REPORT

Level 1 and Level 2 Water Report

Proposed Renfrew Golf Pit, Horton Township, Renfrew County, Ontario

Submitted to:

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1.0 INTRODUCTION

WSP Canada Inc. (WSP, formerly Golder Associates Ltd.) was retained by Thomas Cavanagh Construction Limited (Cavanagh) to conduct hydrogeological and hydrological studies at the proposed Renfrew Golf Pit located on Part Lots 23, 24 and 25, Concession 1, Horton Township, Renfrew County, Ontario (see Figure 1). The purpose of these studies is to provide supporting documentation for a licence application for a Class 'A' licence for a Pit Below the Groundwater Table, under the *Aggregate Resources Act* (ARA). The site is currently zoned Extractive Industrial-holding (EM-h). The removal of the holding zone is subject to the completion and acceptance of several studies including a Hydrogeology Study. This Water Report is intended to satisfy the requirements for a Hydrogeology Study in support of removing the holding zone.

1.1 Site Description

The proposed pit is located adjacent to the Renfrew Golf Club at the terminus of Golf Course Road in Horton Township, Renfrew County (Figure 1). The majority of the site is dominated by natural cover in the form of meadows, thickets, and deciduous and mixed forests subject to forestry activities. West and south of the site are agricultural lands. To the north and northeast are forested areas, and the Renfrew Golf Club is located to the southeast. A public trail runs adjacent to the western boundary of the site (former rail line). The only building on site consists of a small pump house near Clubhouse Lake.

Beyond the site boundary, the nearest residences are located along Golf Course Road and Harveys Crescent to the south and southwest (see road locations on Figure 2). In addition, the buildings associated with the Renfrew Golf Club are located southeast of the site. The approximate locations of private water supply wells, with a UTM Reliability Code of 5 or less (i.e., the location provided in the database is expected to be within 300 m or less of the actual location), within 500 metres of the proposed extraction area (as provided in the Ministry of the Environment, Conservation and Parks Water Well Information System; MECP WWIS) are shown on Figure 2.

The ground surface elevation within the site ranges from approximately 130 to 180 metres above sea level (mASL). The lowest elevations are found in the vicinity of Clubhouse Lake and the highest elevations are found in the northwest portion of the site (see detailed topography on Figure 1).

Surface water features on the site are limited to a small section of a low-order off-site intermittent stream in the southwest portion of the site that flows into Clubhouse Lake, a portion of a primarily off-site marsh just upstream from Clubhouse Lake and a small shallow round pond in the southern portion of the site. In the vicinity of the site beyond the proposed license boundary, there is a low-order streams and wetlands located along the eastern boundary, and a large pond feature known as 'Clubhouse Lake' adjacent to the southern portion of the site. The locations of the water features are shown on Figures 1 and 2.

1.2 Site Development

The site consists of a 40.5-hectare (ha) area proposed to be licensed under the ARA, of which the proposed extraction area occupies 31.6 ha. The property is owned by the applicant (Cavanagh). The intention is to remove overburden material within the extraction area down to the bedrock surface (or until non-marketable material is encountered) for areas where the water table is located within the bedrock (i.e., in the northern half of the site). Extraction of the first lift will commence in the southern portion of the extraction area and will proceed radially towards the north, east and west setback limits. The first lift will extend to the water table, or the bedrock/non-marketable material surface, whichever is encountered first.

Usable material identified below the water table will be extracted in the second lift. Excavation can proceed up to a maximum of 10 metres below the water table. Extraction below the water table will primarily occur in the southern half of the site and will result in the formation of a pit lake within this area.

Based on the nature of the subsurface materials, the final pit floor elevation will vary from approximately 135 mASL to 154 mASL in the north/northwest portion of the site to 120 mASL in the southern portion of the site and will be primarily controlled by the elevation of the bedrock within the extraction area. Only unconsolidated materials (sand, gravel, etc.) will be removed from the site. Any bedrock encountered on the site will remain in place.

Extraction operations below the groundwater table will not involve dewatering of the excavation. The material within the below water portion of the pit will be scooped out from below the water table and stockpiled on dry land adjacent to the pit lake allowing the water to drain from the extracted material.

