	<0.1	<0.1
Chloride	mg/L	–	250	–	30	30	12	13	11
Colour	TCU	–	5	–	24	23	2	4	4
Conductivity	uS/cm	–	–	–	629	650	554	536	532
DOC	mg/L	–	–	–	8	7.8	–	–	–
Fluoride	mg/L	1.5	–	–	0.1	0.1	0.07	0.07	0.07
Hardness as CaCO3	mg/L	–	–	100	*311*	*318*	*288*	*278*	*278*
Ion Balance	-	–	–	–	0.97	0.96	–	–	–
Nitrate	mg/L	10	–	–	<0.10	<0.10	<0.10	0.10	0.16
Nitrite	mg/L	1	–	–	<0.10	<0.10	<0.10	<0.10	<0.10
Organic Nitrogen (calculated)	mg/L	–	–	0.15	*0.28*	*0.39*	<0.1	<0.1	<0.1
pH	-	–	–	8.5	7.74	7.82	7.56	7.57	7.56
Sulphate	mg/L	–	500	–	68	71	51	51	51
Sulphide	mg/L	–	0.05	–	<0.01	<0.01	<0.01	<0.01	<0.01
Tannin & Lignin	mg/L	–	–	–	1	1	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen	mg/L	–	–	–	0.29	0.4	<0.1	<0.1	<0.1
Total Dissolved Solids	mg/L	–	500	–	409	422	330	310	320
Total Organic Carbon	mg/L	–	–	–	–	–	1	1	1
Turbidity	NTU	–	5	–	0.2	0.4	0.3	0.3	0.3
Metals									
Calcium (dissolved)	mg/L	–	–	–	95	96	89	85	84
Iron (dissolved)	mg/L	–	0.3	–	0.14	0.14	0.02	0.02	0.03
Magnesium (dissolved)	mg/L	–	–	–	18	19	16	16	16
Manganese (dissolved)	mg/L	–	0.05	–	0.13	0.19	0.05	0.05	0.04
Sodium (dissolved)	mg/L	200	–	–	11	10	2	2	2
Potassium (dissolved)	mg/L	–	–	–	2	2	2	2	2
Petroleum Hydrocarbons									
Benzene	ug/L	1	–	–	<0.5	<0.5	–	–	–
Ethylbenzene	ug/L	140	1.6	–	<0.5	<0.5	–	–	–
m/p-xylene	ug/L	–	–	–	<0.4	<0.4	–	–	–
o-xylene	ug/L	–	–	–	<0.4	<0.4	–	–	–
Toluene	ug/L	60	24	–	<0.5	<0.5	–	–	–
Xylene; total	ug/L	90	20	–	<0.5	<0.5	–	–	–
Phenols									
Phenols	mg/L	–	–	–	<0.001	0.002	0.005	<0.002	<0.002

Table 6: Groundwater Analytical Results for Subdivision Characteristics

Parameter	Units	ODWQS-Health[1]	ODWQS-AO[2]	ODWQS-OG[3]	TW21-01		St. Pierre Well		
					1st Hour of Pumping Test	24th Hour of Pumping Test	1st Hour of Pumping Test	7th Hour of Pumping Test	12th Hour of Pumping Test
					2021-11-10	2021-11-11	02-Apr-92	02-Apr-92	02-Apr-92
VOCs									
1,1,1,2-tetrachloroethane	ug/L	–	–	–	<0.5	<0.5	–	–	–
1,1,1-trichloroethane	ug/L	–	–	–	<0.4	<0.4	–	–	–
1,1,2,2-tetrachloroethane	ug/L	–	–	–	<0.5	<0.5	–	–	–
1,1,2-trichloroethane	ug/L	–	–	–	<0.4	<0.4	–	–	–
1,1-dichloroethane	ug/L	–	–	–	<0.4	<0.4	–	–	–
1,1-dichloroethylene	ug/L	14	–	–	<0.5	<0.5	–	–	–
1,2-dibromoethane	ug/L	–	–	–	<0.2	<0.2	–	–	–
1,2-dichlorobenzene	ug/L	200	3	–	<0.4	<0.4	–	–	–
1,2-dichloroethane	ug/L	5	–	–	<0.2	<0.2	–	–	–
c-1,2-Dichloroethylene	ug/L	–	–	–	<0.4	<0.4	–	–	–
t-1,2-Dichloroethylene	ug/L	–	–	–	<0.4	<0.4	–	–	–
1,2-dichloropropane	ug/L	–	–	–	<0.5	<0.5	–	–	–
c-1,3-Dichloropropylene	ug/L	–	–	–	<0.2	<0.2	–	–	–
t-1,3-Dichloropropylene	ug/L	–	–	–	<0.2	<0.2	–	–	–
1,3,5-trimethylbenzene	ug/L	–	–	–	<0.3	<0.3	–	–	–
1,3-dichlorobenzene	ug/L	–	–	–	<0.4	<0.4	–	–	–
1,4-dichlorobenzene	ug/L	5	1	–	<0.4	<0.4	–	–	–
Bromodichloromethane	ug/L	–	–	–	<0.3	<0.3	–	–	–
Bromoform	ug/L	–	–	–	<0.4	<0.4	–	–	–
Bromomethane	ug/L	–	–	–	<0.5	<0.5	–	–	–
Carbon Tetrachloride	ug/L	2	–	–	<0.2	<0.2	–	–	–
Chloroethane	ug/L	–	–	–	<0.2	<0.2	–	–	–
Chloroform	ug/L	–	–	–	<0.5	<0.5	–	–	–
Chloromethane	ug/L	–	–	–	<0.2	<0.2	–	–	–
Dibromochloromethane	ug/L	–	–	–	<0.3	<0.3	–	–	–
Dichlorodifluoromethane	ug/L	–	–	–	<0.5	<0.5	–	–	–
Dichloromethane	ug/L	–	–	–	<4.0	<4.0	–	–	–
Monochlorobenzene	ug/L	80	30	–	<0.5	<0.5	–	–	–
Styrene	ug/L	–	–	–	<0.5	<0.5	–	–	–
Tetrachloroethylene	ug/L	–	–	–	<0.3	<0.3	–	–	–
Trichloroethylene	ug/L	5	–	–	<0.3	<0.3	–	–	–
Trichlorofluoromethane	ug/L	–	–	–	<0.5	<0.5	–	–	–
Vinyl Chloride	ug/L	1	–	–	<0.2	<0.2	–	–	–

Created by: DH
Checked by: BH

Footnotes:

	Tables should be read in conjunction with the accompanying document.
	Bacteria concentrations are in counts per 100 mL
	All values in mg/L unless otherwise noted
uS/cm	Microsiemens per centimetre
TCU	Colour is equivalent to colour produced by 1 mg of platinum cobalt (True Colour Unit)
NTU	Tnephelometric Turbidity Units
<	Indicates parameter not detected above laboratory method detection limit.
>	Indicates parameter detected above equipment analytical range.
–	Chemical not analyzed or criteria not defined.
Value	Parameter is greater than ODWQS(169/03)-Health
Value	Parameter is greater than ODWQS-AO
Value	Parameter is greater than ODWQS-OG
(1)	Ontario Drinking Water Quality Standards - Health Based Standards (June 2003, revised January 2020).
(2)	Ontario Drinking Water Quality Standards - Aesthetic Objectives. Aesthetic Objectives are established for parameters that may impair the taste, odour or colour of water or which may interfere with good water quality control practices. For certain parameters, both aesthetic objectives and health-related MACs have been derived (June 2003, revised July 2017).
(3)	Ontario Drinking Water Quality Standards - Operational Guidelines. Operational Guidelines are established for parameters that, if not controlled, may negatively affect the efficient and effective treatment, disinfection and distribution of the water (June 2003, revised June 2006).

KEY MAP

SCALE 1:50,000

LEGEND

●	WINCHESTER WELL LOCATION
⊕	APPROXIMATE BOREHOLE/MONITORING WELL LOCATION
◆	APPROXIMATE TEST WELL LOCATION
◆	APPROXIMATE ST. PIERRE PUMPING WELL LOCATION
⊕	APPROXIMATE BOREHOLE LOCATION, PREVIOUS INVESTIGATION
■	APPROXIMATE STAFF GAUGE LOCATION
●	APPROXIMATE POINT OF DISCHARGE FROM PUMPING TEST
—	ROADWAY
—	TOPOGRAPHIC CONTOUR, metres above sea level (masl)
—	WATERCOURSE
☐	TOWNSHIP, CONCESSION, AND LOT
▭	INTERPRETED LIMITS OF MOREWOOD ESKER
▭	APPROXIMATE SITE BOUNDARY

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2020
2. SERVICE LAYER CREDITS: SOURCE: ESRI, MAXAR, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY
SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
3. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83,

0 20 40 80
1:2,000 METRES

CLIENT
J.L. RICHARDS & ASSOCIATES LIMITED

PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY MUNICIPAL CLASS EA

TITLE
SITE PLAN

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-12-16
DESIGNED	—
PREPARED	JEM
REVIEWED	BH
APPROVED	PAS

PROJECT NO.	CONTROL	REV.	FIGURE
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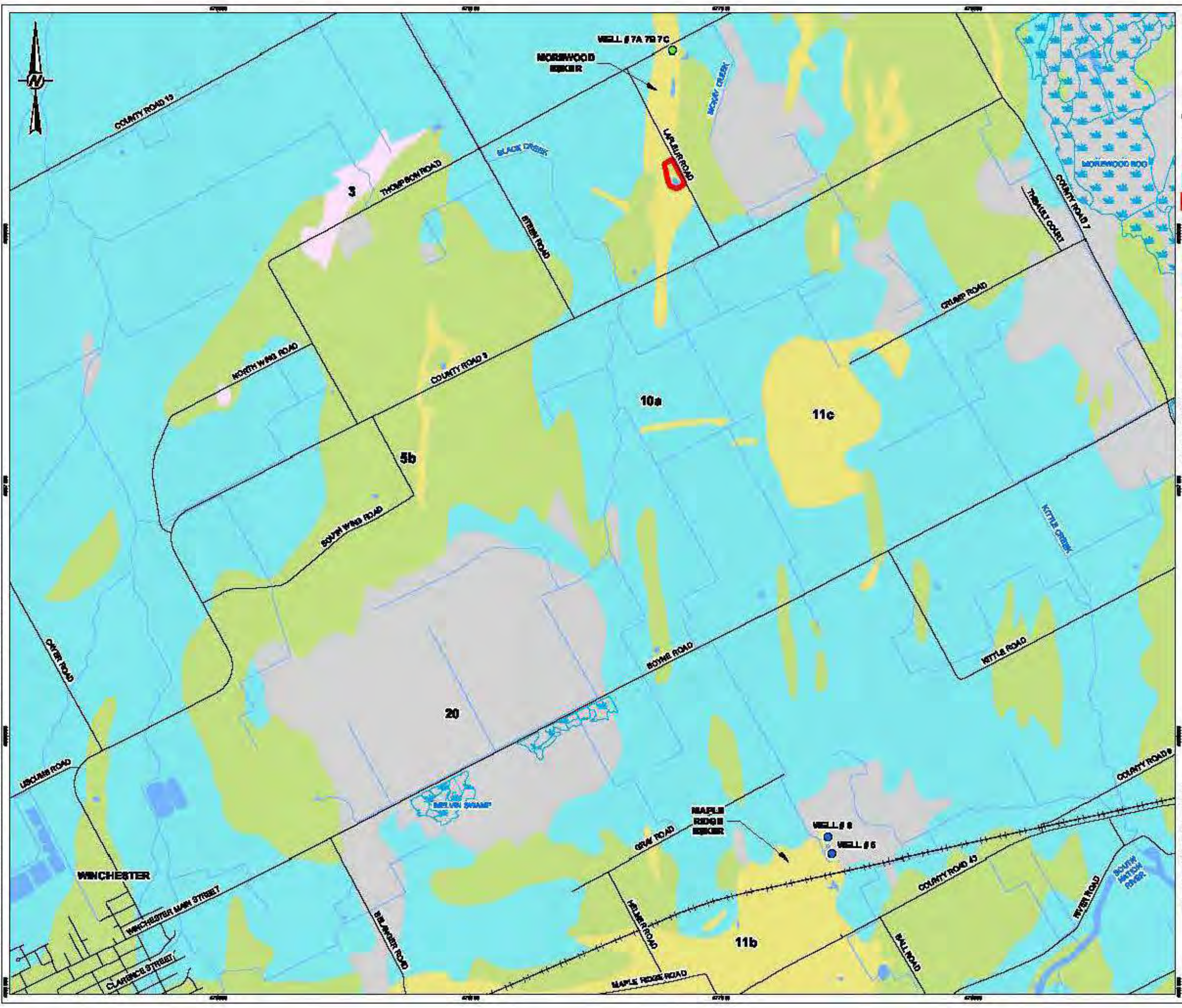

LEGEND

- ● CHESTERVILLE WELL LOCATION
- ● WINCHESTER WELL LOCATION
- ROADWAY
- RAILWAY
- UTILITY LINE
- WATERCOURSE
- WATERBODY
- WETLAND
- APPROXIMATE SITE BOUNDARY

OGS SURFICIAL GEOLOGY

- 3. PALEOZOIC BEDROCK
- 5b. TILL: STONE-POOR, SANDY SILT TO SILTY SAND-TEXTURED TILL ON PALEOZOIC TERRAIN
- 10a. FINE-TEXTURED GLACIOMARINE DEPOSITS: SILT AND CLAY, MINOR SAND AND GRAVEL; MASSIVE TO WELL LAMINATED
- 11b. COARSE-TEXTURED GLACIOMARINE DEPOSITS: SAND, GRAVEL, MINOR SILT AND CLAY; LITTORAL DEPOSITS
- 11c. COARSE-TEXTURED GLACIOMARINE DEPOSITS: SAND, GRAVEL, MINOR SILT AND CLAY; FORESHORE AND BASINAL DEPOSITS
- 20. ORGANIC DEPOSITS: PEAT, MUCK, MARL

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. ONTARIO GEOLOGICAL SURVEY 2010. SURFICIAL GEOLOGY OF SOUTHERN ONTARIO; ONTARIO GEOLOGICAL SURVEY, MISCELLANEOUS RELEASE--DATA 128-REV
2. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2019
3. SERVICE LAYER CREDITS:
4. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83, COORDINATE SYSTEM: UTM ZONE 18, VERTICAL DATUM: CGVD28

0 275 550 1,100

1:25,000 METRES

CLIENT

J.L. RICHARDS & ASSOCIATES LIMITED

PROJECT

TOWNSHIP OF NORTH DUNDAS WATER SUPPLY MUNICIPAL CLASS EA

TITLE

REGIONAL SURFICIAL GEOLOGY

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-12-14
DESIGNED	—
PREPARED	BR
REVIEWED	BH
APPROVED	PAS

PROJECT NO.	CONTROL	REV.	FIGURE
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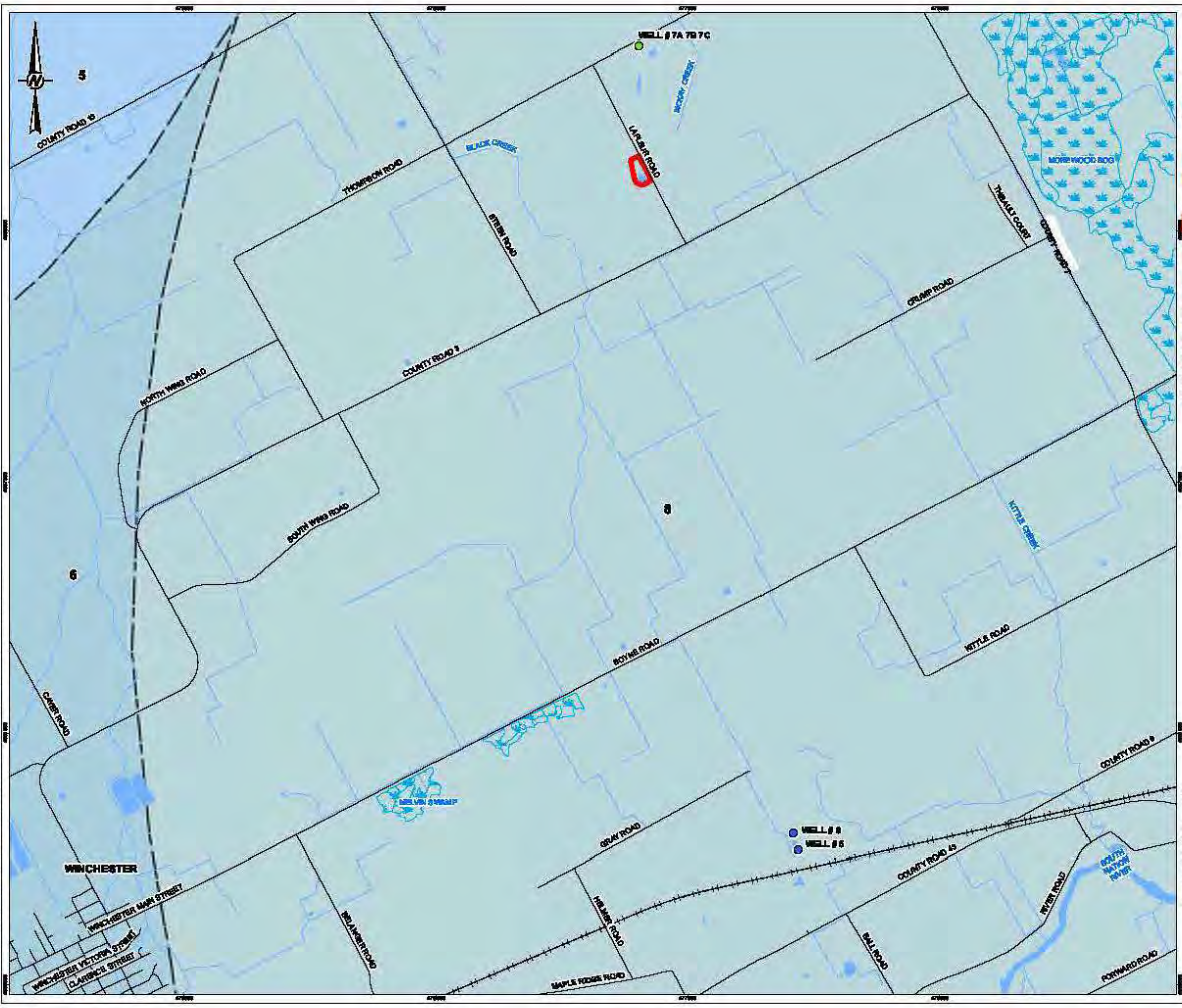


LEGEND

- ● CHESTERVILLE WELL LOCATION
- ● WINCHESTER WELL LOCATION
- ROADWAY
- RAILWAY
- UTILITY LINE
- WATERCOURSE
- WATERBODY
- WETLAND
- FAULT
- APPROXIMATE SITE BOUNDARY

OGS BEDROCK GEOLOGY

- 8: GULL RIVER FORMATION - LIMESTONE, WITH DOLOSTONE BEDS TOWARDS BASE
- 6: ROCKCLIFFE FORMATION - SANDSTONE, SHALE, LIMESTONE, DOLOSTONE
- 5: OXFORD FORMATION - DOLOSTONE, MINOR SHALE AND SANDSTONE

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. ARMSTRONG, D.K AND DODGE, J.E.P. 2007. PALEOZOIC GEOLOGY OF SOUTHERN ONTARIO; ONTARIO GEOLOGICAL SURVEY, MISCELLANEOUS RELEASE--DATA219
2. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2019
3. SERVICE LAYER CREDITS:
4. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83, COORDINATE SYSTEM: UTM ZONE 18, VERTICAL DATUM: CGVD28

0 275 550 1,100

1:25,000 METRES

CLIENT

J.L. RICHARDS & ASSOCIATES LIMITED

PROJECT

TOWNSHIP OF NORTH DUNDAS WATER SUPPLY MUNICIPAL CLASS EA

TITLE

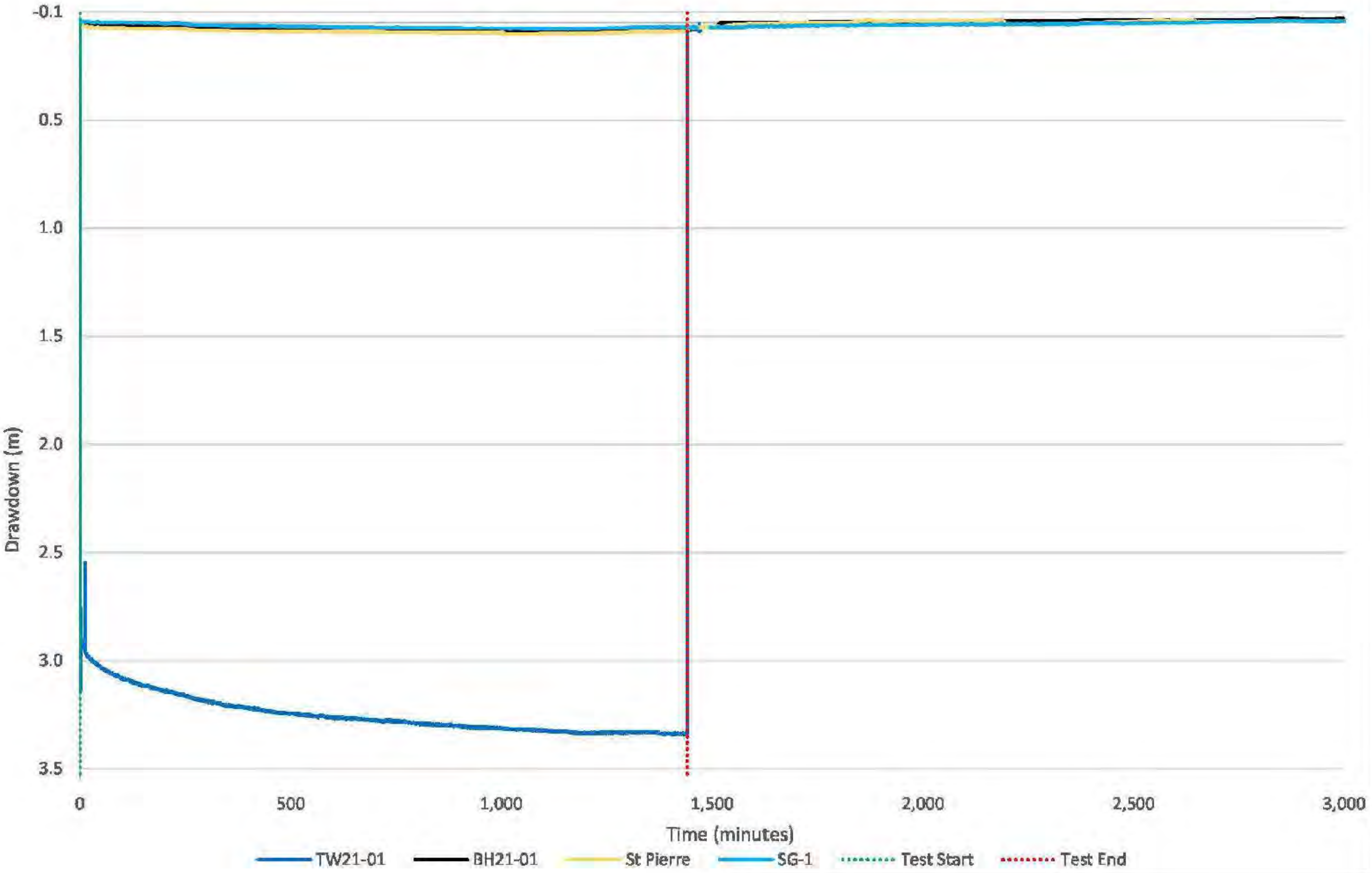
REGIONAL BEDROCK GEOLOGY

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-12-14
DESIGNED	—
PREPARED	BR
REVIEWED	BH
APPROVED	PAS

PROJECT NO.	CONTROL	REV.	FIGURE
19129481	0005	0	3



CLIENT

J.L. RICHARDS & ASSOCIATES LIMITED

CONSULTANT

GOLDER

YYYY-MM-DD	[illegible]
PREPARED	DR
DESIGN	DR
REVIEW	-
APPROVED	—

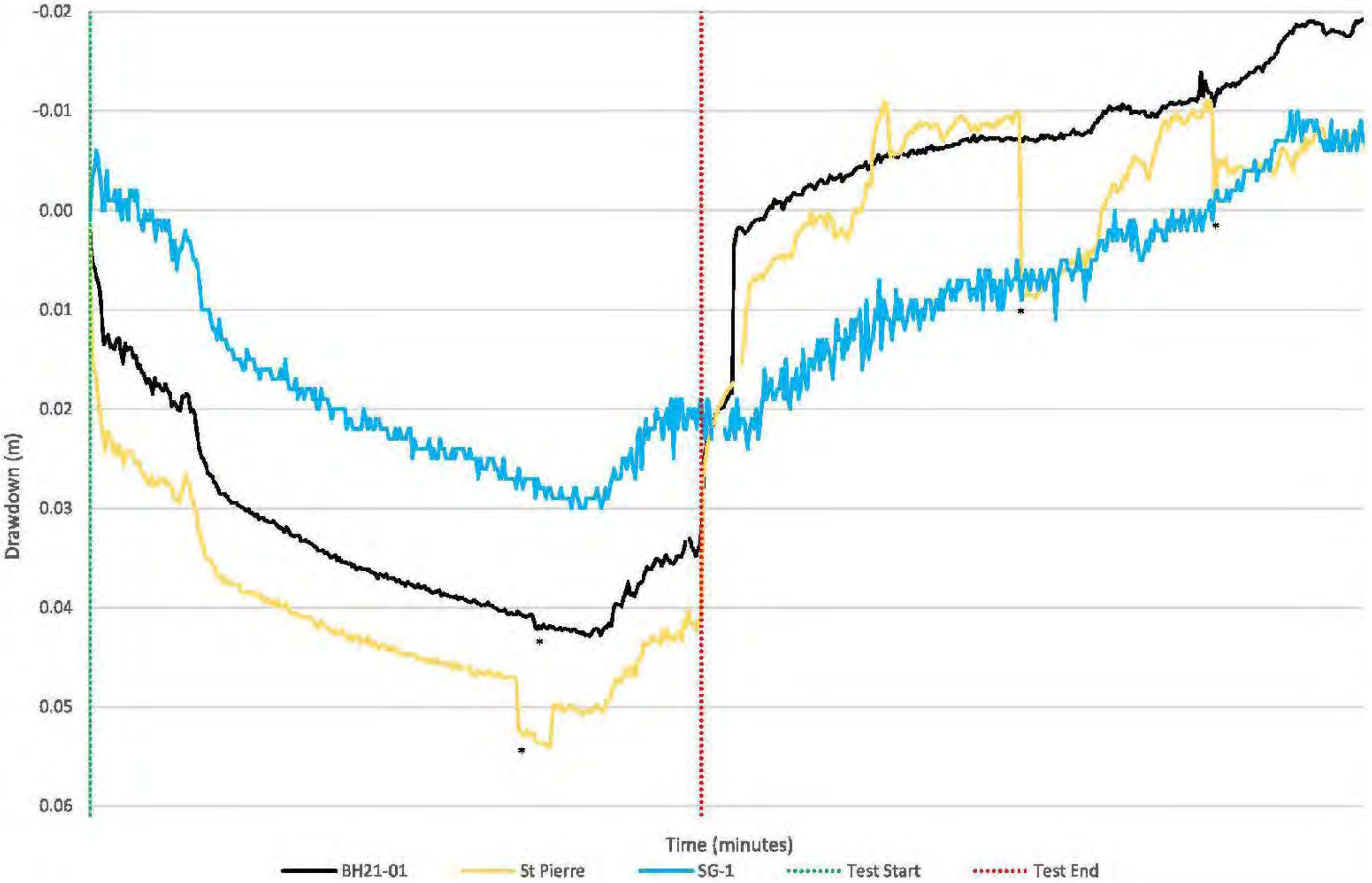
PROJECT

TOWNSHIP OF NORTH DUNDAS MUNICIPAL CLASS EA
NORTH DUNDAS AQUIFER TESTING PROGRAM TW21-01

TITLE

24-HOUR PUMPING TEST AT TW21-01 DRAWDOWN
AT TEST WELL, OBSERVATION WELLS AND POND

PROJECT No.	PHASE	Rev.	FIGURE
19125461	6000	A	4



Note: * denotes possible well interference from Winchester Well #7.

CLIENT

J.L. RICHARDS & ASSOCIATES LIMITED

CONSULTANT

GOLDER

YYYY-MM-DD	[illegible]
PREPARED	[illegible]
DESIGN	[illegible]
REVIEW	[illegible]
APPROVED	[illegible]

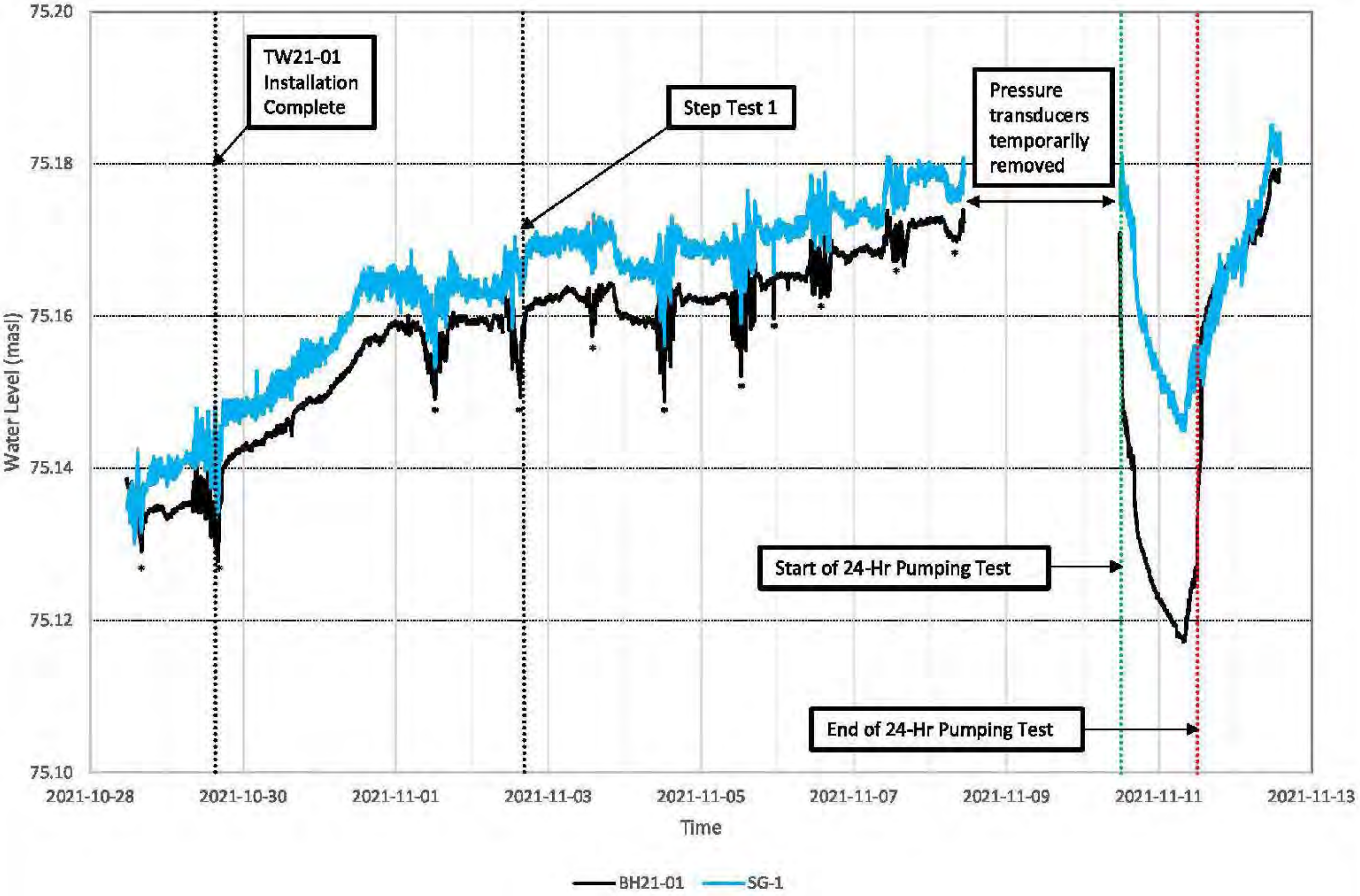
PROJECT

TOWNSHIP OF NORTH DUNDAS MUNICIPAL CLASS EA
NORTH DUNDAS AQUIFER TESTING PROGRAM TW21-01

TITLE

24-HOUR PUMPING TEST AT TW21-01 DRAWDOWN AT
OBSERVATION WELLS AND POND

PROJECT No.	PHASE	Rev.	FIGURE
19125461		0	5



Note: * denotes possible well interference from Winchester Well #7.

CLIENT

J.L. RICHARDS & ASSOCIATES LIMITED

CONSULTANT

GOLDER

YYYY-MM-DD [illegible]
PREPARED DH
DESIGN DH
REVIEW —
APPROVED —

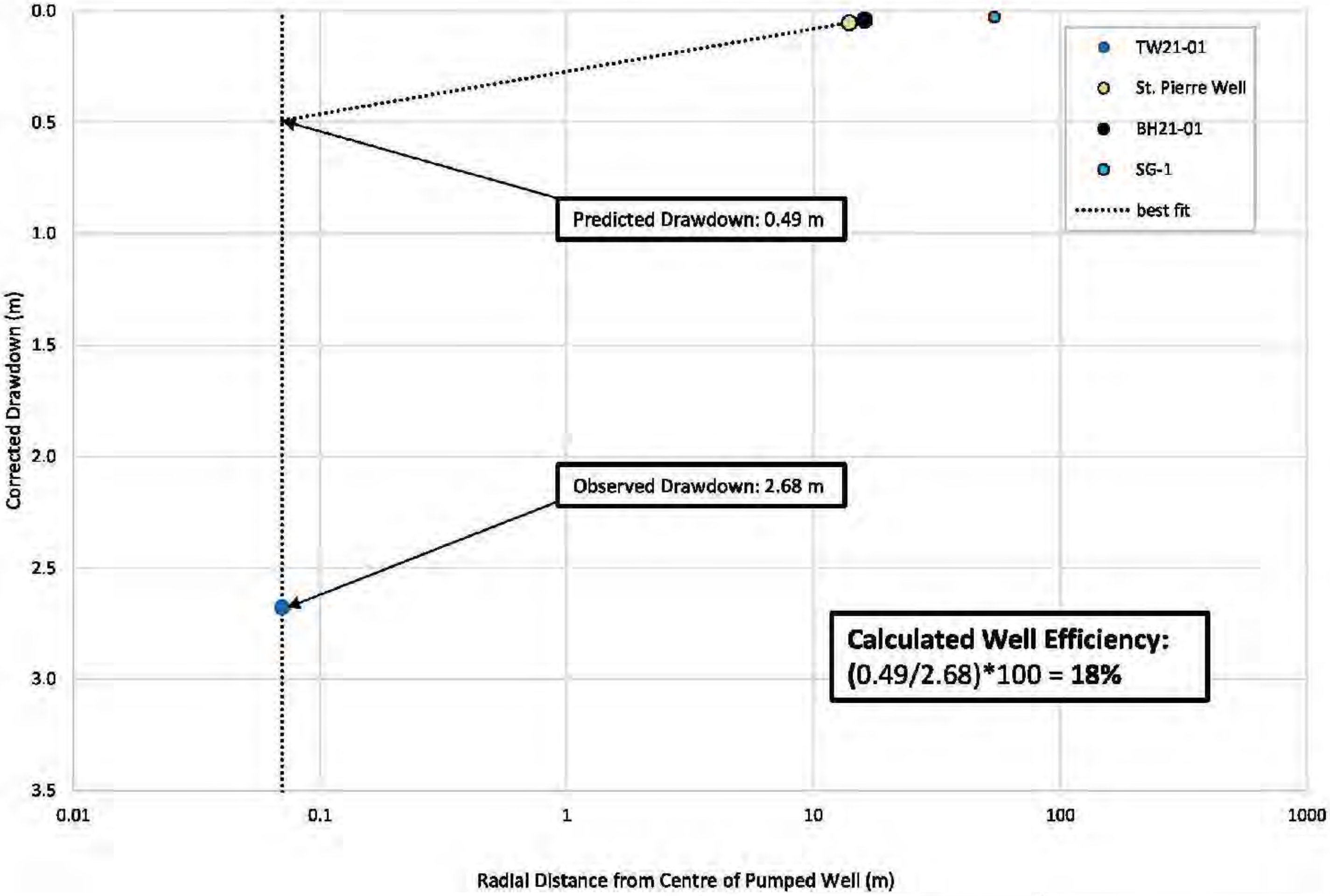
PROJECT

TOWNSHIP OF NORTH DUNDAS MUNICIPAL CLASS EA
NORTH DUNDAS AQUIFER TESTING PROGRAM TW21-01

TITLE

WATER LEVEL ELEVATIONS AT BH21-01 AND SG-1
BETWEEN OCTOBER 28 AND NOVEMBER 12, 2021

PROJECT No.	PHASE	Rev.	FIGURE
19125461		A	6



J.L. RICHARDS & ASSOCIATES LIMITED

GOLDER

DH

DH

—

—

TOWNSHIP OF NORTH DUNDAS MUNICIPAL CLASS EA
NORTH DUNDAS AQUIFER TESTING PROGRAM TW21-01

EFFICIENCY OF TW21-01

19125461

A

7

APPENDIX A

Geotechnical Investigation Completed by Golder (2021)

REPORT

Geotechnical Investigation

Township of North Dundas Municipal Class EA
North Dundas Drinking Water Supply System Capacity Expansion

Submitted to:

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January 2023

Distribution List

1 e-copy - J.L. Richards & Associates Limited

1 e-copy - Golder Associates Ltd.

Table of Contents

1.0 INTRODUCTION

This report presents the results of a geotechnical investigation for a proposed pump station to be constructed as part of municipal infrastructure improvements, which is included as part of the current EA study for the Township of North Dundas located on Lafleur Road south of Thompson Road.

The geotechnical investigation included a review of available previous investigations and published geological mapping, along with a borehole investigation to assess the subsurface conditions at the site. Based on an interpretation of the factual information obtained, a general description of the subsurface conditions is presented. These interpreted subsurface conditions and available project details were used to prepare engineering guidelines on the geotechnical design aspects of the project, including construction considerations, which could influence design decisions.

The reader is referred to the "Important Information and Limitations of This Report", which follows the text but forms an integral part of this document.

2.0 DESCRIPTION OF PROJECT AND SITE

The site is located on Lafleur Road south of Thompson Road in the Township of North Dundas, Ontario. The approximate location of the site is shown on the Key Map inset on the attached Site Plan (Figure 1). The site consists of approximately 2 hectares (5 acres) of undeveloped land that was previously a worked sand and gravel pit. The site is mostly grass covered with high shrubs/bushes and mature trees on the north and east ends of the site boundary. The natural terrain appears to be undulating with ground surface elevations ranging between 76 m and 77 m. There appears to be several stockpiles of sand about 2 m to 3 m high that have become grass covered. There also appears to be a body of water located near the south end of the site boundary which appears to cover about 20% of the site.

It is understood that the proposed new pump station will be located within the northeast portion of the site.

3.0 SITE GEOLOGY

Based on subsurface mapping obtained from the Geological Survey of Canada, the subsurface conditions in this area typically consist of near shore sediments consisting of gravel, sand and boulders underlain by limestone with dolomite interbeds of the Gull River formation. The overburden thickness in this area was anticipated to range between 5 to 10 m depth.

4.0 PREVIOUS INVESTIGATIONS

An investigation was carried out by Golder Associates Ltd. between March 11 and 13, 1992 which consisted of 6 sampled boreholes labelled borehole OW-1 to OW-6 with boreholes OW-1, OW-2 and OW-4 in close proximity to current borehole 21-01. The locations of these boreholes are shown on Figure 1. In general, the subsurface conditions encountered in boreholes OW-1, OW-2 and OW-4 consisted of a 9.9 to 11 m thick layer of sand and gravel underlain by a 2.1 to 3.8 m thick layer of sandy silt till. Auger refusal was achieved in borehole OW-1 at a depth of about 13.7 m. Groundwater measured in all three boreholes on April 1, 1992 indicated water levels ranging from 0.8 to 1.4 m below ground surface the time of the investigation. The Borehole Records are included in Appendix A.

Another investigation carried out by Golder in December 1989, included one borehole, BH 13 in close proximity to the site. The location of BH 13 is approximately 20 m east of the east site boundary line and is shown on Figure 1. At this location, the subsurface conditions consisted of topsoil, over a thick deposit of sand with some silt and traces of gravel. The borehole encountered auger refusal at about 12.4 m below the ground surface at the time of the investigation. A monitoring well installed in Borehole 13 indicated a water level at about elevation 75.6 m (6.7 m below ground surface), measured on April 1992. This Borehole Record is also included in Appendix B.

5.0 PROCEDURE (CURRENT INVESTIGATION)

The fieldwork for this investigation was carried out on October 4, 2021. During that time, one borehole (numbered 21-01) was advanced at the approximate location shown on the attached Site Plan (Figure 1).

The borehole was advanced using a track-mounted drill rig supplied and operated by CCC Geotechnical and Environmental Drilling Ltd. of Ottawa, Ontario. The borehole was advanced to a depth of 9.8 m below the existing ground surface.

Standard Penetration Tests (SPTs) were carried out at regular intervals of depth. Samples of the soils encountered were recovered using split-spoon sampling equipment. Upon completion of the borehole, a monitoring well was installed for subsequent groundwater measurement and hydraulic conductivity testing.

The fieldwork was supervised by personnel from our engineering staff who directed the drilling and in situ testing operations, logged the boreholes and samples, and took custody of the soil samples retrieved. On completion of the drilling operations, samples of the soils were transported to our Ottawa laboratory for further examination and for laboratory testing, which included natural water content and grain size distribution tests on selected soil samples.

One sample of soil from borehole 21-01 was submitted to Eurofins Scientific for basic chemical analyses related to potential sulphate attack on buried concrete elements and corrosion of buried ferrous elements.

The borehole location was selected, marked in the field, and subsequently surveyed by Golder Associates personnel. The coordinates and ground surface elevation of the borehole was measured using a Trimble R8 GPS survey unit. The geodetic reference system used for the survey is the North American Datum of 1983 (NAD83). The coordinates are based on the Universal Transverse Mercator (UTM Zone 18) coordinate system. The elevations are referenced to Geodetic datum (CGVD28).

6.0 SUBSURFACE CONDITIONS (CURRENT INVESTIGATION)

6.1 General

The subsurface conditions encountered in Borehole 21-01 consisted of topsoil overlying native sand and gravel. The Record of Borehole Sheet is included in Appendix A. The results of laboratory grain size distribution testing carried out on four samples of the native sand and gravel are provided in Appendix B. The results of the basic chemical analysis carried out on one sample of soil are provided in Appendix C.

The following sections present a more detailed description of the subsurface conditions encountered in borehole 21-01.

6.2 Topsoil

A 200 mm thick layer of topsoil consisting of silty sand and gravel was encountered at ground surface.

6.3 Gravel and Sand

A deposit of gravel with varying amounts of sand, some silt and occasional cobbles and boulders was encountered beneath the topsoil. The borehole was terminated in a sandy gravel deposit at a depth of 9.8 m below the existing ground surface.

SPTs carried out within the gravel and sand deposits measured 'N' values ranging from 20 to 66 blows per 0.3 m of penetration. The results of this in situ testing indicate a compact to very dense state of packing.

The results of laboratory grain size distribution tests carried out on four samples of the gravel and sand deposit are provided in Appendix B. Moisture contents ranged from 7 to 11% and are shown on the Borehole Record included in Appendix A.

6.4 Groundwater

A monitoring well was installed in borehole 21-01 at a depth of 9.2 m. A groundwater measurement taken on November 12, 2021 indicated that the groundwater was at about 0.9 m depth. It should be noted that the 1992 boreholes measured groundwater to be at 0.8 to 1.4 m in April 1992.

A test well (TW21-01) located about 30 m east of the geotechnical borehole drilled in the current investigation was advanced by Golder Associates between October 25 and 29, 2021. The well was installed to a depth of about 8.8 m. Groundwater measured on November 12, 2021 indicated a water level of 1.2 m below existing ground surface. The Borehole Record is included in Appendix A.

It should also be noted that groundwater levels are expected to fluctuate seasonally. Higher groundwater levels are expected during wet periods of the year, such as spring.

6.5 Corrosion

One sample of soil from borehole 21-01 was submitted to Eurofins Scientific for basic chemical analyses related to potential sulphate attack on buried concrete elements and potential corrosion of buried ferrous elements. The results of this testing are provided in Appendix C and are summarized in the following table.

Table 1: Chemical Analysis Results

Borehole Number / Sample Number	Chloride (%)	Sulphate (%)	pH	Resistivity (Ohm-cm)
21-01 / Sa 2	<0.002	0.01	8.5	8,333

7.0 DISCUSSION

7.1 General

This section of the report provides engineering guidelines on the geotechnical design aspects of the project based on our interpretation of the borehole information and project requirements.

The foundation engineering guidelines presented in this section have been developed in a manner consistent with the procedures outlined in the 2012 Ontario Building Code (OBC) for Limit States Design.

7.2 Site Grading and Preparation

The subsurface conditions on this site generally consist of topsoil over a gravel and sand deposit containing cobbles and boulders.

Any topsoil should be removed from the proposed structure location. It is important that stockpiles, if located on site, not be adjacent to any excavations but rather should be located within any future landscaping areas.

In preparation for construction for the new slab-on-grade, any loose, wet, and disturbed material (including materials disturbed during excavation) should be removed from within the proposed structure areas. If sub-excavation below the subgrade is required, the excavated soils must be replaced with engineered fill comprised of earth fill approved by the engineer or imported granular fill which meet the requirements of OPSS 1010. Soils that are significantly above their optimum water content for compaction or contain significant quantities of organics are not considered suitable for use as engineered fill.

Engineer-approved fill should be placed in maximum 300 mm thick loose lifts and uniformly compacted to 95% of its Standard Proctor Maximum Dry Density (SPMDD) using suitable vibratory compaction equipment. Filling should continue until the design subgrade elevations are achieved.

The engineered fill limits are defined such that the fill extends to at least 1 m beyond the outside edge of the founding level of any footing/slab-on-grade or other settlement sensitive area and then downward and outward at a slope of one horizontal to one vertical (1H:1V). Full-time inspection and in situ density testing should be carried out by a qualified geotechnical engineering firm during placement of engineered fill beneath the proposed structures and/or other settlement sensitive areas.

The final surface of the engineered fill should be protected as necessary from construction and foot traffic and should be sloped to provide positive drainage for surface water during the construction period. If the engineered fill materials will be left exposed (i.e., uncovered) during periods of freezing weather, consideration should be given to placing an additional soil cover above final subgrade to provide for frost protection. The surface of the engineered fill should be inspected by a geotechnical engineer.