The final rehabilitation plan includes a permanent pit lake located within the southern portion of the extraction area. The majority of the area north of the pit lake will be rehabilitated as woodlot (see Figure 9). During rehabilitation, side slopes at 3H:1V will be established. This will result in a decrease of the pit lake storage volume after rehabilitation. The sloping areas around the pit will be rehabilitated using seed mix of native grasses and herbaceous plants. Excavation of areas where the bedrock drops, and the overburden thickens in the northern portion of the site may result in ponded areas within the bedrock lows following rehabilitation. The predicted elevation of the permanent pond will be approximately 130 to 131 mASL.

1.3 Study Objectives

The objective of this study was to fulfill the requirements of a Level 1 and 2 Water Report for the licensing of a Class ‘A’, Pit Below the Groundwater Table, under the ARA. The study includes a hydrogeological and hydrological assessment to establish the groundwater conditions and water balance for the site. The results of the hydrogeological and hydrological investigation are used to assess the potential for adverse effects to groundwater users, surface water resources and natural environment features as a result of the proposed extraction below the groundwater table. The qualifications and experience of the report authors are presented in Appendix A.

2.0 SITE GEOLOGY AND HYDROGEOLOGY

2.1 Surficial Geology

The surficial geology in the vicinity of the site is shown on Figure 3. Published surficial geological mapping indicates that the site is generally covered by ice-contact stratified sand and gravel deposits, with some organic deposits in the low-lying areas at the south of the site and Precambrian bedrock outcrops near the northern boundary. The drilling program completed at the site as part of the hydrogeology study confirmed the presence of overburden ranging from sandy silt to sand to sand and gravel, as discussed further in Section 3.1.1.

Beyond the site, published surficial geology mapping is dominated by Precambrian bedrock outcrops toward the north and east and fine-textured glaciomarine deposits (silt and clay) to the south and west (see Figure 3).

2.2 Bedrock Geology

Published bedrock geology mapping indicates the upper bedrock unit in the vicinity of the site consists of Precambrian Bedrock consisting of Carbonate Metasedimentary Rocks (i.e., marble) (see Figure 4). Immediately southwest of the site, the upper bedrock unit consists of Mafic to Ultramafic Plutonic Rocks.

A review of the MECP WWIS indicates that three of the four supply wells completed within 500 metres of the site extended to depths of 33.5 to 48.2 metres, or elevations of approximately 79.1 to 106.5 mASL, without encountering the bedrock surface. The bedrock surface was encountered at one well within 500 metres of the site (WWIS ID 5500006), at 20.4 metres below ground surface (mbgs) or approximately 119 mASL. Further west of the site, near Harveys Crescent, the bedrock surface is closer to ground surface and was encountered at depths of 1.2 to 13.6 mbgs. The depth to the bedrock can be highly variable within the vicinity of the site due to uneven Precambrian bedrock surface.

2.3 Hydrogeology

2.3.1 Overburden Aquifer

Deposits of coarse and permeable overburden capable of supplying sufficient quantities of groundwater appear to exist locally in the area around the site (see unit 6a on Figure 3). It is estimated that there are approximately four private supply wells located within 500 metres of the proposed license boundary, including two residences along Golf Course Road, the Renfrew Golf Club and the residence located southwest of the site fronting onto Harveys Crescent. The MECP WWIS identifies four private supply wells (5502761, 5513151, 5503554 and 5500006) within 500 metres of the site boundary based on a UTM Reliability Code of 5 or less (within 300 metres); however, they are all located along Golf Course Road (refer to Figure 2). Of those four wells, three (5502761, 5513151 and 5503554) were completed in gravel overburden at depths ranging from 33.5 to 48.2 mbgs, and the other well (5500006) was completed in the bedrock at a depth of 20.4 mbgs. The four wells had static water levels ranging between 0.3 and 4.3 mbgs at the time of drilling.