7.3 Seismic Design and Liquefaction Potential

7.3.1 Seismic Site Class

The seismic design provisions of the 2012 OBC depend, in part, on the shear wave velocity of the upper 30 m of soil and/or rock below founding level. The OBC also permits the Site Class to be specified based solely on the stratigraphy and in situ testing data (i.e., shear strengths and standard penetration test results), rather than from direct measurements of the shear wave velocity.

Based on the corrected SPT 'N' values (corrected for the overburden stress, rod length during sampling, and hammer energy efficiencies), this site can be assigned a Site Class C for seismic design purposes.

7.3.2 Liquefaction Assessment

Seismic liquefaction occurs when earthquake vibrations cause an increase in pore water pressures within the soil. The presence of excess pore water pressures reduces the effective stress between the soil particles, and the soil's frictional resistance to shearing. This phenomenon, which leads to a temporary reduction in the shear strength of the soil, may cause:

- Large lateral movements of even gently sloping ground, referred to as 'lateral spreading'.

- Reduced shear resistance (i.e., bearing capacity) of soils which support foundations, as well as reduced resistance to sliding.
- Reduced shaft resistance for deep foundations as well as reduced resistance to lateral loading.

In addition, 'seismic settlements' may occur once the vibrations and shear stresses have ceased. Seismic settlement is the process whereby the soils stabilize into a denser arrangement after an earthquake, causing potentially large surface settlements.

The following conditions are more prone to experiencing seismic liquefaction:

- Coarse grained soils (i.e., more probable for sands than for silts).
- Soils having a loose state of packing.
- Soils located below the groundwater level.

An assessment of the liquefaction potential of the gravelly and sandy deposits was carried out using the Seed and Idriss (1971) simplified procedure based on SPT N_{60} values from the boreholes. The SPT 'N' values reported on the borehole records were corrected for the overburden stress, rod length during sampling, and hammer energy efficiencies. The assessment was carried out using an earthquake with a magnitude of 6.2 (Ottawa area specified design value) and a peak 'firm ground' acceleration (PGA) of 0.302 g.

The results of the assessment suggest that the soils at this site are not susceptible to liquefaction.

7.4 Frost Protection

All exterior perimeter foundation elements or foundation elements in unheated areas should be provided with a minimum of 1.5 m of earth cover or equivalent insulation for frost protection purposes. Isolated, unheated exterior footings adjacent to surfaces which are cleared of snow cover during winter months should be provided with a minimum of 1.8 m of earth cover or equivalent insulation.

7.5 Shallow Foundations

It is understood that the design of the pump station and any associated structures are currently unknown, but it is understood that there may be a need to construct small, lightly loaded foundations. Preliminary recommendations for shallow foundations are therefore provided below.

The subsurface conditions at this site consist of a thick deposit of compact to very dense native gravel and sand underlain by glacial till (which was not encountered in the 2021 investigation but was encountered in the 1992 investigation). Based on the subsurface conditions it is considered that relatively light structural elements might be supported on conventional spread footings founded on the undisturbed native gravel and sand or engineered fill placed over the native material.

It is assumed that the floor loading for the buildings (i.e., the existing loads from the building around any new foundation) will not exceed 4.8 kPa.

The proposed footings should be designed using the bearing resistance values provided in the table below.

Table 2: Geotechnical Bearing Resistances for Shallow Foundations

Footing Type	Assumed Founding Elevation (m)	Footing Width or Size (metres)	Net Bearing Resistance at SLS (kPa)	Factored Bearing Resistance at ULS (kPa)
Pad	74.2	<u><</u>2.0	350	450
		2.0 – 3.0	400	500
		3.0 – 4.0	480	600
Strip	74.2	<u><</u>1.0	400	500
		1.0 – 1.5	480	600
		1.5 – 2.0	500	650

For larger footings, footings placed at greater depth, increases in floor loading, or increases in exterior grade levels, the above design parameters will change, and new values must be calculated taking any such changes into account. The bearing values should also be reviewed once foundation bearing elevations are known.

The post construction total and differential settlements of footings sized using the above SLS net bearing resistance values should be less than about 25 and 20 mm, respectively, provided that the soil at or below founding level is not disturbed during construction.

Where the resulting excavation leaves the native subgrade level below the proposed underside of footing level, the grade should be raised, within the zone of influence of the footing, with OPSS Granular B Type II placed in maximum 300 mm lifts and compacted to at least 95% of the material's SPMDD using suitable vibratory compaction equipment. The zone of influence is considered to extend out and down from the edge of the footings at a slope of 1 horizontal to 1 vertical. The same foundation design parameters given above can be used for foundations placed on a properly constructed engineered fill pad.

Subgrade modulus values for footings can be developed as indicated in Section 8.5.1.

7.5.1 Raft Slab and/or Slab-on-Grade

A raft slab and/or slab-on-grade may also be considered for the foundation. The geotechnical design of a raft slab and slab-on-grade is typically not governed by bearing resistance, but by maintaining settlement and deformation (particularly differential) of the slab under loading within acceptable limits.

The localized differential settlements (i.e., raft slab deflections) will depend upon the relative stiffness between the footing and the underlying subgrade. The deflections and the resulting forces and bending moments in the slab to be used in its structural design could be determined by structural analysis using a modulus of subgrade reaction, k_s, for the subgrade.

The modulus of subgrade reaction is not a fundamental soil property and its value depends, in part, on the size and shape of the loaded area. For the analysis of the contact stress distribution beneath a raft foundation, its value would depend on the size of the areas over which increased/concentrated contact stresses are anticipated (analogous to equivalent footings beneath the columns); the size of these areas is in turn related to the value of the modulus of subgrade reaction, i.e., they are inter-related.

Accordingly, the analysis of the foundation slab should ideally involve an iterative analysis between the determination of the contact stress distribution by the structural engineer and the geotechnical determination of the modulus of subgrade reaction value, until the two are consistent with each other.

For a 0.3 m by 0.3 m unit section of the concrete slab, the modulus of subgrade reaction may be assumed to be in the range of 100 MPa/m for a concrete slab overlying the native compact to very dense gravel and sand. This unit modulus of subgrade reaction value (k_v) may be modified to a modulus of subgrade reaction value (k_{vb}) for a pad of width B and width to length ratio M using the following equation:

$$k_{vb} = kv\left(\frac{3.28B + 0.3}{6.56B}\right)\text{^}2$$

7.5.2 Resistance to Sliding

Resistance to sliding across the interface between the concrete slab-on-grade or foundations and the native soil at founding level may be calculated using the following parameters:

Table 3: Coefficient of Friction Parameters

Interface	Coefficient of Friction
Concrete – Engineered Fill	0.55
Concrete – Native Gravel and Sand	0.60

A factor of 0.6 should be applied to the lateral resistance obtained with the values given above.

7.5.3 Construction of Slab-on-Grade

In preparation for the construction of the slab-on-grade, all existing topsoil should be removed from beneath the footprint of the proposed slab. Provision should be made for at least 150 mm of Ontario Provincial Standard Specification (OPSS) Granular A to form the base for the slab-on-grade. Any bulk fill required to raise the grade to the underside of the Granular A should consist of OPSS Granular B Type II. The underslab fill should be placed in maximum 300 mm thick loose lifts and should be compacted to at least 98% of the material's SPMDD using suitable vibratory compaction equipment.

7.6 Foundation Excavations & Dewatering

At the time of writing this report, the design of the proposed structure(s) was unknown. Excavations for foundation construction will be through the native gravel and sand.

No unusual problems are anticipated in excavating in the overburden materials using conventional hydraulic excavating equipment. The existing gravelly and sandy deposits in the area of the proposed structure would be classified as Type 3 soils, respectively in accordance with the Occupational Health and Safety Act (OHSA) and therefore open cut side slopes would need to be cut back at an inclination no steeper than 1 horizontal to 1 vertical (1H:1V).

Given the groundwater conditions at the site, it is recommended that any excavations and the underside of any footings, be placed above the groundwater table. This may require the use of insulation as the groundwater depth is less than the recommended frost depth.

7.7 Foundation Wall Backfill

The following guidelines are also provided on the basis that the structure foundations are designed to be 'drained' (i.e., that a watertight foundation is not to be provided).

The foundation walls should be backfilled with non-frost susceptible sand or sand and gravel conforming to the requirements for OPSS Granular A or Granular B Type I or II. Free draining backfill materials are also required if hydrostatic water pressure against the foundation walls (and potential leakage) is to be avoided. The gravelly and sandy soils at this site may be considered as free draining and non-frost susceptible, and therefore could be re-used as backfill against foundation elements within the depth of potential frost penetration (1.8 m). This assumption is based on visual observations and laboratory test results from a single borehole; excavated soils should be reviewed during construction to confirm that the salvaged portions of the sand and gravel are suitable for use as backfill.

As indicated in Section 7.6 above, based on the anticipated depth of excavation, it is expected that the excavation will be carried out in open cut with side slopes no steeper than 1H:1V, or within fully braced trench boxes. The full width of the open or trenched excavations should be backfilled using non-frost susceptible and free draining materials as stated above.

To avoid ground settlements around the foundations, which could affect site grading and drainage, all of the backfill materials should be placed in maximum 300 mm thick lifts, compacted to at least 95% of the material's SPMDD.

The foundation wall backfill (for the full height of the wall) should be drained by means of a perforated pipe subdrain in a surround of 19 mm clear stone, fully wrapped in a geotextile, which leads by positive drainage to a storm sewer or to a sump from which the water is pumped.

7.7.1 Lateral Earth Pressures

The magnitude of the lateral earth pressures acting on the foundation walls depend on the backfill materials and backfill conditions adjacent to the foundation walls. If the backfill materials consist of existing compacted native sand and gravel or granular fill consisting of OPSS Granular A or Granular B Type I or II, then the lateral earth pressures may be taken as:

$$\sigma_h(z) = K\,(\gamma z + q)$$

Where: $\sigma_h(z)$ = Lateral earth pressure on the wall at depth z, kilopascals;

K = Active or at-rest earth pressure coefficient, K_a or K_o, see below;

γ = Unit weight of retained soil, see below;

z = Depth below top of wall, metres; and

q = Uniform surcharge at ground surface to account for traffic and equipment (not less than 15 kPa), plus any surcharge due to adjacent foundation loads.

If the passive resistance to the foundation offered by the backfill soils will be relied upon to resist the lateral loads on the structure, the magnitude of that lateral resistance will depend on the backfill materials and backfill conditions adjacent to the foundation walls. If the backfill materials consist of existing compacted granular fill, sand or sand and gravel (OPSS Granular A or Granular B Type I or II), then the passive resistance acting on the foundation wall may be taken as:

$$\sigma_h(z) = K_p \gamma z$$

Where: $\sigma_h(z)$ = Lateral earth resistance applied to the foundation wall at depth z, kilopascals;

K_p = Passive earth pressure coefficient, see below;

γ = Unit weight of retained soil, see below; and,

z = Depth below top of wall, metres.

The following static earth pressure coefficients assume that the back of the wall is vertical and the ground surface behind the wall is flat (which is understood to be the case):

Material	Native Sand & Gravel	Granular A	Granular B Type II
Soil Unit Weight:	**21 kN/m^3**	**21 kN/m^3**	**22 kN/m^3**
Angle of Internal Friction	**35°**	**35°**	**35°**
Coefficients of static lateral earth pressure:			
Active, K_a	0.27	0.27	0.27
At-rest, K_o	0.43	0.43	0.43
Passive, K_P	3.7	3.7	3.7

These lateral earth pressures would increase under seismic loading conditions. The earthquake-induced dynamic pressure distribution, which is to be added to the static earth pressure distribution, is a linear distribution with maximum pressure at the top of the wall and minimum pressure at its toe (i.e., an inverted triangular pressure distribution). The total pressure distribution (static plus seismic) for design may be determined as follows:

$$\sigma_h(z) = K \gamma z + (K_{AE} - K) \gamma (H\text{-}z)$$

Where: $\sigma_h(z)$ = Lateral earth pressure at depth z, kPa;

K = Static active earth pressure coefficient, K_a **(to be used for yielding walls)**;

K = Static at-rest earth pressure coefficient, K_o **(to be used for non-yielding walls)**;

K_{AE} = Seismic earth pressure coefficient, see below; and

H = Total height of the wall, metres.

The following seismic active pressure coefficients (K_{AE}) for the above backfill cases can be used in design. It should be noted that these seismic earth pressure coefficients assume that the back of the wall is vertical and the ground surface behind the wall is flat (which is understood to be the case).

Material	Seismic Active Pressure Coefficients, K_{AE}		
	Native Gravel and Sand	Granular A	Granular B Type II
Yielding wall	0.38	0.38	0.38
Non-yielding wall	0.54	0.54	0.54

It should be noted that all of the lateral earth pressure equations are given in an unfactored format and will need to be factored for ULS design purposes.

It should also be noted that the above lateral earth pressure equations assume that the foundation walls will be drained. If the walls are design to be water-tight, the walls will have to be designed to resist the additional hydro-static pressure.

Since the native gravel and sand is not considered as frost-susceptible, frost taper is not required in areas where pavement or other hard surfacing will abut any buildings.

7.8 Corrosion and Cement Type

One selected soil sample from borehole 21-01 was submitted to Eurofins Laboratories for basic chemical analyses related to potential sulphate attack on buried concrete elements and potential corrosion of buried ferrous elements. The results of this testing are provided in Appendix C and also noted in Section 5.5.

The results indicate that concrete made with Type GU Portland cement should be acceptable for substructures. The results also indicate a moderate potential for corrosion of exposed ferrous metal, which should be considered in the design of substructures.

8.0 ADDITIONAL CONSIDERATIONS

All foundation and subgrade areas should be inspected by experienced geotechnical personnel prior to filling or concreting to ensure that soil having adequate bearing capacity has been reached and that the bearing surfaces have been properly prepared. The placing and compaction of any engineered fill should be inspected to ensure that the materials used conform to the specifications from both a grading and compaction viewpoint.

At the time of the writing of this report, no details regarding the pump station design were available. Golder Associates should be retained to review the final drawings and specifications for this project prior to tendering to ensure that the guidelines in this report have been adequately interpreted.

Signature Page

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Senior Geotechnical Engineer

BB/CH/hdw
https://golderassociates.sharepoint.com/sites/111069/project files/6 deliverables/geotechnical/draft report/19125451-rev01-jr north dundas geotech report-jan 2022 draft.docx

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Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

IMPORTANT INFORMATION AND LIMITATIONS
OF THIS REPORT (cont'd)

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Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

KEY MAP

SCALE 1:30,000

LEGEND

⊕	APPROXIMATE BOREHOLE/MONITORING WELL LOCATION
●	APPROXIMATE TEST WELL LOCATION
⊕	APPROXIMATE BOREHOLE LOCATION, PREVIOUS INVESTIGATION
—	ROADWAY
—	TOPOGRAPHIC CONTOUR, metres above sea level (masl)
—	WATERCOURSE
☐	TOWNSHIP, CONCESSION, AND LOT
⌐ ¬	INTERPRETED LIMITS OF MOREWOOD ESKER
🟥	APPROXIMATE SITE BOUNDARY

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2020
2. SERVICE LAYER CREDITS: SOURCE: ESRI, MAXAR, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY
SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
3. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83,

0 20 40 80

1:2,000 METRES

CLIENT
J.L. RICHARDS & ASSOCIATES LIMITED

PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY MUNICIPAL CLASS EA

TITLE
SITE PLAN

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-01-06
DESIGNED	—
PREPARED	JEM
REVIEWED	BH
APPROVED	PAS

PROJECT NO.	CONTROL	REV.	FIGURE
19129481	0006	0	1

APPENDIX A

Borehole Logs - Current Investigation

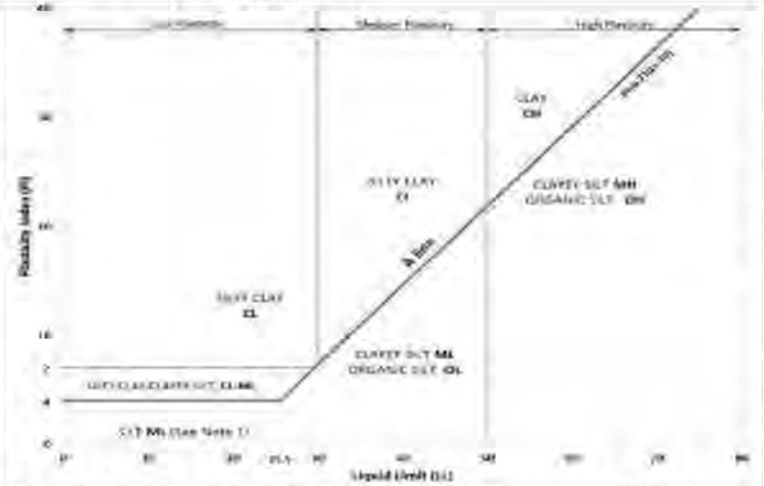
Borehole Logs – Previous Investigations (Golder)

METHOD OF SOIL CLASSIFICATION

The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)

Organic or Inorganic	Soil Group	Type of Soil		Gradation or Plasticity	$Cu = \frac{D_{60}}{D_{10}}$	$Cc = \frac{(D_{30})^2}{D_{10}xD_{60}}$	Organic Content	USCS Group Symbol	Group Name
INORGANIC (Organic Content ≤30% by mass)	COARSE-GRAINED SOILS (>50% by mass is larger than 0.075 mm)	GRAVELS (>50% by mass of coarse fraction is larger than 4.75 mm)	Gravels with ≤12% fines (by mass)	Poorly Graded	<4	≤1 or ≥3	≤30%	GP	GRAVEL
				Well Graded	≥4	1 to 3		GW	GRAVEL
			Gravels with >12% fines (by mass)	Below A Line	n/a			GM	SILTY GRAVEL
				Above A Line	n/a			GC	CLAYEY GRAVEL
		SANDS (≥50% by mass of coarse fraction is smaller than 4.75 mm)	Sands with ≤12% fines (by mass)	Poorly Graded	<6	≤1 or ≥3		SP	SAND
				Well Graded	≥6	1 to 3		SW	SAND
			Sands with >12% fines (by mass)	Below A Line	n/a			SM	SILTY SAND
				Above A Line	n/a			SC	CLAYEY SAND

Organic or Inorganic	Soil Group	Type of Soil	Laboratory Tests	Field Indicators					Organic Content	USCS Group Symbol	Primary Name
				Dilatancy	Dry Strength	Shine Test	Thread Diameter	Toughness (of 3 mm thread)			
INORGANIC (Organic Content ≤30% by mass)	FINE-GRAINED SOILS (≥50% by mass is smaller than 0.075 mm)	SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below)	Liquid Limit <50	Rapid	None	None	>6 mm	N/A (can't roll 3 mm thread)	<5%	ML	SILT
				Slow	None to Low	Dull	3mm to 6 mm	None to low	<5%	ML	CLAYEY SILT
				Slow to very slow	Low to medium	Dull to slight	3mm to 6 mm	Low	5% to 30%	OL	ORGANIC SILT
			Liquid Limit ≥50	Slow to very slow	Low to medium	Slight	3mm to 6 mm	Low to medium	<5%	MH	CLAYEY SILT
				None	Medium to high	Dull to slight	1 mm to 3 mm	Medium to high	5% to 30%	OH	ORGANIC SILT
		CLAYS (PI and LL plot above A-Line on Plasticity Chart below)	Liquid Limit <30	None	Low to medium	Slight to shiny	~ 3 mm	Low to medium	0% to 30% (see Note 2)	CL	SILTY CLAY
			Liquid Limit 30 to 50	None	Medium to high	Slight to shiny	1 mm to 3 mm	Medium		CI	SILTY CLAY
			Liquid Limit ≥50	None	High	Shiny	<1 mm	High		CH	CLAY
HIGHLY ORGANIC SOILS (Organic Content >30% by mass)		Peat and mineral soil mixtures							30% to 75%	PT	SILTY PEAT, SANDY PEAT
		Predominantly peat, may contain some mineral soil, fibrous or amorphous peat							75% to 100%		PEAT



Note 1 – Fine grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are non-plastic (i.e. a PL cannot be measured) are named SILT.

Note 2 – For soils with <5% organic content, include the descriptor "trace organics" for soils with between 5% and 30% organic content include the prefix "organic" before the Primary name.

Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML.

For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between "clean" and "dirty" sand or gravel.

For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.

A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to indicate a range of similar soil types within a stratum.

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
SILT/CLAY	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

Percentage by Mass	Modifier
>35	Use 'and' to combine major constituents (*i.e.*, SAND and GRAVEL)
> 12 to 35	Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable
> 5 to 12	some
≤ 5	trace

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve frictions are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); Nd:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC	Rock core
SC	Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample

SOIL TESTS

w	water content
PL , w_p	plastic limit
LL , w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, Gs)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

1. Tests anisotropically consolidated prior to shear are shown as CAD, CAU.

NON-COHESIVE (COHESIONLESS) SOILS

Compactness[2]

Term	SPT 'N' (blows/0.3m)[1]
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	>50

1. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.
2. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grainsize. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

COHESIVE SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N'[1,2] (blows/0.3m)
Very Soft	<12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	>200	>30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Water Content

Term	Description
w < PL	Material is estimated to be drier than the Plastic Limit.
w ~ PL	Material is estimated to be close to the Plastic Limit.
w > PL	Material is estimated to be wetter than the Plastic Limit.

GOLDER

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\,\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
NP	non-plastic
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c′	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p′	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1 $\tau = c' + \sigma' \tan \phi'$

2 shear strength = (compressive strength)/2

PROJECT: 19125451

RECORD OF BOREHOLE: 21-01

SHEET 1 OF 2

LOCATION: N 4999471.3 ;E 476602.8

BORING DATE: October 4, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m
GROUND SURFACE	76.04			
TOPSOIL - (SM-GM) SILTY SAND and GRAVEL; dark brown; moist	0.00			
(GP-GM) Sandy GRAVEL, some non-plastic fines; brown, contains cobbles and boulders; non-cohesive, moist to wet, compact	75.84 0.20	1	SS	28
		2	SS	27
(GP-GM) GRAVEL and SAND, some non-plastic fines; brown, contains cobbles and boulders; non-cohesive, wet, compact to very dense	73.91 2.13	3	SS	20
		4	SS	22
		5	SS	21
		6	SS	39
		7	SS	45
		8	SS	43
		9	SS	51
		10	SS	40
(GW-GM) Sandy GRAVEL, some non-plastic fines; grey, contains cobbles and boulders; non-cohesive, wet, dense to very dense	67.66 8.38	11	SS	49
		12	SS	66
End of Borehole	66.28 9.76			

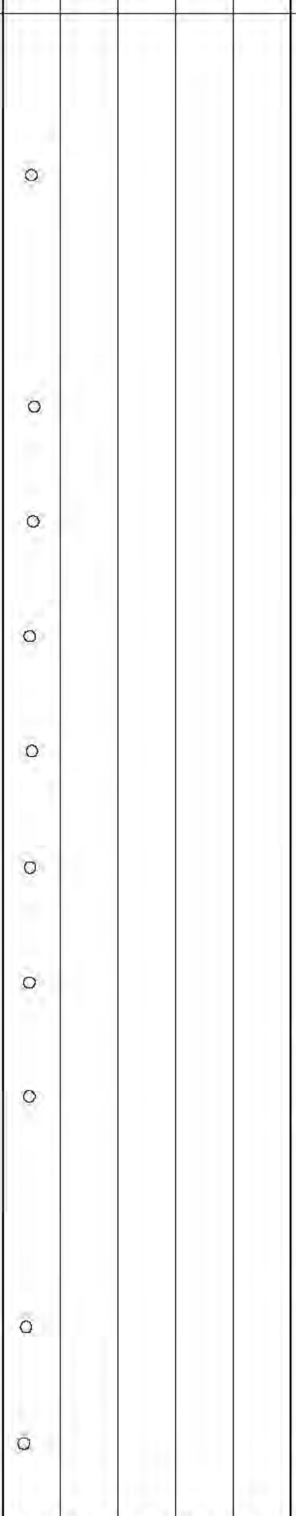
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

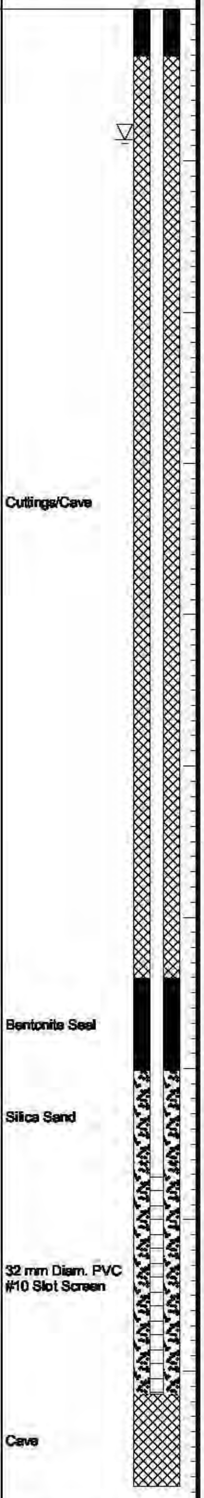
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING



PIEZOMETER OR STANDPIPE INSTALLATION



CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

LOGGED: RI
CHECKED: CRG

PROJECT: 19125451

RECORD OF BOREHOLE: 21-01

SHEET 2 OF 2

LOCATION: N 4999471.3 ;E 476602.8

BORING DATE: October 4, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{6} 10^{5} 10^{4} 10^{3} WATER CONTENT PERCENT Wp ├──○W──┤ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.30m				
		— CONTINUED FROM PREVIOUS PAGE —									
10		Note(s) 1. Water level in well screen at 0.86 mbgs (Elev. 75.18 m) on November 12, 2021									
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

DEPTH SCALE

1 : 50

LOGGED: RI

CHECKED: CRG

PROJECT: 19125451

RECORD OF BOREHOLE: TW21-01

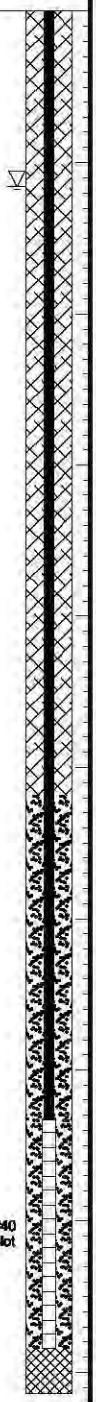
SHEET 1 OF 1

LOCATION: N 4999480.2 ;E 476616.3

BORING DATE: October 25, 27-29, 2021

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.30m				
		GROUND SURFACE		76.34							
0	Tricone Rotary Mud Drilling	Probably SAND and GRAVEL		0.00							
5		Probable GRAVEL to sandy GRAVEL		71.16 5.18							
9		End of Borehole		67.20 9.14							



Note(s)

1. Water level in well screen at 1.16 mbgs (Elev. 75.18 m) on November 12, 2021

DEPTH SCALE

1 : 50

LOGGED: RI

CHECKED: DH

PROJECT: 921-2709

RECORD OF BOREHOLE OW-1

SHEET 1 OF 1

LOCATION: See Plan

BORING DATE: Mar 11to13,1992

DATUM: Geodetic

DIP:

SAMPLER HAMMER, 63.5kg; DROP, 760 mm

BORING METHOD: Power Auger, 200mm Diam (Hollow Stem)

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)
0	Ground Surface	76.98 0.00
0 – 5.40	Very dense brown SAND and GRAVEL, trace silt, some cobbles, nested cobbles from 2.3 to 2.8 metres	71.58 5.40
5.40 – 9.91	Compact to dense grey fine to coarse GRAVEL, some sandier zones, many cobbles	67.07 9.91
9.91 – 13.66	Very dense dark grey sandy silt, some gravel, trace clay, some cobbles and boulders (GLACIAL TILL)	63.32 13.66
13.66	End of Hole Auger Refusal	

SAMPLES NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB. TESTING
1	50 DO	47		
2	50 DO	75		MH
3	50 DO	61		
4	50 DO	34		
5	50 DO	29		MH
6	50 DO	53		
7	50 DO	135		
8	50 DO	76		MH

GAS CONCENTRATION ⊕ ( )

% LEL ☐

HYDRAULIC CONDUCTIVITY, K, cm/s

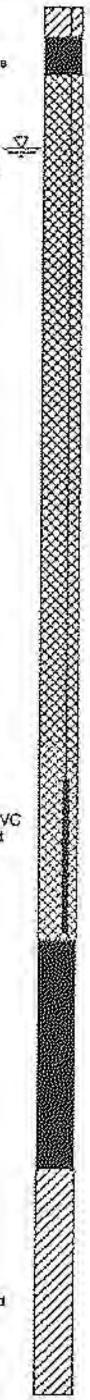
WATER CONTENT, PERCENT

Wp ⊢—○W—⊣ Wl

20 40 60 80

INSTALLATIONS

A



Native Backfill

Bentonite Seal

Native & Caved Backfill

50mm PVC #10 Slot Screen

Native and Caved Backfill

W.L. In Screen at Elev.75.61m Apr. 1, 1991

DATA INPUT: Disk 11, Stever

DEPTH SCALE (ALONG HOLE)

1 to 75

Golder Associates

LOGGED: P.A.S

CHECKED:

PROJECT: 921-2709

RECORD OF BOREHOLE OW-2

SHEET 1 OF 1

LOCATION: See Plan

BORING DATE: Mar 16,1992

DATUM: Geodetic

DIP:

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

BORING METHOD: Power Auger 200mm Diam (Hollow Stem)

SOIL PROFILE

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)
0	Ground Surface	76.48 0.00
0–4.30	Compact brown SAND and GRAVEL, trace silt, some cobbles	72.18 4.30
4.30–10.21	Dense grey SANDY GRAVEL, some cobbles	66.27 10.21
10.21–13.93	Compact to very dense grey sandy silt, some gravel, trace clay (GLACIAL TILL)	62.55 13.93
13.93	End of Hole	

SAMPLES

NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB. TESTING
1	50 DO	18		
2	50 DO	30		
3	50 DO	34		
4	50 DO	43		
5	50 DO	35		M
6	50 DO	34		
7	50 DO	27		
8	50 DO	> 100		
9	50 DO	> 100		

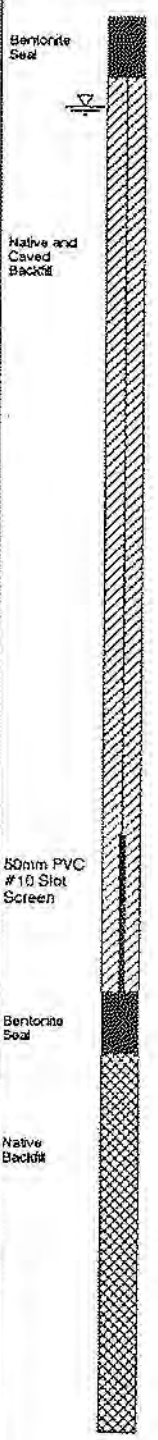
GAS CONCENTRATION ⊕ ( )

% LEL □

HYDRAULIC CONDUCTIVITY, k, cm/s

WATER CONTENT, PERCENT Wp W Wl 20 40 60 80

INSTALLATIONS



W.L in Screen at Elev.75.60m Apr. 1, 1992

DEPTH SCALE (ALONG HOLE)

1 to 75

Golder Associates

LOGGED: P.A.S

CHECKED: PRS

DATA INPUT: Disk 11, Stever

PROJECT: 921-2709
LOCATION: See Plan
DIP:

RECORD OF BOREHOLE OW-3

BORING DATE: Mar 18,1992

SHEET 1 OF 1
DATUM: Geodetic
SAMPLER HAMMER, 63.5kg; DROP, 760 mm

BORING METHOD: Power Auger 200mm Diam (Hollow Stem)

SOIL PROFILE

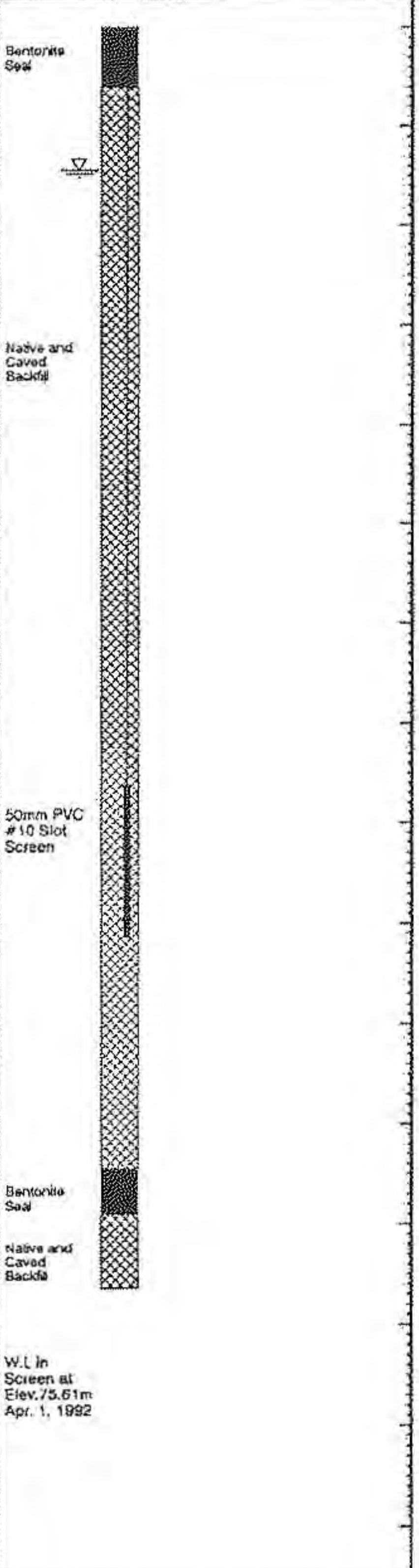
DESCRIPTION	ELEV. DEPTH (m)
Ground Surface	77.04 0.00
Dense grey brown SAND and GRAVEL, trace silt	74.94 2.10
Compact to dense grey fine to medium SAND, trace gravel, some gravelly sand bands	69.14 7.90
Compact grey medium to coarse SAND, trace to some fine gravel	66.31 10.73
Compact to dense grey sandy silt, some gravel and cobbles, trace clay, boulders (GLACIAL TILL)	64.39 12.65
End of Hole Auger Refusal	

SAMPLES

NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB TESTING
1	50 DO	39		
2	50 DO	10		
3	50 DO	22		
4	50 DO	43		
5	50 DO	20		
6	50 DO	21		
7	50 DO	27		

GAS CONCENTRATION ⊕ ( )
% LEL ☐
HYDRAULIC CONDUCTIVITY, k, cm/s
WATER CONTENT, PERCENT
Wp W Wl
20 40 60 80

INSTALLATIONS



W.L in Screen at Elev.75.61m Apr. 1, 1992

DEPTH SCALE (ALONG HOLE)
1 to 75

DATA INPUT: Disk 11, Stever

Golder Associates

LOGGED: P.A.S
CHECKED: PAS

PROJECT: 921-2709

RECORD OF BOREHOLE OW-4

SHEET 1 OF 1

LOCATION: See Plan

BORING DATE: Mar 17,1992

DATUM: Geodetic

DIP:

SAMPLER HAMMER, 63.5kg; DROP, 760 mm

BORING METHOD: Power Auger, 200mm Diam (Hollow Stem)

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
	Ground Surface	76.36
0	Compact brown to grey fine to coarse GRAVEL, trace sand, occasional cobbles	0.00
10.52	Compact grey SAND and GRAVEL, some silt	65.84 10.52
10.98	Probably Glacial Till	65.36 10.98
13.11	End of Hole	63.25 13.11

SAMPLES NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB. TESTING
1	50 DO	12		
2	50 DO	9		
3	50 DO	25		
4	50 DO	16		
5	50 DO	20		
6	50 DO	14		
7	50 DO	35		

GAS CONCENTRATION ⊕ ( )

% LEL □

HYDRAULIC CONDUCTIVITY, k, cm/s

WATER CONTENT, PERCENT
Wp W Wl
20 40 60 80

INSTALLATIONS

A

Native and Caved Backfill

50mm PVC #10 Slot Screen

Bentonite Seal

Native and Caved Backfill

W.L in Screen at Elev.75.60m Apr. 1, 1992

DATA INPUT: Disk 11. Stever

DEPTH SCALE (ALONG HOLE)
1 to 75

Golder Associates

LOGGED: P.A.S
CHECKED:

PROJECT: 921-2709
LOCATION: See Plan
DIP:

RECORD OF BOREHOLE OW-5

BORING DATE: Mar.20,1992
SAMPLER HAMMER, 63.5kg; DROP, 760 mm

SHEET 1 OF 1
DATUM: Geodetic

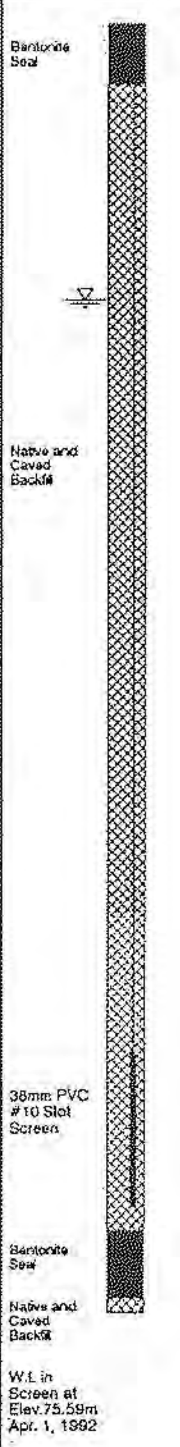
DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB. TESTING
	Power Auger 200mm Diam (Hollow Stem)	Ground Surface		78.31					
0		TOPSOIL		0.00					
		Brown SILTY SAND, trace gravel, occasional cobble		0.18					
1		Brown CLAYEY SILT		77.40 0.91	1	AS			
2		Loose brown SILTY fine SAND		76.79 1.52	2	50 DO	9		
3		Compact grey fine SAND, occasional sandy silt to clayey silt layer		76.16 2.15	3	50 DO	12		
4 5 6 7 8 9 10 11		Loose to compact grey fine to medium SAND		74.61 3.70	4 5 6	50 DO 50 DO 50 DO	5 11 12		 M
12		Dense grey sandy silt, some gravel, trace clay (GLACIAL TILL)		67.03 11.28		50 DO	>100		
13 14 15		End of Hole Auger Refusal		65.60 12.71					

GAS CONCENTRATION ⊕ ( )
% LEL ☐

HYDRAULIC CONDUCTIVITY, K, cm/s
WATER CONTENT, PERCENT
Wp ⊢—O^W—⊣ Wl
20 40 60 80

INSTALLATIONS

A



DATA INPUT: Disk 11, Stever

DEPTH SCALE (ALONG HOLE)
1 to 75

Golder Associates

LOGGED: P.A.S
CHECKED:

PROJECT: 921-2709

RECORD OF BOREHOLE OW-6

SHEET 1 OF 2

LOCATION: See Plan

BORING DATE: Mar.19,1992

DATUM: Geodetic

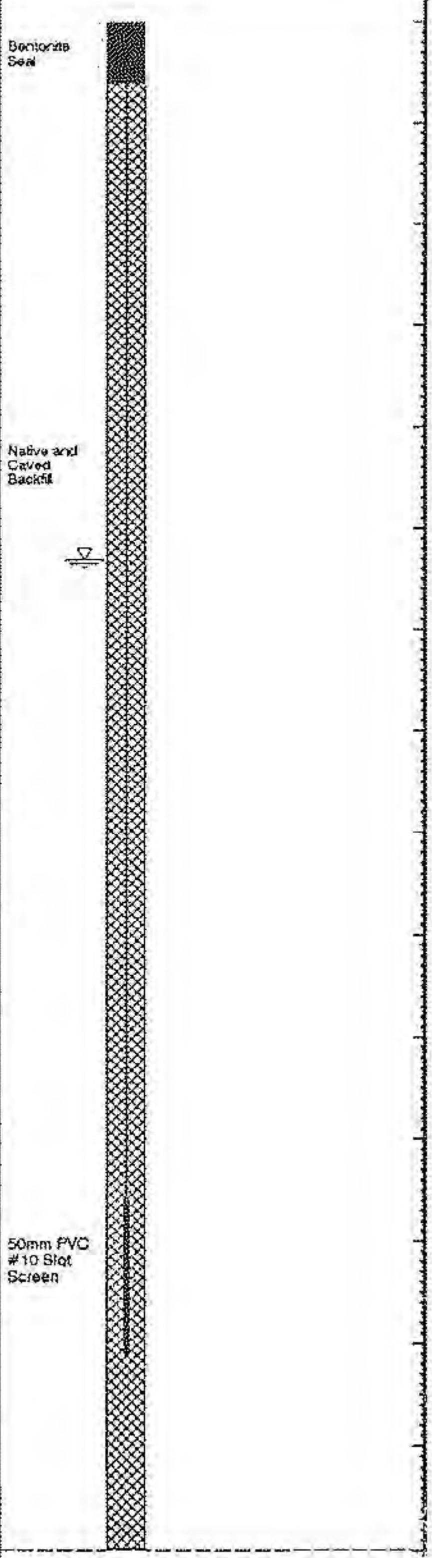
DIP:

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm.

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB. TESTING	GAS CONCENTRATION ⊕ ( ) / % LEL ☐	HYDRAULIC CONDUCTIVITY, k, cm/s / WATER CONTENT, PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80
		Ground Surface		80.72							
0	Power Auger 200mm Diam (Hollow Stem)	TOPSOIL		0.00							
				0.21							
1		Loose to compact brown SILTY SAND to fine SAND, some gravel			1	AS					
2					2	50 DO	9				
				78.43 2.29							
3					3	50 DO	17				
4											
5											
6					4	50 DO	14				
7		Compact grey fine to medium SAND, trace to some silt to SILTY fine SAND, occasional sandy silt layer, medium sand layer from 9.0 - 10.0 metre depth									
8					5	50 DO	11				
9					6	50 DO	13				
10											
11					7	50 DO	14				
12					8	50 DO	15				
13											
14											
15		Dense grey sandy silt, some gravel, trace clay (GLACIAL TILL)		65.76							

CONTINUED ON NEXT PAGE

INSTALLATIONS



DEPTH SCALE (ALONG HOLE)
1 to 75

Golder Associates

LOGGED: P.A.S
CHECKED: MS

DATA INPUT: Disk 11, Stever

PROJECT: 921-2709

LOCATION: See Plan

DIP:

RECORD OF BOREHOLE OW-6

BORING DATE: Mar 19,1992

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

SHEET 2 OF 2

DATUM, Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES					GAS CONCENTRATION ⊕ ( ) / % LEL □	HYDRAULIC CONDUCTIVITY, K, cm/s / WATER CONTENT, PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	INSTALLATIONS A
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB. TESTING			
		CONTINUED FROM PREVIOUS PAGE										
15	Power Auger 200mm Diam. (Hollow Stem)	Dense grey sandy silt, some gravel, trace clay (GLACIAL TILL)	▨	64.87	9	50 DO	57					Native and Caved Backfill ▩
16		End of Hole		15.85								W.L in Screen at Elev.75.43m Apr. 1, 1992
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												

DATA INPUT: Disk 11, Stever

DEPTH SCALE (ALONG HOLE)

1 to 75

Golder Associates

LOGGED: P.A.S

CHECKED: PAS

RECORD OF BOREHOLE 13

SHEET 1 of 2

LOCATION See Figure 6

BORING DATE Dec.18&19, 1989

DATUM Geodetic

SAMPLER HAMMER, 63.5kg, DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg, DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (M)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3M	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m / SHEAR STRENGTH Cu, kPa nat.V.- + Q.- ● rem.V.- ⊕ U.- ○	HYDRAULIC CONDUCTIVITY, k, CM/SEC / WATER CONTENT, PERCENT Wp W Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
0	Power Auger 200mm Diam. (Hollow Stem)	Ground Surface	82.28							
		TOPSOIL	0.00							Bentonite Seal
		Compact to dense brown fine SAND, some silt, trace gravel, occasional silt seam	0.21							Backfill
2				1	50 DO	21				
3		Very dense to compact grey medium to fine SAND, trace silt and some gravel	79.00 3.26	2	50 DO	65				
5				3	50 DO	56				
6				4	50 DO	34				▽
8				5	50 DO	27			M	
9				6	50 DO	29			M	
10		Hole Continued	72.28 10.00							Caved Backfill

0
15 ◆ 5 PERCENT AXIAL STRAIN AT FAILURE
10

DEPTH SCALE
1 : 50

Golder Associates

LOGGED J.COBISA
CHECKED TB

RECORD OF BOREHOLE 13

SHEET 2 of 2

LOCATION: See Figure 6

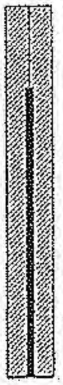
BORING DATE: Dec.18&19, 1989

DATUM: Geodetic

SAMPLER HAMMER, 63.5kg, DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg, DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (M)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3M	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m / SHEAR STRENGTH Cu, kPa nat.V.- + Q.- ● rem.V.- ⊕ U.- ○	HYDRAULIC CONDUCTIVITY, k, CM/SEC / WATER CONTENT, PERCENT Wp W Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
10		Hole Continued		72.26							Caved Backfill
	Power Auger 200mm Diam. (Hollow Stem)			10.00							
11		Compact grey fine to medium SAND, trace gravel			7	50 DO	27				38mm PVC #10 Slot Screen
12				69.89	8	50 DO	0				
		End of Hole Auger Refusal		12.37							W.L. in Well Screen at Elev. 75.56m Apr. 1, 1992
13											
14											
15											
16											
17											
18											
19											
20											



15-◆-5 PERCENT AXIAL STRAIN AT FAILURE 0 10

DEPTH SCALE
1 : 50

Golder Associates

LOGGED J.COBISA

CHECKED DB

APPENDIX B

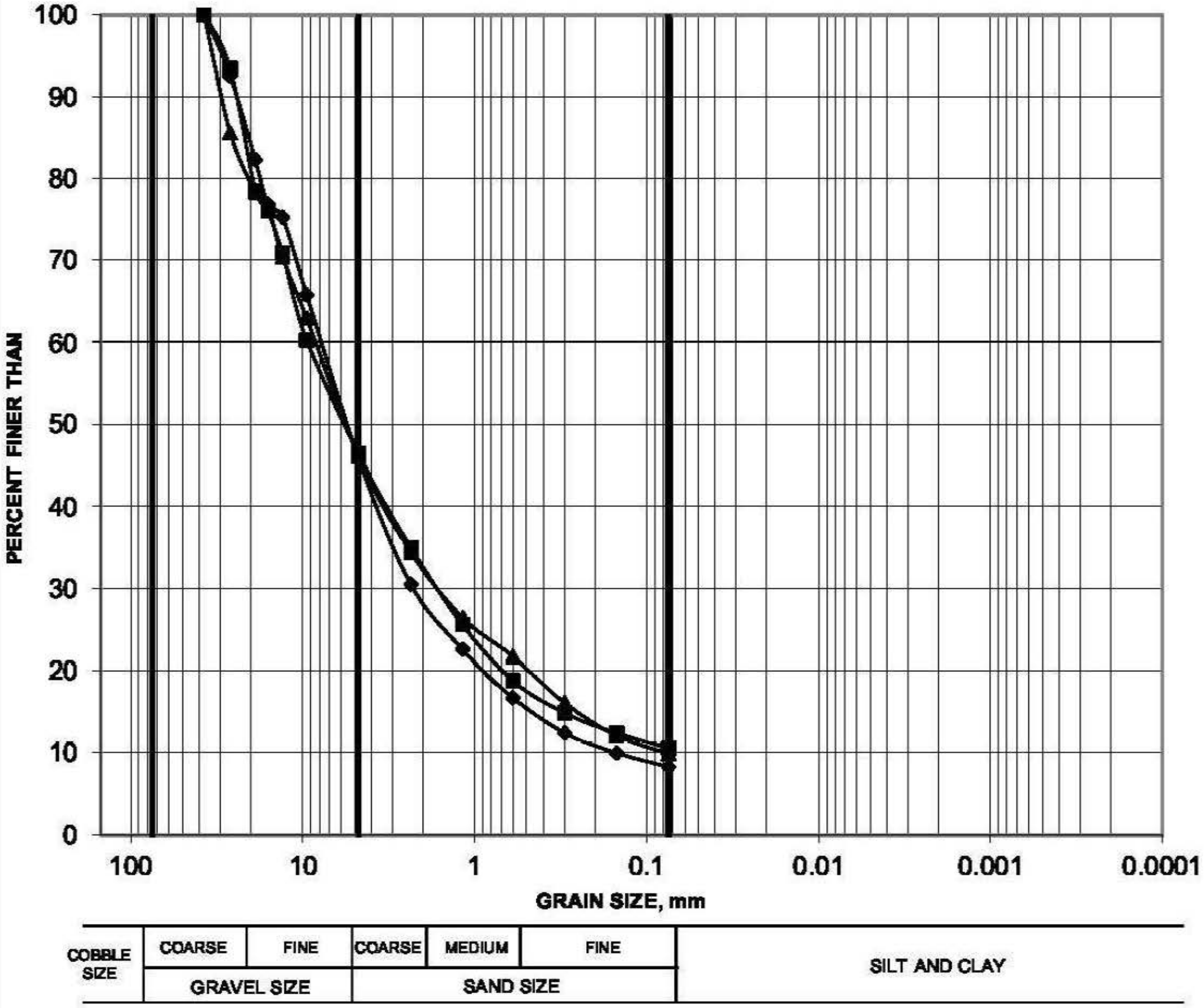
Grain Size Distribution Curves – Current Investigation

Grain Size Distribution Curves – Golder 1992 Investigation

GRAIN SIZE DISTRIBUTION

FIGURE 1

(GP-GM) SANDY GRAVEL & (GP-GM) GRAVEL and SAND



				Constituents (%)			
	Borehole	Sample	Depth (m)	Gravel	Sand	Silt	Clay
■	21-01	1	0.76-1.37	54	35	11	
◆	21-01	4	3.05-3.66	54	38	8	
▲	21-01	7	5.33-5.94	54	36	10	

GOLDER
MEMBER OF WSP

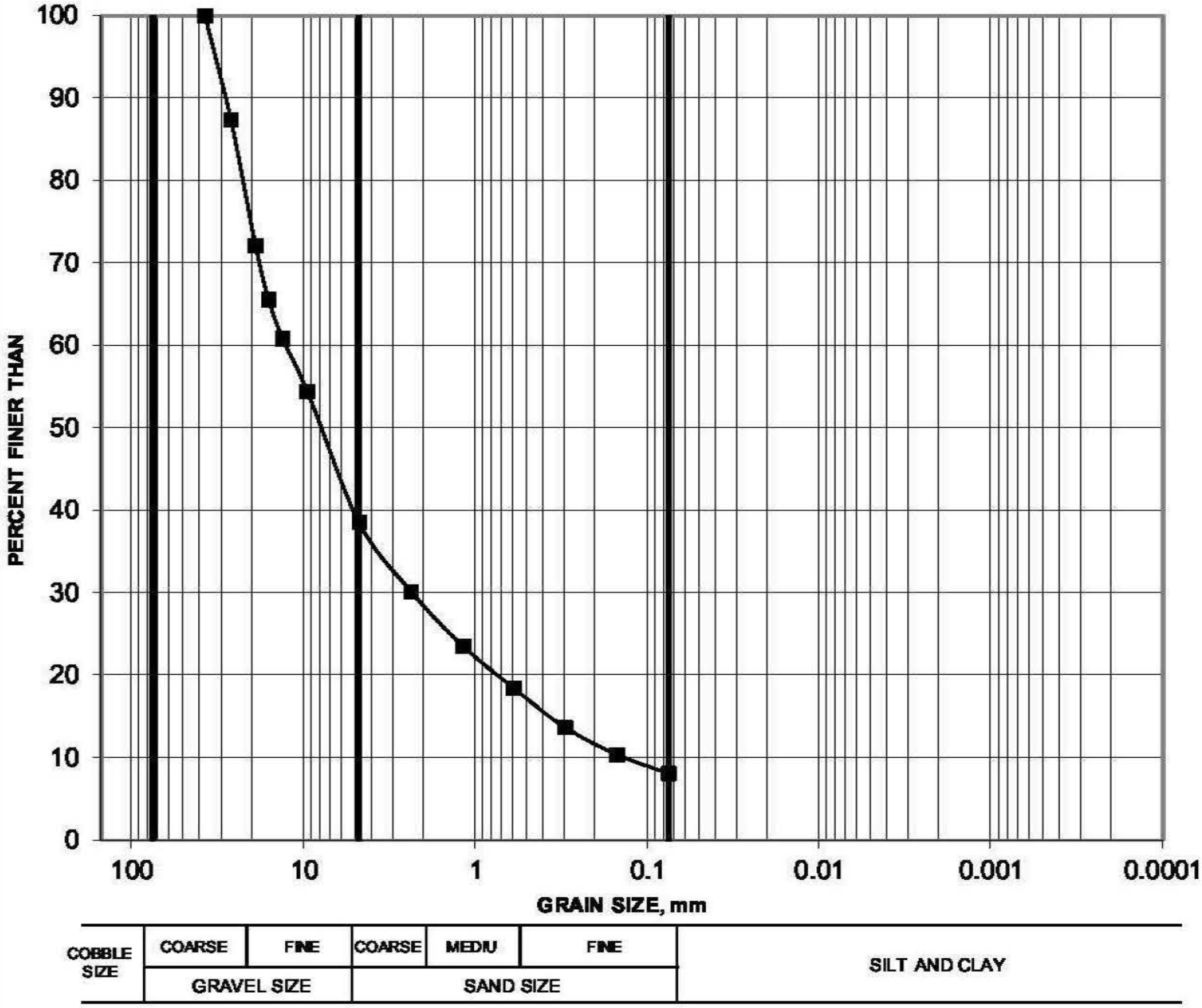
Project: 19125451

https://golderassociates.sharepoint.com/sites/35409g/Shared Documents/Active/2019/19125451/figures/

Created by: CW
Checked by: MI

GRAIN SIZE DISTRIBUTION	FIGURE 2

(GW-GM) SANDY GRAVEL



				Constituents (%)			
	Borehole	Sample	Depth (m)	Gravel	Sand	Silt	Clay
—■—	21-01	11	8.38-8.99	61	31	8	

Project: 19125451

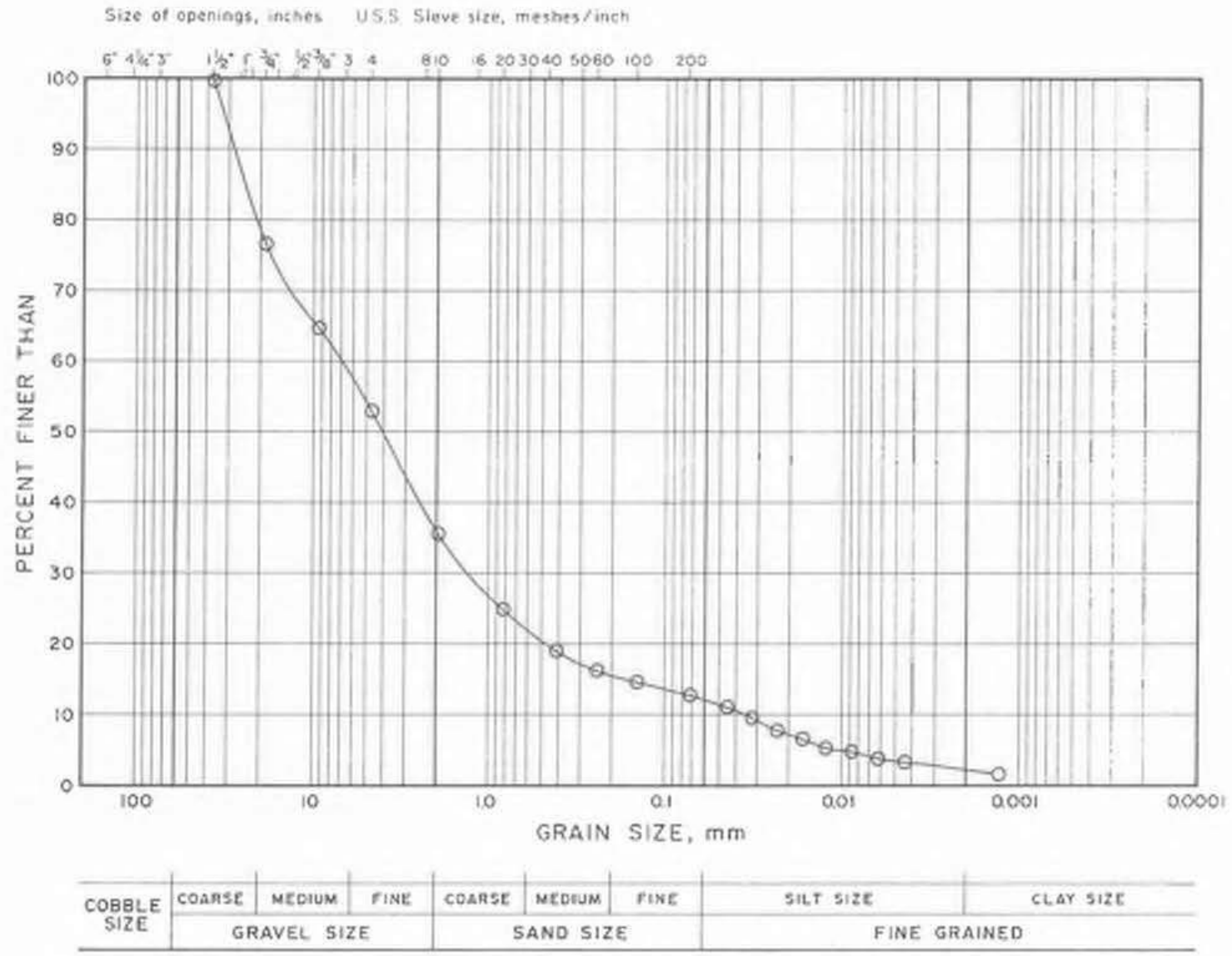
GOLDER
MEMBER OF WSP

Created by:	CW
Checked by:	MI

GRAIN SIZE DISTRIBUTION

FIGURE B-1

SILTY SAND AND GRAVEL



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV. (m)
○	OW-1	2	73.70

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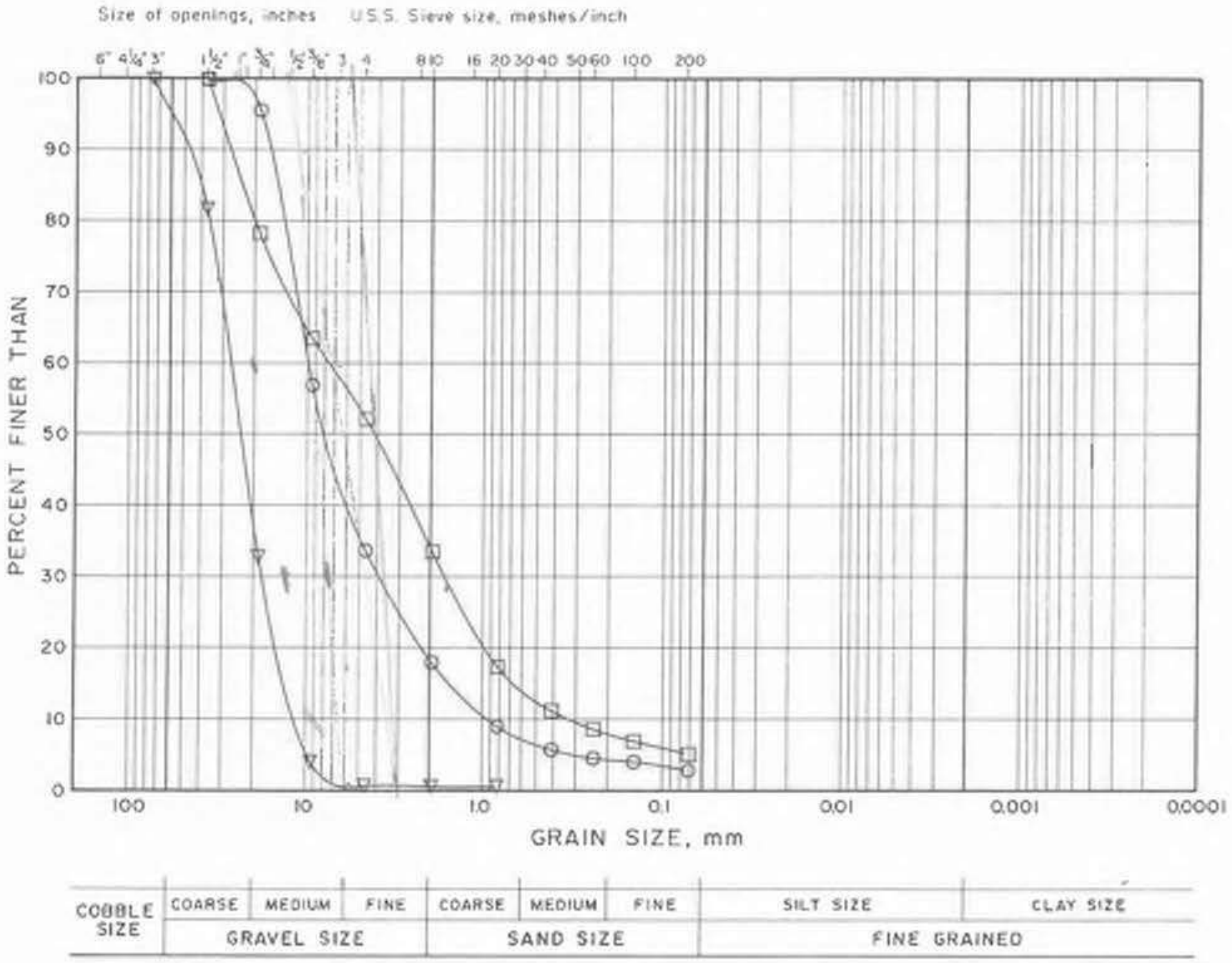
GRAIN SIZE DISTRIBUTION

FIGURE B-2

GRAVEL TO SANDY GRAVEL



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV. (m)
○	OW-1	5	69.05
□	OW-2	5	68.55
▽	OW-4		71.86

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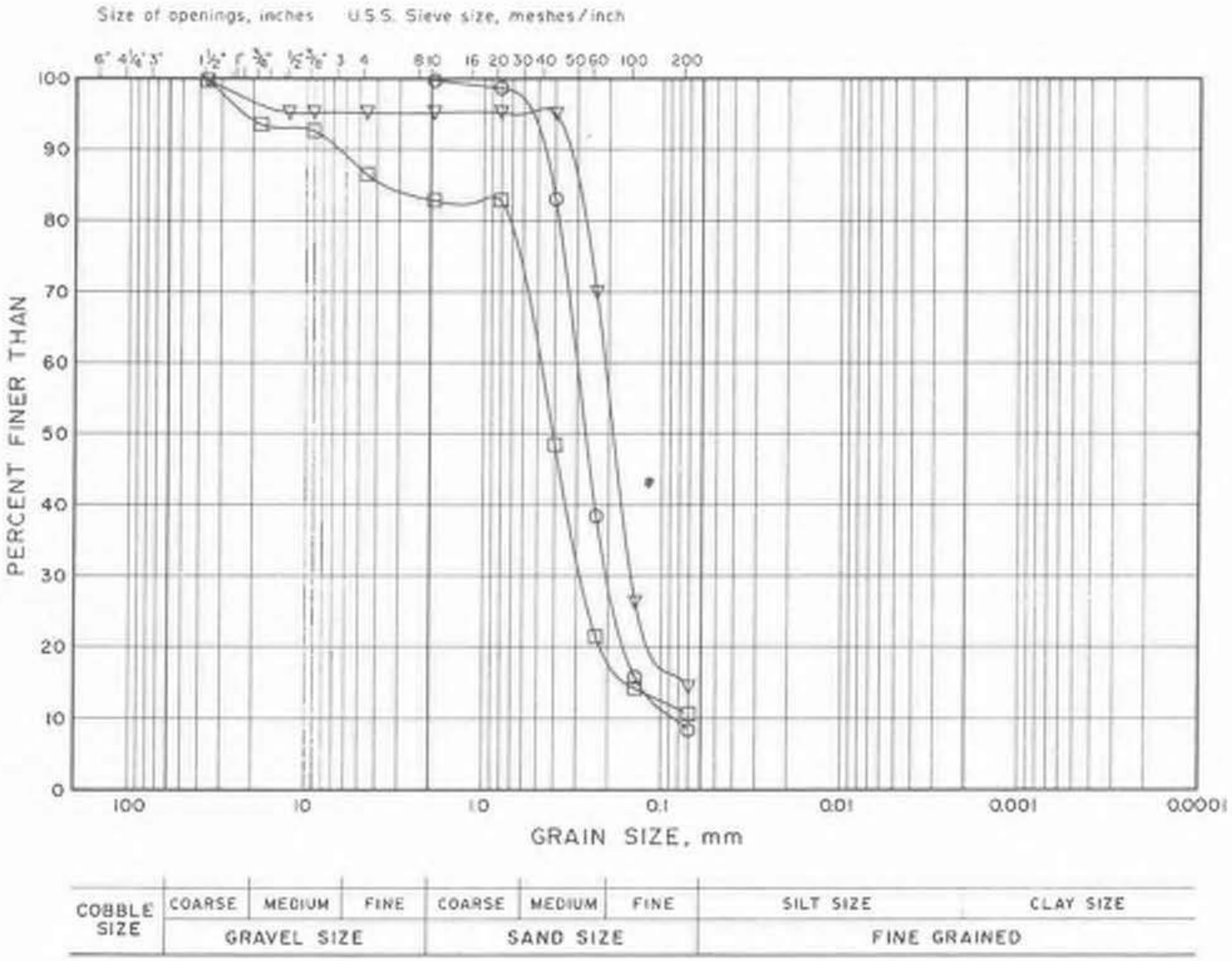
GRAIN SIZE DISTRIBUTION

FIGURE B-3

FINE TO MEDIUM SAND



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV. (m)
○	OW-5	5	71.85
□	13	5	74.45
▽	13	6	72.80

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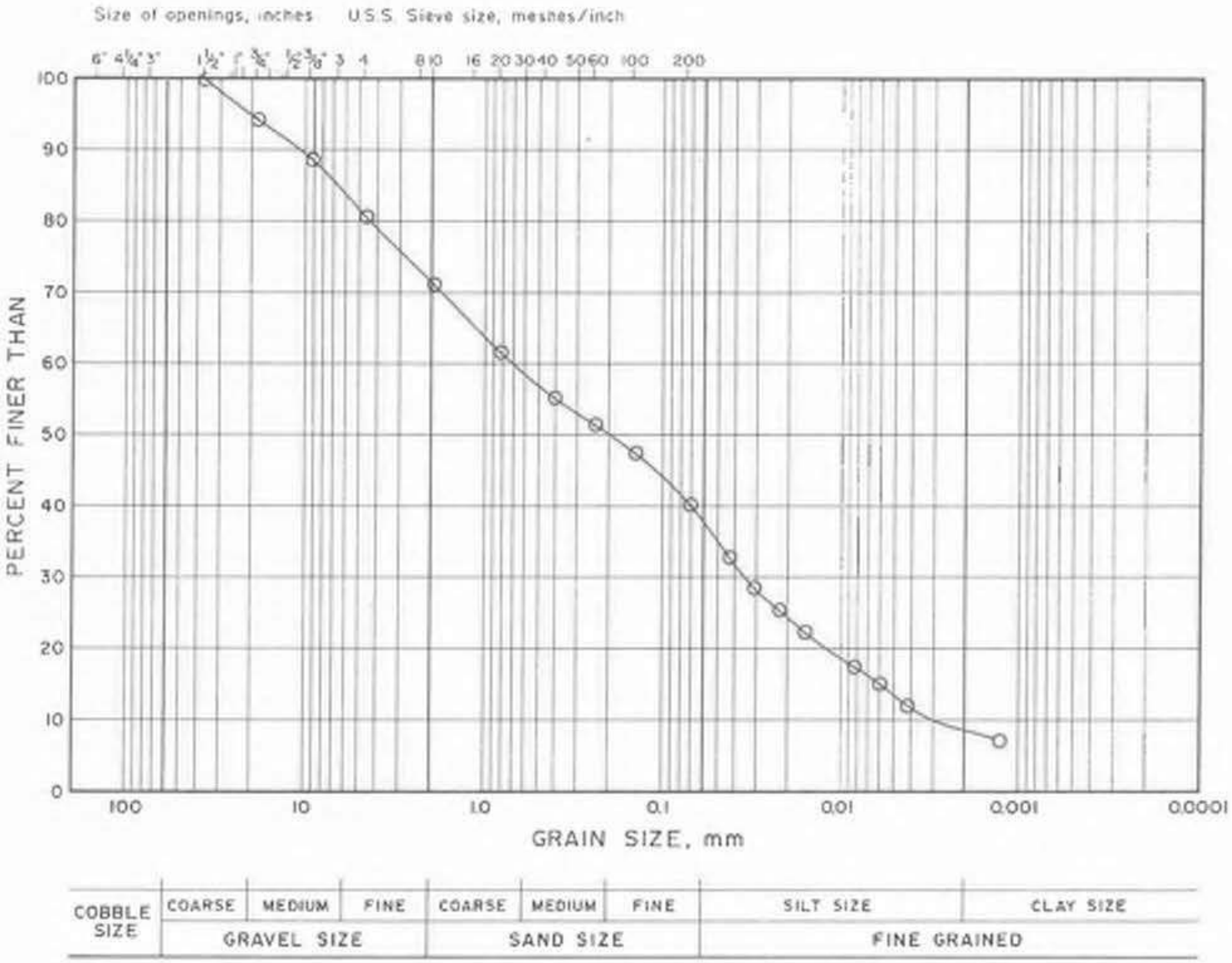
GRAIN SIZE DISTRIBUTION

FIGURE B-4

GLACIAL TILL



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV. (m)
○	OW-1	8	64.45

Project 921-2709

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APPENDIX C

Results of Chemical Analyses

eurofins | Environment Testing

Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Chaitanya Raj Goyal
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1965819
Date Submitted: 2021-10-29
Date Reported: 2021-11-05
Project: 19125451
COC #: 881977

				Lab I.D.	1592565
				Sample Matrix	Soil
				Sample Type	
				Sampling Date	2021-10-04
				Sample I.D.	21-01 sa2 / 5-7'
Group	**Analyte**	**MRL**	**Units**	**Guideline**	
Anions	Cl	0.002	%		<0.002
	SO4	0.01	%		<0.01
General Chemistry	Electrical Conductivity	0.05	mS/cm		0.125
	pH	2.00			8.53
	Resistivity	1	ohm-cm		8333

Guideline = *** = Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

APPENDIX B

Record of Boreholes and Water Well Record

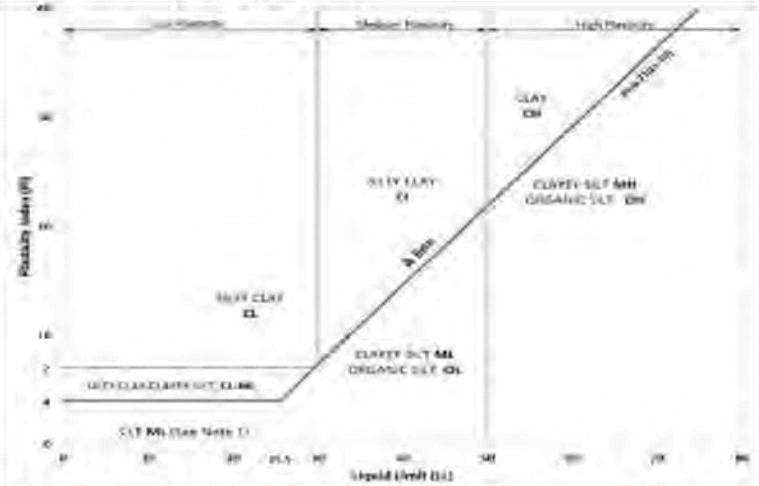
APPENDIX B-I

Current Investigation

The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)

Organic or Inorganic	Soil Group	Type of Soil		Gradation or Plasticity	$Cu = \frac{D_{60}}{D_{10}}$	$Cc = \frac{(D_{30})^2}{D_{10}xD_{60}}$	Organic Content	USCS Group Symbol	Group Name
INORGANIC (Organic Content ≤30% by mass)	COARSE-GRAINED SOILS (>50% by mass is larger than 0.075 mm)	GRAVELS (>50% by mass of coarse fraction is larger than 4.75 mm)	Gravels with ≤12% fines (by mass)	Poorly Graded	<4	≤1 or ≥3	≤30%	GP	GRAVEL
				Well Graded	≥4	1 to 3		GW	GRAVEL
			Gravels with >12% fines (by mass)	Below A Line	n/a			GM	SILTY GRAVEL
				Above A Line	n/a			GC	CLAYEY GRAVEL
		SANDS (≥50% by mass of coarse fraction is smaller than 4.75 mm)	Sands with ≤12% fines (by mass)	Poorly Graded	<6	≤1 or ≥3		SP	SAND
				Well Graded	≥6	1 to 3		SW	SAND
			Sands with >12% fines (by mass)	Below A Line	n/a			SM	SILTY SAND
				Above A Line	n/a			SC	CLAYEY SAND

Organic or Inorganic	Soil Group	Type of Soil	Laboratory Tests	Field Indicators					Organic Content	USCS Group Symbol	Primary Name
				Dilatancy	Dry Strength	Shine Test	Thread Diameter	Toughness (of 3 mm thread)			
INORGANIC (Organic Content ≤30% by mass)	FINE-GRAINED SOILS (≥50% by mass is smaller than 0.075 mm)	SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below)	Liquid Limit <50	Rapid	None	None	>6 mm	N/A (can't roll 3 mm thread)	<5%	ML	SILT
				Slow	None to Low	Dull	3mm to 6 mm	None to low	<5%	ML	CLAYEY SILT
				Slow to very slow	Low to medium	Dull to slight	3mm to 6 mm	Low	5% to 30%	OL	ORGANIC SILT
			Liquid Limit ≥50	Slow to very slow	Low to medium	Slight	3mm to 6 mm	Low to medium	<5%	MH	CLAYEY SILT
				None	Medium to high	Dull to slight	1 mm to 3 mm	Medium to high	5% to 30%	OH	ORGANIC SILT
		CLAYS (PI and LL plot above A-Line on Plasticity Chart below)	Liquid Limit <30	None	Low to medium	Slight to shiny	~ 3 mm	Low to medium	0% to 30% (see Note 2)	CL	SILTY CLAY
			Liquid Limit 30 to 50	None	Medium to high	Slight to shiny	1 mm to 3 mm	Medium		CI	SILTY CLAY
			Liquid Limit ≥50	None	High	Shiny	<1 mm	High		CH	CLAY
HIGHLY ORGANIC SOILS (Organic Content >30% by mass)		Peat and mineral soil mixtures							30% to 75%	PT	SILTY PEAT, SANDY PEAT
		Predominantly peat, may contain some mineral soil, fibrous or amorphous peat							75% to 100%		PEAT



Note 1 – Fine grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are non-plastic (i.e. a PL cannot be measured) are named SILT.

Note 2 – For soils with <5% organic content, include the descriptor "trace organics" for soils with between 5% and 30% organic content include the prefix "organic" before the Primary name.

Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML.

For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between "clean" and "dirty" sand or gravel.

For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.

A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to indicate a range of similar soil types within a stratum.

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
SILT/CLAY	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

Percentage by Mass	Modifier
>35	Use 'and' to combine major constituents (*i.e.*, SAND and GRAVEL)
> 12 to 35	Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable
> 5 to 12	some
≤ 5	trace

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve frictions are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); Nd:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC	Rock core
SC	Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample

SOIL TESTS

w	water content
PL , w_p	plastic limit
LL , w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, Gs)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

1. Tests anisotropically consolidated prior to shear are shown as CAD, CAU.

NON-COHESIVE (COHESIONLESS) SOILS

Compactness[2]

Term	SPT 'N' (blows/0.3m)[1]
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	>50

1. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.
2. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grainsize. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

COHESIVE SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N'[1,2] (blows/0.3m)
Very Soft	<12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	>200	>30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Water Content

Term	Description
w < PL	Material is estimated to be drier than the Plastic Limit.
w ~ PL	Material is estimated to be close to the Plastic Limit.
w > PL	Material is estimated to be wetter than the Plastic Limit.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index $= (w_l - w_p)$
NP	non-plastic
w_s	shrinkage limit
I_L	liquidity index $= (w - w_p) / I_p$
I_C	consistency index $= (w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction $= \tan\delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1 $\tau = c' + \sigma' \tan\phi'$
2 shear strength = (compressive strength)/2

PROJECT: 19125451

RECORD OF BOREHOLE: 21-01

SHEET 1 OF 2

LOCATION: N 4999471.3 ;E 476602.8

BORING DATE: October 4, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.04							
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL - (SM-GM) SILTY SAND and GRAVEL; dark brown; moist		0.00							
		(GP-GM) Sandy GRAVEL, some non-plastic fines; brown, contains cobbles and boulders; non-cohesive, moist to wet, compact		75.84 0.20							▽
1					1	SS	28		○		
					2	SS	27				
2		(GP-GM) GRAVEL and SAND, some non-plastic fines; brown, contains cobbles and boulders; non-cohesive, wet, compact to very dense		73.91 2.13							
					3	SS	20		○		
3					4	SS	22		○		Cuttings/Cave
4					5	SS	21		○		
5					6	SS	39		○		
					7	SS	45		○		
6					8	SS	43		○		Bentonite Seal
7					9	SS	51		○		Silica Sand
8					10	SS	40				
		(GW-GM) Sandy GRAVEL, some non-plastic fines; grey, contains cobbles and boulders; non-cohesive, wet, dense to very dense		67.66 8.38							32 mm Diam. PVC #10 Slot Screen
					11	SS	49		○		
9					12	SS	66		○		Cave
		End of Borehole		66.28 9.76							
10											

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50

WSP GOLDER

LOGGED: RI

CHECKED: CRG

PROJECT: 19125451

RECORD OF BOREHOLE: 21-01

SHEET 2 OF 2

LOCATION: N 4999471.3 ;E 476602.8

BORING DATE: October 4, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{6} 10^{5} 10^{4} 10^{3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.30m				
		— CONTINUED FROM PREVIOUS PAGE —									
10		Note(s) 1. Water level in well screen at 0.86 mbgs (Elev. 75.18 m) on November 12, 2021									
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

DEPTH SCALE

1 : 50

LOGGED: RI

CHECKED: CRG

PROJECT: 19125451

RECORD OF BOREHOLE: TW21-01

SHEET 1 OF 1

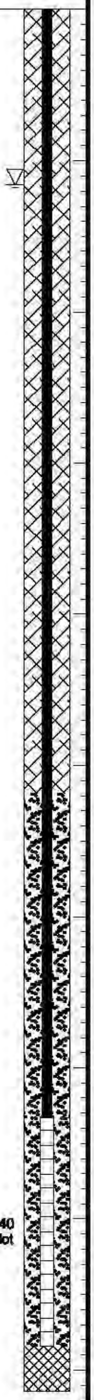
LOCATION: N 4999480.2 ;E 476616.3

BORING DATE: October 25, 27-29, 2021

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.34							
0	Tricone Rotary Mud Drilling	Probably SAND and GRAVEL		0.00							
5		Probable GRAVEL to sandy GRAVEL		71.16 5.18							
9		End of Borehole		67.20 9.14							

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10



Note(s)

1. Water level in well screen at 1.16 mbgs (Elev. 75.18 m) on November 12, 2021

MIS-BHS 001 19125451.GPJ GAL-MIS.GDT 1/25/23 JEM

DEPTH SCALE

1 : 50

LOGGED: RI

CHECKED: DH

Ontario Ministry of the Environment, Conservation and Parks

Measurements recorded in: ☐ Metric ☑ Imperial

Well Tag No. (Place Sticker and/or Print Below) 4337548

Well Record

Regulation 903 Ontario Water Resources Act

Page ____ of ____

Well Owner's Information

First Name:
Last Name/Organization: Corp. of the township of North Dundas
E-mail Address: arutley@northdundas.com
☐ Well Constructed by Well Owner
Mailing Address (Street Number/Name): 636 ST. Lawrence St. P.O. Box 489
Municipality: Township of North Dundas
Province: ON
Postal Code: K0C 2K0
Telephone No. (inc. area code): 774-2105

Well Location

Address of Well Location (Street Number/Name): [redacted] La Fleur Road
Township: North Dundas
Lot: 14
Concession: 9
County/District/Municipality: Stormont, Dundas & Glengarry
City/Town/Village: Winchester
Province: **Ontario**
Postal Code: K0C 2K0
UTM Coordinates: Zone: NAD 8 3 | 18 Easting: [illegible] Northing: [illegible]
Municipal Plan and Sublot Number:
Other:

Overburden and Bedrock Materials/Abandonment Sealing Record (see instructions on the back of this form)

General Colour	Most Common Material	Other Materials	General Description	Depth (m/ft) From	To
	gravel	sand		0	17
	gravel			17	30

#40 slot screen from 24-29' [illegible] gravel pack

Annular Space

Depth Set at (m/ft) From	To	Type of Sealant Used (Material and Type)	Volume Placed (m³/ft³)
0	7	Bentonite slurry	
7	20	holeplug	

Results of Well Yield Testing

After test of well yield, water was:
☑ Clear and sand free
☐ Other, specify
If pumping discontinued, give reason:
Pump intake set at (m/ft): 25'
Pumping rate (l/min / GPM): 15+ [illegible]
Duration of pumping: 24 hrs + ____ min
Final water level end of pumping (m/ft): 9.8
If flowing give rate (l/min/GPM):
Recommended pump depth (m/ft): 25
Recommended pump rate (l/min/GPM): 100
Well production (l/min/GPM): 100 +
Disinfected? ☑ Yes ☐ No

Draw Down Time (min)	Water Level (m/ft)	Recovery Time (min)	Water Level (m/ft)
Static Level	6.7		
1	9.3	1	full
2	9.3	2	[illegible]
3	9.4	3	[illegible]
4	9.4	4	
5	9.4	5	
10	9.4	10	
15	9.5	15	
20	9.6	20	
25	9.6	25	
30	9.6	30	
40	9.7	40	
50	9.8	50	
60	9.8	60	

Method of Construction

☐ Cable Tool
☑ Rotary (Conventional)
☐ Rotary (Reverse)
☐ Boring
☐ Air percussion
☐ Other, specify
☐ Diamond
☐ Jetting
☐ Driving
☐ Digging

Well Use

☐ Public
☐ Domestic
☐ Livestock
☐ Irrigation
☐ Industrial
☐ Other, specify
☐ Commercial
☑ Municipal
☑ Test Hole
☐ Cooling & Air Conditioning
☐ Not used
☐ Dewatering
☐ Monitoring

Construction Record - Casing

Inside Diameter (cm/in)	Open Hole OR Material (Galvanized, Fibreglass, Concrete, Plastic, Steel)	Wall Thickness (cm/in)	Depth (m/ft) From	To
6¼"	Steel	.188	-2	24

Status of Well

☐ Water Supply
☐ Replacement Well
☑ Test Hole
☐ Recharge Well
☐ Dewatering Well
☐ Observation and/or Monitoring Hole
☐ Alteration (Construction)
☐ Abandoned, Insufficient Supply
☐ Abandoned, Poor Water Quality
☐ Abandoned, other, specify
☐ Other, specify

Construction Record - Screen

Outside Diameter (cm/in)	Material (Plastic, Galvanized, Steel)	Slot No.	Depth (m/ft) From	To
5½"	Stainless Steel	#40	24	29'

Water Details

Water found at Depth 29 (m/ft) ☐ Gas Kind of Water: ☐ Fresh ☐ Untested ☐ Other, specify
Water found at Depth (m/ft) ☐ Gas Kind of Water: ☐ Fresh ☐ Untested ☐ Other, specify
Water found at Depth (m/ft) ☐ Gas Kind of Water: ☐ Fresh ☐ Untested ☐ Other, specify

Hole Diameter

Depth (m/ft) From	To	Diameter (cm/in)
0	30	10"

Map of Well Location

Please provide a map below following instructions on the back.

Comments:

Well Contractor and Well Technician Information

Business Name of Well Contractor: [illegible]
Well Contractor's Licence No.: 3 1 7 4 1 9
Business Address (Street Number/Name): 233 [illegible] Road
Municipality: [illegible]
Province: Ont.
Postal Code: [illegible]
Business E-mail Address: [illegible]
Bus. Telephone No. (inc. area code): [illegible]
Name of Well Technician (Last Name, First Name): [illegible]
Well Technician's Licence No.: [illegible]
Signature of Technician and/or Contractor:
Date Submitted: [illegible]

Well owner's information package delivered ☐ Yes ☐ No
Date Package Delivered: Y Y Y Y M M D D
Date Work Completed: [illegible]

Ministry Use Only
Audit No. Z367708
Received

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Contractor's Copy

APPENDIX B-II

Previous Investigation

PROJECT: 921-2709

RECORD OF BOREHOLE OW-1

SHEET 1 OF 1

LOCATION: See Plan

BORING DATE: Mar 11to13,1992

DATUM: Geodetic

DIP:

SAMPLER HAMMER, 63.5kg; DROP, 760 mm

BORING METHOD: Power Auger 200mm Diam (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
Ground Surface	76.98 0.00
Very dense brown SAND and GRAVEL, trace silt, some cobbles, nested cobbles from 2.3 to 2.8 metres	71.58 5.40
Compact to dense grey fine to coarse GRAVEL, some sandier zones, many cobbles	67.07 9.91
Very dense dark grey sandy silt, some gravel, trace clay, some cobbles and boulders (GLACIAL TILL)	63.32 13.66
End of Hole Auger Refusal	

SAMPLES NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB. TESTING
1	50 DO	47		
2	50 DO	75		MH
3	50 DO	61		
4	50 DO	34		
5	50 DO	29		MH
6	50 DO	53		
7	50 DO	136		
8	50 DO	76		MH

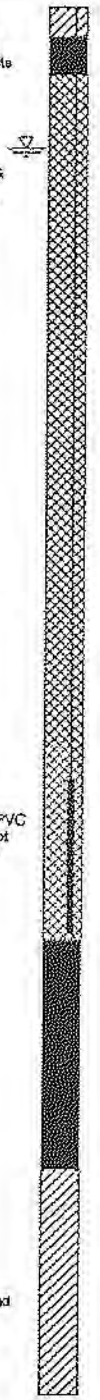
GAS CONCENTRATION ⊕ ( )

% LEL ☐

HYDRAULIC CONDUCTIVITY, K, cm/s

WATER CONTENT, PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80

INSTALLATIONS



W.L in Screen at Elev.75.61m Apr. 1, 1991

DATA INPUT: Disk 11, Stever

DEPTH SCALE (ALONG HOLE)
1 to 75

Golder Associates

LOGGED: P.A.S
CHECKED:

PROJECT: 921-2709

RECORD OF BOREHOLE OW-2

SHEET 1 OF 1

LOCATION: See Plan

BORING DATE: Mar 16,1992

DATUM: Geodetic

DIP:

SAMPLER HAMMER, 63.5kg; DROP, 760 mm

BORING METHOD: Power Auger 200mm Diam (Hollow Stem)

GAS CONCENTRATION ⊕ ( ) — % LEL ☐

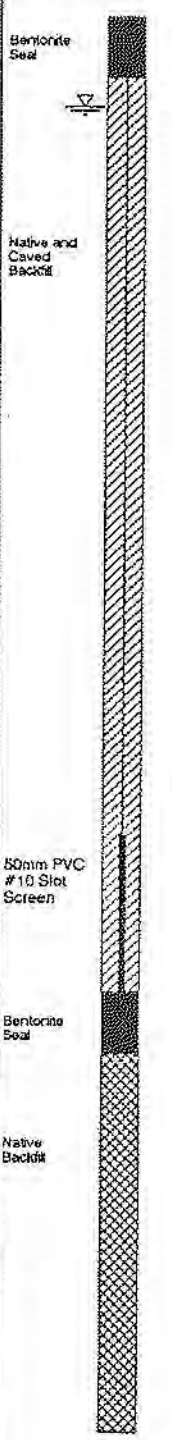
HYDRAULIC CONDUCTIVITY, k, cm/s

WATER CONTENT, PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
Ground Surface	76.48 0.00
Compact brown SAND and GRAVEL, trace silt, some cobbles	72.18 4.30
Dense grey SANDY GRAVEL, some cobbles	66.27 10.21
Compact to very dense grey sandy silt, some gravel, trace clay (GLACIAL TILL)	62.55 13.93
End of Hole	

NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB. TESTING
1	50 DO	18		
2	50 DO	30		
3	50 DO	34		
4	50 DO	43		
5	50 DO	35		M
6	50 DO	34		
7	50 DO	27		
8	50 DO	> 100		
9	50 DO	> 100		

INSTALLATIONS



W.L in Screen at Elev.75.60m Apr. 1, 1992

DATA INPUT: Disk 11, Slever

DEPTH SCALE (ALONG HOLE)

1 to 75

Golder Associates

LOGGED: P.A.S

CHECKED: PAS

PROJECT: 921-2709

RECORD OF BOREHOLE OW-3

SHEET 1 OF 1

LOCATION: See Plan
BORING DATE: Mar 18,1992
DATUM: Geodetic
DIP:
SAMPLER HAMMER: 63.5kg; DROP, 760 mm

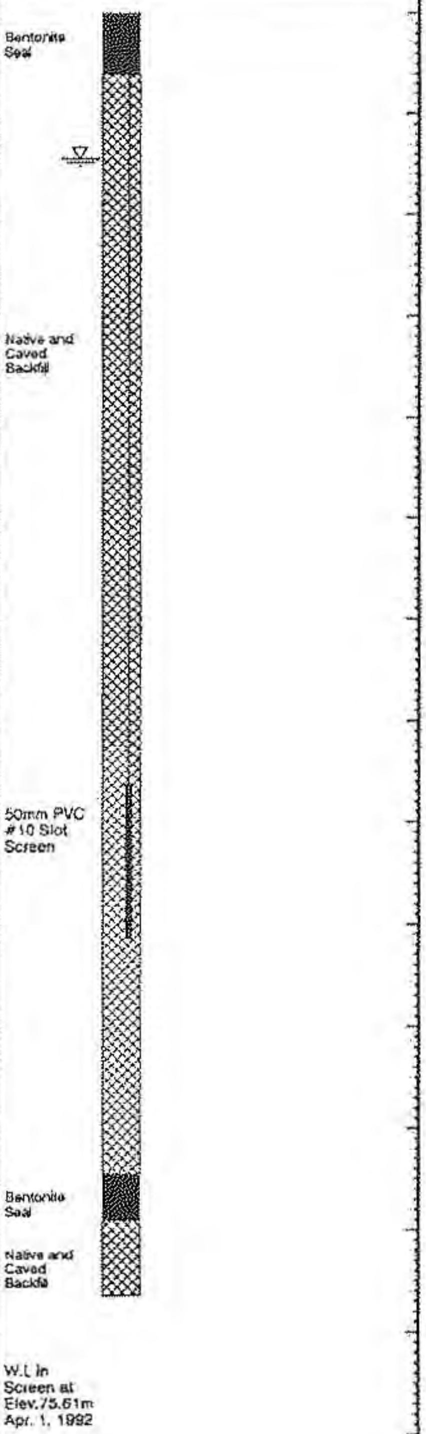
BORING METHOD: Power Auger 200mm Diam (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)
Ground Surface	77.04 0.00
Dense grey brown SAND and GRAVEL, trace silt	74.94 2.10
Compact to dense grey fine to medium SAND, trace gravel, some gravelly sand bands	69.14 7.90
Compact grey medium to coarse SAND, trace to some fine gravel	66.31 10.73
Compact to dense grey sandy silt, some gravel and cobbles, trace clay, boulders (GLACIAL TILL)	64.39 12.65
End of Hole Auger Refusal	

NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB TESTING
1	50 DO	39		
2	50 DO	10		
3	50 DO	22		
4	50 DO	43		
5	50 DO	20		
6	50 DO	21		
7	50 DO	27		

GAS CONCENTRATION ⊕ ( )
% LEL □
HYDRAULIC CONDUCTIVITY, k, cm/s
WATER CONTENT, PERCENT
Wp ⊢—○W—⊣ Wl
20 40 60 80

INSTALLATIONS



DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

DATA INPUT: Disk 11, Stever

DEPTH SCALE (ALONG HOLE)
1 to 75

Golder Associates

LOGGED: P.A.S
CHECKED: PAS

PROJECT: 921-2709

RECORD OF BOREHOLE OW-4

SHEET 1 OF 1

LOCATION: See Plan

BORING DATE: Mar 17, 1992

DATUM: Geodetic

DIP:

SAMPLER HAMMER, 63.5kg; DROP, 760 mm

BORING METHOD: Power Auger 200mm Diam (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
Ground Surface	76.36 0.00
Compact brown to grey fine to coarse GRAVEL, trace sand, occasional cobbles	
Compact grey SAND and GRAVEL, some silt	65.84 10.52
Probably Glacial Till	65.36 10.98
End of Hole	63.25 13.11

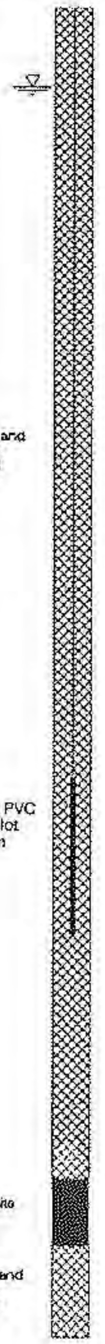
NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB. TESTING
1	50 DO	12		
2	50 DO	9		
3	50 DO	25		
4	50 DO	16		
5	50 DO	20		
6	50 DO	14		
7	50 DO	35		

GAS CONCENTRATION ( ) ⊕ % LEL ☐

HYDRAULIC CONDUCTIVITY, k, cm/s

WATER CONTENT, PERCENT Wp W Wl 20 40 60 80

INSTALLATIONS



Native and Caved Backfill

50mm PVC #10 Slot Screen

Bentonite Seal

Native and Caved Backfill

W.L in Screen at Elev.75.60m Apr, 1, 1992

DATA INPUT: Disk 11. Stever

DEPTH SCALE (ALONG HOLE)
1 to 75

Golder Associates

LOGGED: P.A.S
CHECKED:

PROJECT: 921-2709

LOCATION: See Plan

DIP:

RECORD OF BOREHOLE OW-5

BORING DATE: Mar.20,1992

SHEET 1 OF 1

DATUM: Geodetic

SAMPLER HAMMER, 63.5kg; DROP, 760 mm

BORING METHOD: Power Auger 200mm Diam (Hollow Stem)

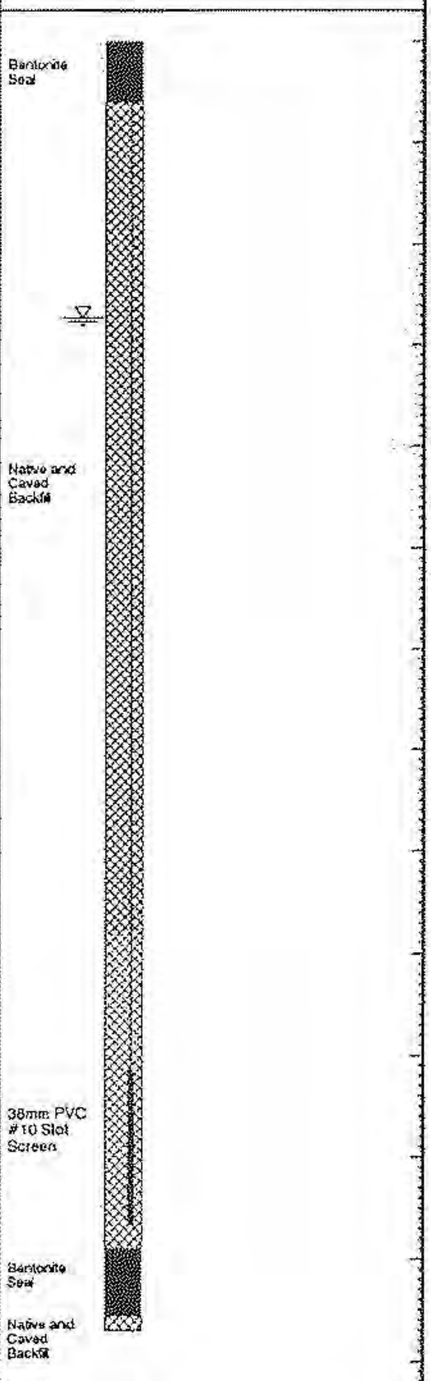
GAS CONCENTRATION ⊕ ( ) % LEL □

HYDRAULIC CONDUCTIVITY, K, cm/s

WATER CONTENT, PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB. TESTING
Ground Surface	78.31					
TOPSOIL	0.00					
Brown SILTY SAND, trace gravel, occasional cobble	0.18 77.40					
Brown CLAYEY SILT	0.91 76.79	1	AS			
Loose brown SILTY fine SAND	1.52 76.16	2	50 DO	9		
Compact grey fine SAND, occasional sandy silt to clayey silt layer	2.15 74.61	3	50 DO	12		
Loose to compact grey fine to medium SAND	3.70 67.03	4	50 DO	5		
		5	50 DO	11		M
		6	50 DO	12		
Dense grey sandy silt, some gravel, trace clay (GLACIAL TILL)	11.28 65.60		50 DO	>100		
End of Hole Auger Refusal	12.71					

INSTALLATIONS



W.L in Screen at Elev.75.59m Apr. 1, 1992

DATA INPUT: Disk 11, Stever

DEPTH SCALE (ALONG HOLE)

1 to 75

Golder Associates

LOGGED: P.A.S

CHECKED: PC

PROJECT: 921-2709

RECORD OF BOREHOLE OW-6

SHEET 1 OF 2

LOCATION: See Plan
BORING DATE: Mar 19,1992
DATUM: Geodetic
DIP:
SAMPLER HAMMER, 63.5kg; DROP, 760 mm.