2.3.2 Bedrock Aquifer

Beyond the vicinity of the site, the surficial geology is dominated by Precambrian bedrock outcrops toward the north and northeast and glaciomarine silt and clay to the south and west. In these areas, the Precambrian bedrock is the main source of potable groundwater. Groundwater flow in the Precambrian bedrock is attributed to secondary porosity produced by fractures that have developed from tectonic processes (Golder, 2003). The density of fractures in the bedrock tends to decrease with depth (Golder, 2003). Estimates of hydraulic conductivity in fractured igneous and metamorphic rocks ranges from 10^{-8} to 10^{-4} metres per second (Freeze and Cherry, 1979). The actual value of hydraulic conductivity in the region are typically at the low end of the range (Golder, 2003). Generally, the fracture zones in the Precambrian bedrock yield marginal to adequate quantities of water for domestic use (Golder, 2003).

3.0 STUDY METHODS AND RESULTS

3.1 Hydrogeological Investigation

A hydrogeological assessment in support of the application was completed for the site. The hydrogeological assessment involved the following tasks:

- Review of available data/information and site visit
- MECP Water Well Inventory (discussed in Section 2.0)
- Borehole investigation and monitoring well installations
- Groundwater level monitoring program
- Assessment of potential impacts related to the development and rehabilitation of the proposed pit

3.1.1 Boreholes and Monitoring Well Installations

A hydrogeological field investigation was carried out on June 16 and 17, 2021 at the site. The objective of the field investigation was to install groundwater level monitoring wells to define the elevation of the water table at the site. As part of the field program, four boreholes were advanced across the site. The boreholes are identified as BH21-01 through BH21-04 and the borehole locations are shown on Figure 1. The boreholes were advanced using a track-mounted hollow stem auger drill supplied and operated by Marathon Drilling Company Ltd. of Ottawa, Ontario. The boreholes were advanced to depths of 4.6 to 11.5 mbgs. This corresponds to borehole bottom elevations ranging from approximately 125.0 (BH21-04) to 141.0 (BH21-02) mASL.

All field work was monitored by WSP staff who staked the boreholes in the field in advance of drilling, monitored drilling operations, logged the boreholes and samples, and took custody of the soil samples retrieved. Monitoring wells consisting of 51-millimetre diameter Schedule 40 PVC screen and riser were installed in the sand overburden in boreholes BH21-01, BH21-02 and BH21-04. Borehole BH21-03 was advanced to auger refusal on interpreted bedrock at 11.5 mbgs without encountering the water table; therefore, no monitoring well was installed in this borehole. The locations and geodetic ground surface elevations of the boreholes were surveyed by WSP.

Borehole logs summarizing the subsurface conditions encountered in the boreholes drilled at the site as part of the current investigation are included in Appendix B.

3.1.2 Previous Studies

In 2017 and 2018, an aggregate resource investigation was carried out at the site by the former site owner, Miller Group Inc. The results of the test pit and borehole field investigation were subsequently reviewed by GRI Inc. and presented in a technical memo (GRI Inc., 2018). The site plan, test pit logs and borehole logs from that investigation are provided in Appendix C. Stratigraphic information from the investigation has been incorporated into the following section.

3.1.3 Site Stratigraphy

In general, the subsurface conditions in which the boreholes were advanced consist of a thin topsoil layer, underlain by sand deposits ranging from sand and gravel to sandy silt. Two stratigraphic cross-sections running through the property are shown on Figure 5 (refer to Figure 1 for cross-section locations). There is significant variation in the ground surface elevation at the site. Based on available topographic data, the ground surface elevation is estimated to range from approximately 130 mASL in the southern portion of the site to approximately 180 mASL in the northwestern portion.

In the boreholes advanced during the current investigation (BH21-01 through BH21-04), the materials encountered consist primarily of alternating layers of fine sand and sandy silt or silty sand, with a combined thickness of at least 4.3 metres to 11.4 metres. Some fine to medium and fine to coarse sand was also encountered at BH21-03. In the deeper boreholes described by GRI Inc. (2018) (TW1 through TW6), there were alternating layers of sand (ranging from fine to medium, to medium to coarse), sand and gravel, and silty sand. The total thickness of sand units at these boreholes ranged from approximately 8 metres (TW-2) to 40 metres (TW-1).

Auger refusal on interpreted bedrock was encountered at 11.5 mbgs at BH21-03. Bedrock was not encountered at BH21-01, BH21-02 or BH21-04. In the deeper boreholes (GRI Inc., 2018), the bedrock was reported at depths of 11.5 to 42 mbgs, usually overlain by a layer of glacial till measuring 1 to 5 metres thick. As shown on cross-section B-B’ on Figure 5, the bedrock surface rises northward, from approximately 42 mbgs at TW1 to 11.5 mbgs at TW2. This rising bedrock surface is consistent with the presence of mapped bedrock outcrops near the northern boundary of the site (Figure 3).

3.1.4 Hydraulic Conductivity Testing

Well response tests were completed in the monitoring wells installed in BH21-01, BH21-02 and BH21-04 using the rising/falling head method. The well response tests provide an estimate of the horizontal hydraulic conductivity of the overburden materials adjacent to the monitoring well interval at each location. The response testing was performed by displacing water by inserting/removing a plastic slug and monitoring the recovery to the static water level by measuring the depth to the water using a water level tape and/or pressure transducer and datalogger at frequent intervals.

For analysis, the intervals for response testing were defined as the monitoring well screen. This definition of screen length was used to maintain the assumption for horizontal flow to the piezometer screen. The details regarding the locations of the test interval for each monitoring well are provided on the borehole logs in Appendix B. The well response test analyses are provided in Appendix D. The hydraulic conductivity value from each test was calculated using the Hvorslev (1951) method.

A summary of the well response testing results from on-site monitoring are provided in the following table:

Table 1: Hydraulic Conductivity Estimates from On-Site Hydraulic Testing

Monitoring Well	Estimated Hydraulic Conductivity (metres per second)	Statigraphy of Screened Interval
BH21-01	1×10^{-5}	silty sand
BH21-02	5×10^{-6}	sandy silt
BH21-04	2×10^{-5}	silty sand to sand and silt

These estimates are consistent with the range of hydraulic conductivity values reported for silty sand (Freeze and Cherry, 1979). The hydraulic conductivity values estimated from the well response testing ranges from 5×10^{-6} to 2×10^{-5} metres per second (m/s) with a geometric average of 1×10^{-5} m/s.

3.1.5 Groundwater Monitoring and Flow Direction

Groundwater monitoring sessions were undertaken between June 22, 2021 and March 04, 2023. During each groundwater monitoring event, the depth to the groundwater level below the top of the surveyed monitoring well casing was recorded in order to determine the groundwater level fluctuations in the area that occur within the overburden. The water level elevations are provided in the following table and plotted against time on Figure 6.

Table 2: Groundwater Elevations

Date	Groundwater Elevations (metres above sea level)				
	BH21-01	BH21-02	BH21-04	TW1	TW5
22-Jun-21	132.29	142.40	127.49	130.21	136.15
30-Jul-21	132.34	142.68	127.64	130.18	136.14

Date	Groundwater Elevations (metres above sea level)				
	BH21-01	BH21-02	BH21-04	TW1	TW5
29-Aug-21	132.28	142.70	127.49	130.07	136.64
30-Sep-21	132.32	142.80	127.53	130.09	136.67
11-Oct-21	132.27	142.51	127.52	130.05	136.65
27-Nov-21	132.19	142.47	127.45	130.03	136.63
10-Dec-21	132.11	142.33	127.36	130.01	136.59
04-Jan-22	132.09	142.28	127.29	129.99	136.57
10-Feb-22	131.98	142.17	127.07	129.91	136.50
03-Mar-22	131.97	142.15	127.11	129.95	136.55
08-Apr-22	132.68	143.12	127.94	130.18	136.33
06-May-22	132.63	143.06	127.88	130.11	136.25
28-Jun-22	132.60	143.10	127.79	130.34	136.71
07-Jul-22	132.50	142.97	127.82	130.05	136.21
05-Aug-22	132.66	142.69	127.36	130.34	136.70
09-Sep-22	132.63	142.65	127.32	130.31	136.69
08-Oct-22	132.63	142.65	127.36	130.31	136.67
01-Nov-22	132.68	142.68	127.36	130.43	136.73
03-Dec-22	132.69	142.70	127.38	130.41	136.74
06-Jan-23	132.53	142.60	127.34	130.36	136.72
05-Feb-23	132.48	142.57	127.32	130.35	136.68
04-Mar-23	132.46	142.57	127.34	130.34	136.66