BORING METHOD: Power Auger, 200mm Diam (Hollow Stem)

SOIL PROFILE

DEPTH SCALE METRES	DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)
0	Ground Surface		80.72
	TOPSOIL		0.00
	Loose to compact brown SILTY SAND to fine SAND, some gravel		0.21
2			78.43 2.29
	Compact grey fine to medium SAND, trace to some silt to SILTY fine SAND, occasional sandy silt layer, medium sand layer from 9.0 - 10.0 metre depth		
15	Dense grey sandy silt, some gravel, trace clay (GLACIAL TILL)		65.76
	CONTINUED ON NEXT PAGE		

SAMPLES

NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB. TESTING
1	AS	-		
2	50 DO	9		
3	50 DO	17		
4	50 DO	14		
5	50 DO	11		
6	50 DO	13		
7	50 DO	14		
8	50 DO	15		

GAS CONCENTRATION ⊕ ( )

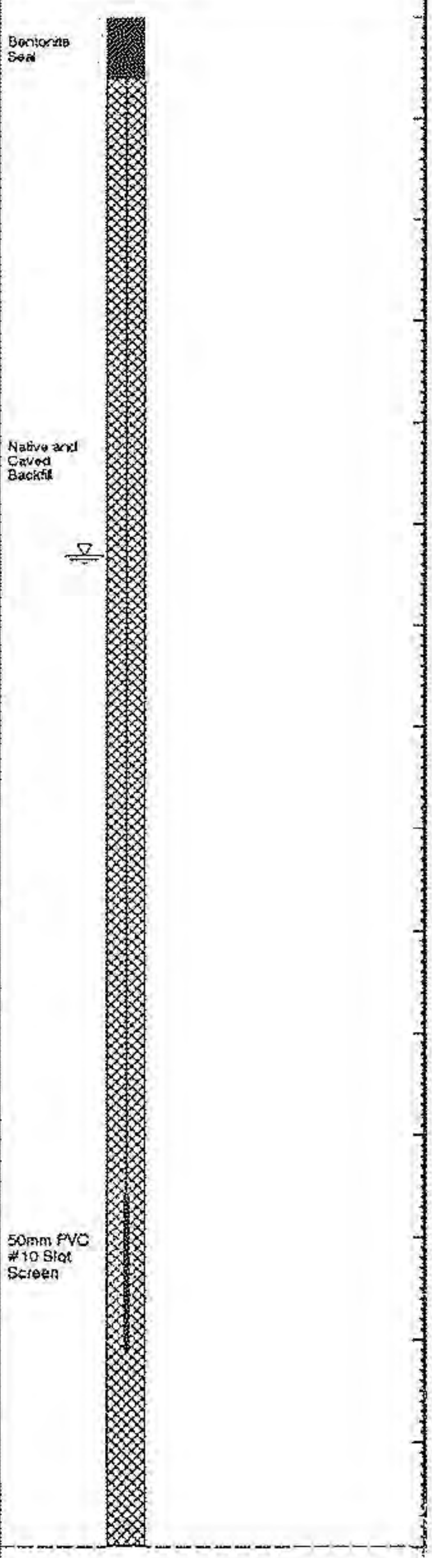
% LEL ☐

HYDRAULIC CONDUCTIVITY, k, cm/s

WATER CONTENT, PERCENT
Wp ⊢—○W—⊣ Wl
20 40 60 80

INSTALLATIONS

A



DATA INPUT: Disk 11, Stever

DEPTH SCALE (ALONG HOLE)
1 to 75

Golder Associates

LOGGED: P.A.S
CHECKED: MS

PROJECT: 921-2709
LOCATION: See Plan
DIP:

RECORD OF BOREHOLE OW-6

BORING DATE: Mar 19,1992

SHEET 2 OF 2
DATUM: Geodetic

SAMPLER HAMMER, 63.5 kg; DROP, 760 mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES					GAS CONCENTRATION ( ) ⊕	HYDRAULIC CONDUCTIVITY, k, cm/s	INSTALLATIONS
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB. TESTING	% LEL □	WATER CONTENT, PERCENT Wp W Wl 20 40 60 80	A
		CONTINUED FROM PREVIOUS PAGE										
15	Power Auger 200mm Diam (Hollow Stem)	Dense grey sandy silt, some gravel, trace clay (GLACIAL TILL)	▨	64.87	9	50 DO	57					Native and Caved Backfill ▨
16		End of Hole		15.85								W.L in Screen at Elev.75.43m Apr. 1, 1992
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												

DATA INPUT: Disk 11, Steve

DEPTH SCALE (ALONG HOLE)
1 to 75

Golder Associates

LOGGED: P.A.S
CHECKED: PAS

APPENDIX C

Grain Size Curves

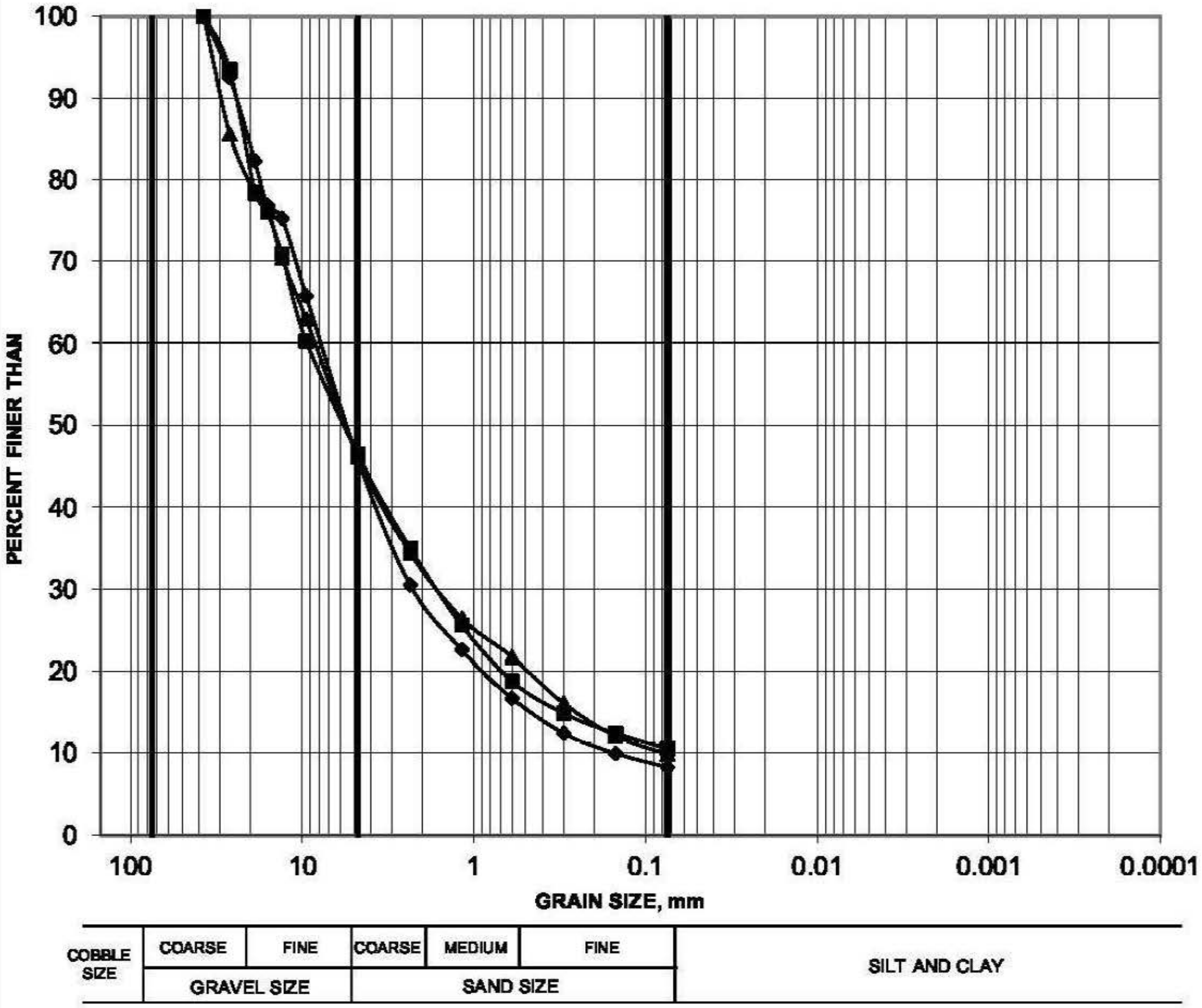
APPENDIX C-I

Current Investigation

GRAIN SIZE DISTRIBUTION

FIGURE 1

(GP-GM) SANDY GRAVEL & (GP-GM) GRAVEL and SAND



			Constituents (%)			
Borehole	Sample	Depth (m)	Gravel	Sand	Silt	Clay
■ 21-01	1	0.76-1.37	54	35	11	
◆ 21-01	4	3.05-3.66	54	38	8	
▲ 21-01	7	5.33-5.94	54	36	10	

GOLDER
MEMBER OF WSP

Project: 19125451

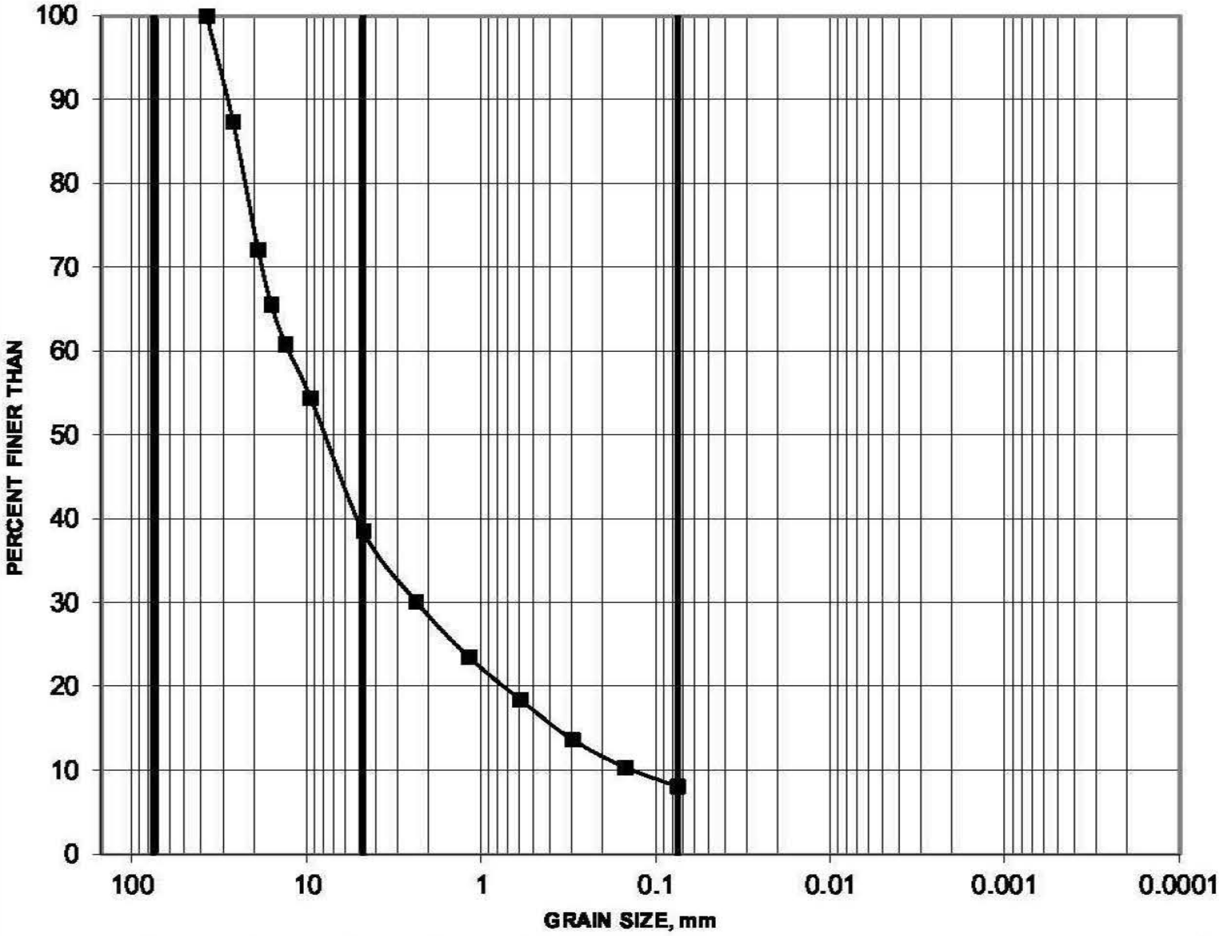
Created by:	CW
Checked by:	MI

https://golderassociates.sharepoint.com/sites/35409g/Shared Documents/Active/2019/19125451/figures/

GRAIN SIZE DISTRIBUTION

FIGURE 2

(GW-GM) SANDY GRAVEL



COBBLE SIZE	COARSE	FINE	COARSE	MEDIU	FINE	SILT AND CLAY
	GRAVEL SIZE		SAND SIZE			

	Borehole	Sample	Depth (m)	Constituents (%)			
				Gravel	Sand	Silt	Clay
■	21-01	11	8.38-8.99	61	31	8	

GOLDER
MEMBER OF WSP

Project: 19125451

Created by: CW
Checked by: MI

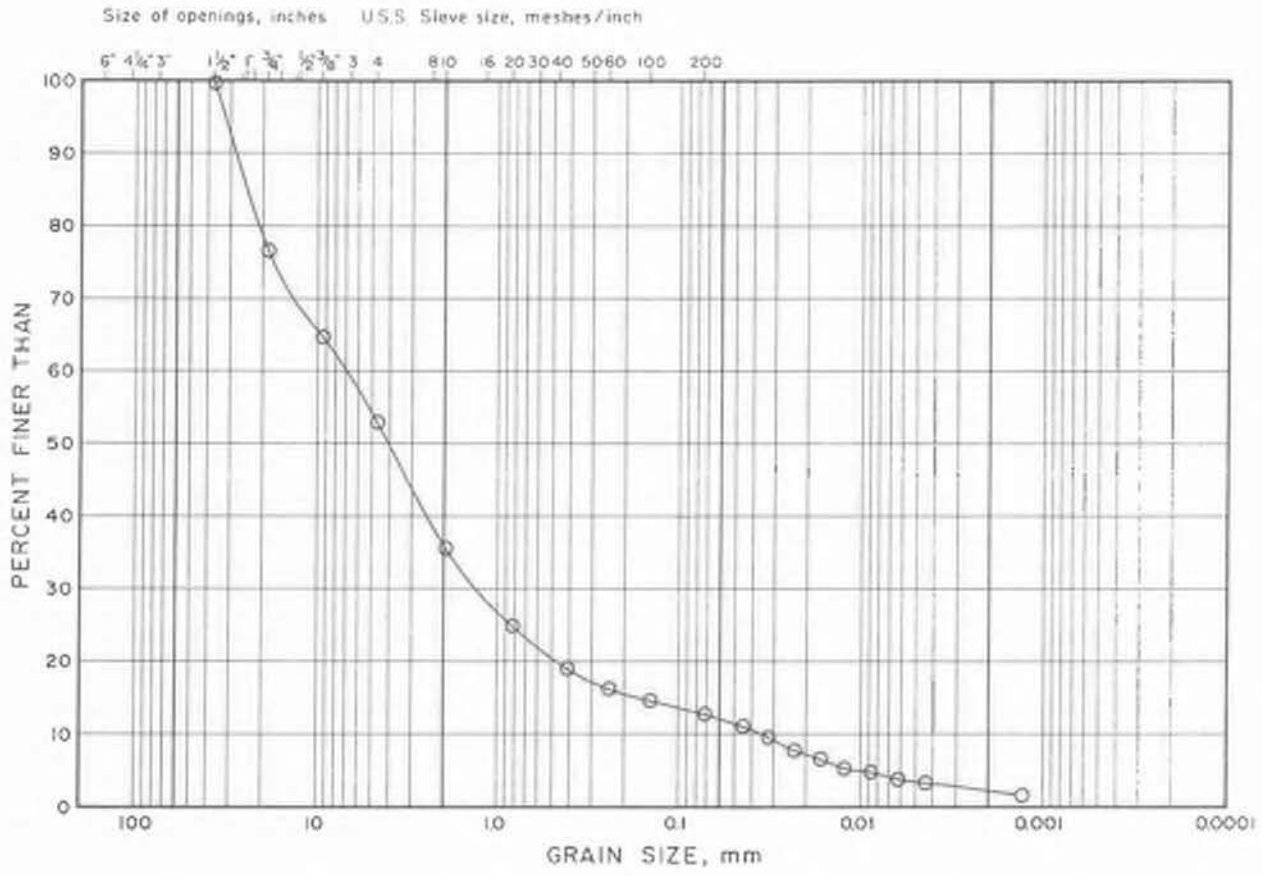
APPENDIX C-II

Previous Investigation

GRAIN SIZE DISTRIBUTION

FIGURE B-1

SILTY SAND AND GRAVEL



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV. (m)
○	OW-1	2	73.70

Project 921-2709

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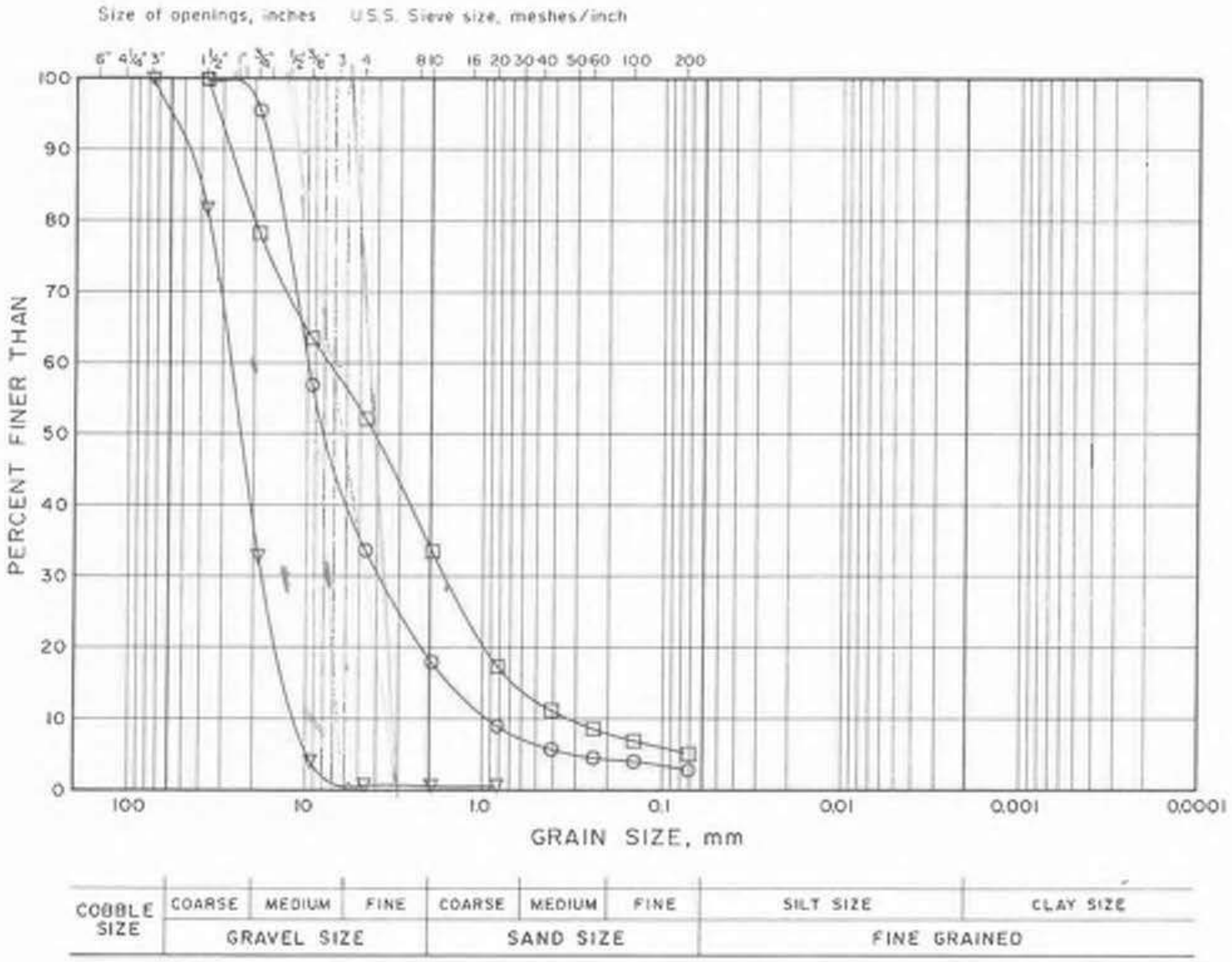
FORM PRODUCED MAY 1986

(Imperial)

GRAIN SIZE DISTRIBUTION

FIGURE B-2

GRAVEL TO SANDY GRAVEL



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV. (m)
○	OW-1	5	69.05
☐	OW-2	5	68.55
▽	OW-4		71.86

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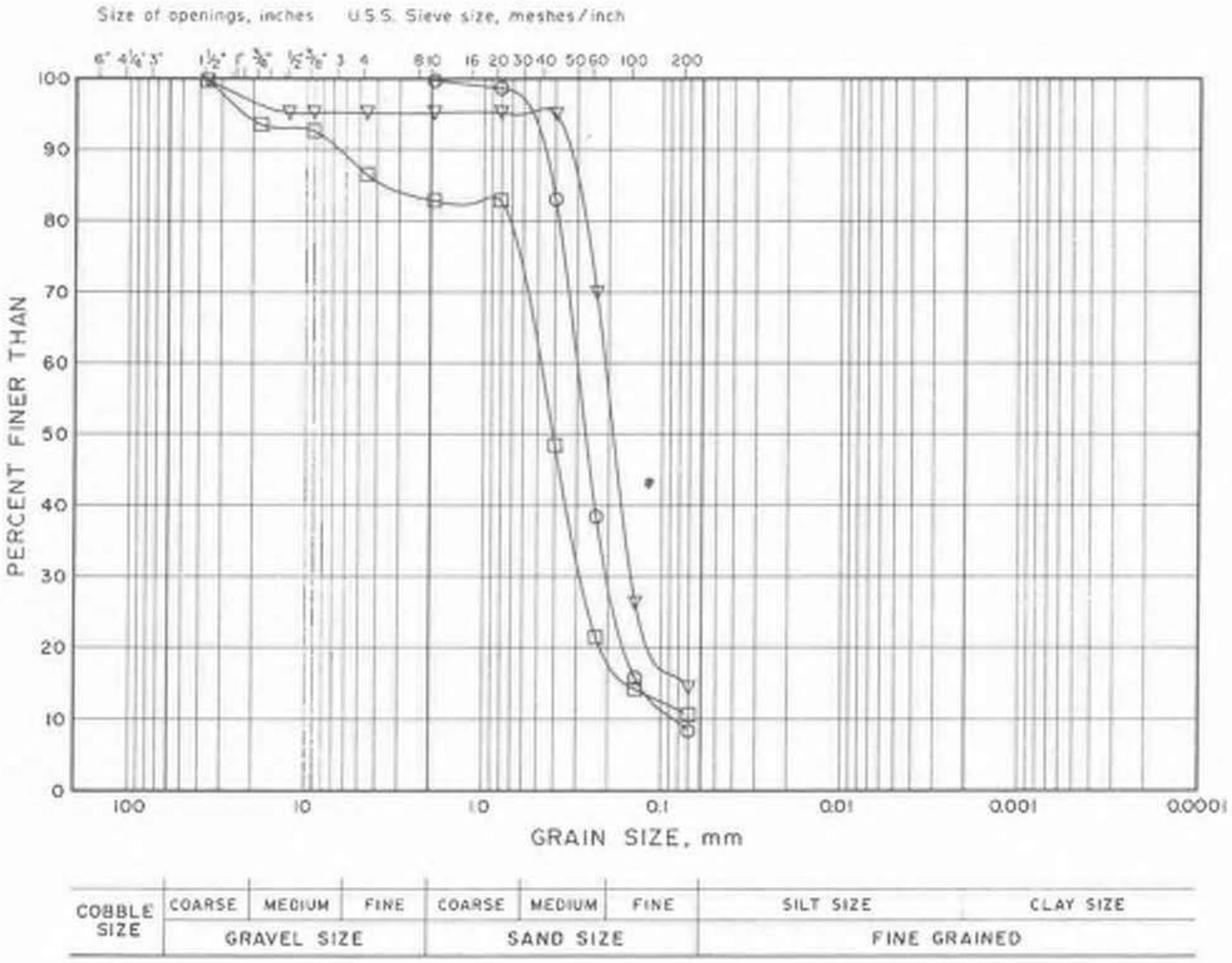
GRAIN SIZE DISTRIBUTION

FIGURE B-3

FINE TO MEDIUM SAND



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV. (m)
○	OW-5	5	71.85
□	13	5	74.45
▽	13	6	72.80

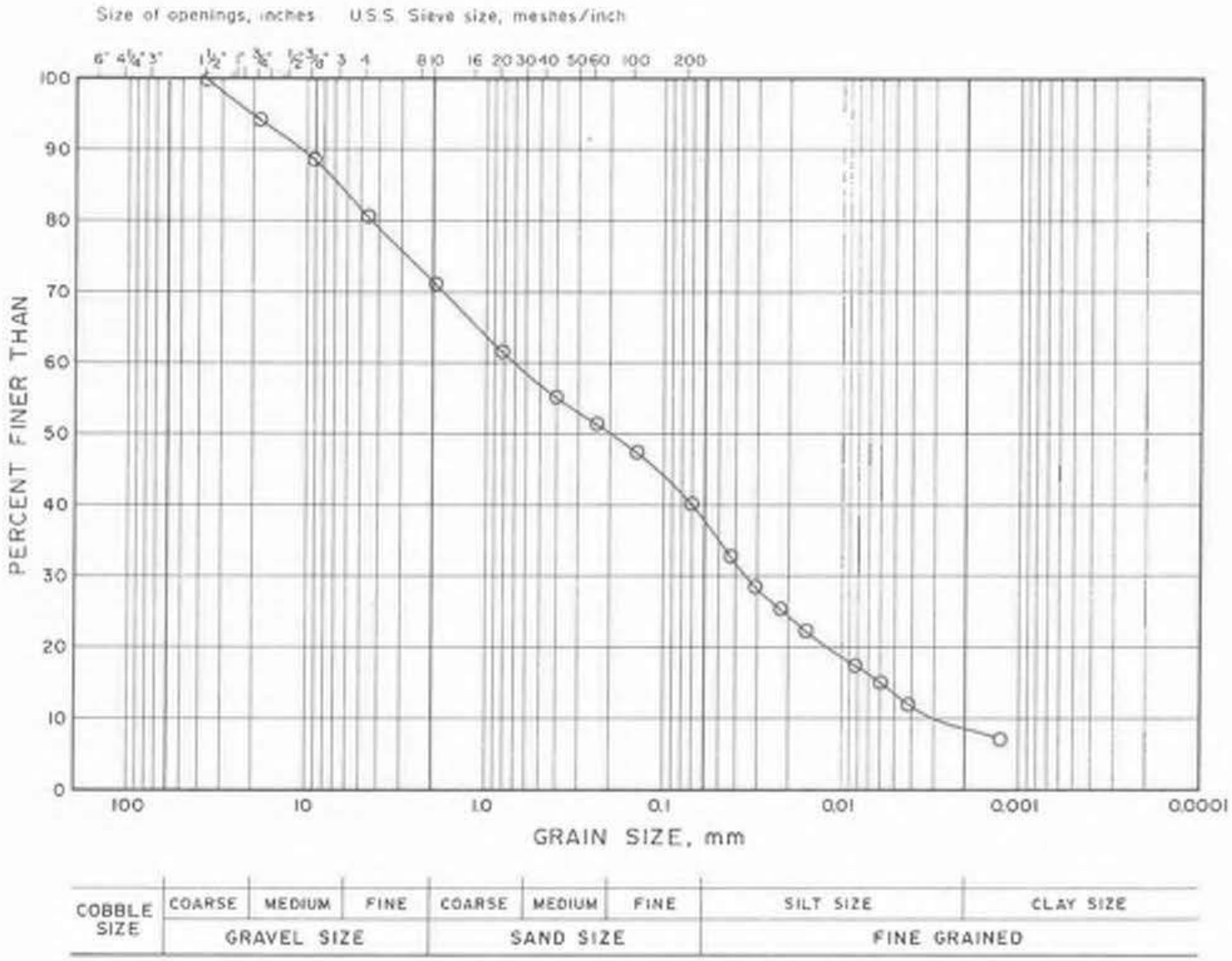
Project 921-2709

Golder Associates

GRAIN SIZE DISTRIBUTION

FIGURE B-4

GLACIAL TILL



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV. (m)
○	OW-1	8	64.45

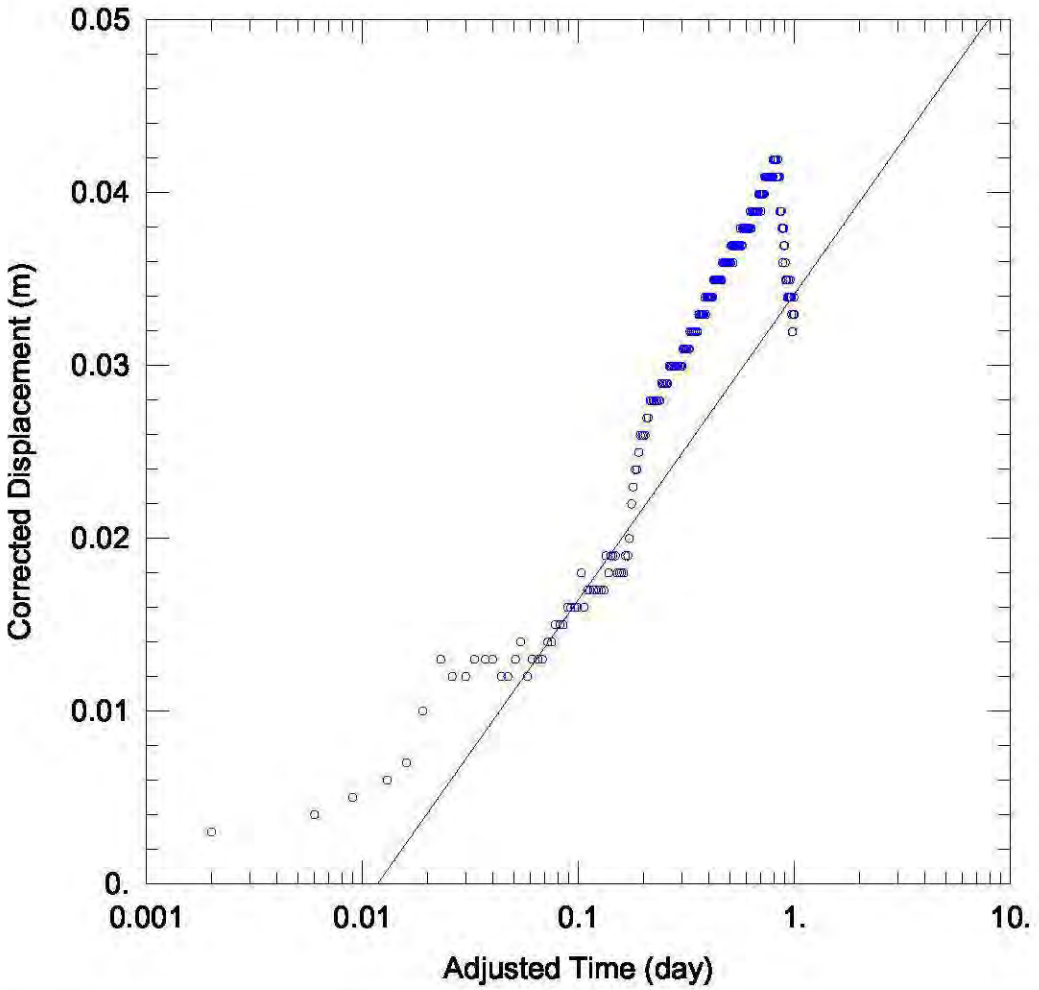
Project 921-2709

Golder Associates

FORM PRODUCED MAY 1986

APPENDIX D

TW21-01 Pumping Test Analysis



WELL TEST ANALYSIS

Data Set: C:\...\BH21-01 Cooper Jacob_early.aqt
Date: 12/16/21 Time: 16:03:08

PROJECT INFORMATION

Company: Golder Associates Ltd.
Client: JLR
Project: 19125451
Location: North Dundas
Test Well: TW21-02
Test Date: November 10-11, 2021

AQUIFER DATA

Saturated Thickness: 9. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TW21-01	476617	4999475.8

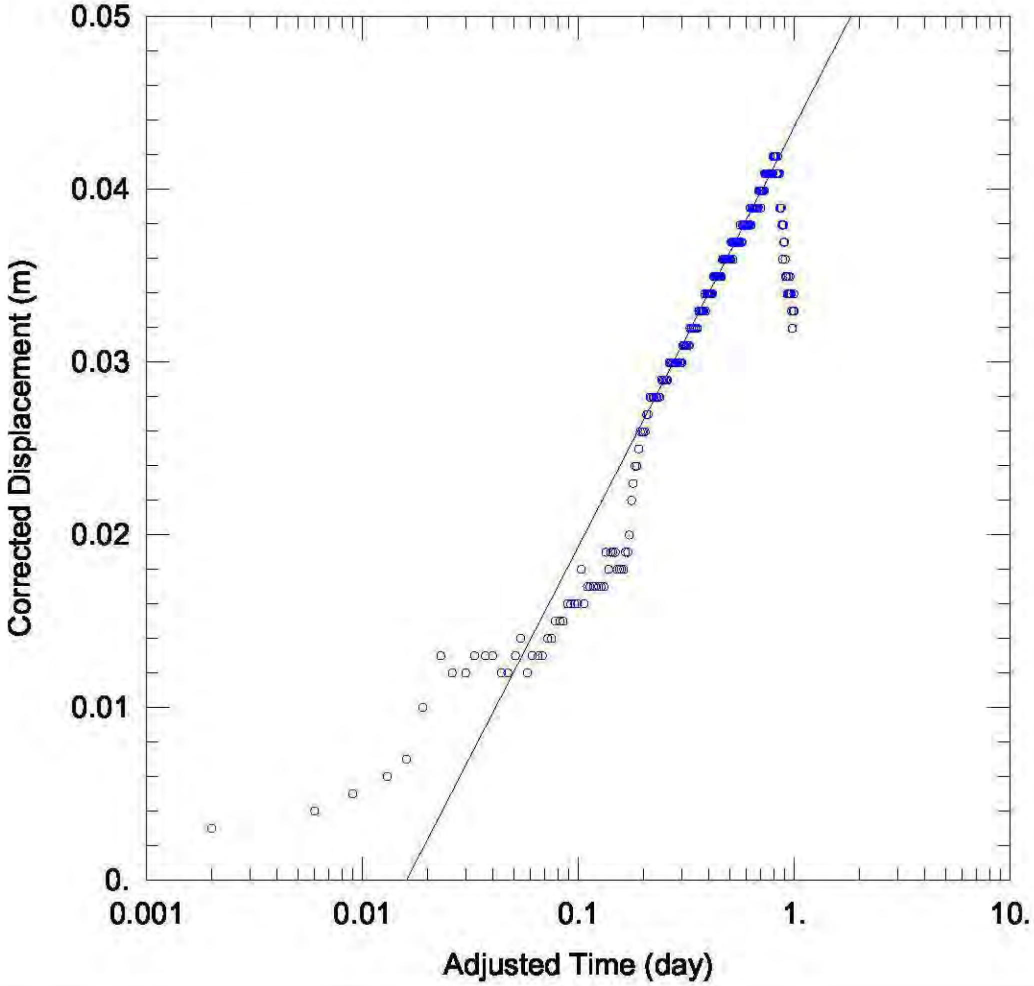
Observation Wells

Well Name	X (m)	Y (m)
○ BH21-01	476601	4999472

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 6042.2 m^2/day
S = 0.5891



WELL TEST ANALYSIS

Data Set: C:\...\BH21-01 Cooper Jacob_late.aqt
Date: 12/16/21 Time: 16:09:21

PROJECT INFORMATION

Company: Golder Associates Ltd.
Client: JLR
Project: 19125451
Location: North Dundas
Test Well: TW21-02
Test Date: November 10-11, 2021

AQUIFER DATA

Saturated Thickness: 9. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TW21-01	476616.289	4999480.238

Observation Wells

Well Name	X (m)	Y (m)
○ BH21-01	476602.83	4999471.344

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 4401.7 m^2/day
S = 0.604

APPENDIX E

Laboratory Certificates of Analysis

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Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Ms. Dale Holtze
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1966650
Date Submitted: 2021-11-11
Date Reported: 2021-11-19
Project: 19125451
COC #: 215679

Dear Dale Holtze:

Please find attached the analytical results for your samples. If you have any questions regarding this report, please do not hesitate to call (613-727-5692).

Report Comments:

Addrine
Thomas
2021.11.19
12:39:14 -05'00'

APPROVAL: ______________________________
Addrine Thomas, Inorganics Supervisor

All analysis is completed at Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) unless otherwise indicated.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is accredited by CALA, Canadian Association for Laboratory Accreditation to ISO/IEC 17025 for tests which appear on the scope of accreditation. The scope is available at: http://www.cala.ca/scopes/2602.pdf.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is licensed by the Ontario Ministry of the Environment, Conservation, and Parks (MECP) for specific tests in drinking water (license #2318). A copy of the license is available upon request.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is accredited by the Ontario Ministry of Agriculture, Food, and Rural Affairs for specific tests in agricultural soils.

Please note: Field data, where presented on the report, has been provided by the client and is presented for informational purposes only. Guideline values listed on this report are provided for ease of use (informational purposes) only. Eurofins recommends consulting the official provincial or federal guideline as required. Unless otherwise stated, measurement uncertainty is not taken into account when determining guideline or regulatory exceedances.