As shown on Figure 6, the pre-development groundwater elevations (i.e., background conditions) in the vicinity of the site ranged from a low of 127.07 mASL at BH21-4 in March 2022 to a high of 143.12 mASL at BH21-2 in April 2022. Groundwater depths range from 2.6 (BH21-4) to 33.6 (TW-1) mbgs across the site. Groundwater elevations in all monitoring wells are generally stable (i.e., vary by less than one metre) and display minor seasonal variations.

Based on groundwater elevation data collected during the pre-development period, the general groundwater flow direction in the vicinity of the site is influenced by the topography of the site and seasonal water table fluctuations. Groundwater generally flows from northeast to southwest across the site towards Clubhouse Lake (see Figure 1).

3.2 Hydrological Investigation and Water Balance Analysis

A water balance was completed for existing, operational and rehabilitation conditions for the study area. The study area includes the land within the property boundary of the proposed pit and contributing catchments. The total study area is approximately 229.9 ha. For detailed water balance tables refer to Appendix E.

3.2.1 Surface Water Monitoring

Two Staff Gauges (SG) and two Drive-point Piezometers (DP) were installed in the wetland along the western site boundary and the watercourse along the eastern site boundary, to monitor the surface water levels: SG-1 and DP-1 for the west wetland, and SG-2 and DP-2 for the east watercourse.

A list of these monitoring stations, their locations (referenced to UTM NAD83 Zone 18), surveyed top of gauge elevation in mASL and their installation dates are provided in Table 3. The approximate locations of these surface water monitoring stations are shown on Figure 1.

Table 3: Surface Water Monitoring Locations

Station Name	Top of Gauge Elevation (mASL)	Easting (m)	Northing (m)	Installation Date	Measurements
DP-1	128.327	362304	5041666	July, 2021	Water Depths
DP-2	148.032	362476	5042320		
SG-1	128.307	362303	5041644		
SG-2	148.837	362477	5042316		

3.2.1.1 Surface Water Elevations

The depths to water (DTW) surface from the surveyed top of gauge elevations were manually recorded during monthly site visits at the staff gauge and drive-point piezometer locations presented in Table 3. Surface water elevations at the monitoring stations were then obtained by subtracting the DTW from the surveyed top of gauge elevations.

The DTW data were recorded during the period from July 2021 through March 2023. Table 4 presents the calculated surface water elevations at each monitoring station.

Table 4: Summary of Surface Water Elevations at the Monitoring Stations

Period of Record	Surface Water Elevation[1] (meters above sea level)			
	SG-1	DP-1[a]	SG-2	DP-2[a]
31-Jul-21	127.607	---	147.557	---
29-Aug-21	127.967	---	147.562	---

Period of Record	Surface Water Elevation[1] (meters above sea level)			
	SG-1	DP-1[a]	SG-2	DP-2[a]
30-Sep-21	127.997	---	147.557	---
11-Oct-21	127.977	127.887	147.557	147.282
27-Nov-21	128.017	127.917	147.572	147.302
10-Dec-21	Frozen	127.977	147.547	147.242
4-Jan-22	Frozen	Frozen	147.557	147.252
10-Feb-22	Frozen	Frozen	Frozen	Frozen
3-Mar-22	Frozen	Frozen	147.567	147.232
17-Apr-22	Frozen	Frozen	147.687	147.492
6-May-22	128.167	128.127	147.667	147.462
28-Jun-22	128.207	128.147	147.567	147.412
7-Jul-22	128.147	128.107	147.652	147.452
5-Aug-22	128.147	128.037	147.497	147.242
9-Sep-22	128.162	128.087	147.482	147.222
8-Oct-22	128.127	128.027	147.507	147.222
1-Nov-22	128.127	128.147	147.497	147.232
3-Dec-22	128.237	128.157	147.517	147.242
6-Jan-23	Frozen	Frozen	147.507	Frozen
5-Feb-23	Frozen	Frozen	147.517	147.212
4-Mar-23	Frozen	Frozen	147.492	Frozen

Notes:
[a] Surface water elevation is calculated based on the DP-inside measurements.

Figure 6 shows the variation of the surface water elevations against time at the different monitoring locations. Missing data during winter months corresponds to frozen conditions (see Table 4). The available surface water elevation data at SG-1 shows a slightly increasing trend over time. Location SG-1 tends to be frozen for a longer period of time compared to location SG-2 (see Table 4).

The surface water data of SG-1 and shallow groundwater data at DP-1 reflect quasi-constant water elevations throughout the period of record with a slight increase of approximately 0.15 m between the periods: August through December 2021, and May through December 2022. Based on the similarity in the surface water and shallow groundwater elevation data measured at SG-1 and DP-1, the wetland in this area is interpreted to be an expression of the groundwater table in this portion of the site.

A slight seasonal increase in the surface water elevations of approximately 0.20 metres is observed in the data of SG-2 and DP-2 during the period early March through early July 2022 that is attributed to minimal response to precipitation and snow melt events. SG-2 is used to measure surface water levels and DP-2 is used to measure shallow groundwater levels. The surface water and groundwater elevation data for SG-2 and DP-2 are presented on Figure 6. As shown on Figure 6, the shallow groundwater elevation measured at DP-2 is typically 0.25 to 0.3 metres below the surface water elevations measured at SG-2. The available water elevation data indicates that the surface water feature is consistently perched above the groundwater table and the groundwater is not discharging to the surface water feature. At the time DP-2 was installed, a fine-grained silt layer was noted at shallow depth below the surface water feature. This silt layer is interpreted to separate the surface water feature from the underlying sand and gravel deposit at the site.

Overall, the surface water elevation data at SG-1 and DP-1, and SG-2 and DP-2; along with the topographic contour mapping in Figure 1, suggest that the collected runoff in the stream that flows around the northeast side of the site eventually discharges into Clubhouse Lake. The surface water and shallow groundwater elevations measured at SG-1 and DP-1 indicate the wetland feature upstream from Clubhouse Lake is an expression of the local shallow groundwater table. The surface water and shallow groundwater elevations measured at SG-2 and DP-2 indicate the surface water feature along the eastern boundary of the site is disconnected from the groundwater table and is interpreted to be surface water fed.

3.2.1.2 Water Quality Assessment

Surface water grab samples at three locations were taken on June 27, 2022, to assess the baseline water quality around the site. The samples were labelled: SW-1, SW-2 and SW-3 and they were taken at the locations of SG-1, SG-2 and Clubhouse Lake, respectively (see sample locations on Figure 1). The collected samples were analysed at the third-party accredited lab Bureau Veritas.

The samples were analysed for general chemistry parameters, metals and petroleum hydrocarbons. The lab results of the samples collected showed that there were no Provincial Water Quality Objectives (PWQO) exceedances for the analyzed parameters, except for total iron (Fe) at SW-1 that recorded 350 µg/L compared to the PWQO of 300 µg/L. At SW-3 (Clubhouse Lake), which is downstream of SW-1, the corresponding iron test result records 170 µg/L, which is less than the PWQO of 300 µg/L. It is expected that this minor exceedance at SW-1 is localized within the west wetland. A table summarizing the water quality results from the baseline sampling event at the three noted locations, along with their Certificates of Analyses from the analytical lab are included in Appendix G.

3.2.2 Water Balance Methodology

A water balance assessment related to the proposed extraction area of the pit development was carried out to assess the potential hydrogeological impacts with respect to change in surplus, including potential impacts to downstream surface water features. The assessment included the existing, operational (full extraction), and rehabilitated conditions within the proposed extraction limits.