Certificate of Analysis

Client:	Golder Associates Ltd. (Ottawa) 1931 Robertson Road Ottawa, ON K2H 5B7		Report Number:	1966650
			Date Submitted:	2021-11-11
			Date Reported:	2021-11-19
			Project:	19125451
Attention:	Ms. Dale Holtze		COC #:	215679
PO#:				
Invoice to:	Golder Associates Ltd. (Ottawa)			

Lab I.D.	1595125
Sample Matrix	GW
Sample Type	
Sampling Date	2021-11-10
Sample I.D.	TW21-01-1HR

Group	Analyte	MRL	Units	Guideline	
Anions	Cl	1	mg/L	AO 250	30
	F	0.10	mg/L	MAC 1.5	0.10
	N-NO2	0.10	mg/L	MAC 1.0	<0.10
	N-NO3	0.10	mg/L	MAC 10.0	<0.10
	SO4	1	mg/L	AO 500	68
General Chemistry	Alkalinity as CaCO3	5	mg/L	OG 30-500	235
	Colour (Apparent)	2	TCU	AO 5	24*
	Conductivity	5	uS/cm		629
	DOC	0.5	mg/L	AO 5	8.0*
	pH	1.00		6.5-8.5	7.74
	Phenols	0.001	mg/L		<0.001
	S2-	0.01	mg/L	AO 0.05	<0.01
	TDS (COND - CALC)	1	mg/L	AO 500	409
	Turbidity	0.1	NTU	AO 5	0.2
Hardness	Hardness as CaCO3	1	mg/L	OG 80-100	311*
Indices/Calc	Ion Balance	0.01			0.97
Metals	Ca	1	mg/L		95
	Fe	0.03	mg/L	AO 0.3	0.14
	Fe (total)	0.03	mg/L		0.13
	K	1	mg/L		2
	Mg	1	mg/L		18
	Mn	0.01	mg/L	AO 0.05	0.13*
	Mn (total)	0.01	mg/L		0.14
	Na	2	mg/L	AO 200	11
Microbiology	Escherichia Coli	0	ct/100mL	MAC 0	0

Guideline = ODWSOG *** = Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

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Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Ms. Dale Holtze
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1966650
Date Submitted: 2021-11-11
Date Reported: 2021-11-19
Project: 19125451
COC #: 215679

				Lab I.D.	1595125
				Sample Matrix	GW
				Sample Type	
				Sampling Date	2021-11-10
				Sample I.D.	TW21-01-1HR
Group	**Analyte**	**MRL**	**Units**	**Guideline**	
Microbiology	Faecal Coliforms	0	ct/100mL		0
	Faecal Streptococcus	0	ct/100mL		0
	Heterotrophic Plate Count	0	ct/1mL		9
	Total Coliforms	0	ct/100mL	MAC 0	0
Nutrients	N-NH3	0.010	mg/L		<0.010
	Total Kjeldahl Nitrogen	0.100	mg/L		0.290
Subcontract	Tannin & Lignin	0.1	mg/L		1.0
VOCs Surrogates	1,2-dichloroethane-d4	0	%		98
	4-bromofluorobenzene	0	%		78
	Toluene-d8	0	%		101
Volatiles	1,1,1,2-tetrachloroethane	0.5	ug/L		<0.5
	1,1,1-trichloroethane	0.4	ug/L		<0.4
	1,1,2,2-tetrachloroethane	0.5	ug/L		<0.5
	1,1,2-trichloroethane	0.4	ug/L		<0.4
	1,1-dichloroethane	0.4	ug/L		<0.4
	1,1-dichloroethylene	0.5	ug/L	MAC 14	<0.5
	1,2-dibromoethane	0.2	ug/L		<0.2
	1,2-dichlorobenzene	0.4	ug/L	MAC 200	<0.4
	1,2-dichloroethane	0.2	ug/L	IMAC 5	<0.2
	1,2-dichloropropane	0.5	ug/L		<0.5
	1,3,5-trimethylbenzene	0.3	ug/L		<0.3
	1,3-dichlorobenzene	0.4	ug/L		<0.4
	1,4-dichlorobenzene	0.4	ug/L	MAC 5	<0.4
	Benzene	0.5	ug/L	MAC 1	<0.5
	Bromodichloromethane	0.3	ug/L		<0.3

Guideline = ODWSOG *** = Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

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Certificate of Analysis

Client:	Golder Associates Ltd. (Ottawa) 1931 Robertson Road Ottawa, ON K2H 5B7	Report Number:	1966650
		Date Submitted:	2021-11-11
		Date Reported:	2021-11-19
		Project:	19125451
Attention:	Ms. Dale Holtze	COC #:	215679
PO#:			
Invoice to:	Golder Associates Ltd. (Ottawa)		

				Lab I.D.	1595125
				Sample Matrix	GW
				Sample Type	
				Sampling Date	2021-11-10
				Sample I.D.	TW21-01-1HR
Group	**Analyte**	**MRL**	**Units**	**Guideline**	
Volatiles	Bromoform	0.4	ug/L		<0.4
	Bromomethane	0.5	ug/L		<0.5
	c-1,2-Dichloroethylene	0.4	ug/L		<0.4
	c-1,3-Dichloropropylene	0.2	ug/L		<0.2
	Carbon Tetrachloride	0.2	ug/L	MAC 2	<0.2
	Chloroethane	0.2	ug/L		<0.2
	Chloroform	0.5	ug/L		<0.5
	Chloromethane	0.2	ug/L		<0.2
	Dibromochloromethane	0.3	ug/L		<0.3
	Dichlorodifluoromethane	0.5	ug/L		<0.5
	Dichloromethane	4.0	ug/L	MAC 50	<4.0
	Ethylbenzene	0.5	ug/L	MAC 140	<0.5
	m/p-xylene	0.4	ug/L		<0.4
	Monochlorobenzene	0.5	ug/L	MAC 80	<0.5
	o-xylene	0.4	ug/L		<0.4
	Styrene	0.5	ug/L		<0.5
	t-1,2-Dichloroethylene	0.4	ug/L		<0.4
	t-1,3-Dichloropropylene	0.2	ug/L		<0.2
	Tetrachloroethylene	0.3	ug/L	MAC 10	<0.3
	Toluene	0.5	ug/L	MAC 60	<0.5
	Trichloroethylene	0.3	ug/L	MAC 5	<0.3
	Trichlorofluoromethane	0.5	ug/L		<0.5
	Vinyl Chloride	0.2	ug/L	MAC 1	<0.2
	Xylene; total	0.5	ug/L	MAC 90	<0.5

Guideline = ODWSOG *** = Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

eurofins | Environment Testing

Certificate of Analysis

Client:	Golder Associates Ltd. (Ottawa) 1931 Robertson Road Ottawa, ON K2H 5B7		Report Number: Date Submitted: Date Reported: Project: COC #:	1966650 2021-11-11 2021-11-19 19125451 215679
Attention:	Ms. Dale Holtze			
PO#:				
Invoice to:	Golder Associates Ltd. (Ottawa)			

QC Summary

Analyte	Blank	QC % Rec	QC Limits
Run No 412173 **Analysis/Extraction Date** 2021-11-12 **Analyst** MeC **Method** AMBCOLM1			
Escherichia Coli			
Faecal Coliforms			
Faecal Streptococcus			
Heterotrophic Plate Count			
Total Coliforms			
Run No 412239 **Analysis/Extraction Date** 2021-11-12 **Analyst** AK **Method** C SM2130B			
Turbidity	<0.1 NTU	100	70-130
Run No 412248 **Analysis/Extraction Date** 2021-11-12 **Analyst** SD **Method** EPA 200.8			
Iron	<0.03 mg/L	106	80-120
Manganese	<0.01 mg/L	109	80-120
Run No 412252 **Analysis/Extraction Date** 2021-11-12 **Analyst** AsA **Method** C SM4500-S2-D			
S2-	<0.01 mg/L	89	80-120
Run No 412294 **Analysis/Extraction Date** 2021-11-12 **Analyst** AsA **Method** SM 5310B			

Guideline = ODWSOG *** = Guideline Exceedence**

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QC Summary

Analyte	**Blank**	**QC % Rec**	**QC Limits**
DOC	<0.5 mg/L	107	80-120
Run No 412298 **Analysis/Extraction Date** 2021-11-15 **Analyst** AA **Method** C SM2120C			
Colour (Apparent)	<2 TCU	96	90-110
Run No 412360 **Analysis/Extraction Date** 2021-11-15 **Analyst** AsA **Method** SM2320,2510,4500H/F			
Alkalinity (CaCO3)	<5 mg/L	104	90-110
Conductivity	<5 uS/cm	101	90-110
F	<0.10 mg/L	105	90-110
pH		99	90-110
Run No 412367 **Analysis/Extraction Date** 2021-11-16 **Analyst** AET **Method** EPA 351.2			
Total Kjeldahl Nitrogen	<0.100 mg/L	93	70-130
Run No 412384 **Analysis/Extraction Date** 2021-11-16 **Analyst** R R **Method** SM 4110			
Chloride	<1 mg/L	100	90-110
N-NO2	<0.10 mg/L	109	90-110
N-NO3	<0.10 mg/L	99	90-110
SO4	<1 mg/L	100	90-110

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Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Ms. Dale Holtze
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1966650
Date Submitted: 2021-11-11
Date Reported: 2021-11-19
Project: 19125451
COC #: 215679

QC Summary

Analyte	Blank	QC % Rec	QC Limits
Run No 412406 **Analysis/Extraction Date** 2021-11-16 **Analyst** Z S **Method** M SM3120B-3500C			
Potassium	<1 mg/L	105	87-113
Run No 412412 **Analysis/Extraction Date** 2021-11-16 **Analyst** AET **Method** SM5530D/EPA420.2			
Phenols	<0.001 mg/L	50	73-127
Run No 412455 **Analysis/Extraction Date** 2021-11-17 **Analyst** SKH **Method** EPA 350.1			
N-NH3	<0.010 mg/L	112	80-120
Run No 412465 **Analysis/Extraction Date** 2021-11-17 **Analyst** Z S **Method** M SM3120B-3500C			
Calcium	<1 mg/L	98	90-110
Magnesium	<1 mg/L	102	76-124
Sodium	<2 mg/L	107	82-118
Run No 412472 **Analysis/Extraction Date** 2021-11-17 **Analyst** Z S **Method** C SM2340B			
Hardness as CaCO3			
Ion Balance			
TDS (COND - CALC)			

Guideline = ODWSOG *** = Guideline Exceedence**

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Certificate of Analysis

Client:	Golder Associates Ltd. (Ottawa) 1931 Robertson Road Ottawa, ON K2H 5B7
Attention:	Ms. Dale Holtze
PO#:	
Invoice to:	Golder Associates Ltd. (Ottawa)

Report Number:	1966650
Date Submitted:	2021-11-11
Date Reported:	2021-11-19
Project:	19125451
COC #:	215679

QC Summary

Analyte	Blank	QC % Rec	QC Limits
Run No 412490 **Analysis/Extraction Date** 2021-11-14 **Analyst** AX **Method** EPA 8260			
Tetrachloroethane, 1,1,1,2-	<0.5 ug/L	86	60-130
Trichloroethane, 1,1,1-	<0.4 ug/L	94	60-130
Tetrachloroethane, 1,1,2,2-	<0.5 ug/L	100	60-130
Trichloroethane, 1,1,2-	<0.4 ug/L	105	60-130
Dichloroethane, 1,1-	<0.4 ug/L	91	60-130
Dichloroethylene, 1,1-	<0.5 ug/L	93	60-130
1,2-dibromoethane	<0.2 ug/L		60-130
Dichlorobenzene, 1,2-	<0.4 ug/L	82	60-130
Dichloroethane, 1,2-	<0.2 ug/L	97	60-130
Dichloropropane, 1,2-	<0.5 ug/L	88	60-130
1,3,5-trimethylbenzene	<0.3 ug/L	85	60-130
Dichlorobenzene, 1,3-	<0.4 ug/L	90	60-130
Dichlorobenzene, 1,4-	<0.4 ug/L	85	60-130
Benzene	<0.5 ug/L	88	60-130
Bromodichloromethane	<0.3 ug/L	92	60-130
Bromoform	<0.4 ug/L	101	60-130

Guideline = ODWSOG *** = Guideline Exceedence**

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Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Ms. Dale Holtze
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1966650
Date Submitted: 2021-11-11
Date Reported: 2021-11-19
Project: 19125451
COC #: 215679

QC Summary

Analyte	Blank	QC % Rec	QC Limits
Bromomethane	<0.5 ug/L	91	60-130
Dichloroethylene, 1,2-cis-	<0.4 ug/L	87	60-130
Dichloropropene,1,3-cis-	<0.2 ug/L	81	60-130
Carbon Tetrachloride	<0.2 ug/L	90	60-130
Chloroethane	<0.2 ug/L	92	60-130
Chloroform	<0.5 ug/L	90	60-130
Chloromethane	<0.2 ug/L		60-130
Dibromochloromethane	<0.3 ug/L	103	60-130
Dichlorodifluoromethane	<0.5 ug/L	89	60-130
Methylene Chloride	<4.0 ug/L	117	60-130
Ethylbenzene	<0.5 ug/L	82	60-130
m/p-xylene	<0.4 ug/L	84	60-130
Chlorobenzene	<0.5 ug/L	99	60-130
o-xylene	<0.4 ug/L	91	60-130
Styrene	<0.5 ug/L	87	60-130
Dichloroethylene, 1,2-trans-	<0.4 ug/L	85	60-130
Dichloropropene,1,3-trans-	<0.2 ug/L	84	60-130
Tetrachloroethylene	<0.3 ug/L	81	60-130

Guideline = ODWSOG *** = Guideline Exceedence**

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Certificate of Analysis

Client:	Golder Associates Ltd. (Ottawa) 1931 Robertson Road Ottawa, ON K2H 5B7
Attention:	Ms. Dale Holtze
PO#:	
Invoice to:	Golder Associates Ltd. (Ottawa)

Report Number:	1966650
Date Submitted:	2021-11-11
Date Reported:	2021-11-19
Project:	19125451
COC #:	215679

QC Summary

Analyte	Blank	QC % Rec	QC Limits
Toluene	<0.5 ug/L	88	60-130
Trichloroethylene	<0.3 ug/L	88	60-130
Trichlorofluoromethane	<0.5 ug/L	92	60-130
Vinyl Chloride	<0.2 ug/L	89	60-130
Run No 412505 **Analysis/Extraction Date** 2021-11-17 **Analyst** AX **Method** EPA 8260			
Xylene Mixture			
Run No 412541 **Analysis/Extraction Date** 2021-11-18 **Analyst** SD **Method** EPA 200.8			
Fe (total)	<0.03 mg/L		80-120
Mn (total)	<0.01 mg/L		
Run No 412627 **Analysis/Extraction Date** 2021-11-15 **Analyst** AET **Method** SUBCONTRACT-A			
Tannin & Lignin	<0.10 mg/L	95	

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Certificate of Analysis

Client:	Golder Associates Ltd. (Ottawa) 1931 Robertson Road Ottawa, ON K2H 5B7	Report Number:	1966694
		Date Submitted:	2021-11-11
		Date Reported:	2021-11-22
		Project:	19125451
Attention:	Ms. Dale Holtze	COC #:	215708
PO#:			
Invoice to:	Golder Associates Ltd. (Ottawa)		

Dear Dale Holtze:

Please find attached the analytical results for your samples. If you have any questions regarding this report, please do not hesitate to call (613-727-5692).

Report Comments:

Sarah
Horner
2021.11.22
14:48:37
-05'00'

APPROVAL:

Sarah Horner, Inorganics Technician

All analysis is completed at Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) unless otherwise indicated.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is accredited by CALA, Canadian Association for Laboratory Accreditation to ISO/IEC 17025 for tests which appear on the scope of accreditation. The scope is available at: http://www.cala.ca/scopes/2602.pdf.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is licensed by the Ontario Ministry of the Environment, Conservation, and Parks (MECP) for specific tests in drinking water (license #2318). A copy of the license is available upon request.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is accredited by the Ontario Ministry of Agriculture, Food, and Rural Affairs for specific tests in agricultural soils.

Please note: Field data, where presented on the report, has been provided by the client and is presented for informational purposes only. Guideline values listed on this report are provided for ease of use (informational purposes) only. Eurofins recommends consulting the official provincial or federal guideline as required. Unless otherwise stated, measurement uncertainty is not taken into account when determining guideline or regulatory exceedances.

Certificate of Analysis

Client:	Golder Associates Ltd. (Ottawa) 1931 Robertson Road Ottawa, ON K2H 5B7
Attention:	Ms. Dale Holtze
PO#:	
Invoice to:	Golder Associates Ltd. (Ottawa)

Report Number:	1966694
Date Submitted:	2021-11-11
Date Reported:	2021-11-22
Project:	19125451
COC #:	215708

				Lab I.D.	1595241
				Sample Matrix	GW
				Sample Type	
				Sampling Date	2021-11-11
				Sample I.D.	TW21-01-24HR
Group	**Analyte**	**MRL**	**Units**	**Guideline**	
Anions	Cl	1	mg/L	AO 250	30
	F	0.10	mg/L	MAC 1.5	0.10
	N-NO2	0.10	mg/L	MAC 1.0	<0.10
	N-NO3	0.10	mg/L	MAC 10.0	<0.10
	SO4	1	mg/L	AO 500	71
General Chemistry	Alkalinity as CaCO3	5	mg/L	OG 30-500	241
	Colour (Apparent)	2	TCU	AO 5	23*
	Conductivity	5	uS/cm		650
	DOC	0.5	mg/L	AO 5	7.8*
	pH	1.00		6.5-8.5	7.92
	Phenols	0.001	mg/L		0.002
	S2-	0.01	mg/L	AO 0.05	<0.01
	TDS (COND - CALC)	1	mg/L	AO 500	422
	Turbidity	0.1	NTU	AO 5	0.4
Hardness	Hardness as CaCO3	1	mg/L	OG 80-100	318*
Indices/Calc	Ion Balance	0.01			0.96
Metals	Ca	1	mg/L		96
	Fe	0.03	mg/L	AO 0.3	0.14
	Fe (total)	0.03	mg/L		0.11
	K	1	mg/L		2
	Mg	1	mg/L		19
	Mn	0.01	mg/L	AO 0.05	0.19*
	Mn (total)	0.01	mg/L		0.19
	Na	2	mg/L	AO 200	10
Microbiology	Escherichia Coli	0	ct/100mL	MAC 0	0

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Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Ms. Dale Holtze
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1966694
Date Submitted: 2021-11-11
Date Reported: 2021-11-22
Project: 19125451
COC #: 215708

				Lab I.D.	1595241
				Sample Matrix	GW
				Sample Type	
				Sampling Date	2021-11-11
				Sample I.D.	TW21-01-24HR
Group	**Analyte**	**MRL**	**Units**	**Guideline**	
Microbiology	Faecal Coliforms	0	ct/100mL		0
	Faecal Streptococcus	0	ct/100mL		0
	Heterotrophic Plate Count	0	ct/1mL		19
	Total Coliforms	0	ct/100mL	MAC 0	13*
Nutrients	N-NH3	0.010	mg/L		<0.010
	Total Kjeldahl Nitrogen	0.100	mg/L		0.400
Subcontract	Tannin & Lignin	0.1	mg/L		1.0
VOCs Surrogates	1,2-dichloroethane-d4	0	%		97
	4-bromofluorobenzene	0	%		71
	Toluene-d8	0	%		107
Volatiles	1,1,1,2-tetrachloroethane	0.5	ug/L		<0.5
	1,1,1-trichloroethane	0.4	ug/L		<0.4
	1,1,2,2-tetrachloroethane	0.5	ug/L		<0.5
	1,1,2-trichloroethane	0.4	ug/L		<0.4
	1,1-dichloroethane	0.4	ug/L		<0.4
	1,1-dichloroethylene	0.5	ug/L	MAC 14	<0.5
	1,2-dibromoethane	0.2	ug/L		<0.2
	1,2-dichlorobenzene	0.4	ug/L	MAC 200	<0.4
	1,2-dichloroethane	0.2	ug/L	IMAC 5	<0.2
	1,2-dichloropropane	0.5	ug/L		<0.5
	1,3,5-trimethylbenzene	0.3	ug/L		<0.3
	1,3-dichlorobenzene	0.4	ug/L		<0.4
	1,4-dichlorobenzene	0.4	ug/L	MAC 5	<0.4
	Benzene	0.5	ug/L	MAC 1	<0.5
	Bromodichloromethane	0.3	ug/L		<0.3

Guideline = ODWSOG

*** = Guideline Exceedence**

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Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Ms. Dale Holtze
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1966694
Date Submitted: 2021-11-11
Date Reported: 2021-11-22
Project: 19125451
COC #: 215708

				Lab I.D.	1595241
				Sample Matrix	GW
				Sample Type	
				Sampling Date	2021-11-11
				Sample I.D.	TW21-01-24HR
Group	**Analyte**	**MRL**	**Units**	**Guideline**	
Volatiles	Bromoform	0.4	ug/L		<0.4
	Bromomethane	0.5	ug/L		<0.5
	c-1,2-Dichloroethylene	0.4	ug/L		<0.4
	c-1,3-Dichloropropylene	0.2	ug/L		<0.2
	Carbon Tetrachloride	0.2	ug/L	MAC 2	<0.2
	Chloroethane	0.2	ug/L		<0.2
	Chloroform	0.5	ug/L		<0.5
	Chloromethane	0.2	ug/L		<0.2
	Dibromochloromethane	0.3	ug/L		<0.3
	Dichlorodifluoromethane	0.5	ug/L		<0.5
	Dichloromethane	4.0	ug/L	MAC 50	<4.0
	Ethylbenzene	0.5	ug/L	MAC 140	<0.5
	m/p-xylene	0.4	ug/L		<0.4
	Monochlorobenzene	0.5	ug/L	MAC 80	<0.5
	o-xylene	0.4	ug/L		<0.4
	Styrene	0.5	ug/L		<0.5
	t-1,2-Dichloroethylene	0.4	ug/L		<0.4
	t-1,3-Dichloropropylene	0.2	ug/L		<0.2
	Tetrachloroethylene	0.3	ug/L	MAC 10	<0.3
	Toluene	0.5	ug/L	MAC 60	<0.5
	Trichloroethylene	0.3	ug/L	MAC 5	<0.3
	Trichlorofluoromethane	0.5	ug/L		<0.5
	Vinyl Chloride	0.2	ug/L	MAC 1	<0.2
	Xylene; total	0.5	ug/L	MAC 90	<0.5

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---

QC Summary

Analyte	**Blank**	**QC % Rec**	**QC Limits**
Run No 412209 **Analysis/Extraction Date** 2021-11-13 **Analyst** MeC **Method** AMBCOLM1			
Escherichia Coli			
Faecal Coliforms			
Faecal Streptococcus			
Heterotrophic Plate Count			
Total Coliforms			
Run No 412239 **Analysis/Extraction Date** 2021-11-12 **Analyst** AK **Method** C SM2130B			
Turbidity	<0.1 NTU	100	70-130
Run No 412252 **Analysis/Extraction Date** 2021-11-12 **Analyst** AsA **Method** C SM4500-S2-D			
S2-	<0.01 mg/L	89	80-120
Run No 412294 **Analysis/Extraction Date** 2021-11-12 **Analyst** AsA **Method** SM 5310B			
DOC	<0.5 mg/L	107	80-120
Run No 412298 **Analysis/Extraction Date** 2021-11-15 **Analyst** AA **Method** C SM2120C			
Colour (Apparent)	<2 TCU	96	90-110

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Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Ms. Dale Holtze
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1966694
Date Submitted: 2021-11-11
Date Reported: 2021-11-22
Project: 19125451
COC #: 215708

QC Summary

Analyte	Blank	QC % Rec	QC Limits
Run No 412347 **Analysis/Extraction Date** 2021-11-15 **Analyst** SD **Method** EPA 200.8			
Iron	<0.03 mg/L	106	80-120
Manganese	<0.01 mg/L	111	80-120
Run No 412360 **Analysis/Extraction Date** 2021-11-15 **Analyst** AsA **Method** SM2320,2510,4500H/F			
Alkalinity (CaCO3)	<5 mg/L	104	90-110
Conductivity	<5 uS/cm	101	90-110
F	<0.10 mg/L	105	90-110
pH		99	90-110
Run No 412384 **Analysis/Extraction Date** 2021-11-16 **Analyst** R R **Method** SM 4110			
Chloride	<1 mg/L	100	90-110
N-NO2	<0.10 mg/L	109	90-110
N-NO3	<0.10 mg/L	99	90-110
SO4	<1 mg/L	100	90-110
Run No 412412 **Analysis/Extraction Date** 2021-11-16 **Analyst** AET **Method** SM5530D/EPA420.2			
Phenols	<0.001 mg/L	50	73-127

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Client:	Golder Associates Ltd. (Ottawa) 1931 Robertson Road Ottawa, ON K2H 5B7
Attention:	Ms. Dale Holtze
PO#:	
Invoice to:	Golder Associates Ltd. (Ottawa)

Report Number:	1966694
Date Submitted:	2021-11-11
Date Reported:	2021-11-22
Project:	19125451
COC #:	215708

QC Summary

Analyte	Blank	QC % Rec	QC Limits
Run No 412465 **Analysis/Extraction Date** 2021-11-17 **Analyst** Z S **Method** M SM3120B-3500C			
Calcium	<1 mg/L	98	90-110
Potassium	<1 mg/L	102	87-113
Magnesium	<1 mg/L	102	76-124
Sodium	<2 mg/L	107	82-118
Run No 412490 **Analysis/Extraction Date** 2021-11-16 **Analyst** AX **Method** EPA 8260			
Tetrachloroethane, 1,1,1,2-	<0.5 ug/L	86	60-130
Trichloroethane, 1,1,1-	<0.4 ug/L	94	60-130
Tetrachloroethane, 1,1,2,2-	<0.5 ug/L	100	60-130
Trichloroethane, 1,1,2-	<0.4 ug/L	105	60-130
Dichloroethane, 1,1-	<0.4 ug/L	91	60-130
Dichloroethylene, 1,1-	<0.5 ug/L	93	60-130
1,2-dibromoethane	<0.2 ug/L		60-130
Dichlorobenzene, 1,2-	<0.4 ug/L	82	60-130
Dichloroethane, 1,2-	<0.2 ug/L	97	60-130
Dichloropropane, 1,2-	<0.5 ug/L	88	60-130

Guideline = ODWSOG

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Certificate of Analysis

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PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1966694
Date Submitted: 2021-11-11
Date Reported: 2021-11-22
Project: 19125451
COC #: 215708

QC Summary

Analyte	Blank	QC % Rec	QC Limits
1,3,5-trimethylbenzene	<0.3 ug/L	85	60-130
Dichlorobenzene, 1,3-	<0.4 ug/L	90	60-130
Dichlorobenzene, 1,4-	<0.4 ug/L	85	60-130
Benzene	<0.5 ug/L	88	60-130
Bromodichloromethane	<0.3 ug/L	92	60-130
Bromoform	<0.4 ug/L	101	60-130
Bromomethane	<0.5 ug/L	91	60-130
Dichloroethylene, 1,2-cis-	<0.4 ug/L	87	60-130
Dichloropropene,1,3-cis-	<0.2 ug/L	81	60-130
Carbon Tetrachloride	<0.2 ug/L	90	60-130
Chloroethane	<0.2 ug/L	92	60-130
Chloroform	<0.5 ug/L	90	60-130
Chloromethane	<0.2 ug/L		60-130
Dibromochloromethane	<0.3 ug/L	103	60-130
Dichlorodifluoromethane	<0.5 ug/L	89	60-130
Methylene Chloride	<4.0 ug/L	117	60-130
Ethylbenzene	<0.5 ug/L	82	60-130
m/p-xylene	<0.4 ug/L	84	60-130

Guideline = ODWSOG

*** = Guideline Exceedence**

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

QC Summary

Analyte	Blank	QC % Rec	QC Limits
Chlorobenzene	<0.5 ug/L	99	60-130
o-xylene	<0.4 ug/L	91	60-130
Styrene	<0.5 ug/L	87	60-130
Dichloroethylene, 1,2-trans-	<0.4 ug/L	85	60-130
Dichloropropene,1,3-trans-	<0.2 ug/L	84	60-130
Tetrachloroethylene	<0.3 ug/L	81	60-130
Toluene	<0.5 ug/L	88	60-130
Trichloroethylene	<0.3 ug/L	88	60-130
Trichlorofluoromethane	<0.5 ug/L	92	60-130
Vinyl Chloride	<0.2 ug/L	89	60-130
Run No 412508 **Analysis/Extraction Date** 2021-11-17 **Analyst** SKH **Method** EPA 351.2			
Total Kjeldahl Nitrogen	<0.100 mg/L	101	70-130
Run No 412522 **Analysis/Extraction Date** 2021-11-18 **Analyst** AET **Method** C SM2340B			
Hardness as CaCO3			
Ion Balance			
TDS (COND - CALC)			

Guideline = ODWSOG *** = Guideline Excedence**

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

eurofins | Environment Testing

Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Ms. Dale Holtze
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1966694
Date Submitted: 2021-11-11
Date Reported: 2021-11-22
Project: 19125451
COC #: 215708

QC Summary

Analyte	Blank	QC % Rec	QC Limits
Run No 412541 **Analysis/Extraction Date** 2021-11-18 **Analyst** SD **Method** EPA 200.8			
Fe (total)	<0.03 mg/L		80-120
Mn (total)	<0.01 mg/L		
Run No 412549 **Analysis/Extraction Date** 2021-11-18 **Analyst** SKH **Method** EPA 350.1			
N-NH3	<0.010 mg/L	98	80-120
Run No 412552 **Analysis/Extraction Date** 2021-11-18 **Analyst** AX **Method** EPA 8260			
Xylene Mixture			
Run No 412714 **Analysis/Extraction Date** 2021-11-15 **Analyst** R S **Method** SUBCONTRACT-A			
Tannin & Lignin	<0.10 mg/L	95	

Guideline = ODWSOG *** = Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

REPORT

Wellhead Protection Area Study and Vulnerability Assessment

Township of North Dundas Municipal Class Environmental Assessment for the North Dundas Drinking Water Supply System Capacity Expansion

Submitted to:

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January 2023

Distribution List

1 e-copy - J.L. Richards & Associates Ltd.

1 e-copy - Corporation of the Township of North Dundas

1 e-copy - Ontario Clean Water Agency

1 e-copy - Golder Associates Ltd.

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APPENDICES

1.0 INTRODUCTION

1.1 Background

Golder Associates Ltd. (Golder, member of WSP) was retained by J.L. Richards & Associates Limited (JLR) on behalf of the Township of North Dundas (Township) to provide consulting engineering services for the Municipal Environmental Assessment (Class EA) of the North Dundas Drinking Water Supply System Capacity Expansion. The Class EA is being undertaken to provide a solution to address water supply capacity for both residential and industrial use for the future 20-year projection period and provide water supply system reliability over the 20-year future projection period for the Village of Winchester (Winchester) and the Village of Chesterville (Chesterville) in the Township. As part of the project, Golder was retained to complete a Wellhead Protection Area (WHPA) study in support of the Township Class EA for the proposed location for a new communal water supply well, located on Lafleur Road on Lot 14, Concession 9 in the Geographic Township of Winchester, Township of North Dundas, Ontario.

This document is to be used to support the Class EA for a proposed communal water supply well and not for modifications to the existing Source Protection Plan. Once through the Class EA process, and after a water supply well has been constructed and tested, an updated WHPA Study will have to be completed to implement modifications to the Source Protection Plan.

As shown on Figure 1, the proposed communal well site is located approximately 1 kilometre southeast of the Winchester Wellfield No. 7 (7a, 7b and 7c or Wellfield No. 7 Site). The proposed well site lies within the limits of the existing WHPA established for the Wellfield No. 7 municipal water supply (refer to Figure 1) as part of the Source Protection Plan requirements completed for the Raisin River Conservation Authority (RRCA) and South Nation Conservation (SNC), also referred to as the Raisin-South Nation Source Protection Region (RRCA and SNC 2016).

The combined population of Winchester and Chesterville is approximately 4,071 (Statistics Canada, 2017). These communities are located approximately 50 kilometres (km) south of the City of Ottawa, within the Township of North Dundas. Their populations are projected to increase due to their proximity to the City of Ottawa and future potential developments. The ultimate population is estimated to grow to between 6,039 and 7,229 by the 20-year projection period (2039) based on projected low and high growth scenarios, where the maximum daily water demand is estimated to range between 7,736 cubic metres per day (m^3/d) and 8,570 m^3/d (JLR 2020).

The North Dundas Drinking Water System (System) supplies treated water to Winchester and Chesterville. The System currently derives its water supply from three municipal wells completed in bedrock (Winchester Wells No. 1, 5 and 6), and two well fields completed in overburden sediments, comprised of three municipal wells (Winchester Wells No. 7a, 7b, and 7c) and two municipal wells (Chesterville Wells No. 5 and 6) and is managed by the Ontario Clean Water Agency (OCWA). The System has a future deficit of 2,595 m^3/day and 3,429 m^3/day based on the 2039 projected maximum day demand for both low growth and high growth scenarios, compared to the current operational limit of the existing communal wells (59.5 L/s or 5,141 m^3/day) which assumes the largest well is out of service (Well No. 7b or 7c) (JLR 2020). It is understood the Class EA studies will consider options including upgrading the System to include the addition of new municipal supply wells and a watermain to convey surface water to the System from Morrisburg, located in the Township of South Dundas, to meet and provide reliability to the 20-year future projected period scenarios.

Golder previously conducted a series of hydrogeological investigations to assess the capacity of the overburden aquifer (herein referred to as the Morewood Esker) at the proposed well site in 1992 and 2021. The hydrogeological investigations included drilling and aquifer testing programs to find an additional water supply resource for the Township as documented in *Groundwater Supply Investigation St. Pierre Property Village of Winchester Water Supply Study* (Golder 1992) and the *North Dundas Drinking Water Supply System Capacity Expansion Aquifer Testing Program, Township of North Dundas Municipal Class Environmental Assessment* (Golder 2021). The studies found that a viable water supply exists within the portion of the Morewood Esker underlying the proposed well site, approximately 7 km northeast of Winchester. Based on the results of the aquifer testing programs, it is inferred that the construction of a municipal supply well at the proposed site (with one well as stand-by for firm capacity) would be capable of supplying an additional 20 L/s to 30 L/s (1,728 to 2,592 m^3/day) to Winchester.

1.2 Objective

The objective of the current assessment is to develop a preliminary estimate of the Well Head Protection Areas (WHPAs) for a proposed new municipal supply well, including its potential interaction with the existing Wellfield No. 7 in the Morewood Esker complex. The assessment also contains the completion of the vulnerability assessment, which includes system characterization, delineation of vulnerable areas, vulnerability area scoring and significant threats inventory associated with Source Protection Plan requirements for the Raisin-South Nation Source Protection Region (RRCA and SNC 2016).

1.3 Scope of Work

To meet the above objective, the following scope of work was completed:

- The conceptual hydrogeological model in the area of the proposed well site was refined, giving consideration to previous pumping test programs completed by Golder in the Morewood Esker (Golder 1992, 1995a and 2021) and publicly available information (e.g., surficial geology mapping of the Morewood Esker, general conceptual models of esker deposits in this region by the Geological Survey of Canada (GSC 2007), well records, borehole logs and groundwater elevation data).
- Refinement of the previous regional groundwater model in the area developed by WESA (2011) to reflect the updated conceptual hydrogeological model in the area of the proposed well site.
- Calibration of the refined groundwater model to groundwater elevations and regional flow patterns.
- Completion of forecast simulations with the refined model to develop preliminary WHPAs for the proposed well site as well as Wellfield No. 7.
- Complete a vulnerability assessment consistent with Source Protection requirements for the preliminary WHPAs in accordance with the December 2021 Technical Rules under the Clean Water Act (Technical Rules) (MECP 2021). This includes development of aquifer vulnerability mapping and an inventory of potential significant drinking water threats.

This report is organized as follows: Section 2.0 describes the refinements to the conceptual hydrogeological model; Section 3.0 outlines the refinement to the numerical groundwater flow model; Section 4.0 presents the preliminary WHPAs for the proposed well site and Wellfield 7; Section 5.0 summarizes the vulnerability assessment; Sections 6.0 though 8.0 describe land uses within the WHPA and the threats analysis; while an overall summary is provided in Section 9.0. Limitations on the use of the findings in this report, and relevant references in completing the assessment are provided in Sections 10.0 and 11.0, respectively.

2.0 REFINEMENTS TO CONCEPTUAL MODEL

2.1 Regional Context

The majority of the water supply for the North Dundas Drinking Water Supply System originates from glacio-fluvial deposits within the wider Study Area. These long and narrow ice-contact stratified drifts are north-south trending features comprised of well-sorted coarse sands and gravels that deposited in melt-water channels within glaciers that covered the area long ago. The most prominent features within the wider Study Area are the Morewood Esker (part of the Vars-Winchester Esker Complex) and the Maple Ridge Esker, both of which are labelled on Figure 1. There is also the Loughlin Ridge located approximately 11 km west of Winchester.

The Vars-Winchester Esker has been the subject of investigations by the Geological Survey of Canada, using geophysical methods to locate and characterize the esker where it is not present at surface but is buried beneath marine clay deposits. These studies have been focused on sections of the Vars-Winchester esker in the Russell-Embrun area, north of the Morewood Esker.

The Morewood Esker is a north-south linear feature that is some 7.5 km long by approximately 250 metres (m) wide at the surface (average subsurface width of the esker is ~800 m (GSC 2007)). The presence of the esker is reflected by topography and the position of a number of sand and gravel pits located along the esker. The esker material generally consists of a highly permeable and transmissive 100 to 200 m wide esker core of well sorted sand and gravel, cobbly gravels and sandy gravels. The core is flanked (called the carapace) by finer soils, grading from sands to silts and clays. The esker is entrenched into the glacial till and its base is generally at or near the underlying bedrock surface; the sandy flanks of the esker are frequently overlain by marine clays. The surficial signature of the esker core is delineated in places by a small topographical ridge reworked by nearshore processes (former beach). Elsewhere the presence of the esker core is only inferred and may be discontinuous in places (GSC 2007; Golder, 1995a and 2003).

The Maple Ridge Esker is comprised of an assortment of sand, gravel, clay, ice-contact stratified drift, and till, and has been referred to as a terminal moraine. This esker deposit is oriented east-west, and its eastern end portion is located approximately 4 km west of Chesterville. Its surface expression is approximately 3 km in length and between 0.2 and 1.5 km wide. The core of the esker consists of coarse sand and gravel with gravel content increasing towards the north. In the southern portion of the esker, glacial till exists (Golder, 2003a). Several sand pits are present towards the east end of the Maple Ridge Esker.

Based on the available surficial geology mapping, there is no surficial feature reflecting the presence of the Vars-Winchester Esker in the intervening land area that extends 4 km north-south between the southern end of the Morewood Esker and the north side of the Maple Ridge Esker. Previous investigations in this intervening area between these two esker features as part of several previous studies to provide additional groundwater supplies for Winchester and Chesterville have found that the overburden is of generally limited thickness, and the soil conditions encountered are not the coarse granular core or finer sand flanks that are characteristic of the esker. The geophysical studies used to locate the esker where it is buried beneath clay soil deposits were not carried out in this intervening area. Although the Vars-Winchester Esker is shown as being present in this intervening area in published information (GSC 2007), it has not been encountered in previous targeted investigations, suggesting that it may be discontinuous in this area of the Township.

2.2 Existing Wellhead Protection Areas

During the original source protection planning undertaken by the RRCA and SNC, an Assessment Report for the South Nation Source Protection Area was completed. As part of the Assessment Report, a WHPA Study and a vulnerability assessment was completed for Wellfield No. 7. The following four wellhead protection zones were defined for the wellfield:

- Zone A – 100 metre radius pathogen security/prohibition zone
- Zone B – 2-year horizontal Time of Travel (ToT) pathogen management zone
- Zone C – 5-year ToT dense non-aqueous phase liquid /contaminant protection zone
- Zone D – 25-year ToT secondary protection zone

These zones are used to assist in identifying the various levels of potential risks faced by municipal supply wells from pathogens and chemical contaminants. Figure 1 shows the capture zones that comprise the existing WHPA for Wellfield No. 7. The site for the proposed new municipal supply well falls within WHPA-C for Wellfield No. 7.

The definition of the current Wellfield No. 7 WHPA is based on the results of groundwater modelling and, as such, reflects the approach taken to the modelling. From review of the modelling approach used for the Winchester Wellfield No. 7 (SNC and RRC, 2016a; WESA, 2011), the area of the Morewood Bog located about 3 km east of both Wellfield No. 7 and the proposed well site was defined in the model as a regional recharge area. This regional recharge area is reflected in the shape and extent of the capture zones of the Wellfield No. 7 wells that swings east from the wells towards the Bog. However, this conceptualization did not consider that much of the recharge to the Morewood Esker occurs from direct precipitation on areas of the permeable esker core materials that are exposed at surface. Previous investigations in the intervening area between the Morewood Esker and the Maple Ridge Esker (located to the south of the Morewood Esker) have not been able to locate the esker (either exposed or buried). It is interpreted, therefore, that much of the recharge to the Morewood Esker is much more local and occurs on the mapped esker itself. The potential for an actual connection between the groundwater in the area of the Morewood Bog (to which the source water protection requirements currently apply) is unlikely; however, it is currently reflected in the capture zones of the Wellfield No. 7 WHPAs.

A detailed conceptual basis for the original numerical model construction is provided in WESA 2011; a summary is provided below, which includes the model revisions completed by Golder as part of this WHPA study.

2.3 Refinements in Vicinity of Morewood Esker

Within regional context during this investigation, a detailed review has taken place of the conditions of the Morewood Esker and the following refinements to the geological conceptual model have been made:

- <u>Extent of the Morewood Esker</u>: The extent of the esker is consistent with the surficial geological mapping as shown on Figure 1. The esker material consists of a highly conductive, 100 to 200 metre wide, esker core of well sorted sand and gravel, cobbles and gravel and sandy gravel where the coarse grained glaciofluvial deposits form an excellent local aquifer. These sandy gravels extend from the surface to a depth of approximately 10 to 14 metres. The saturated thickness ranges from 0 to 16 m, with an average of 9 m. The Morewood Esker is principally unconfined, but confined conditions persist where the marine clays overlie coarse-grained materials of the deposits, or where the deposits are entirely buried (if present). The aquifer is recharged by infiltrating precipitation (diffuse) and by the surface ponds created by local gravel extraction operations below the water table. The majority of the recharge will occur where the coarse granular central core and sandy flanks of the esker are exposed at the surface. The esker is entrenched into the glacial till and its base is generally at or near the underlying bedrock surface; it is frequently overlain by marine clays at the margins. The signature of the esker core is delineated in places by a small topographic ridge reworked by nearshore processes (former beach).

- Lateral extent of sand carapace: Based on additional geological data and the findings of previous hydrogeological investigations completed by Golder within the study area (Golder 1990, 1995a), in the area of the Morewood esker the esker core is interpreted to be flanked on the sides by sand and silty sand deposits (herein referred to as the sand carapace) of moderate permeability, ranging between 0.4 and 2 km wide (GSC 2007). These sands have a thickness of up to 16 m in the vicinity of the core but are interpreted to pinch out approximately 190 m from the core contact in each direction (Golder 2003). Golder's interpreted extent of the sand carapace on the flanks of the Morewood Esker is shown on Figure 1. A schematic of the interpreted Morewood Esker cross-section showing the interpreted sand carapace is provided in Figure 2.
- Hydrogeologic properties of primary stratigraphic units: The primary hydrogeological stratigraphic units of the study area consist of the Morewood Esker core, surrounding sand carapace, which may be overlain by marine muds (basin clays) and underlain by sandy silt till, sub-till sediment and bedrock. Review of the hydrogeological properties assigned to the various hydraulic units in the original modelling approach for the Winchester Wellfield No. 7 indicates higher permeabilities than expected for stratigraphic units such as basin mud (1×10^{-6} metres per second, m/s), sub-till sediments (8×10^{-4} m/s) and bedrock (5×10^{-4} m/s) (WESA 2011). Based on Golder's understanding of the materials present and results of aquifer testing programs completed within the study area, the horizontal hydraulic conductivity was reduced to the following values:1×10^{-7} m/s for the basin mud, 1×10^{-4} m/s for the sub-till sediment and 1×10^{-5} to 1×10^{-7} m/s for bedrock.
- Groundwater flow directions: Based on the groundwater elevation data, the general direction of natural groundwater flow within the Morewood Esker is to the north, following the long axis of the esker as illustrated in Figure 3. However, a component of groundwater flow is in a southerly direction in the south portion of the esker, forming a groundwater divide approximately 500 m north of County Road 3. It has been considered that this condition is likely a result of the topographic high t that is present in this area (Golder 1996). Based on the historic groundwater elevation data available from PGWMN (previously referred to as WESA-16; refer to Figure 3), the presence of this groundwater divide does not appear to have been altered by the pumping activities at Winchester Wellfield No. 7 (Golder 2008). Long-term groundwater monitoring data completed by Golder up to the start of operation of Winchester Wellfield No. 7 on March 21, 1997, and subsequent monitoring data completed by OCWA suggests that the divide is a relatively transient feature. As would be expected in permeable coarse-grained deposits, the horizontal hydraulic gradient within the esker is quite low and has been measured to be 1×10^{-4} (Golder 1996).

3.0 GROUNDWATER MODEL REFINEMENT

3.1 Model Background

As part of Golder's data review, conceptual model development and calibration of a 3-D groundwater flow model for the proposed well site, Golder submitted a formal request to South Nation Conservation (SNC) on May 20, 2022, for background information and any previous modelling files for the study area. Laura Crites (SNC Planning Technician) provided available modeling files and supporting technical reports on June 28, 2022. A key component of the information provided was the 3D groundwater flow model developed by WESA (2011) in support of the existing Source Protection Assessment Reports (e.g., including the capture zone, vulnerability, and threats assessment reports for Wellfield No. 7). A brief overview of the background of the WESA (2011) model is provided below:

- WESA developed a groundwater flow model in 2011 to conduct a WHPA and groundwater vulnerability assessment for the Winchester and Chesterville municipal well fields, using the finite difference code MODFLOW. They utilized Earth FX Viewlog 3, ESRI ArcGIS and Microsoft Visual Basic 6 as the pre- and post-processing tools. Golder's understanding is that the MODFLOW code within Earth FX Viewlog is a proprietary version of the publicly available MODFLOW code.
- The WESA 2011 groundwater flow model covered an area of 1,017 km^2 (33.9 km x 30 km), as illustrated on Figure 4. The finite difference grid consisted of 1,009 columns, 968 rows and 8 layers, for a total of ~ 7.8 million cells. In the area of Wellfield No. 7 and the proposed well site, the finite difference grid discretization (in plan) was on the order of 25m. Overall details of the WESA 2011 model boundary conditions, hydraulic conductivity parameterization and recharge distribution are outlined in the WESA 2011 report.

Given the WESA 2011 model provided an existing representation of the regional flow system in the project area, this model was used as the initial basis for the 3D Groundwater Flow model for the proposed well site. However, to allow for greater efficiency in the numerical simulations, this model was reduced in size considerably to focus on the local study area. As shown on Figure 4, the updated model for the current study is reduced in size to 328 km^2 (17.5 km x 18.7 km), with a total number of grid cells of ~ 3.28 million. In addition, the model was converted into a commercially available version of the MODFLOW code (described later in Section 3.2). Additional refinements to the smaller model were then made to reflect the updated conceptual model in the vicinity of Wellfield No. 7, the proposed well site and the Morewood Esker. These refinements are described in Section 3.3 below.

3.2 Model Code

The commercially available MODFLOW-2000 code (Harbaugh et al. 2000) is used in the current study to simulate groundwater flows in the model. MODFLOW-2000 is developed by the United States Geological Survey and is recognized as an industry standard for general purpose groundwater flow modelling. It is modular in nature and uses the finite difference formulation of the groundwater flow equation in its solution.

MODPATH (Pollock, 1989), a companion code to MODFLOW, is used to conduct particle tracking for capture zone delineation. SAMG (Algebraic Multigrid Methods for Systems) developed by the Fraunhofer Institute for Algorithms and Scientific Computing (FhG-SCAI) is used to solve the groundwater flow equations in this analysis. Visual MODFLOW (Version 4.6.0.169) was used as the pre- and post-processor for the simulations presented in this report.

3.3 Model Refinements and Local Calibration

As noted earlier, the model developed by WESA (2011) was used as the initial basis of the groundwater model for the current assessment and was subject to several refinements to focus on the proposed well site. The following summarizes the specific refinements made to the 2011 WESA model and its calibration to information local to the proposed well site.

3.3.1 Model Refinements

- As shown on Figure 4, the refined model covers a smaller area than the original WESA 2011 model. The grid spacing in the area of the proposed well site and Wellfield No. 7 remains at ~ 25 m.
- The modelled hydro stratigraphy and boundary conditions implemented in the WESA 2011 model were (in general) retained during the current modelling work, though locally some adjustments in the extent of the hydrostratigraphic units were changed. For example, the extent of the core of the esker was adjusted at the surface to reflect conditions as they exist on site (discussed earlier in Section 2 and illustrated on Figure 4). In addition to the esker core, an additional hydrostratigraphic zone was added to approximate the presence of a sand carapace on either side of the core. A width of ~ 400 m was assumed for the carapace, as illustrated on Figure 4.
- The hydraulic conductivities for each hydrostratigraphic unit in the model were adjusted during the model calibration process, the results of which are illustrated on Figure 5. In addition to values established for the esker and its sand carapace, revised values were implemented for the previously existing units in the model (refer to Tables on Figure 5).
- Recharge rates were also updated for each of the geologic units, based on their subcrop location. The final recharge rates established through the model calibration process are illustrated on Figure 6.

3.3.2 Calibration Results

Model calibration involved the refinement of hydraulic conductivities and recharge rates of various geological units in the model until the simulated hydraulic head distribution compared reasonably well with the measured conditions in the study area. The simulation runs were carried out at steady state, with Wellfield No. 7 pumping at 1,486 m^3/day (representative of the 2018 average daily taking). The following calibration targets were used in this assessment:

- Water levels at 22 monitoring wells in the area of the proposed well site. This data was collected since the start of operation of Wellfield No. 7 on March 21, 1997. These monitoring locations include a series of borehole monitoring locations near Wellfield No. 7 (Golder boreholes monitored in 2009 and 2012) and study area water levels from 2001 (Golder 2003) The location of these monitoring wells is provided on Figure 3.
- Water levels from 3282 wells extracted from the MECP water well database. While this information is of (generally) lower accuracy than the 22 monitoring wells noted above, this provides a secondary check on the reasonableness of the model calibration.

The results from the model calibration process are shown on Figure 7. A review of the results allows the following observations:

- The simulated groundwater elevations in the overburden (as represented by model layer #3), are consistent (in general) with those conceptualized from the monitoring well data (refer to Figure 7). Groundwater flow occurs from the higher topography in the east towards the Morewood Esker with discharge to the lowlands west of the esker (or pumping systems within the esker). Within the esker itself, hydraulic gradients are relatively low in the area of the proposed well site and Wellfield No. 7. This approximation of the groundwater flow system on a conceptual level forms the primary basis for calibration.

- A scatter plot of the simulated hydraulic head versus the average head for the target observation points shows the simulated points are reasonably approximated by the 45-degree line. The mean error (ME) with respect to the 22 monitoring well estimates is 1.18 m, with a normalized root mean squared error (nRMS) of 24.8%. This nRMS represents the lowest of the calibration runs completed, though it is recognized that it larger than sometimes achieved for regional and local flow systems. The reason for this may stem from the more than 10-year period of record from which the observation well groundwater elevation data is drawn, as well as the very low hydraulic gradients in the esker.

4.0 WELLHEAD PROTECTION AREA DELINEATION

4.1 Pumping Wells and Rates

Recognizing the potential interference between Wellfield No. 7 and the proposed well site, both wells are considered in the development of WHPAs for this assessment. The rates established for these wells are outlined below:

- The current pumping rate at Wellfield No. 7 (JLR 2020) is estimated at 17.2 L/s (1,486 m^3/day), while its maximum rate in the Permit to Take Water (PTTW) is 22.5 L/s (1,944 m^3/d). This corresponds to a "max day factor" of 1.3. This is much lower than a typical "max day factor" calculated for the Winchester/Chesterville drinking water system, which was in the 1.6 to 2.15 range (JLR, 2020). For the purpose of developing the WHPAs in the current assessment, the long-term pumping rate applied at Wellfield No. 7 remained at 17.2 L/s.

- The Maximum Daily Demand (MDD) for the proposed well site is 30 L/s (2,592 m^3/d). Assuming a "max day factor" of 1.7, a typical estimate when establishing average day demands for municipal supply wells, this translates to a pumping rate of 17.6 L/s (1,520 m^3/day). This rate was therefore applied for long-term pumping at the proposed well site in this assessment.

The simulated pumping of the proposed well at the proposed well site would affect the size and orientation of the existing Wellfield No. 7 WHPAs. To estimate the combined WHPAs, 'particles' were traced backwards in space and time in MODFLOW from critical depths at both Wellfield No. 7 and the proposed well site for three travel times: 2 years for WHPA-B, 5 years for WHPA-C and 25 years for WHPA-D. A polygon was drawn around each of the critical backwards travel times to create the individual zones and then superimposed to create the WHPA. A 100-metre radius WHPA-A was then overlain at each well location.

4.2 Base Case WHPA Delineation

To develop the WHPAs for the proposed well sites, the calibrated groundwater flow model was updated to reflect the pumping rates described in Section 4.1, and backward particle tracking completed to determine the 2-year, 5 year and 25-year time of travel zones. In addition to the pumping rates described in Section 4.1, the capture zone estimates consider the effective porosities listed in Figure 5.

Figure 8 (image on the left-hand side) presents the results of the WHPA delineation with the refined groundwater model for the Base Case WHPAs. A review of Figure 8 (image on the left-hand side), allows the following observations:

- The 2 year ToT WHPA extends up to 900 m from Well no. 7 (North) and 400 m (South) from the proposed well, aligned primarily in a north-south direction within the core of the esker.
- The 5 year ToT WHPA extends up to 1.3 km (North) from Well no. 7 (North) and 1 km (South) from the proposed well . While primarily contained within the core of the esker, there is some lateral capture of groundwater in the surrounding sand carapace.
- The 25 year ToT extends up to 2.6 km (North) from Well no. 7 and 1.9 km (South) from the proposed well. The primary area of capture remains the esker core and its sand carapace, although there is some capture simulated for the materials that border the sand carapace east and south of the esker complex. This is consistent with the conceptual understanding of the regional groundwater flow system, and likely reflects (in the simulated model) a small contribution from the surrounding tills, sub-till sediments and/or weathered bedrock units.

4.3 Uncertainty Analysis and Final WHPA Delineation

The capture zones (and corresponding WHPAs) discussed in Section 4.2 represent the "best-estimates" from the groundwater modelling process. However, it is recognized that there is some uncertainty associated with the groundwater flow system, and therefore the actual zones of capture from the wells in the Morewood Esker. Recognizing the uniqueness of the flow system in this particular case, which depends heavily on the mapped distribution of the Morewood Esker (including both its core and surrounding sand carapace), the approach to addressing uncertainty in this assessment was to consider a 100-metre buffer zone for WHPAs B, C and D around the outside perimeter of the base case estimates. The resulting (final) WHPAs are illustrated on Figure 8 (image on the right-hand side). The increase in area within each WHPA as a result of this approach to uncertainty is as follows: ~ 90% increase for the 2 year ToT; ~ 60% increase for the 5 year ToT; and ~ 20% increase for the 25 year ToT.

5.0 VULNERABILITY ASSESSMENT AND SCORING

Surface and subsurface contaminants pose a risk to groundwater resources and can have long-lasting impacts that can impair water quality conditions. The intrinsic vulnerability of the aquifer refers to the level of protection provided by the geological materials overlying the aquifer and is independent of the potential contaminant. The Technical Rules document the methods for assigning the intrinsic vulnerability of groundwater, identification of transport pathways that may increase the vulnerability, delineation of WHPAs and procedures for assigning vulnerability scores. The groundwater quality vulnerability analysis was carried out as follows:

- Delineate WHPA (Technical Rules V (42), V.3 (47 – 50.1));
- Assess groundwater intrinsic vulnerability (Technical Rules IV.1 (37 – 38.2));

- Determine impact of transport pathways (Technical Rules IV.1 (39 – 41));
- Assign groundwater vulnerability scores (Technical Rules VII.3 (82 – 83)); and
- Determine level of uncertainty in vulnerability assessment (Technical Rules I.4 (13 – 15)). The delineation of the WHPA including uncertainty is described in the previous section and the remaining components are described below

5.1 Aquifer Vulnerability Index

The vulnerability of the Morewood Esker (current and proposed municipal well supply aquifer) was calculated using the Aquifer Vulnerability Index (AVI) method. The AVI is a method for mapping the susceptibility of an aquifer to surficial contaminants and was based on both the refined conceptual model information (i.e., layers, hydraulic conductivity, etc.), geological information available from previous Golder investigations (Golder 1989, 1995a) and geological mapping (GSC 2007) completed within the limits or vicinity of the Morewood Esker, geological information from the MECP Water Well Information System (WWIS) database and the previous assessment presented in WESA (2010). It is noted that the scoring previously completed by WESA used the Surface Well Advection (SWAT) vulnerability scoring method at the request of the RRCA and SNC. For the purpose of this assessment, the AVI method was deemed an appropriate methodology based on Golder's understanding of the refined conceptual model of the Morewood Esker.

The AVI assigns a score (index) at each well location using the following method:

- Areas where the supply aquifer is unconfined: multiplying the depth to the aquifer by the "hydraulic conductivity factor'; or,
- Areas where the supply aquifer is confined (within sand carapace region and beyond esker core): multiplying the thickness of the unit by the "hydraulic conductivity factor" and summing the product for all layers above the supply aquifer.

This index value is then interpolated between the well locations to produce a complete spatial assessment (map) of the intrinsic vulnerability of the aquifer(s). The AVI scores were converted into "low", "medium" or "high" aquifer vulnerability values based on Technical Rule IV.1 (38) as follows:

- High Aquifer Vulnerability – AVI less than 30;
- Medium Aquifer Vulnerability – AVI between 30 and 80; and
- Low Aquifer Vulnerability – AVI greater than 80.

The resulting AVI map, presented in Figure 9, shows that the area within the limits of WHPA-A is generally classified as having a "high" intrinsic vulnerability, WHPA-B has both "high" and "medium" intrinsic vulnerability, while WHPA-C and WHPA-D located within the extent of the sand carapace are generally classified as having a "medium" intrinsic vulnerability. A "low" vulnerable area is mapped beyond the sand carapace in WHPA-D.

5.2 Vulnerability Score and Mapping Methodology

The WHPAs were overlain/integrated with the AVI map for the study area to produce vulnerability scoring maps. The vulnerability scoring and mapping was performed using the methodology outlined in the Technical Rules. The Vulnerability Score of the WHPA is determined by the intrinsic vulnerability classification and the WHPA zone (Table 1). A Vulnerability Score of 10 represents a high Vulnerability versus a score of 2 that represents a Low vulnerability within the WHPA; the Vulnerability Score decreases with distance away from the well and with decreasing aquifer vulnerability.

Table 1: WHPA Vulnerability Score

Intrinsic Vulnerability	WHPA-A (100 m Radius)	WHPA-B (2 Year ToT)	WHPA-C (5 Year ToT)	WHPA-D (25 Year ToT)
High	10	10	8	6
Medium	10	8	6	4
Low	10	6	4	2

5.3 Results of the Vulnerability Scoring

Figure 10 presents the vulnerability scoring for the WHPAs for the study area. A score of 10 is assigned to WHPA-A regardless of the intrinsic vulnerability classification as this area is near the wellheads. The majority of the Winchester Wellfield No. 7 and the proposed new municipal supply well WHPA-As lie within their respective site property boundaries. This means that the Township would have control over land use activities within the most vulnerable WHPA and could manage the property to avoid any Significant Threats within this zone. The land north of Wellfield No. 7 within WHPA-A is comprised of a rural residential property, while the land east of the proposed well's WHPA-A is comprised of agricultural land, both which may be subject to threats.

5.3.1 Vulnerability Score Modifiers

Constructed Transport Pathways

The Technical Rules allow for increasing the Vulnerability Score based on transport pathways that are anthropogenic in origin, including:

- Private water wells, unused water wells and abandoned water wells;
- Construction of underground services;
- Subsurface excavations; and,
- Pit and quarries.

A constructed preferential pathway is "a pathway, or shortcut, that can make it easier for a contaminant to be transported to a drinking water source". The vulnerability of the surficial Morewood Esker is being assessed to account for the natural protection provided by the materials overlying the aquifer of interest (where present). However, anthropogenic activities can bypass this natural physical protection thereby increasing the vulnerability.

An analysis of potential preferential pathways within the WHPAs was conducted as part of this study, which were identified through a review of aerial photography, location of private water wells and a windshield survey conducted by Golder personnel on September 30, 2022. The identified potential preferential pathways are presented in the next sections followed by an assessment of the potential preferential pathways to determine if the vulnerability should be adjusted.

Private well records and monitoring wells within the WHPAs were examined. A total of 20 water well records are listed in the MECP WWIS database, which are indicated as being for private water supply and that fall within the WHPA (Figure 10). An additional two unlisted water supply wells are also identified within the proposed well WHPA (on-site well historically referred to as St-Pierre well within property limits of the proposed well site and a water supply well at 1780 Lafleur Road, located approximately 250 m to the north, refer to Figure 11), based on Golder's knowledge of previous of hydrogeological investigations completed within the area. All private water supply wells are completed within the bedrock aquifer underlying the Morewood Esker, therefore do not pose a significant risk for the unconfined supply aquifer. An exception to this is the St-Pierre well that consists of a slotted steel casing installed within the Morewood Esker; however, the well is no longer operational. At least 16 monitoring wells screened within the Morewood Esker and/or sand carapace still remain within the WHPA, of which 15 are monitored by OCWA in support of the operation of Wellfield No. 7. However, it is understood the monitoring wells are completed with a casing height above grade, secure and in good condition, therefore do not pose a significant risk for the supply aquifer.

Water from Wellfield No. 7 is transported south towards Winchester via an underground watermain located along Lafleur Road at about 2 metre depth within the extent of the Morewood Esker, which then travels west along County Road 3 to the Village of Winchester. A section of this watermain is located within and crosses the esker core and sand carapace; this watermain trench does not create a greater risk of contamination to the supply aquifer than the aquifer materials that are exposed at surface. Beyond the esker the trench is within glacial till or clay soils and not directly connected to the supply aquifer. It is also noted that the pipe is carrying water and not a potentially contaminating liquid. Therefore, this does not pose a significant risk for the supply aquifer.

A total of three pits, Aggregate Resource Act (ARA) license areas 5783, 5868 and 19708, are located within the WHPA-A or WHPA-B. This includes the proposed well site, which consists of a partially developed licensed aggregate pit (portion of ARA license area 5783) (refer to Figure 11). The current and/or future pit operations within the WHPA may pose a transport pathway of potential concern.

5.3.2 Vulnerability Uncertainty

The Technical Rules require an analysis of the uncertainty, characterized as high or low, be made for the completed Vulnerability and WHPA assessments. Within the Technical Rules a specific uncertainty analysis is not outlined but indicates that the following factors are to be considered in the analysis:

- The distribution, variability, quality and relevance of data used in the assessment;
- The ability of the methods and models used to accurately reflect the flow processes in the hydrogeological system;
- The quality assurance and quality control procedures applied; and,
- The extent and level of calibration and validation achieved for models used or calculations or general assessments completed.

In addition, previous guidance documents (MOE, 2006) list some of the factors where it would be reasonable to expect that a **low** uncertainty would be applied:

- In areas where the density of the data is high, and there is a high level of confidence in the quality of the data;
- In areas where hydrogeological studies have been completed to confirm the regional scale mapping that has been completed; and,
- Where a numerical model has been sufficiently calibrated to observed data that includes aquifer testing at the well location, and water level data across the capture zone footprint, and there is a high level of confidence in the representation of the flow system (and flow system boundaries) through local hydrogeological studies, or subsequent verification simulations.

The vulnerability assessment for the new proposed municipal well and Wellfield No. 7 is based on a combination of the information provided by the numerical model, and a review of the geological and hydrogeological data available in previous investigations completed by Golder and the MECP WWIS. The WHPA delineation was also based on the numerical flow model and therefore the uncertainty associated with both items are similar as they are both linked with the ability of the numerical flow model to satisfactorily represent actual conditions.

The model updates in the study area are based on high-quality drill logs and aquifer testing. The subsequent model calibration (Section 3.3) demonstrates that the model can achieve a reasonable representation of hydrogeologic conditions, particularly in the area of the proposed well site. Considering these factors, the level of uncertainty is considered low in the area of the proposed well site and Wellfield No. 7 and increases to the outer reaches of the WHPA-D area. However, as described previously, the final WHPA-D incorporates a conservative "uncertainty envelope" (100 m buffer), which, in effect, reduces overall uncertainty in the capture zone results. As such, the overall vulnerability and WHPA uncertainty is characterized as Low.

5.3.3 Adjustments to Vulnerability Accounting for Preferential Pathways

Constructed preferential pathways may provide a faster pathway for the potential threats and contaminants to travel to the aquifer and ultimately to Wellfield No. 7 and the proposed new municipal supply well site. As part of this study, preferential pathways were reviewed and analyzed to determine their effect on the aquifer vulnerability. The vulnerability of the aquifer may be increased by any land use activity or feature that disturbs the surface above the aquifer, or which artificially enhances flow to that aquifer. In areas where preferential pathways exist, the intrinsic vulnerability can be increased to reflect the higher vulnerability caused by the constructed pathway (i.e., from low to moderate or high and/or moderate to high). In some cases, the intrinsic vulnerability index is already high and can not be further increased. Based on the assessed presence of preferential pathways and modified vulnerability index, the resultant vulnerability score increases to reflect the identified enhanced vulnerability. When modifying the intrinsic vulnerability, the following factors were evaluated according to Technical Rule IV.1 (41):

1) Hydrogeological conditions;
2) The type and design of any transport pathways;
3) The cumulative impact of any transport pathways; and,
4) The extent of any assumptions used in the assessment of the vulnerability of the groundwater.

Our interpretation of the Technical Rules is that the vulnerability of the aquifer should only be increased to account for a preferential pathway where there is sufficient confidence in the available data to justify increasing the vulnerability. The vulnerability should be adjusted to account for deep excavations, pits and quarries, etc., where it is documented that the features penetrate a confining unit or remove sufficient material and thus decrease the natural protection of the material overlying the municipal aquifer. These areas are delineated based on supporting documentation including air photo interpretation and local knowledge of the study areas.

A greater degree of interpretation is required to determine whether the presence of a well (used, unused, decommissioned) warrants an increase in the calculation of vulnerability ranking. The existence of a well(s) that would pose a significant risk to the municipal aquifer is considered an exception, not a rule. Wells can pose varying degrees of risk to a municipal aquifer; however, a well constructed into a municipal aquifer does not necessarily pose a risk to the municipal aquifer. A true risk of a well acting as a transport pathway to the municipal aquifer is mainly influenced by the actual construction of the well (i.e., presence and competence of the annular seal); given the available information from most well records, there is no way of confidently assessing if annular seals are properly installed in the well without a site well inspection, which is not a practical exercise. Since the nearby water supply wells (unlisted and listed in the MECP well records) are constructed into the bedrock aquifer underlying the Morewood Esker, there are no confirmed private well pathways and, as such, no increases to vulnerability due to the presence of private wells have been included. However, the decommissioning of abandoned wells or unused wells (i.e., St-Pierre well) is an important part of source protection and these potential wells within the WHPA should be investigated by the Township as part of future studies. This is not only for the protection of municipal drinking water sources, but also the protection of the quality of the groundwater resource for all users. Since the pits and the subsurface excavations for the watermain, where the esker core is near surface, are already located within the high vulnerability area, there is no need to adjust the vulnerability scoring.

6.0 DRINKING WATER ISSUES

The objective of the Issues evaluation is to identify drinking water Issues where the existing or trending concentration of a parameter or pathogen would result in the deterioration of the quality of water for use as a source of drinking water (Technical Rules X1.1).

6.1 Drinking Water Issues Evaluation

A Drinking Water Issue is defined in the Technical Rules as:

- The presence of a parameter or pathogen in water at a well or monitoring well if the parameter is listed in Schedule 1, 2 or 3 of the Ontario Drinking Water Standards (ODWS) or Table 4 of the Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines; and,
- The parameter is present at a concentration that may result in the deterioration of the quality of water for use as a source of drinking water; or
- There is a trend of increasing concentrations of the parameter or pathogen, and a continuation of that trend would result in the deterioration of the quality of the water for use as a source of drinking water.

The MECP has indicated that naturally occurring parameters that exceed the Ontario Drinking Water Quality Standards (ODWQS, MOE, 2003) (e.g., iron and manganese) should be noted in assessment reports but not be listed as Drinking Water Issues unless there is concern that human activities would adversely affect the concentration.

The water quality results from well testing completed at the proposed well site indicates that the water quality meets the ODWQS for all parameters tested except for the maximum allowable concentration (MAC) of total coliforms, aesthetic parameters manganese and colour and operational guidelines hardness and organic nitrogen (Golder 2022). The MAC was exceeded for total coliforms in the final sample collected towards the end of the 24-hour pumping test. The source of the total coliforms is unknown but may be related to groundwater under the influence of the nearby pond present at the time of the pumping test, which is subject to potential water quality contamination from local and nearby migratory bird species. As part of this assessment, it is assumed that the existing on-site pond will be filled in with suitable soils prior to the proposed well site being developed as a municipal water supply. The manganese and colour exceedance are considered to be a naturally occurring condition of the aquifer. Given the isolated hydrogeologic setting and calcium-bicarbonate type aquifer, the hardness and organic nitrogen in the aquifer are considered to be from a naturally occurring condition of the aquifer.

Groundwater quality at Wellfield No. 7 is routinely monitored as part of on-going groundwater supply activities for the Township (OCWA 2019). The results of the testing indicate the presence of the water quality is good, with occasional detections of non-pathogenic bacteria in raw water supply. Water treatment was sufficient to reduce these detections to below the ODWQS. Based on the testing completed by OCWA under Ontario Regulation 170/03, inorganic and organic parameters met the standards.

A Groundwater Under the Direct Influence (GUDI) study was completed for the Winchester Wellfield No. 7 in 2002 (Golder 2002). Winchester Wells No. 7b and 7c were determined not to be GUDI, whereas Winchester Well No. 7a was determined to be potentially GUDI based on the criteria defined in MOE, 2001. In a follow-up study (Golder 2002a), results from particle counting concluded that the aquifer is providing effective in-situ filtration for Winchester Well No. 7a.

7.0 MANAGED LAND AND LIVESTOCK DENSITY

7.1 Managed Land

The Technical Rules (Part II, Rule 16(9)) require that the percentage of managed lands be assessed within the vulnerable areas. The calculated percent managed land is used in the threat assessment to determine the nutrient application related threats including application of Agricultural Source Material (ASM), commercial fertilizer and Non-Agricultural Source Material (NASM). Managed land is broken into two subsets; agricultural managed lands and non-agricultural managed lands. Agricultural managed lands include areas of crop land, fallow and pastureland that may receive nutrients. Non-agricultural managed lands include golf courses, sports fields and residential lawns and other built-up grassed areas that may receive nutrients (primarily commercial fertilizers). The percentage of managed land is considered to be the sum of agricultural managed land and non-agricultural managed land divided by the total land area of the vulnerable zone. It should be noted that the area only includes those parts of a property that are within the vulnerable zone regardless of whether the property extends beyond the zone.

The managed lands are to be identified within each WHPA zone where the Vulnerability Score for that area is high enough for Activities to be considered a Significant, Moderate or Low Drinking Water Threat. WHPAs with managed lands of less than 40% of the total land area are considered as areas with low potential contamination risk, 40 to 80% as moderate potential contamination risk and over 80% as high potential contamination risk related to nutrient application.

For the purposes of this assessment, the methodology used to calculate percent managed land included a review of aerial imagery, and a windshield survey completed in September 2022. Figure 11 illustrates the distribution of agricultural and non-agricultural managed land within the WPHA and includes the location of the three licensed ARA pits. The percent managed lands are mapped per the following classes: less than 40%, 40 to 80%; and greater than 80%. As shown in Figure 12, the contamination risk related to nutrient application increases further away from the existing Wellfield No. 7 and proposed new municipal supply well. WHPA-A has the percent managed lands as less than 40% and is subject to a low potential contamination risk. A moderate potential contamination risk exists within WHPA-B, which is mapped as 40 to 80% managed lands. WHPA-C and WHPA-D have greater than 80% managed land and are therefore subject to high potential risk of contamination related to nutrient application.

7.2 Livestock Density

The Technical Rules (Part II, Rule 16(16)) require the mapping of livestock density. Livestock density is defined as the number of nutrient units over a given area and is expressed by dividing the nutrient units by the number of acres in the agricultural managed land area or the livestock grazing area depending on the threat being assessed. The livestock density is calculated for the purposes of determining the circumstances related to the application of nutrients.

The calculation of livestock density involves the following steps:

- Estimate the number of each category of animal present.
- Convert the numbers of each animal present into nutrient units (to allow for all animals to be compared on an equivalent unit of measure).
- Sum the total nutrient units of all animals present and divide by the agricultural managed land within the same WHPA. The maximum livestock density of an area is based on the assumption that all existing barns are in service to full capacity based on their size. Nutrient units are calculated for an entire property; however, nutrient units on a property that crosses a WHPA boundary are prorated for the area within that WHPA zone.
- The total nutrient units (NU) of all livestock generated nutrients in the WHPA is divided by the acreage of the agricultural managed land.

For the purpose of this study, the methodology used to calculate livestock density included identifying agricultural properties within a WHPA based on reviewing satellite imagery for suspected livestock barns and conducting a windshield survey (completed in September 2022). If the livestock density is less than 0.5 NU/acre, the area is considered to have low potential for nutrient application exceeding crop requirements, if livestock density is over 0.5 and less than 1.0 NU/acre, the area is considered to have moderate potential for nutrient unit application exceeding requirements and if livestock density is over 1.0 NU/acre, the area is considered to have a high potential for nutrient application exceeding requirements.

A total of three livestock operations (dairy, horse and beef farms) were identified within the WHPA. A beef farm was identified within the northern limits of WHPA-C at 13214 which results in an estimated livestock density of >1.0 NU/acre. A livestock density of <0.5 NU/acre was estimated for WHPA-D which includes a horse farm identified within the northern limits of WHPA-D at 13300 County Road 13 and a dairy farm identified at 13077 County Road 3 within the southern boundary of WHPA-D. No livestock operations were identified in WHPA-A and WHPA-B, therefore a livestock density of <0.5 NU/acre was assigned to these areas. The mapped livestock density is presented in Figure 13.

7.3 Impervious Area Mapping

The Technical Rules require calculation and mapping of the percentage of impervious land where road salt can be applied. This impervious surface area mapping is used in the risk scoring and assessment of Threat Circumstances relating to road salt application. For this assessment, total impervious land is defined as the surface area of all highways and other impervious land surfaces used for vehicular traffic and parking and all pedestrian paths.

Impervious features and their associated areas within the WHPAs were manually quantified using the GIS measurement tool and using Google satellite imagery. Impervious land is mapped per the following classes: less than 1%; 1% to 8%; 8% to 80%; and greater than 80% groupings. It was found that the percent impervious land within all of the designated WHPA areas (WHPA-A, -B, -C and -D) was between 1.1% and 8.0 % (Figure 14).

8.0 DRINKING WATER THREATS

8.1 Threat Assessment Methodology

A threat assessment was performed as part of this study to identify, evaluate and rank the significant threats to the Morewood Esker water supply occurring on individual properties located within the WHPA. A Drinking Water Threat is an Activity or Condition that adversely affects or has the potential to adversely affect the quality of drinking water and includes an Activity or Condition that is prescribed in the Technical Rules. An Activity is a current land use whereas a Condition is the result of past Activities at a location in which contamination of the subsurface has occurred.

The MECP defines the following as prescribed Threats:

1) The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act;
2) The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage;
3) The application of agricultural source material (ASM) to land;
4) The storage of ASM;
5) The management of ASM;
6) The application of non-agricultural source material (NASM) to land;
7) The handling and storage of NASM;
8) The application of commercial fertilizer to land;
9) The handling and storage of commercial fertilizer;
10) The application of pesticide to land;
11) The handling and storage of pesticide;
12) The application of road salt;
13) The handling and storage of road salt;
14) The storage of snow;
15) The handling and storage of fuel;

16) The handling and storage of a dense non-aqueous phase liquid (DNAPL);
17) The handling and storage of an organic solvent;
18) The management of runoff that contains chemicals used in the de-icing of aircraft;
19) An Activity that takes water from an aquifer or surface water body without returning the water taken to the same aquifer or surface water body;
20) An Activity that reduces the recharge of an aquifer; and,
21) The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard (generation of ASM).

Prescribed Threats 19 and 20 are considered water quantity Threats and are not within the scope of this report.

Following the identification of the above listed threats, the threat assessment involved ranking a threat as significant, moderate or low based on the vulnerability score and the circumstance information in the Tables of Drinking Water Threats listed in the Technical Rules, which detail specific 'Circumstances' for each prescribed Activity to determine if the Threat would be characterized as Significant, Moderate or Low. The Source Water Protection Portal developed as a cooperative project between the MECP and Upper Thames River Conservation Authority (UTRCA) was used to access the Provincial Tables of Drinking Water Threat web-based tool to identify where activities would be significant, moderate or low (MECP and UTRCA 2022).

In accordance with the Source Protection Plan developed for the Raisin-South Nation Source Protection Region (RRCA and SNC 2016), the main objective of the threats assessment is to identify any potential significant threats. A significant threat to a source of drinking water is a threat with a high likelihood of rendering a current or future drinking water source impaired, unusable or unsustainable, combined with a potential route for the threat to enter the source water. According to the Technical Rules, significant threats can occur within the following areas in a WHPA:

- Vulnerability of 8 – 10 for chemical threats;
- Vulnerability of 10 in WHPA-A and WHPA-B for pathogen threats;
- WHPA-A, WHPA-B and WHPA-C for DNPAL threats; and,
- The entire Issue Contributing Area if an Issue is present.

Figures 15, 16 and 17 identify the potential areas where Chemical, Pathogen and DNAPL, respectively, would be Significant Drinking Water Threats within the WHPAs.

A search of the Federal Contaminated Sites Inventory and MECP Record of Site Conditions (includes those filed since July 1, 2011) revealed no historical contamination within the WHPA (Treasury Board of Canada Secretariat 2022 and MECP 2022). Review of available water quality data within the study area does not indicate any evidence of groundwater contamination as a result of current and/or former land use operations within the study area (refer to Section 6.1). Based on Golder's understanding of historic land use practices and the primarily rural agricultural setting, no areas were identified within the WHPA that would constitute a significant condition in accordance with Technical Rule 140.

8.1.1 Significant Threat Enumeration Results

The Technical Rules require estimation of the number of locations at which an Activity is a significant drinking water threat. This enumeration of significant threats was completed as part of this assessment.

A summary of the significant threat risk scoring results, grouped by threat type, are included in Table 2. These include the total number of identified significant threats within the applicable WHPA.

Table 2: Enumeration of Significant Threats in WHPA

	Threat	Number of Significant Threats in WHPA-A	Number of Parcels with Significant Threats in WHPA-A	WHPA-A Vulnerability Score	Number of Significant Threats in WHPA-B	Number of Parcels with Significant Threats in WHPA-B	WHPA-B Vulnerability Score
1	The establishment, operation, or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act	0	0	-	0	0	-
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	1[1]	1[1]	10[1]	2[1]	2[1]	10[1]
3	The application of ASM to land	0	0	-	9[3]	9[3]	10[3]
4	The storage of ASM	0	0	-	0	0	-
5	The management of ASM	0	0	-	0	0	-
6	The application of NASM to land	0	0	-	0	0	-
7	The handling and storage of NASM	0	0	-	0	0	-
8	The application of commercial fertilizer to land	0	0	-	0	0	-
9	The handling and storage of commercial fertilizer	0	0	-	0	0	-
10	The application of pesticide to land	0	0	-	8[2]	8[2]	10[2]
11	The handling and storage of pesticide	0	0	-	0	0	-
12	The application of road salt	0	0	-	0	0	-
13	The handling and storage of road salt	0	0	-	0	0	-
14	The storage of snow	0	0	-	0	0	-
15	The handling and storage of fuel	1[2]	1[2]	10[2]	2[2]	2[2]	10[2]
16	The handling and storage of a DNAPL	0	0	-	0	0	-
17	The handling and storage of an organic solvent	0	0	-	0	0	-
18	The management of runoff that contains chemicals used in the de-icing of aircrafts	0	0	-	0	0	-
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard	0	0	-	0	0	-
22	The establishment and operation of a liquid hydrocarbon pipeline	0	0	-	0	0	-
	TOTAL	(2[2], 1[3])	2	-	(12[2], 11[3])	9	-

Notes:

[1] Denotes chemical and pathogen threat applicable to WHPA

[2] Denotes chemical threat only applicable to WHPA

[3] Denotes pathogen threat only applicable to WHPA

There are a total of 23 significant threats identified within the WHPA on 11 parcels (many threats are located on the same property). Figure 18 identifies the approximate locations of the 14 significant chemical threats identified (8 non-point sources and 6 point sources). Figure 19 identifies the approximate locations of the 12 significant pathogen threats identified (9 non-point sources and 3 point sources).

It is important to note that enumeration of threats is based on a number of circumstances at individual properties, which were evaluated using conservative assumptions and a precautionary approach during discussion with select property owners. It is expected that these threats, and mitigation measures, will be further investigated by the Risk Management Official. A copy of Table 13: Winchester – Activities, Vulnerable Areas, Treats and Policies included in the Source Protection Plan is provided in Appendix A and includes the list of prescribed activities, threat applicability and policy implementer.

There are four types of threats present within the WHPA: the establishment, operation and maintenance of a system that collects, stores, transmits, treats or disposes of sewage; the application of ASM to land; the handling and storage of fuel and; the application of pesticide to land.

The establishment, operation and maintenance of a system that collects, stores, transmits, treats or disposes of sewage is related to septic systems identified at three residential properties, of which one is located in the Wellfield No. 7 WHPA-A at 13225 Thompson Road, and two are located in WHPA-B at 13243 Thompson Road and 1780 Lafleur Road. The Source Protection Plan Policies SEWG-4 and SEWG-5 (included in Appendix A) references existing requirements under the Ontario Building Code for private on-site sewage (septic systems) and future development to minimize the threat to drinking water quality (RRCA and SNC 2016).

The application of ASM and commercial fertilizer is assumed at the 11 parcels of land with cash crop (corn and soybean) agricultural operations identified within WHPA-B. The Source Protection Plan policies AG-1 and AG-2 (included in Appendix A) references existing requirements to minimize the threat associated to drinking water quality (RRCA and SNC 2016).

The handling and storage of fuel was identified at Wellfield No. 7 (windshield survey with follow up correspondence with OCWA in October 2022) for an on-site backup generator, which will supply power to the municipal pump house during power failure, and at 13243 Thompson Road for refueling equipment associated with the active pit operations at ARA license 19708 based on a telephone discussion with the pit owner on October 12, 2022. It is noted 13243 Thompson Road is comprised of a residential property and active pit operation (ARA license 19708), whereby handling and fuel storage are limited to the northern portion of the residential property and not within the limits of ARA license area and in accordance with the conditions of the ARA license. The Source Protection Plan Policy FUEL-1 (a copy is included in Appendix A) references existing and future fuel storage oil (O.Reg. 213/01) Risk Management Plan Requirements to minimize the significant drinking water threat. A telephone conversation between Golder and the pit manager for ARA license 5868 on October 12, 2022, confirmed pit operation equipment is refueled by a licensed fuel truck at entrance to the pit at Lafleur Road and no handling or fuel storage occurs on-site.

The application of pesticide is assumed at the 8 parcels of land identified within WHPA-B, where the managed land area (on each parcel) ranges from one hectare to greater than 10 hectares. The Source Protection Plan policies PEST-1 and PEST-2 (included in Appendix A) reference existing requirements to minimize the threat associated with drinking water quality (RRCA and SNC 2016).

The Vulnerability Assessment completed for Wellfield No. 7 (WESA 2010) previously identified the handling and storage of a DNAPL as a significant threat within the WHPA at the two ARA license areas 5868 and 19708. Recent conversations with the pit manager and/or property owner as part of the current WHPA study confirm DNAPLs are currently not stored on-site and/or may only be handled for incidental use. Source Protection Plan policies CHEM-1 and CHEM-2 (refer to Appendix A) have prohibited the handling and storage of DNAPLs apart from incidental volumes that are not subject to a Risk Management Plan.

8.1.2 Moderate and Low Threat Enumeration

In addition to the significant threats, enumeration of moderate and low threats was also completed as part of this assessment at the request of SNC in an email correspondence with Michael Melaney (Hydrogeologist) and Dale Holtze (Golder) on October 13, 2022. The results of the threat enumeration are presented by threat type.

A summary of the moderate and low threat risk scoring results, grouped by threat type, are included in Table 3 and Table 4. These include the total number of identified moderate and low threats within the applicable WHPA.

Table 3: Enumeration of Moderate Threats in WHPA

	Threat	Number of Moderate Threats in WHPA-A	Number of Parcels with Moderate Threats in WHPA-A	WHPA-A Vulnerability Score	Number of Moderate Threats in WHPA-B	Number of Parcels with Moderate Threats in WHPA-B	WHPA-B Vulnerability Score	Number of Moderate Threats in WHPA-C	Number of Parcels with Moderate Threats in WHPA-C	WHPA-C Vulnerability Score
1	The establishment, operation, or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act	0	0	-	0	0	-	0	0	-
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	0	0	-	0	0	-	2[2]	2[2]	8[2]
3	The application of ASM to land	0	0	-	9[2] 9[3]	9[2] 9[3]	10[2] 8[3]	6[2]	6[2]	6[2]
4	The storage of ASM	0	0	-	0	0	-	1[2]	1[2]	8[2]
5	The management of ASM	0	0	-	0	0	-	0	0	-
6	The application of NASM to land	0	0	-	0	0	-	0	0	-
7	The handling and storage of NASM	0	0	-	0	0	-	0	0	-
8	The application of commercial fertilizer to land	1[2]	1[2]	10[2]	8[2]	8[2]	10[2]	6[2]	6[2]	8[2]
9	The handling and storage of commercial fertilizer	0	0	-	0	0	-	0	0	-
10	The application of pesticide to land	0	0	-	9[2]	9[2]	8[2]	6[2]	6[2]	8[2]
11	The handling and storage of pesticide	0	0	-	0	0	-	0	0	-
12	The application of road salt	0	0	-	0	0	-	0	0	-
13	The handling and storage of road salt	0	0	-	0	0	-	0	0	-
14	The storage of snow	0	0	-	0	0	-	0	0	-
15	The handling and storage of fuel	0	0	-	8[2]	8[2]	10[2]	6[2]	6[2]	8[2]
16	The handling and storage of a DNAPL	0	0	-	0	0	-	0	0	-
17	The handling and storage of an organic solvent	0	0	-	0	0	-	0	0	-

	Threat	Number of Moderate Threats in WHPA-A	Number of Parcels with Moderate Threats in WHPA-A	WHPA-A Vulnerability Score	Number of Moderate Threats in WHPA-B	Number of Parcels with Moderate Threats in WHPA-B	WHPA-B Vulnerability Score	Number of Moderate Threats in WHPA-C	Number of Parcels with Moderate Threats in WHPA-C	WHPA-C Vulnerability Score
18	The management of runoff that contains chemicals used in the de-icing of aircrafts	0	0	-	0	0	-	0	0	-
21	The use of land as livestock grazing an outdoor confinement area or a farm-animal yard	0	0	-	0	0	-	1[2]	1[2]	8[2]
22	The establishment and operation of a liquid hydrocarbon pipeline	0	0	-	0	0	-	0	0	-
	TOTAL	1[2]	1[2]	-	34[2], 9[3]	9[1]	-	28[2]	6[1]	-

Notes:
[1] Denotes chemical and pathogen threat applicable to WHPA
[2] Denotes chemical threat only applicable to WHPA
[3] Denotes pathogen threat only applicable to WHPA

There are a total of 72 moderate threats identified within the WHPA on 14 parcels (many threats are located on the same property). Figure 18 identifies the approximate locations of the 64 moderate chemical threats identified (60 non-point sources and 4 point sources). Figure 19 identifies the approximate locations of the 9 moderate non-point source pathogen threats identified.

Table 4: Enumeration of Low Threats in WHPA

	Threat	Number of Low Threats in WHPA-B	Number of Parcels with Low Threats in WHPA-B	WHPA-B Vulnerability Score	Number of Low Threats in WHPA-C	Number of Parcels with Low Threats in WHPA-C	WHPA-C Vulnerability Score	Number of Low Threats in WHPA-D	Number of Parcels with Low Threats in WHPA-D	WHPA-D Vulnerability Score
1	The establishment, operation, or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act	0	0	-	1	1	6	6	6	6
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	0	0	-	0	0	-	0	0	-
3	The application of ASM to land	9	9	8	12	12	6	6	6	6
4	The storage of ASM	0	0	-	0	0	-	0	0	-
5	The management of ASM	0	0	-	0	0	-	0	0	-
6	The application of NASM to land	0	0	-	0	0	-	0	0	-
7	The handling and storage of NASM	0	0	-	0	0	-	0	0	-
8	The application of commercial fertilizer to land	9	9	8	12	12	6	6	6	6
9	The handling and storage of commercial fertilizer	0	0	-	0	0	-	0	0	-
10	The application of pesticide to land	0	0	-	12	12	6	6	6	6
11	The handling and storage of pesticide	0	0	-	0	0	-	0	0	-
12	The application of road salt	0	0	-	0	0	-	0	0	-
13	The handling and storage of road salt	0	0	-	0	0	-	0	0	-
14	The storage of snow	0	0	-	0	0	-	0	0	-
15	The handling and storage of fuel	9	9	8	11	11	6	6	6	6
16	The handling and storage of a DNAPL	0	0	-	0	0	-	0	0	-

	Threat	Number of Low Threats in WHPA-B	Number of Parcels with Low Threats in WHPA-B	WHPA-B Vulnerability Score	Number of Low Threats in WHPA-C	Number of Parcels with Low Threats in WHPA-C	WHPA-C Vulnerability Score	Number of Low Threats in WHPA-D	Number of Parcels with Low Threats in WHPA-D	WHPA-D Vulnerability Score
17	The handling and storage of an organic solvent	0	0	-	0	0	-	0	0	-
18	The management of runoff that contains chemicals used in the de-icing of aircrafts	0	0	-	0	0	-	0	0	-
21	The use of land as livestock grazing an outdoor confinement area or a farm-animal yard	0	0	-	0	0	-	1	1	8
22	The establishment and operation of a liquid hydrocarbon pipeline	0	0	-	0	0	-	0	0	-
	TOTAL	27	9	-	36	12	-	24	6	-

Note: All low threats in WHPA relate to chemical threats

There are a total of 87 low threats identified within the WHPA on 18 parcels (many threats are located on the same property). Figure 18 identifies the approximate locations of the 16 significant chemical threats identified (80 non-point sources and 7 point sources).

9.0 SUMMARY

As part of the vulnerability assessment for a proposed new municipal supply well in support of the Township of North Dundas Water Supply Expansion Class EA, wellhead protection areas were delineated, vulnerability mapping was confirmed at the WPHA scale and vulnerability scoring was completed. Individual WHPA-A zones were delineated for Wellfield No. 7 and the proposed municipal well; however, WHPA-B, -C and -D overlap for the two sites. The revised WHPA for Wellfield No.7 takes into consideration Golder's revised conceptual model for the Morewood Esker, including extents, hydrogeological properties, recharge and groundwater flow conditions.

The vulnerability mapping performed for the WHPAs in relation to the simultaneous operation of Winchester Wellfield No. 7 and the proposed new municipal supply well located at the proposed well site indicates the vulnerability near the wells (WHPA-A) is high (10) and decreases with distance away from the municipal wells.

The uncertainty associated with delineating the WHPAs, preparing the vulnerability mapping and assigning the vulnerability scoring is considered to be low.

Impervious area, managed land and livestock density maps were prepared to help identify potential future significant threats.

No issues have been identified at Wellfield No.7 and the proposed municipal well site.

There are a total of 23 significant threats identified within the WHPA on 11 parcels (many threats are located on the same property). Figure 18 identifies the approximate locations of the 14 significant chemical threats identified (8 non-point sources and 6 point sources). Figure 19 identifies the approximate locations of the 12 significant pathogen threats identified (9 non-point sources and 3 point sources).

The information collected and compiled as part of the future Source Water Protection Technical Studies will help with the implementation of source protection initiatives.

10.0 DATA LIMITATIONS

10.1 Use of This Report

This report has been prepared by Golder Associates Ltd. (Golder) for use by J.L. Richards & Associates Limited and its agents. The report, which specifically includes all tables, figures and appendices, is based on data and information collected by Golder Associates Ltd. and is based solely on the conditions of the properties at the time of the work, supplemented by historical information and data obtained by Golder Associates Ltd. as described in this report. Each of these reports must be read and understood collectively and can only be relied upon in their totality.

Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore authenticity of any electronic media versions of Golder's report should be verified.

Golder Associates Ltd. has relied in good faith on all information provided and does not accept responsibility for any deficiency, misstatements, or inaccuracies contained in the reports as a result of omissions, misinterpretation, or fraudulent acts of the persons contacted or errors or omissions in the reviewed documentation.

The assessment of environmental conditions and possible hazards at this site has been made using the results of physical measurements and chemical analyses of liquids from a limited number of locations. The site conditions between sampling locations have been inferred based on conditions observed at sampling locations. Conditions may vary from these sampled locations.

The services performed, as described in this report, were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

Any use which a third party makes of this report, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder Associates Ltd. 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 findings and conclusions of this report are valid only as of the date of this report. If new information is discovered in future work, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this report, and to provide amendments as required.

10.2 Groundwater Modelling General Limitations

Hydrogeological investigations and groundwater modelling are dynamic and inexact sciences. They are dynamic in the sense that the state of any hydrological system is changing with time and the science is continually developing new techniques to evaluate these systems. They are inexact in the sense that field data provides a fraction of information for the site or model domain; as such a truly complete, comprehensive characterization of the groundwater system is not possible. Therefore, every groundwater model is, by necessity, a simplification of a reality.

The professional groundwater modelling services described in this report are conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions. The results of previous or simultaneous work provided by sources other than Golder and quoted and/or used herein are considered as having been obtained according to recognized and accepted professional rules and practices, and therefore deemed valid.

The model presented herein provides a predictive scientific tool to evaluate the impacts of specified hydrological stressors on a real groundwater system and to compare various scenarios in support of a decision-making process. The model's accuracy is bound to the normal uncertainty associated to groundwater modelling and no warranty, express or implied, is made.

Signature Page

Golder Associates Ltd.

LICENSED PROFESSIONAL ENGINEER
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100110984
26 Jan-2023
PROVINCE OF ONTARIO

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https://golderassociates.sharepoint.com/sites/111089/project files/6 deliverables/hydrogeology/whpa/final/19125451-r-rev0_whpa report_26jan2023.docx

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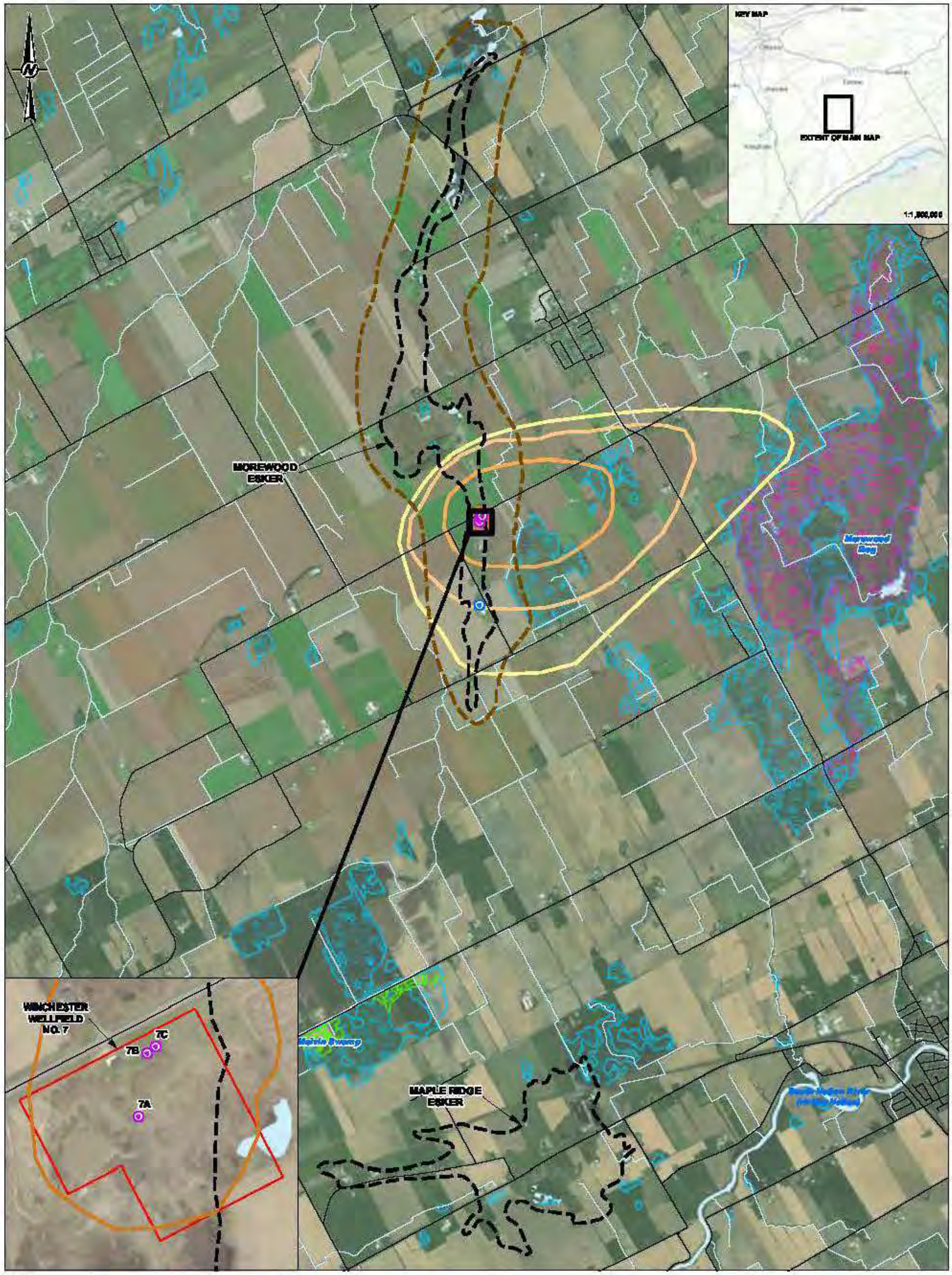

LEGEND

◎	PROPOSED NEW MUNICIPAL SUPPLY WELL
◎	MUNICIPAL SUPPLY WELL
—	ROADS
⌐ ¬	ESKER CORE
⌐ ¬	SAND CARAPACE
▨	UNEVALUATED WETLAND
🟩	EVALUATED WETLAND (NO SIGNIFICANCE)
▨	PROVINCIALLY SIGNIFICANT WETLAND (PSW)
▭	WATERBODY
▭	WINCHESTER WELLFIELD NO. 7 PROPERTY BOUNDARY

EXISTING WHPA AREAS

▭	WHPA-A
▭	WHPA-B
▭	WHPA-C
▭	WHPA-D

0 500 1,000 2,000

1:40,000 METRES

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N
3. INTERPRETED SAND CARAPACE APPROXIMATED BASED ON THE GEOLOGICAL SURVEY OF CANADA OPEN FILE 5894 (GSC 2007) AND PREVIOUS INVESTIGATIONS COMPLETED BY GOLDER WITHIN THE VICINITY OF THE STUDY AREA.