The water balance assessment relied on meteorological data obtained from Environment and Climate Change Canada (ECCC) for the Ottawa International Airport (ID 6106000) Meteorological Station for the period from 1939 to 2019. The water balance was based on land use data and existing soil types as identified through the subsurface investigation activities at the site. Land use at the site under the existing conditions was identified from previous ecological mapping studies conducted in support of the Natural Environment Report for the site as shown in Appendix F. Land use under the operational conditions was based on the ARA Site Plan where a portion of the extraction is expected to be flooded and the remainder is extracted above the water table to the bedrock surface or until non-marketable material is encountered (see Figure 8). The rehabilitation plan assumes that a portion of the proposed pit will be flooded, the above water table areas will be rehabilitated, and the setback areas will remain vegetated (see Figure 9). The land use data were compiled to estimate the total area of each land use within the site boundary. Meteorological data and information from this investigation were used with Table 3.1: Hydrologic Cycle Component Values, from the Ontario Ministry of Environment, Conservation and Parks (MECP) Stormwater Management (SWM) Planning and Design Manual (2003), to identify appropriate Water Holding Capacities (WHC) for each land use. For detailed water balance tables, refer to Appendix E.

Water balance calculations are based on the following equation, which is described in more detail below:

$$P = S + ET + Surplus$$

Where:

P = precipitation

S = change in soil water storage

ET = evapotranspiration

Surplus = Surplus water (available for runoff or infiltration).

The various water balance components are typically presented in millimetres (mm) per time step over their respective sub-catchments and represent the amount of water per unit of watershed area.

Precipitation data obtained from ECCC for the Ottawa International Airport station indicate a mean annual precipitation (P) of 904 millimetres per year (mm/yr).

Short-term or seasonal changes in soil water storage (S) are anticipated to occur on an annual basis as demonstrated by the typically dry conditions in the summer months and the wet conditions in the winter and spring seasons. Long-term changes (e.g., year to year) in soil water storage are considered negligible in this assessment.

Evapotranspiration (ET) refers to water lost to the atmosphere from vegetated surfaces. The term combines evaporation (i.e., water lost from soil or water surfaces) and transpiration (i.e., water lost from plants and trees). Potential ET refers to the loss of water from a vegetated surface to the atmosphere under conditions of an unlimited water supply. The actual rate of ET is typically less than the potential rate under dry conditions (e.g., during the summer months when there is a moisture deficit). The mean annual potential ET for the study area is approximately 610 mm/yr based on the data provided by ECCC.

For temperate region watersheds, soil storage is typically relatively stable year-round, remaining at or near the field capacity except for the typical mid- to late-summer dry period. As such, the change in soil storage is a minor component in the water budget, particularly at an annual scale. The mean annual water surplus (Surplus) is, therefore, estimated as the difference between P and the actual ET. The water surplus represents the total amount of water available for either surface runoff (R) or groundwater infiltration (I) on an annual basis. On a monthly basis, surplus water remains after actual evapotranspiration has been removed from the sum of rainfall and snowmelt, and maximum soil or snowpack storage is exceeded. Maximum soil storage is quantified using a water holding capacity (WHC) specific to the soil type and land use. The WHC data obtained from ECCC for the Ottawa International Airport station (ID 6106000) is shown in Table E-1, Appendix E.

Annual surplus values generated from the water balance method may be further divided into annual estimates of runoff and infiltration values. This is done by estimating an infiltration factor for each land use (including topography, soils and cover) based on literature values, then multiplying the infiltration factor by the surplus estimate to produce an approximate value for annual infiltration. The remaining surplus not accounted for in the infiltration is assumed to run off. For this analysis, the infiltration estimates from Table 3.1 of the MECP SWM Planning and Design Manual (2003) were used to estimate an infiltration factor.

3.2.3 Catchment Delineation

The total site area is approximately 40.5 ha. It is located 9 km northwest of the Town of Renfrew. The site has a natural drainage divide across its northwest portion (see Figure 7). The majority of the site, on the east of the drainage divide, falls within Clubhouse catchment area, whereas the minor part of the site to the west of the drainage divide falls within a smaller catchment of an unnamed pond. The location of Clubhouse Lake and the unnamed pond are shown on Figure 7. Under pre-development conditions, surface runoff from approximately 85% of the site flows southeast to the Clubhouse Lake and the remaining 15% flows west into the unnamed pond (see Figure 7). Both Clubhouse Lake and the unnamed pond are tributaries to the Crozier Creek. Crozier Creek is a tributary of Bonnechere River, which drains easterly towards the Ottawa River near Ferguson’s Beach.