CLIENT
J.L. RICHARDS & ASSOCIATES LIMITED

PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION
CLASS EA

TITLE
STUDY AREA

CONSULTANT

WSP GOLDER

YYYY-MM-DD	2022-01-25
DESIGNED	—
PREPARED	RJD/MG
REVIEWED	DH
APPROVED	FAS

PROJECT NO.	CONTROL	REV.	FIGURE
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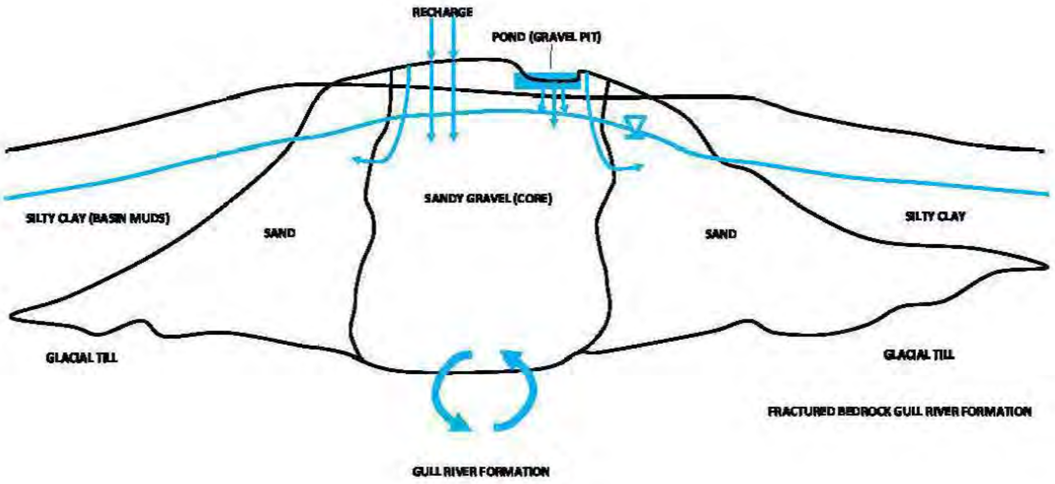

LEGEND

▽ Water Table

NOTES

1. CONCEPTUAL MOREWOOD ESKER SCHEMATIC BASED ON GEOLOGICAL SURVEY OF CANADA OPEN FILE 5624 (GSC 2007).

CLIENT
J.L. Richards & Associates Limited

CONSULTANT
WSP GOLDER

YYYY-MM-DD	[illegible]
PREPARED	DH
DESIGN	DH
REVIEW	BH
APPROVED	BH

PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION
CLASS EA

TITLE
Schematic of Morewood Esker Cross-Section

PROJECT No.
19125451

FIGURE
2

LEGEND

◎	PROPOSED NEW MUNICIPAL SUPPLY WELL
◎	MUNICIPAL SUPPLY WELL
◈	APPROXIMATE BOREHOLE/MONITORING WELL LOCATION
88.88	GROUNDWATER ELEVATION, mASL (MAY 7, 2019)
↑	INTERPRETED DIRECTION OF GROUNDWATER FLOW
- -	INTERPRETED LOCATION OF GROUNDWATER DIVIDE
—	ROADS
—	WATERCOURSE
▨	WATERBODY
▨	UNEVALUATED WETLAND
⬚	ESKER CORE
⬚	SAND CARAPACE

0 125 250 500

1:15,000 METRES

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. INTERPRETED SAND CARAPACE APPROXIMATED BASED ON THE GEOLOGICAL SURVEY OF CANADA OPEN FILE 5524 (GSC 2007) AND PREVIOUS INVESTIGATIONS COMPLETED BY GOLDER WITHIN THE VICINITY OF THE STUDY AREA.
3. GROUNDWATER ELEVATION DATA PROVIDED BY ONTARIO CLEAN WATER AGENCY AS PART OF THE ONGOING GROUNDWATER MONITORING PROGRAM FOR THE OPERATION OF WINCHESTER WELLFIELD NO. 7.
4. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N

CLIENT

J.L. RICHARDS & ASSOCIATES LIMITED

PROJECT

TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

TITLE

GROUNDWATER ELEVATION MAP (MAY 7, 2019)

CONSULTANT

WSP GOLDER

YYYY-MM-DD	2020-01-28
DESIGNED	—
PREPARED	RRD/MG
REVIEWED	DH
APPROVED	FAS

PROJECT NO.	CONTROL	REV.	FIGURE
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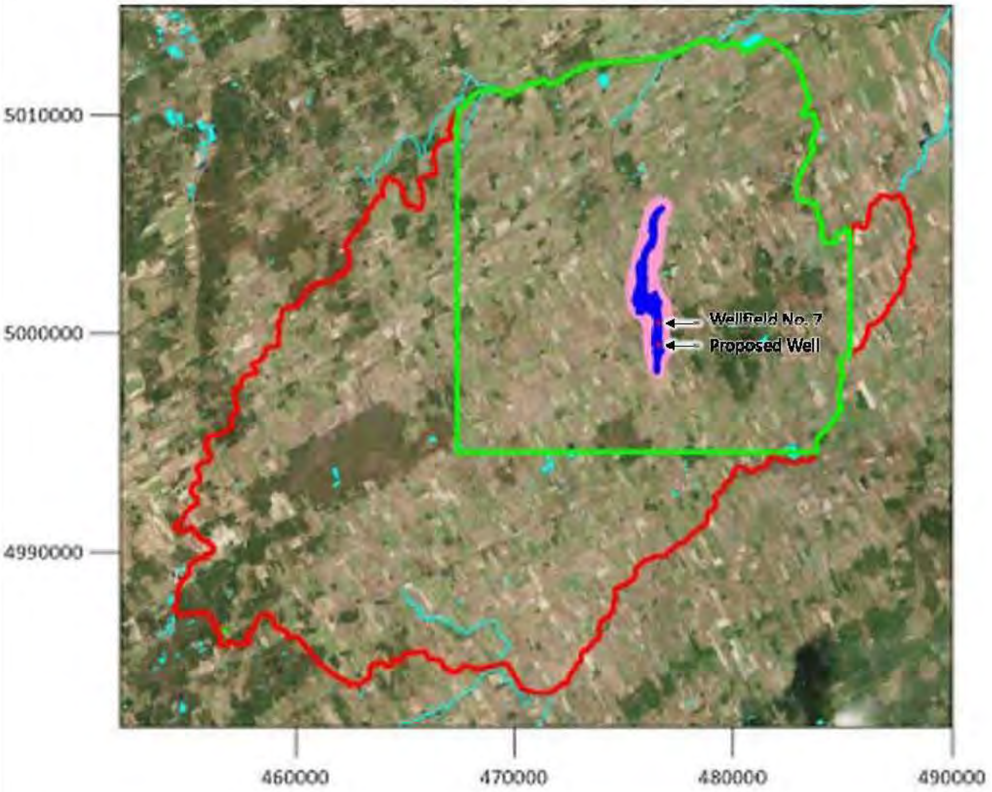


WESA (2011) Groundwater Model

- Total area of 1,017 km²
- MODFLOW Model comprised of 968 rows, 1009 columns, and 8 layers
- Total number of finite difference cells is ~ 7.8 million.
- Discretization in the area of the Proposed Well and Wellfield No.7 is ~ 25 metres.

Groundwater Model for Current Assessment

- Total area of 328 km²
- MODFLOW Model comprised of 650 rows, 632 columns, and 8 layers
- Total number of finite difference cells is ~3.3 million.
- Discretization in the area of the Proposed Well and Wellfield No. 7 is ~ 25 metres.

LEGEND

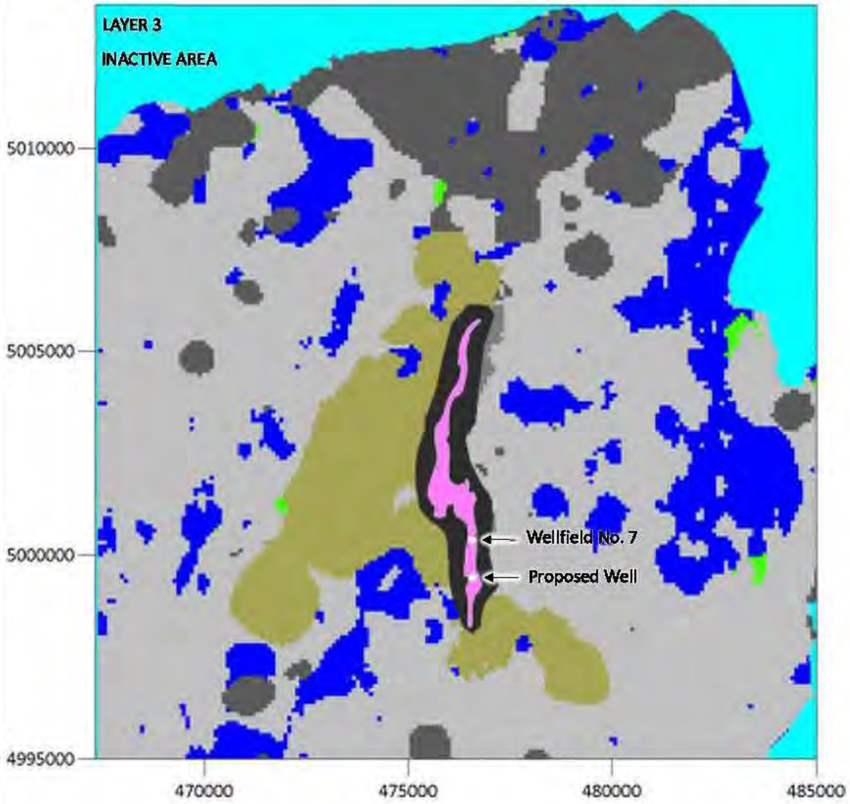
🟥 WESA Model Active Area
🟩 Golder Model Active Area
🟦 Inferred Extent of Morewood Esker Core
▭ Inferred Extent of Sand Carapace
● Municipal Supply Well

NOTES

1. COORDINATE SYSTEM: UTM NAD 83 ZONE 18N
2. INTERPRETED SAND CARAPACE APPROXIMATED BASED ON THE GEOLOGICAL SURVEY OF CANADA OPEN FILE 5624 (GSC 2007) AND PREVIOUS INVESTIGATIONS COMPLETED BY GOLDER WITHIN THE VICINITY OF THE STUDY AREA

CLIENT		
J.L. Richards & Associates Limited		
CONSULTANT	YYYY-MM-DD	[illegible]
WSP GOLDER	PREPARED	GK
	DESIGN	GK
	REVIEW	[illegible]
	APPROVED	BH

PROJECT	
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA	
TITLE	
EXTENT OF LOCAL GROUNDWATER FLOW MODEL	
PROJECT No.	FIGURE
19126451	4



Hydraulic Conductivity			
Material	**Kx/Ky (m/s)**	**Kz (m/s)**	**Effective Porosity**
Regional Esker	5.0E-03	5.0E-03	0.30
Regional Basin Mud	1.0E-07	1.0E-08	0.25
Regional Sandy Silt Till	4.0E-05	4.0E-06	0.25
Sub Till Sediment	1.0E-04	1.0E-05	0.25
Paleozoic Bedrock (Shallow)	1.0E-05	1.0E-06	0.05
Paleozoic Bedrock (Deep)	1.0E-07	1.0E-08	0.01
Morewood Esker Core	5.0E-03	5.0E-03	0.30
Local Basin Mud	5.0E-07	5.0E-08	0.25
Local Sandy Silt Till	4.0E-05	4.0E-06	0.25
Sand Carapace	2.0E-04	2.0E-05	0.30

	Hydro stratigraphic Unit	Model Layer
🟪	Morewood Esker Core	1,2,3,4
⬛	Sand Carapace	3,4
🟫	Basin Mud	2,3
▩	Local Sandy Silt Till	2,3
⬜	Regional Sandy Silt Till	2,3,4
🟦	Paleozoic Bedrock	2,3,4,5,6,7,8
🟩	Sub Till Sediment	2,3,4,5
◼	Esker (Regional)	2,3

LEGEND

NOTES

1. COORDINATE SYSTEM: UTM NAD 83 ZONE 18N
2. INTERPRETED SAND CARAPACE APPROXIMATED BASED ON THE GEOLOGICAL SURVEY OF CANADA OPEN FILE 5624 (GSC 2007) AND PREVIOUS INVESTIGATIONS COMPLETED BY GOLDER WITHIN THE VICINITY OF THE STUDY AREA

CLIENT
J.L. Richards & Associates Limited

CONSULTANT
WSP GOLDER

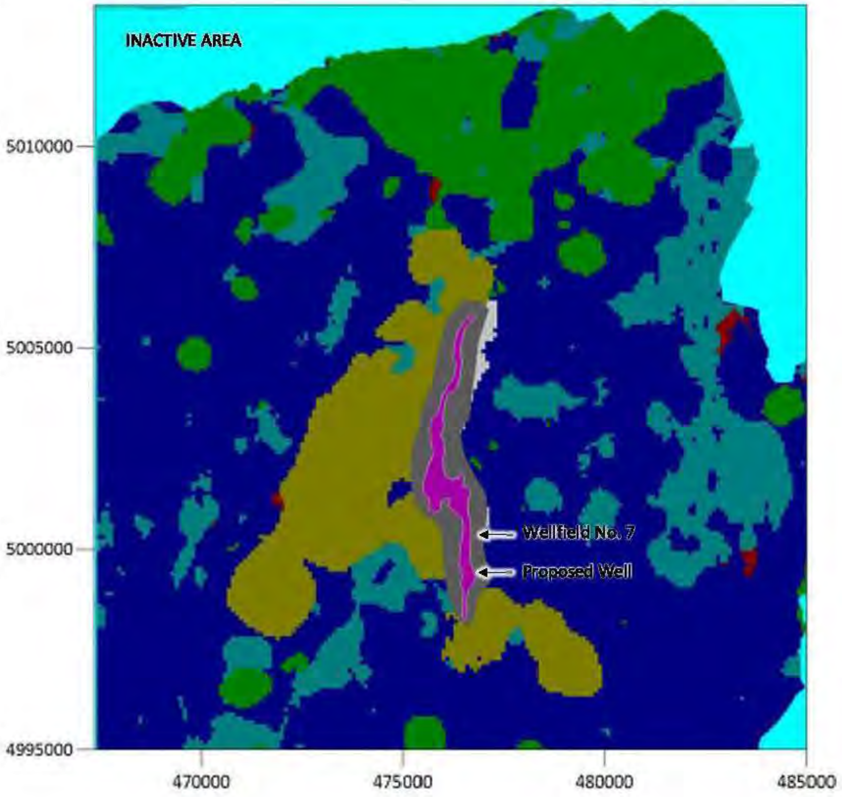
YYYY-MM-DD	2022-10-12
PREPARED	GK
DESIGN	GK
REVIEW	GD
APPROVED	BH

PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

TITLE
HYDRAULIC CONDUCTIVITY PARAMETERIZATION IN THE MODEL

PROJECT No.
19126451

FIGURE
5



RECHARGE	
Material	mm/yr
Regional Esker	350
Regional Sandy Silt Till	15
Sub Till Sediment	15
Paleozoic Bedrock	15
Morewood Esker Core	350
Basin Mud	5
Local Sandy Silt Till	15
Sand Carapace	100

Recharge Zone	Hydrostratigraphic Unit
🟪	Morewood Esker Core
▨	Sand Carapace
🟫	Local Basin Mud
⬜	Local Sandy Silt Till
🟦	Regional Sandy Silt Till
▩	Paleozoic Bedrock
🟥	Sub Till Sediment
🟩	Esker (Regional)

LEGEND

NOTES

1. COORDINATE SYSTEM: UTM NAD 83 ZONE 18N
2. INTERPRETED SAND CARAPACE APPROXIMATED BASED ON THE GEOLOGICAL SURVEY OF CANADA OPEN FILE 5624 (GSC 2007) AND PREVIOUS INVESTIGATIONS COMPLETED BY GOLDER WITHIN THE VICINITY OF THE STUDY AREA

CLIENT
J.L. Richards & Associates Limited

CONSULTANT

WSP GOLDER

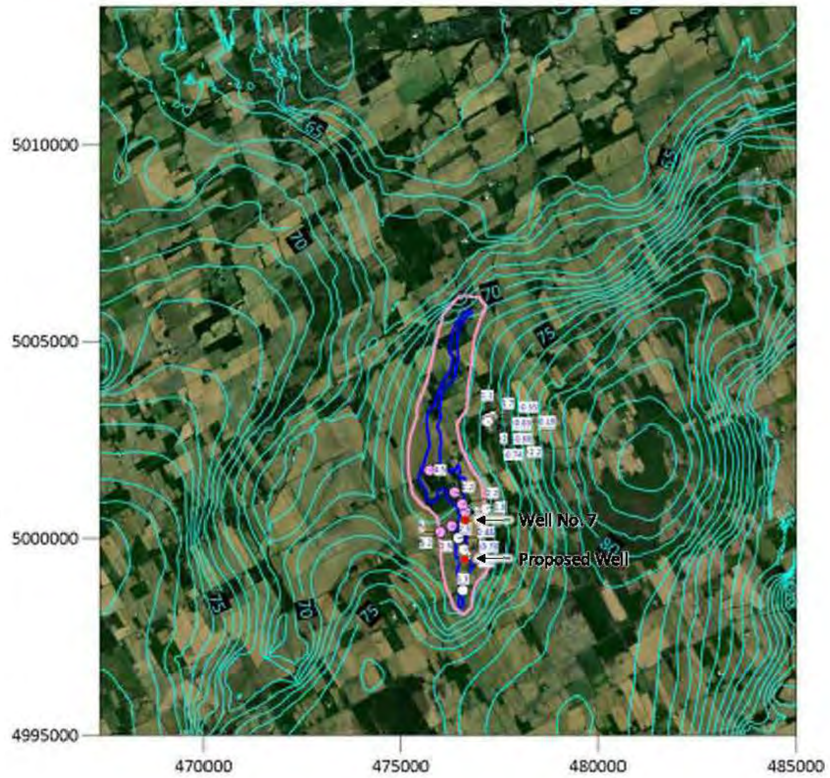
YYYY-MM-DD	2022-10-12
PREPARED	GK
DESIGN	GK
REVIEW	GD
APPROVED	BH

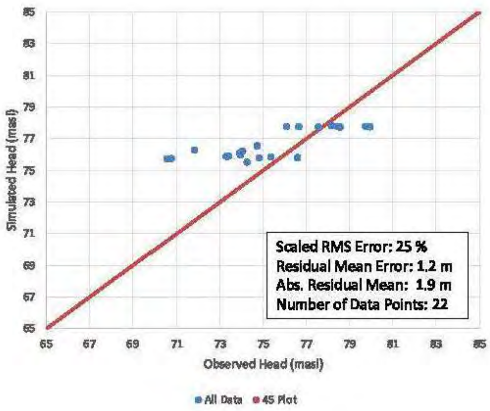
PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

TITLE
RECHARGE DISTRIBUTION IN THE MODEL

PROJECT No.
19126451

FIGURE
6





Scaled RMS Error: 25 %
Residual Mean Error: 1.2 m
Abs. Residual Mean: 1.9 m
Number of Data Points: 22

Residual Error (m)
(Simulated minus Observed Groundwater Elevation)

- ● -10 to -2.0
- ○ -2.0 to 2.0
- ● 2.0 to 10

LEGEND

- Morewood Esker Core Outline
- Sand Carapace Outline
- Groundwater Elevation Contour

NOTES

1. COORDINATE SYSTEM: UTM NAD 83 ZONE 18N
2. INTERPRETED SAND CARAPACE APPROXIMATED BASED ON THE GEOLOGICAL SURVEY OF CANADA OPEN FILE 5624 (GSC 2007) AND PREVIOUS INVESTIGATIONS COMPLETED BY GOLDER WITHIN THE VICINITY OF THE STUDY AREA

CLIENT
J.L. Richards & Associates Limited

CONSULTANT
WSP GOLDER

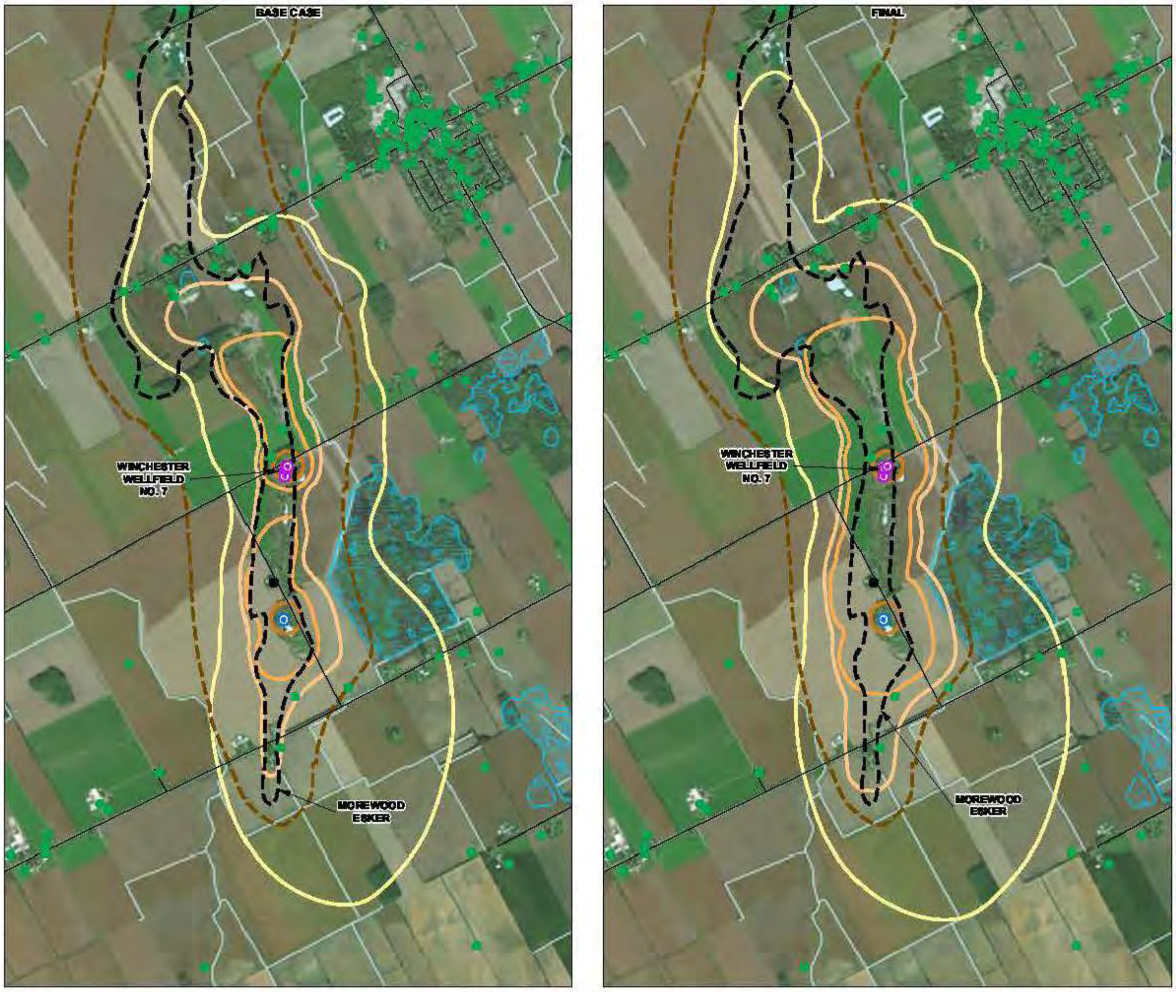
YYYY-MM-DD	2022-10-12
PREPARED	GK
DESIGN	GK
REVIEW	BD
APPROVED	BH

PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

TITLE
RESULTS OF MODEL CALIBRATION

PROJECT No.
19126451

FIGURE
7



LEGEND

- ● UNLISTED WATER SUPPLY WELL
- ◎ PROPOSED NEW MUNICIPAL SUPPLY WELL
- ◎ MUNICIPAL SUPPLY WELL
- ● MECP WELL RECORD
- — ROADS
- ⬚ ESKER CORE
- ⬚ SAND CARAPACE
- ▨ UNEVALUATED WETLAND
- ▭ WATERBODY
- ▭ WHPA-A
- ▭ WHPA-B
- ▭ WHPA-C
- ▭ WHPA-D

0 250 500 1,000

1:25,000 METRES

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. INTERPRETED SAND CARAPACE APPROXIMATED BASED ON THE GEOLOGICAL SURVEY OF CANADA OPEN FILE 5834 (GSC 2007) AND PREVIOUS INVESTIGATIONS COMPLETED BY GOLDER WITHIN THE VICINITY OF THE STUDY AREA.
3. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N

CLIENT
J.L. RICHARDS & ASSOCIATES LIMITED

PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

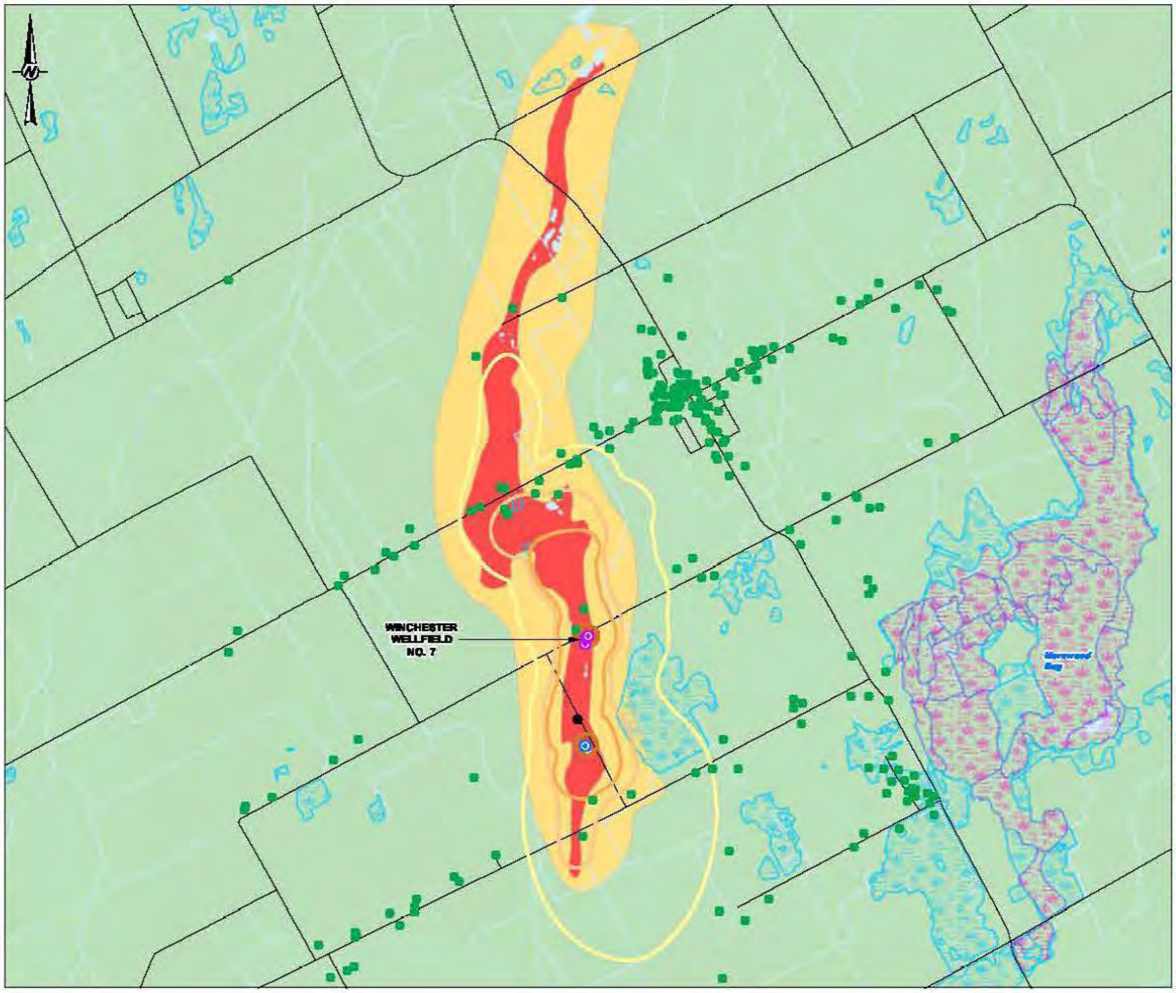
TITLE
WHPA DELINEATION

CONSULTANT

WSP GOLDER

YYYY-MM-DD	2022-01-25
DESIGNED	—
PREPARED	RRD/MG
REVIEWED	DH
APPROVED	PAS

PROJECT NO.	CONTROL	REV.	FIGURE
19126461	0010	0	8



LEGEND

- ● UNLISTED WATER SUPPLY WELL
- ◎ PROPOSED NEW MUNICIPAL SUPPLY WELL
- ◎ MUNICIPAL SUPPLY WELL
- ■ MECP WELL RECORD
- — ROADS
- ▨ UNEVALUATED WETLAND
- ▨ PROVINCIALLY SIGNIFICANT WETLAND (PSW)
- ▭ WATERBODY
- ▭ WHPA-A
- ▭ WHPA-B
- ▭ WHPA-C
- ▭ WHPA-D

AQUIFER VULNERABILITY INDEX

- 🟥 HIGH
- 🟨 MEDIUM
- 🟩 LOW

0 300 600 1,200

1:20,000 METRES

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N

CLIENT
J.L. RICHARDS & ASSOCIATES LIMITED

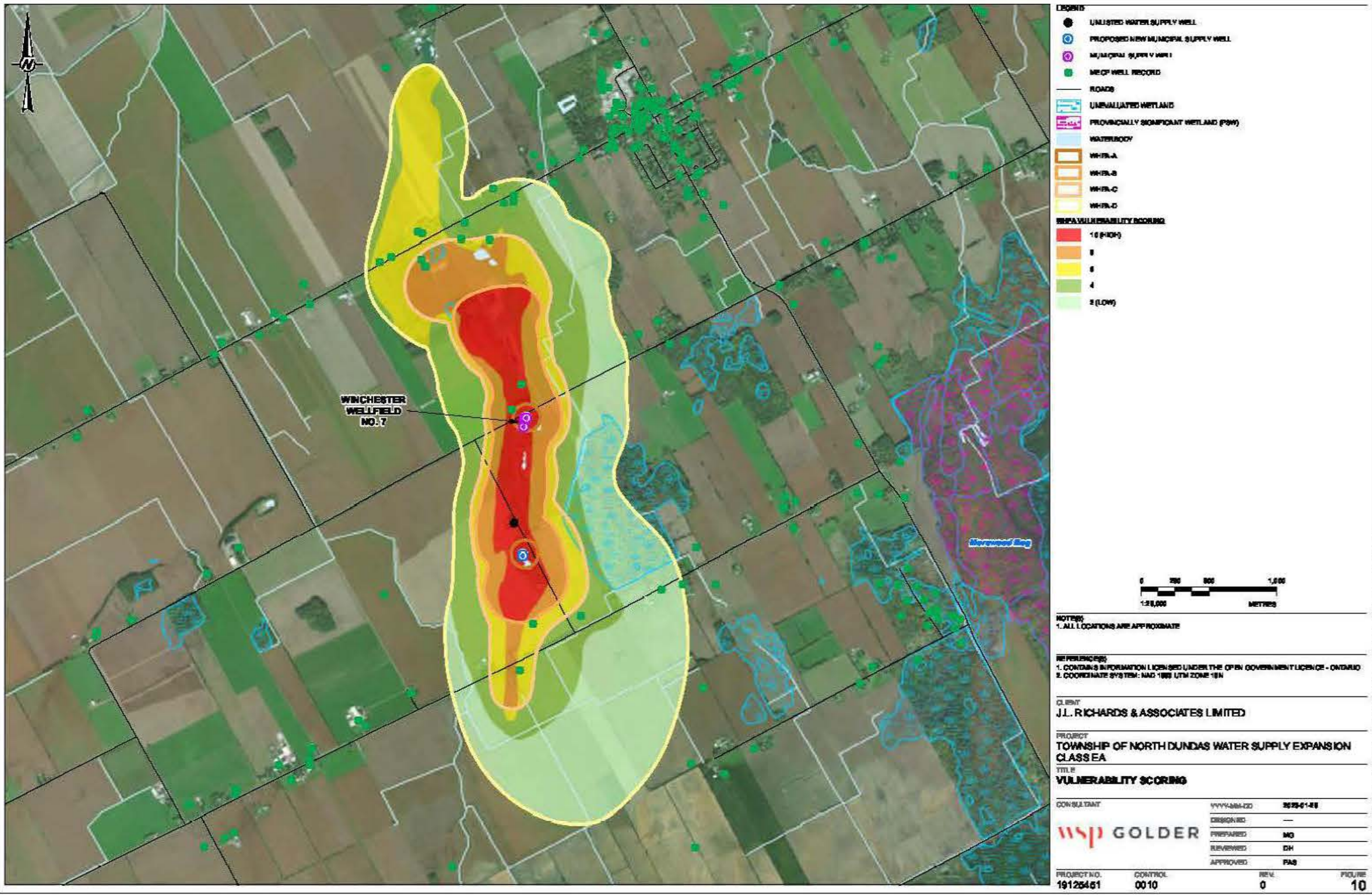
PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

TITLE
AQUIFER VULNERABILITY INDEX (AVI) MAPPING

CONSULTANT
WSP GOLDER

YYYY-MM-DD	[illegible]
DESIGNED	—
PREPARED	RRD/MG
REVIEWED	DH
APPROVED	PAS

PROJECT NO.	CONTROL	REV.	FIGURE
19125461	0010	0	9



NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N

CLIENT
J.L. RICHARDS & ASSOCIATES LIMITED

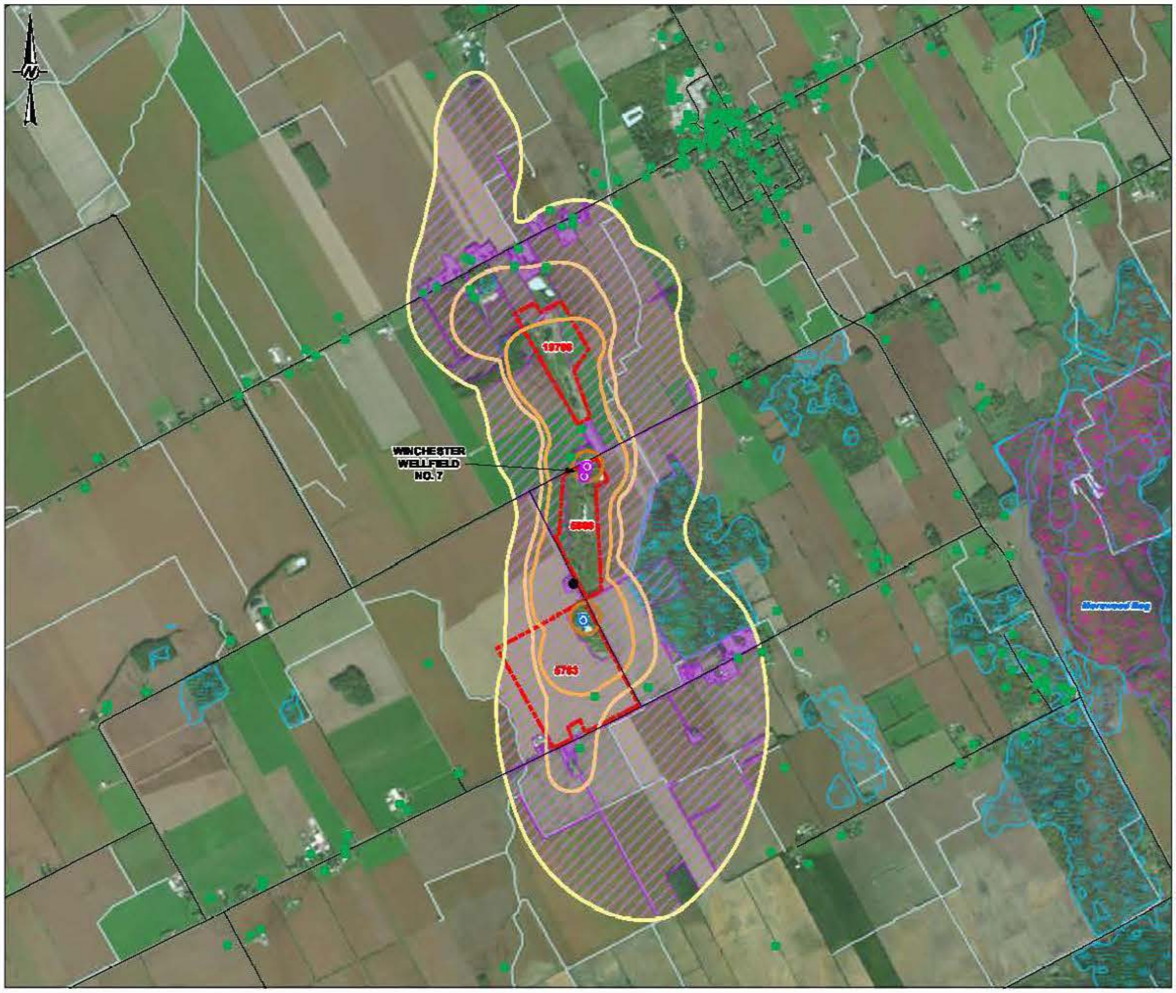
PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

TITLE
VULNERABILITY SCORING

CONSULTANT

YYYY-MM-DD	[illegible]
DESIGNED	—
PREPARED	MG
REVIEWED	DH
APPROVED	FAS

PROJECT NO.	CONTROL	REV.	FIGURE
19125461	0010	0	10



LEGEND

- ● UNLISTED WATER SUPPLY WELL
- ◎ PROPOSED NEW MUNICIPAL SUPPLY WELL
- ◎ MUNICIPAL SUPPLY WELL
- ● MECP WELL RECORD
- — ROADS
- ▨ UNEVALUATED WETLAND
- ▨ PROVINCIALLY SIGNIFICANT WETLAND (PSW)
- ■ WATERBODY
- ☐ WHPA-A
- ☐ WHPA-B
- ☐ WHPA-C
- ☐ WHPA-D
- ▨ AGRICULTURAL MANAGED LAND
- ■ NON-AGRICULTURAL MANAGED LAND
- ☐ PIT - MNRF LICENSE ID NUMBER

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. MANAGED AREAS DETERMINED IN PART BY 2019 DRAPE IMAGERY
3. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N

CLIENT
J.L. RICHARDS & ASSOCIATES LIMITED

PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

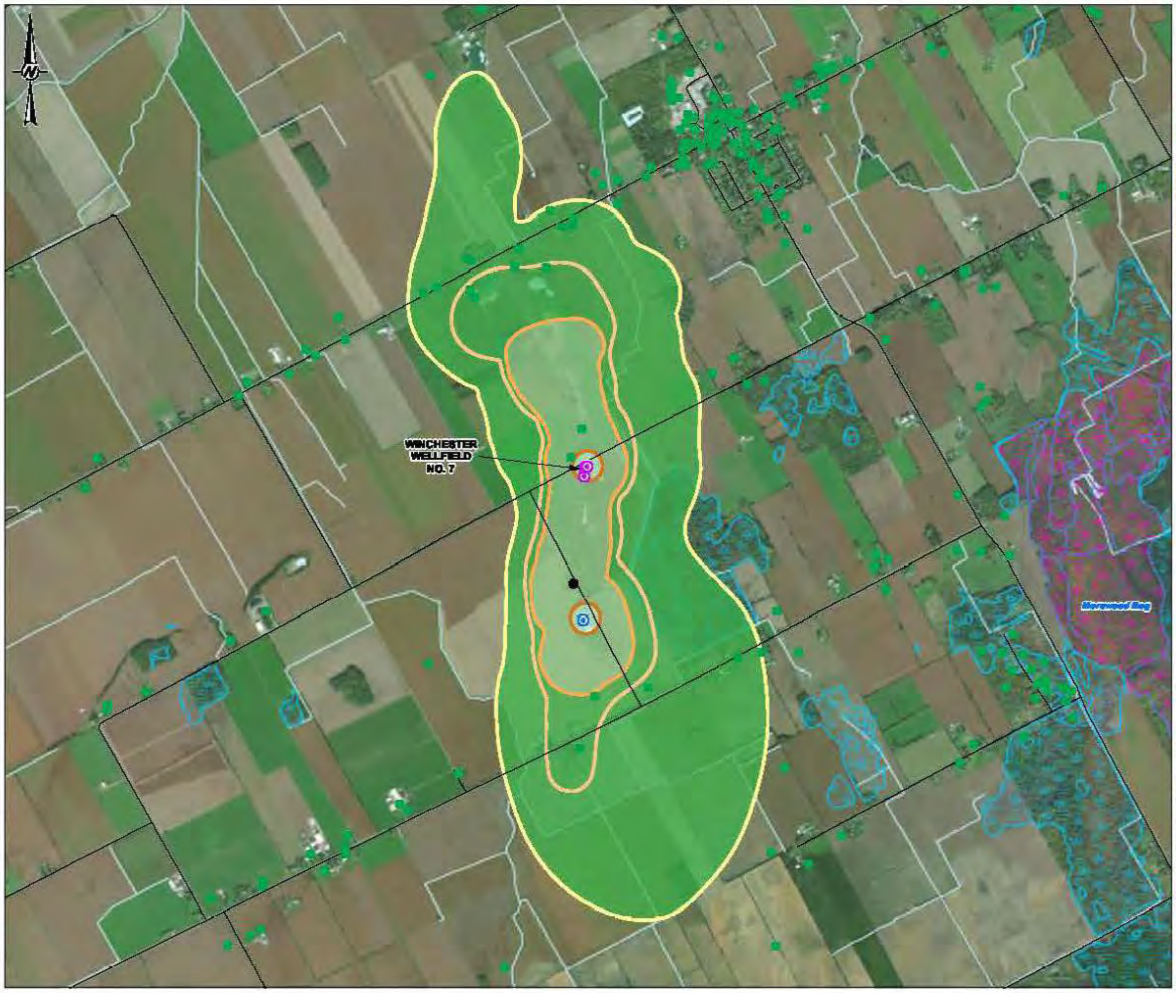
TITLE
MANAGED LAND

CONSULTANT

wsp GOLDER

YYYY-MM-DD	2022-01-28
DESIGNED	—
PREPARED	MG
REVIEWED	DH
APPROVED	FAS

PROJECT NO.	CONTROL	REV.	FIGURE
19125461	0010	0	11



LEGEND

●	UNLISTED WATER SUPPLY WELL
⦿	PROPOSED NEW MUNICIPAL SUPPLY WELL
⦿	MUNICIPAL SUPPLY WELL
●	MECP WELL RECORD
—	ROADS
▨	UNEVALUATED WETLAND
▨	PROVINCIALLY SIGNIFICANT WETLAND (PSW)
■	WATERBODY
☐	WHPA-A
☐	WHPA-B
☐	WHPA-C
☐	WHPA-D

Percent of Managed Land

🟩	MANAGED LAND <40%
🟩	MANAGED LAND 40% - 80%
🟩	MANAGED LAND >80%

0 250 500 1,000

1:25,000 METRES

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N

CLIENT
J.L. RICHARDS & ASSOCIATES LIMITED

PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

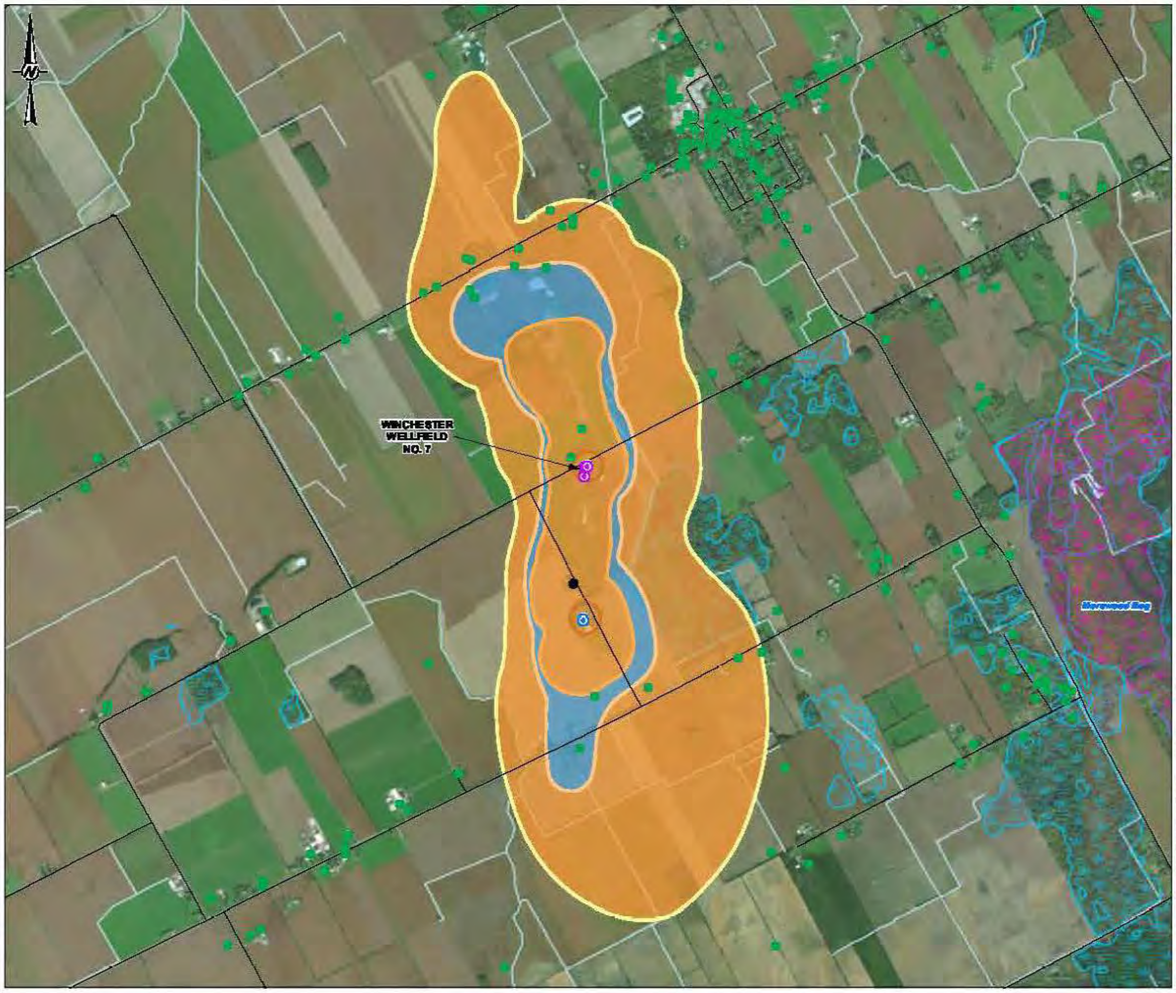
TITLE
MANAGED LAND MAP

CONSULTANT

WSP GOLDER

YYYY-MM-DD	2023-01-[illegible]
DESIGNED	—
PREPARED	MG
REVIEWED	DH
APPROVED	FAS

PROJECT NO.	CONTROL	REV.	FIGURE
19125461	0010	0	12



LEGEND

●	UNLISTED WATER SUPPLY WELL
◎	PROPOSED NEW MUNICIPAL SUPPLY WELL
◎	MUNICIPAL SUPPLY WELL
●	MECP WELL RECORD
—	ROADS
▨	UNEVALUATED WETLAND
▨	PROVINCIALLY SIGNIFICANT WETLAND (PSW)
■	WATERBODY
☐	WHPA-A
☐	WHPA-B
☐	WHPA-C
☐	WHPA-D

Livestock Density

🟧	<0.5 NU/ACRE
🟩	0.5 - 1.0 NU/ACRE
🟦	>1.0 NU/ACRE

0 250 500 1,000

1:25,000 METRES

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N

CLIENT
J.L. RICHARDS & ASSOCIATES LIMITED

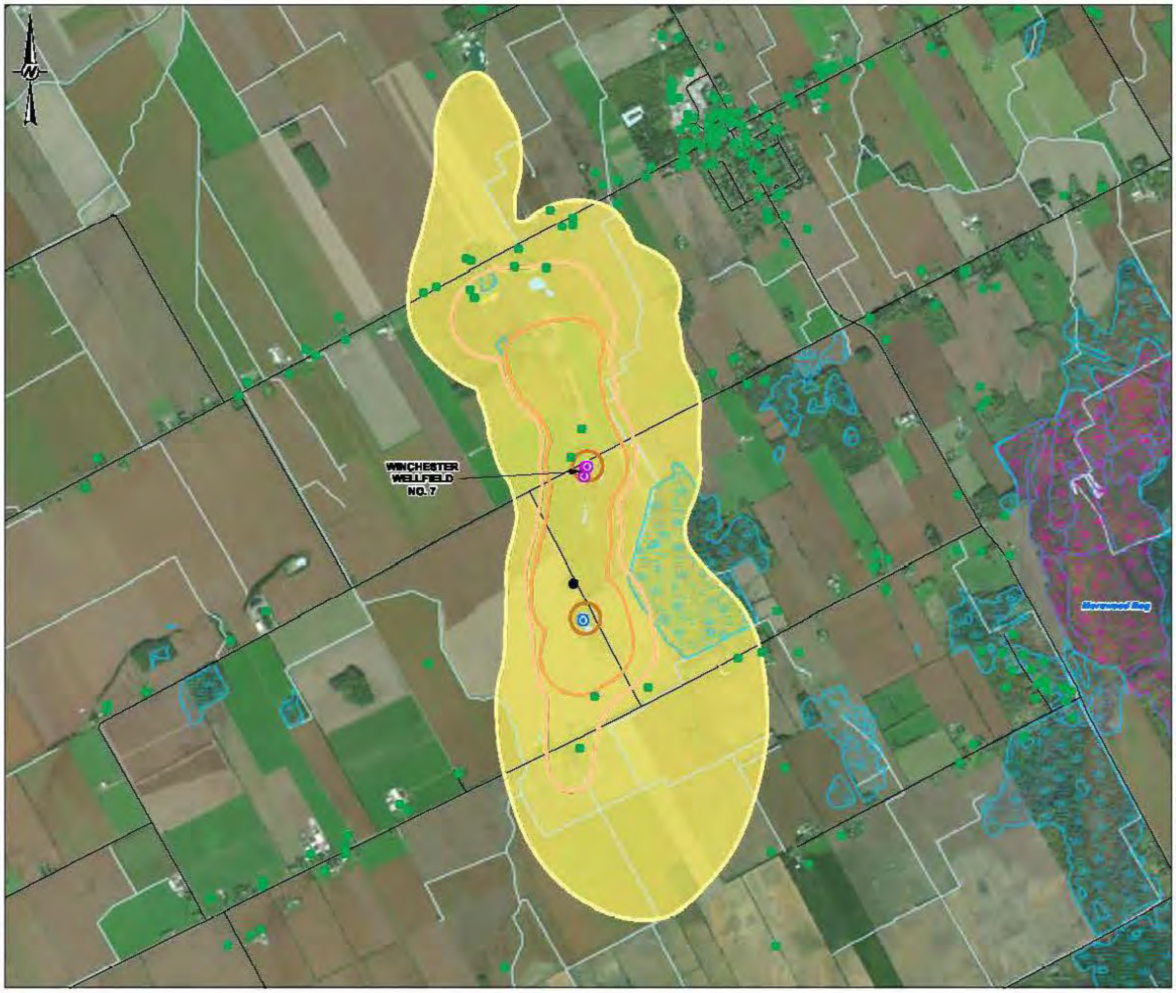
PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

TITLE
LIVESTOCK DENSITY

CONSULTANT

YYYY-MM-DD	[illegible]
DESIGNED	—
PREPARED	RRD/MG
REVIEWED	DH
APPROVED	PAS

PROJECT NO.	CONTROL	REV.	FIGURE
19125461	0010	0	13



LEGEND

- ● UNLISTED WATER SUPPLY WELL
- ◎ PROPOSED NEW MUNICIPAL SUPPLY WELL
- ◎ MUNICIPAL SUPPLY WELL
- ● MECP WELL RECORD
- — ROADS
- ▨ UNEVALUATED WETLAND
- ▨ PROVINCIALLY SIGNIFICANT WETLAND (PSW)
- ■ WATERBODY
- ☐ WHPA-A
- ☐ WHPA-B
- ☐ WHPA-C
- ☐ WHPA-D

PERCENT OF IMPERVIOUS LAND

- ■ 0.0% - 1.0%
- ■ 1.1% - 8.0%
- ■ 8.1% - 80.0%
- ■ 80.0% - 100.0%

0 250 500 1,000
1:25,000 METRES

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N

CLIENT
J.L. RICHARDS & ASSOCIATES LIMITED

PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

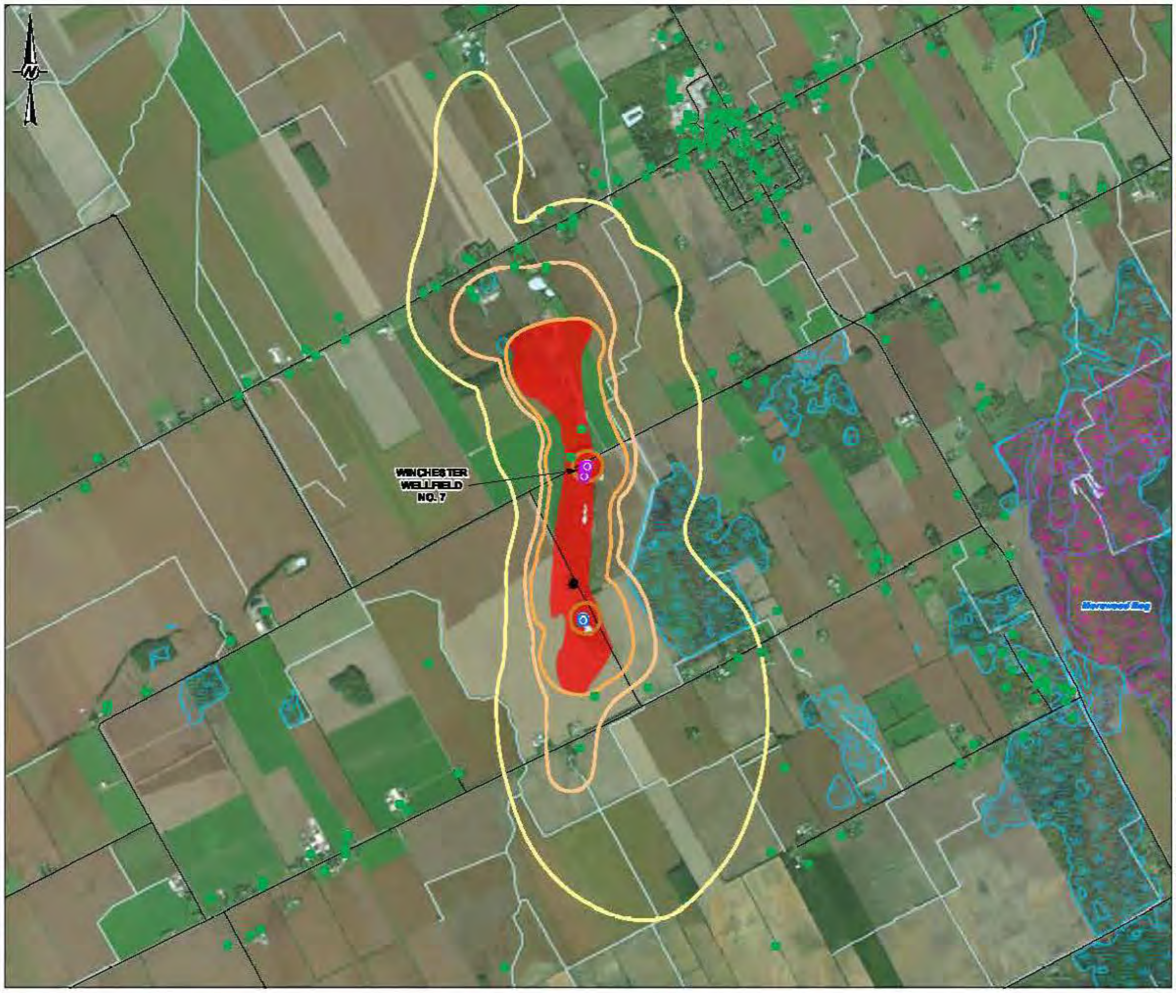
TITLE
IMPERVIOUS AREAS

CONSULTANT

WSP GOLDER

YYYY-MM-DD	2023-01-[illegible]
DESIGNED	—
PREPARED	RRC
REVIEWED	DH
APPROVED	PAS

PROJECT NO.	CONTROL	REV.	FIGURE
19125461	0010	0	14



LEGEND

- ● UNLISTED WATER SUPPLY WELL
- ◎ PROPOSED NEW MUNICIPAL SUPPLY WELL
- ◎ MUNICIPAL SUPPLY WELL
- ● MECP WELL RECORD
- — ROADS
- ▨ UNEVALUATED WETLAND
- ▨ PROVINCIALLY SIGNIFICANT WETLAND (PSW)
- ▨ WATERBODY
- ☐ WHPA-A
- ☐ WHPA-B
- ☐ WHPA-C
- ☐ WHPA-D
- 🟥 SIGNIFICANT RISK OF DRINKING WATER THREAT

0 250 500 1,000
1:25,000 METRES

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N

CLIENT
J.L. RICHARDS & ASSOCIATES LIMITED

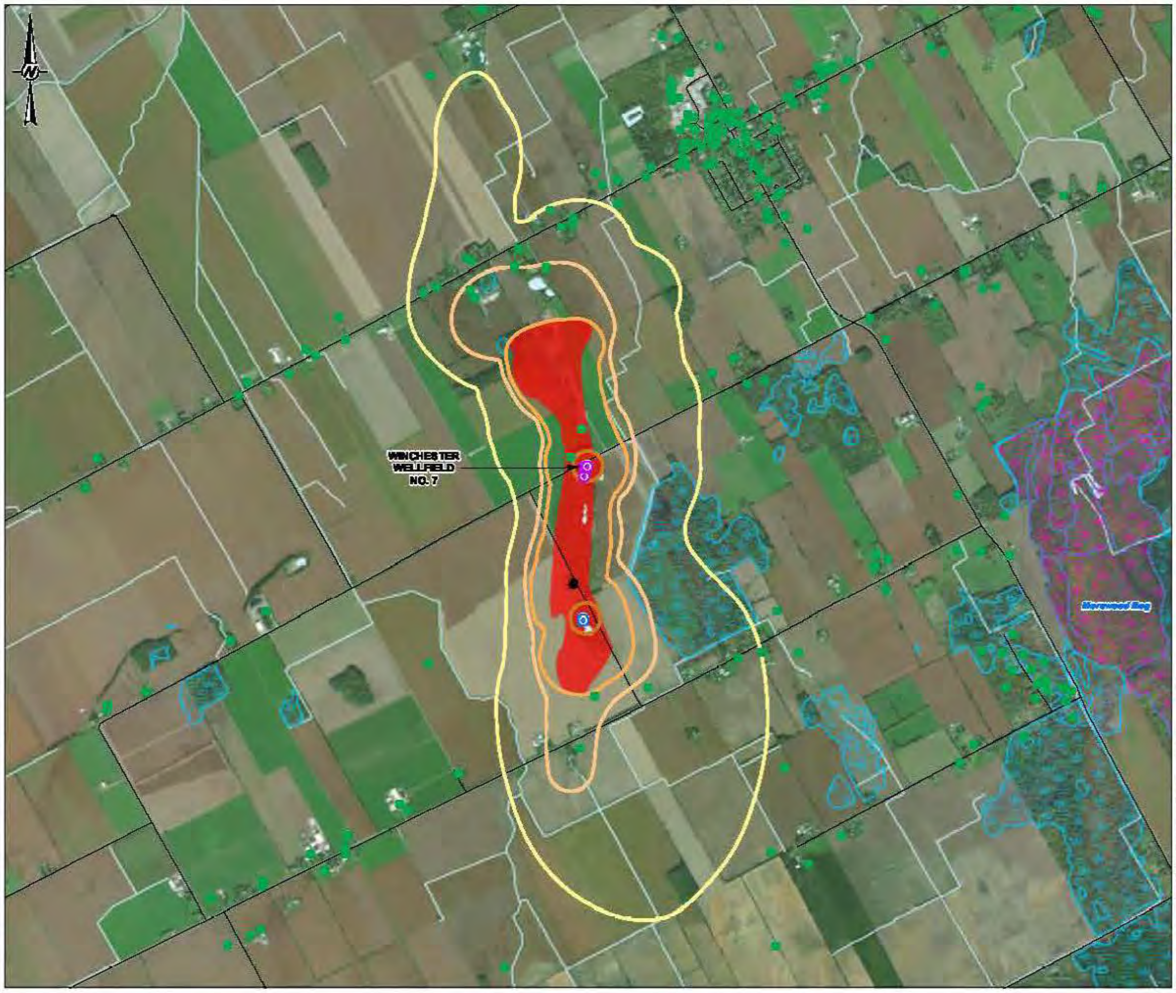
PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

TITLE
POTENTIAL AREA OF SIGNIFICANT RISK OF DRINKING WATER THREATS - CHEMICAL

CONSULTANT
WSP GOLDER

YYYY-MM-DD	[illegible]
DESIGNED	—
PREPARED	RRD/MG
REVIEWED	DH
APPROVED	FAS

PROJECT NO.	CONTROL	REV.	FIGURE
19126461	0010	0	15



NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N

CLIENT
J.L. RICHARDS & ASSOCIATES LIMITED

PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

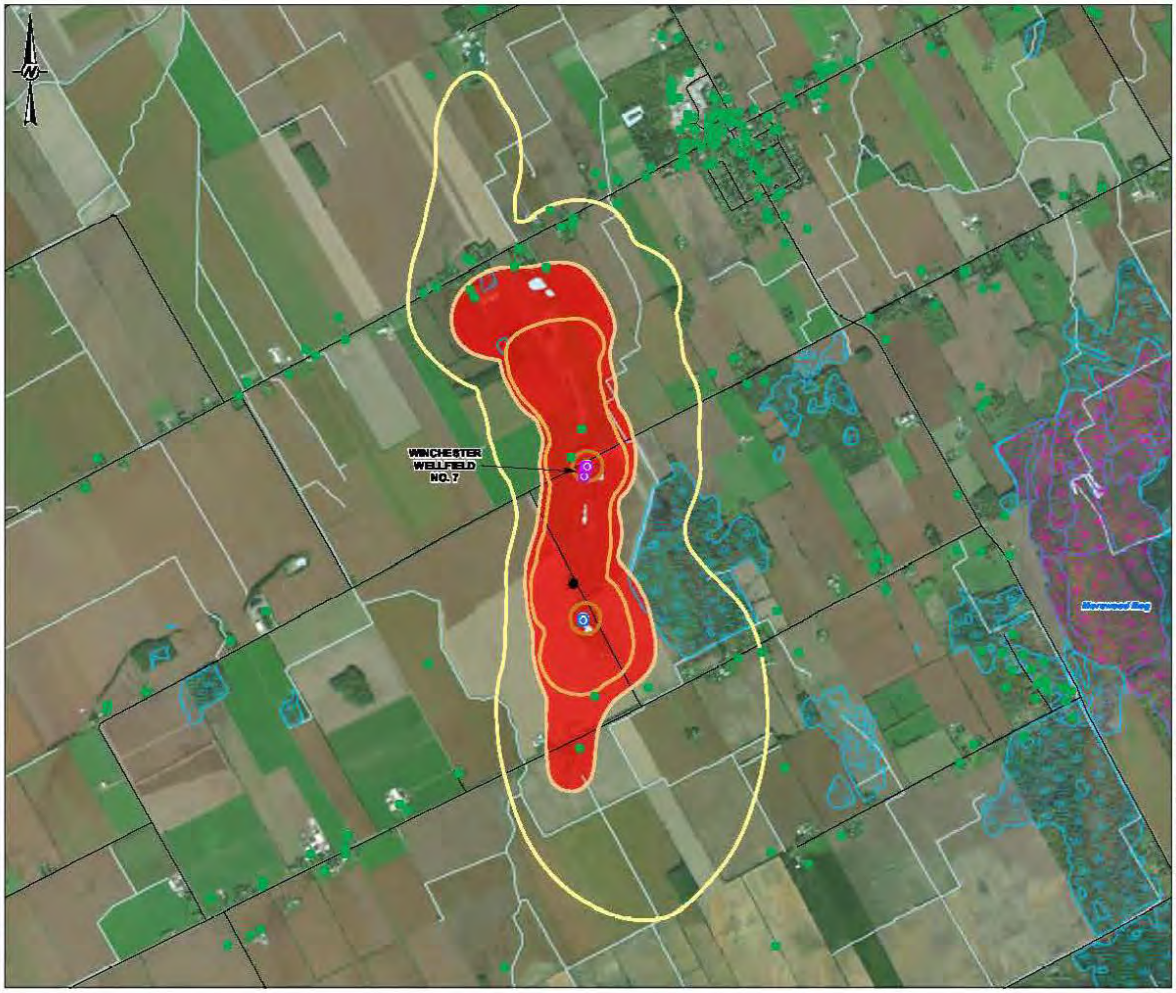
TITLE
POTENTIAL AREA OF SIGNIFICANT RISK OF DRINKING WATER THREATS - PATHOGEN

CONSULTANT

WSP GOLDER

YYYY-MM-DD	[illegible]
DESIGNED	—
PREPARED	RRD/MG
REVIEWED	DH
APPROVED	FAS

PROJECT NO.	CONTROL	REV.	FIGURE
19125461	0010	0	16



LEGEND

- ● UNLISTED WATER SUPPLY WELL
- ◎ PROPOSED NEW MUNICIPAL SUPPLY WELL
- ◎ MUNICIPAL SUPPLY WELL
- ● MECP WELL RECORD
- — ROADS
- ▨ UNEVALUATED WETLAND
- ▨ PROVINCIALLY SIGNIFICANT WETLAND (PSW)
- ▭ WATERBODY
- ▭ WHPA-A
- ▭ WHPA-B
- ▭ WHPA-C
- ▭ WHPA-D
- 🟥 SIGNIFICANT RISK OF DRINKING WATER THREAT

0 250 500 1,000

1:25,000 METRES

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N

CLIENT
J.L. RICHARDS & ASSOCIATES LIMITED

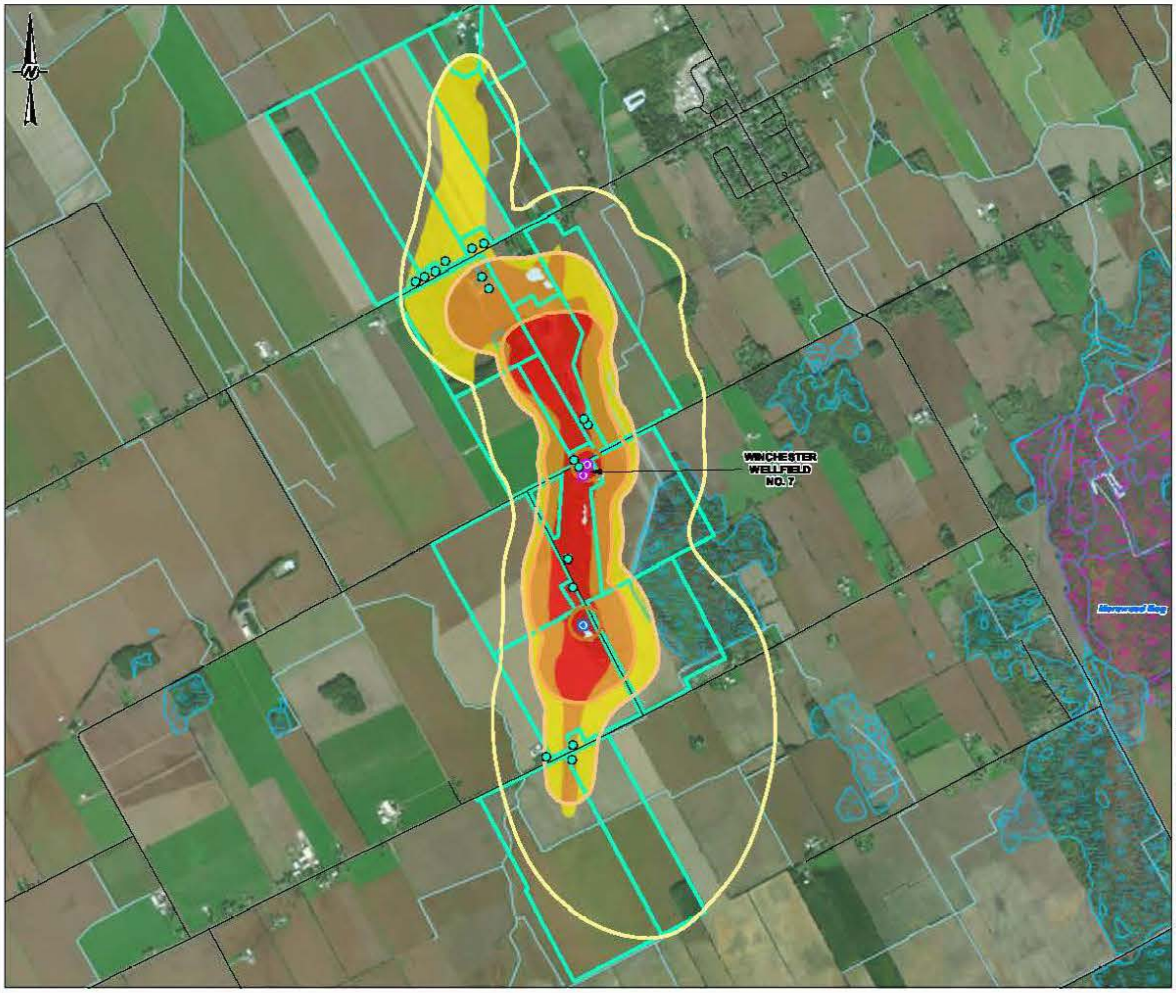
PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

TITLE
POTENTIAL AREA OF SIGNIFICANT RISK OF DRINKING WATER THREATS – DNAPLs

CONSULTANT
WSP GOLDER

YYYY-MM-DD	[illegible]
DESIGNED	—
PREPARED	RRD/MG
REVIEWED	DH
APPROVED	FAS

PROJECT NO.	CONTROL	REV.	FIGURE
19125461	0010	0	17



LEGEND
◎ PROPOSED NEW MUNICIPAL SUPPLY WELL
◎ MUNICIPAL SUPPLY WELL
● CHEMICAL POINT SOURCE
— ROADS

WHPA VULNERABILITY SCORING
🟥 10 (HIGH)
🟧 8
🟨 6
▭ CHEMICAL NON-POINT SOURCE
▭ WHPA-A
▭ WHPA-B
▭ WHPA-C
▭ WHPA-D
▨ UNEVALUATED WETLAND
▨ PROVINCIALLY SIGNIFICANT WETLAND (PSW)
▭ WATERBODY

0 335 670 1,340
1:24,000 METRES

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. PARCEL DATA PROVIDED BY THE UNITED COUNTIES OF STORMONT, DUNDAS AND GLENGARRY
3. ONLY PORTION OF LAND PARCEL WITH A VULNERABILITY SCORE OF 10 AND MANAGED LAND CONTAINS A SIGNIFICANT THREAT.
4. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N

CLIENT
J.L. RICHARDS & ASSOCIATES LIMITED

PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

TITLE
SIGNIFICANT, MODERATE AND LOW CHEMICAL THREAT LOCATIONS

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2023-01-26
DESIGNED	—
PREPARED	MG
REVIEWED	DH
APPROVED	FAS

PROJECT NO.	CONTROL	REV.	FIGURE
19125461	0010	0	18

LEGEND

- ◎ PROPOSED NEW MUNICIPAL SUPPLY WELL
- ◎ MUNICIPAL SUPPLY WELL
- ● PATHOGEN POINT SOURCE
- — ROADS

WHPA VULNERABILITY SCORING

- 🟥 10 (HIGH)
- 🟧 8
- ▭ PATHOGEN NON-POINT SOURCE
- ▭ WHPA-A
- ▭ WHPA-B
- ▨ UNEVALUATED WETLAND
- ▨ PROVINCIALLY SIGNIFICANT WETLAND (PSW)
- ▨ WATERBODY

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. PARCEL DATA PROVIDED BY THE UNITED COUNTIES OF STORMONT, DUNDAS AND GLENGARRY
3. ONLY PORTION OF LAND PARCEL WITH A VULNERABILITY SCORE OF 10 AND MANAGED LAND CONTAINS A SIGNIFICANT THREAT.
4. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N

CLIENT
J.L. RICHARDS & ASSOCIATES LIMITED

PROJECT
TOWNSHIP OF NORTH DUNDAS WATER SUPPLY EXPANSION CLASS EA

TITLE
SIGNIFICANT, MODERATE AND LOW PATHOGEN THREAT LOCATIONS

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2022-01-[illegible]
DESIGNED	—
PREPARED	MG
REVIEWED	DH
APPROVED	PAS

PROJECT NO.	CONTROL	REV.	FIGURE
19125461	0010	0	19

APPENDIX A

Source Protection Plan Reference Documents (RRCA and SNC 2016)

Policy AG-1

Existing and future agricultural activities subject to a Prescribed Instrument

Where the following activities are or could be an existing or future significant threat, the threat shall be managed though the *Nutrient Management Act, 2002* (as amended):

- storage and application of agricultural source material;
- the handling, storage, and application of non-agricultural source material;
- the use of land for an outdoor confinement area or a farm-animal yard; and
- the application of commercial fertilizer to land.

The Ontario Ministry of Agriculture, Food and Rural Affairs will work with farmers to review existing and future Nutrient Management Plans, Strategies, and Non-Agricultural Source Material Plans to ensure that they contain best management practices to ensure that agricultural activities are not, or do not, become a significant drinking water threat. Instruments that exist before the day the Source Protection Plan takes effect must be reviewed and, if necessary, amended within three years.

Note: Additional policies apply. See *MONITORING-3*.

Policy AG-2

Existing and future agricultural activities subject to a Risk Management Plan

Intent

To manage the threat associated with existing and future storage and application of agricultural source material, the use of land for an outdoor confinement area or a farm-animal yard, and the application of commercial fertilizer to land where these activities would be a significant drinking water threat.

Rationale

The Committee realized that ASM can be land applied without a Nutrient Management Plan/Nutrient Management Strategy (e.g. an outdoor confinement area or a farm-animal yard). The Committee felt that Risk Management Plans (RMP) could be used to catch these exceptions and that the RMP should be structured to achieve the same goals as the existing Prescribed Instruments. During the consultation stage OMAFRA stated that Category 1 Non-Agricultural Source Material is sufficiently regulated under the *Nutrient Management Act, 2002*, and should not be subjected to a RMP.

The Committee wanted the RMP to be based on the same principles as a Nutrient Management Plan or Strategy. The RMP would also address all drinking water threat activities on the property in one Plan and take into account the good work already being done by farmers on their properties. The fertilizer RMPs should be modelled after the Canadian Fertilizer Institute guidelines. Farmers will also have the option to voluntarily develop a Nutrient Management Plan with a person certified by OMAFRA. This Plan would be reviewed and approved by the Risk Management Official as a Risk Management Plan.

OMAFRA suggested that this policy be clarified to emphasize that RMPs will be based on the requirements of the Nutrient Management Plans and Strategies, and that the listed components be given as examples of what should be included, rather than minimum requirements.

- Organic solvents are toxic to humans used in many manufacturing processes, which can be result in release to air and water.
- Ethylene/propylene glycol is the active ingredient in aircraft de-icing fluids. While other formulations have been considered, it is noted that glycol continues to be a major chemical used in this application. The runoff of large volumes of de-icing fluids into surface water bodies over a short period of time can lead to oxygen depletion which results in poor water quality and toxicity to aquatic life and mammals.
- The toxicity associated with the de-icing chemical can originate from both the glycol formulation as well as the additives mixed into these formulations.
- Although there are no existing aircraft de-icing operations identified in the Assessment Report, the Source Protection Committee felt it was theoretically possible that an airport could establish prior to the Source Protection Plan taking effect, and therefore an applicable policy was written.
- There are no Prescribed Instruments available for any of the chemical threats. As a result, the Part IV tools described in the *Clean Water Act* were used.

Policy CHEM-1

Risk Management Plans for existing chemical threats

Intent

To manage the threat associated with existing handling and storage of Dense Non-Aqueous Phase Liquids (DNAPLs), organic solvents, and aircraft de-icing using where they would be a significant drinking water threat.

Rationale

The Committee noted that DNAPLs and organic solvents are common in many industries; however, it was understood that these compounds are being phased out due to their hazardous nature. The Committee felt that the development of a Risk Management Plan would sufficiently manage existing significant chemical threats. Prohibiting <u>existing</u> activities was seen as a significant hardship to affected property owners; the Committee felt that an established operation should not be put out of business.

Although DNAPLs are a significant threat at any volume, this policy was not written to capture residential use of incidental volumes of products which may contain DNAPLs (like nail polish); and incidental volumes will not be addressed through a Risk Management Plan. The policy is targeted at the chemicals when stored or handled in a raw form (including chemicals that can degrade into DNAPLs).

Policy CHEM-2

Prohibition of future chemical threats

Intent
To prohibit future handling and storage of Dense Non-Aqueous Phase Liquids (DNAPLs), aircraft de-icing fluids, and organic solvents where the activity could be a significant threat.

Rationale
The Committee considered prohibition the most appropriate option for future non-residential instances of DNAPLs, aircraft de-icing, and organic solvents. This policy is not intended to capture residential use of incidental volumes of DNAPLs.

Prohibition was chosen because these chemicals can very serious, irreversible impacts on drinking water systems. The prohibition is not intended to apply to small volume residential uses (ex. nail polish remover) or household cleaners.

In some cases these chemicals can be replaced with other less harmful products (the prohibition applies to the chemical used, not the business). Business that must use these harmful chemicals will be located outside of the vulnerable area to reduce the risk to drinking water. This is not anticipated to cause undue hardship as these requirements will be flagged early in the planning and approvals process through the restricted land uses policy.

Policy FUEL-1

Existing and future fuel oil storage (O. Reg. 213/01) subject to a Risk Management Plan

The future and existing handling and storage of fuel as defined under Ontario Regulation 213/01 except for the handling and storage of fuel regulated under the *Safe Drinking Water Act, 2002* is designated for the purpose of Section 58 of the *Clean Water Act, 2006* (Risk Management Plan) where this activity is a significant drinking water threat.

The Risk Management Plan shall include the following risk management measures:

DESIGN & OPERATION STANDARDS

- Single-walled steel tanks with side-feed must be replaced immediately
- The replacement of single-walled steel tanks with bottom-feed when the tank is 15 years old (or earlier if a leak detection device indicates a leak)
- The replacement of double-bottom steel tanks with bottom-feed when the tank is 25 years old (or earlier if a leak detection device indicates a leak)
- The installation of oil lines in a manner that protects them from physical damage
- In all cases, new installations of fuel tanks shall meet the most up-to-date standards/technologies available (ex. more leak resistant than a single walled tank)
- Decommissioning of unused fuel oil tanks in accordance with Section 6.16 of the *Ontario Installation Code for Oil-Burning Equipment*.

TRAINING

- Information on procedures to be followed in the event of a spill for businesses and home owners
- Education related to basic filling precautions and procedures for spills during handling (from the *Ontario Installation Code for Oil-Burning Equipment*)

If yearly inspections are required under Section 13 of the Ontario Installation Code for Oil-Burning Equipment the Risk Management Official/Inspector shall request evidence to show that yearly inspections are being done by a certified Oil Burner Technician.

Note: Additional policies apply. See: *MONITORING-1, GENERAL-5,* and *GENERAL-6.*

Policy SEWG-4

Existing and future on-site sewage systems (septic systems)

a. When the Source Protection Plan takes effect, the Municipality shall manage existing and future septic systems and septic system holding tanks where they would be a significant drinking water threat through the *Ontario Building Code Act, 1992* and Ontario Regulation 315/10 (as amended) in accordance with the On-Site Sewage System Maintenance Inspections Program (MMAH, 2011, as updated).

The Municipality shall also ensure that existing septic systems and septic system holding tanks are decommissioned where inspectors determine the need for replacement or when connecting to municipal services. This would require the tank to be pumped out and collapsed/backfilled. The leaching bed can degrade naturally.

b. Where existing or future septic systems or septic system holding tanks are or would be a significant threat (including large septic systems >10,000 L/day) the Municipality shall, within one year of the Plan taking effect, require connection to municipal sewer services (capacity permitting) by passing a Mandatory Connection By-law (under the authority of the *Municipal Act, 2001*) where services are available at the property line in the following situations:

- Failure of a Phase II inspection;
- Principal Authority deems the existing system inadequate to service a proposed redevelopment/renovation; or
- For new development on existing vacant lots of record.

The Municipality shall also explore the potential of municipal servicing within the significant threat areas which currently have private services.

c. It is strongly recommended that the City of Ottawa explore the opportunity to deepen the Shadow Ridge Municipal Well to the Nepean aquifer to reduce the significant threats related to septic systems and septic system holding tanks in the Village of Greely within one year of the Plan taking effect.

Note: Additional policies apply. See: *MONITORING-3 and MONITORING-5*.

Policy SEWG-5

Planning requirements for future and proposed on-site sewage

Intent

To manage the threat associated with on-site sewage where it would be a significant threat, for the development of proposed lots or for any future development of properties with septic systems and/or septic system holding tanks.

Rationale

The Committee felt that the outright prohibition of future on-site sewage systems would restrict development in some communities. It was originally proposed that any new on-site sewage systems should require tertiary treatment; however, it was not known whether this type of treatment would effectively treat the contaminants of concern (pathogens, nitrates etc.). Due to this uncertainty, tertiary system requirements were not included in the policy text.

The Committee agreed that the developer must show that the lots are adequately sized and that existing conditions can accommodate on-site sewage treatment for any future on-site sewage systems where they would be a significant drinking water threat.

Policy SEWG-6

Large (>10,000L/day) on-site sewage systems

Intent

To manage the threat associated with on-site sewage where it would be a significant threat.

Rationale

The use of large (> 10,000 L/day) on-site sewage systems and septic system holding tanks are regulated under an Environmental Compliance Approval under the *Ontario Water Resources Act, 1990*. The Committee determined that the Prescribed Instrument is sufficient to manage the threat in significant areas. These Approvals must be reviewed to ensure conditions are in place to protect sources of drinking water.

4.4 Pesticides

Activities related to Pesticides

The following activities, prescribed as drinking water threats through the *Clean Water Act, 2006* Regulations, are related to pesticides:

- The application of pesticide to land; and
- The handling and storage of pesticide.

Contaminants of Concern

The activities have been prescribed as drinking water threats because under certain circumstances the following contaminants pose a hazard to drinking water sources:

- Atrazine;
- Dicamba;
- Dichlorophenoxy Acetic Acid (D-2,4);
- Dichloropropene-1,3;
- Glyphosate;
- MCPA (2-methyl-4-chlorophenoxyacetic acid);
- MCPB (4-(4-chloro-2-methylphenoxy) butanoic acid);
- Mecoprop;
- Metalaxyl;
- Metolachlor; and
- Pendimethalin.

Policy Considerations

The Source Protection Committee considered all available technical information and Provincial guidance as part of the policy development process. The following points are a summary of the discussion relating to this threat category.

- Pesticides are well regulated at the Federal and Provincial level. People who store or apply pesticides receive appropriate training.
- Manufacturing, processing, and wholesale activities of pesticides are generally permitted on lands that are zoned for industrial uses.
- Storage of pesticides for retail sale or for use in extermination could occur on many properties since this activity is generally associated with agricultural, recreational, institutional, commercial, industrial land uses, and public works (use alongside roads and utility corridors).
- Various forms of legislation, guidelines, and protocols already exist for pesticide manufacturing. For example:
    - Agrichemical Warehousing Standards Association requirements are comprehensive and effectively address all aspects of safely siting a new storage.

  - Golf courses and certain public works must become accredited for Integrated Pest Management and report annually to the public about how they have minimized their pesticide use.
  - Pesticide manufacturers, operators, and vendors must be licensed and report their pesticide storage to local fire departments.
  - Farmers and licensed exterminators must also have completed the Pesticide Safety Course which addresses many aspects of the threat.
  - A pesticide permit issued by the Ministry of the Environment and Climate Change under the *Pesticides Act, 1990* is required for aerial spraying.
  - Ontario's Cosmetic Pesticide Ban prohibits the use of pesticides for cosmetic use with some exceptions for protecting the health and safety of people (e.g., controlling mosquitoes that can transmit West Nile Virus, plants that are poisonous to the touch, fleas on pets, indoor pests or pests that can cause structural damage to a home).

Intent and Rationale

Policy PEST-1

The existing and future application of pesticide to agricultural or commercial land subject to a Prescribed Instrument

Intent
To manage the application of pesticide to land where it would be a significant threat using existing regulations.

Rationale
The Committee believes that existing and future pesticide application can be managed through Ontario's many existing protocols, regulations, and requirements. This approach was used whenever possible to avoid regulatory burden and overlap, and is consistent to the approach used to manage other agricultural-related threats.

Policy PEST-2

The existing and future application, storage and handling of pesticide subject to a Risk Management Plan

Intent
To manage the application, handling, and storage of pesticides on land where it would be a significant threat and is not currently regulated through a Prescribed Instrument.

Rationale
The Committee preferred to use a Risk Management Plan for pesticide application, storage, and handling for operations that are not prohibited through the Cosmetic Pesticide Ban and are not regulated through a Prescribed Instrument. This allows a Risk Management Official to assess the activity and negotiate a site and activity specific Risk Management Plan with the landowner. The Plan will include information on what to do in the case of a spill including contact information for the local drinking water plant operator.

Policy PEST-3

Prohibition of future commercial storage and handling of pesticide

Intent

To prohibit the future manufacturing and processing (industrial/retail handling and storage) of pesticides where they would be a significant threat.

Rationale

The establishment of processing and wholesale facilities for pesticides, including retail outlets and custom applicators, is a serious and unnecessary risk in the vulnerable areas.

The Committee understood that these storages could be associated with larger volumes of pesticide stored for longer periods of time compared to other pesticide users. As with other large scale developments which pose a significant threat to drinking water, these facilities can be established in another suitable location.

There was no Prescribed Instrument available in relation to this specific threat so prohibition was achieved through Section 57 of the *Clean Water Act, 2006.*

Table 13: Winchester – Activities, Vulnerable Areas, Threats and Policies

Prescribed Activity		**WHPA**				**Policy Code and Implementer**				
		A	**B**	**C**	**D**					
Waste Disposal Sites						**Municipality**			**MOE**	
1.1	Application of Septage	X	X*	-	-	WASTE-2			WASTE-1	WASTE-2
1.2	Mine Tailings	X	X*	-	-	WASTE-2	WASTE-3	WASTE-4	WASTE-1	WASTE-2
1.3	Land-farming Petroleum Waste	X	X*	-	-	WASTE-2			WASTE-1	WASTE-2
1.4	Landfill - Hazardous Waste	X	X*	-	-	WASTE-2			WASTE-1	WASTE-2
1.5	Landfill - Municipal Waste	X	X	X**	-	WASTE-2			WASTE-1	WASTE-2
1.6	Landfill - Industrial/Commercial	X	X	X**	-	WASTE-2			WASTE-1	WASTE-2
1.7	Liquid Waste Injection	X	X	X**	-	WASTE-2			WASTE-1	WASTE-2
1.8	PCB Waste Storage	X	X*	-	-	WASTE-2	WASTE-3	WASTE-4		
1.9	Storage of Hazardous Waste	X	X*	-	-	WASTE-2			WASTE-1	WASTE-2
1.10	Storage of Other Waste	X	X*	-	-	WASTE-2			WASTE-1	WASTE-2
Sewage Works						**Municipality**			**MOE**	
2.1	Combined Sewer Discharge	-	-	-	-	SEWG-3			SEWG-2	
2.2	Stormwater Pond Effluent	X	X*	-	-	SEWG-7			SEWG-7	
2.3	Industrial Effluent Discharges	-	-	-	-	SEWG-3			SEWG-2	
2.4	Sanitary Sewers and Pipes	X	X*	-	-	SEWG-1			SEWG-1	
2.5	Septic Systems	X	X*	-	-	SEWG-4	SEWG-5		SEWG-5	SEWG-6
2.6	Septic Holding Tanks	X	X*	-	-	SEWG-4	SEWG-5		SEWG-5	SEWG-6
2.7	Sewage Treatment Bypass	-	-	-	-	SEWG-3			SEWG-2	SEWG-3
2.8	Sewage Treatment Effluent	X	X*	-	-	SEWG-3			SEWG-2	SEWG-3
2.9	Storage of Sewage	X	X	X**	-	SEWG-3			SEWG-2	SEWG-3
Agricultural Activities						**Municipality**			**OMAFRA**	
3	Application of ASM	X	X*	-	-	AG-2			AG-1	
4	Storage of ASM	X	X*	-	-	AG-2			AG-1	
5	Management of ASM^	-	-	-	-					
6	Application of NASM	X	X*	-	-	AG-2			AG-1	
7	Storage of NASM	X	X*	-	-	AG-2			AG-1	
8	Application of Fertilizer	-	-	-	-	AG-2			AG-1	
9	Storage of Commercial Fertilizer	X	X*	-	-	AG-2				
21.1	Grazing - ASM Generation	X	X*	-	-	AG-2			AG-1	
21.2	Pasturing - Farm Animals	X	X*	-	-	AG-2			AG-1	
Pesticides						**Municipality**			**MOE**	
10	Application of Pesticides	X	X*	-	-	PEST-2			PEST-1	
11	Storage of Pesticides	X	X*	-	-	PEST-2	PEST-3			
Salt and Snow						**Municipality**			**MTO**	**S.I.**
12	Application of Road Salt	-	-	-	-	SALT-1			SALT-4	SALT-5
13	Storage of Road Salt	X	X*	-	-	SALT-2	SALT-3			
14	Storage of Snow	X	X*	-	-	SALT-2	SALT-3			
Fuel						**Municipality**			**MOE**	
15	Storage of Fuel	X	X*	-	-	FUEL-1	FUEL-2	FUEL-4	FUEL-3	
Chemicals						**Municipality**				
16	Storage of DNAPLs	X	X	X	-	CHEM-1	CHEM-2			
17	Storage of Organic Solvents	X	X*	-	-	CHEM-1	CHEM-2			
18	Aircraft De-Icing	X	X*	-	-	CHEM-1	CHEM-2			
Water Quantity										
19	Consumptive Activity^	-	-	-	-					
20	Aquifer Depletion^	-	-	-	-					

Threat Applicability	
X	The policy applies in this area.
X*	The policy applies in a portion of this area where the vulnerability score is 10.
X**	The policy applies in a portion of this area where the vulnerability score is 8 or higher.
-	No policies apply in this area as the activity is not considered a significant threat.
^	This activity is not a significant threat within the Source Protection Area.

Policy Implementer	
🟦	Municipality
🟩	MOE
🟨	OMAFRA
🟪	MTO
🟫	Salt Institute