The total drainage area associated with the proposed Renfrew Golf Pit was delineated using the Ontario Watershed Information Tool (OWIT). The total drainage area at the outlets of the two waterbodies, i.e., Clubhouse Lake and the unnamed pond, is approximately 229.9 ha. As mentioned earlier, under existing conditions, this drainage area is split into 2 catchments: Catchment A (approximately 184.2 ha) and Catchment B (approximately 45.7 ha) for the Clubhouse Lake and the unnamed pond, respectively. Catchment A is further subdivided into Main, East and West sub-catchments as shown in Figure 7. East sub-catchment A drains to the wetland system along the northeast boundary of the site. West sub-catchment A drains to the wetland system along the southwestern edge of the site and the Main sub-catchment A is part of the Clubhouse Lake catchment. For the purposes of the water balance analysis, and since the areas of the site within the individual sub-catchments are relatively small compared to the total catchment area where the site is located, the site will be analysed as a whole instead of considering the individual sub-catchments.

As a result of the proposed development, the licensed extraction area (pit footprint) will have an area of approximately 31.6 ha, which is contained within the pre-development drainage areas. The majority of precipitation falling on the pit will be retained within the pit lake, ultimately either evaporating or infiltrating to recharge the groundwater. The pit lake is assumed to have different surface areas during the fully operational and rehabilitation conditions as shown in Figures 8 and 9. The lowest ground surface elevation around the perimeter of the pit lake is 130 mASL and is found at the southern end of the extraction area. The pit lake surface areas during the fully operational and rehabilitation conditions are estimated to be approximately 12.6 ha and 8.3 ha, respectively (as shown on Figure 8 and Figure 9). No excess runoff is expected to discharge off-site under the operational and rehabilitation scenarios considered in this assessment. Therefore, the runoff to the overall catchments is anticipated to be reduced by the same magnitude as their contributing site areas. However, the water intercepted by the pit is anticipated to flow towards Clubhouse Lake and the unnamed pond to the west of the site through groundwater movement.

3.2.4 Water Balance Scenarios

Three scenarios are considered for the water balance assessment at the site under the following conditions.

a) Existing Conditions: Currently, most of the site includes immature and mature forests, with large portions of meadows and pastures in the centre, and small portions of unevaluated wetlands on the periphery of the site.

b) Operational Conditions: Of the 31.6 ha of proposed extraction area, 19.0 ha is assumed to be exposed bedrock and 12.6 ha is assumed to be below water and therefore is considered as a waterbody/pond for water balance calculations, as less surplus is generated from waterbodies than from non-inundated land uses. Further, the expectation is that the majority of the exposed bedrock area will drain to the pit lake during operation with the exception of the area in the northwest portion of the site and along the western boundary where the ground surface slopes steeply towards the west. This area is expected to drain towards the west and the water will infiltrate into the coarse material at the edge of the pit. No dewatering will occur at the pit. For the purposes of this assessment, it is also assumed that the setback allowance area will remain unchanged compared to existing conditions. It is also assumed that the water within the pond will remain on-site, i.e., no off-site discharge, with the pit as a closed depression.

c) Rehabilitated Conditions: Of the 31.6 ha of proposed extraction area, 19.0 ha is assumed to be rehabilitated woodlot, 8.3 ha is assumed to be below water, similar to the operational scenario, and 4.3 ha is grassland peripheral to the pit. Also similarly, the expectation is that the majority of the rehabilitated woodlot area will drain to the pit lake during rehabilitation with the exception of the area in the northwest portion of the site and along the western boundary where the ground surface slopes steeply towards the west. This area is expected to drain towards the west and the water will infiltrate into the coarse material at the edge of the pit. Based on discussions with the natural environment team, during rehabilitation of the woodlot area, it is assumed that approximately 1 metre to 1.5 metres of overburden material will be placed over the exposed bedrock surface then covered with topsoil. The backfill overburden material will be material from the site that is not marketable. For the purposes of this assessment, it is also assumed that the setback allowance area will remain unchanged compared to existing conditions. It is also assumed that the water within the pond will remain on-site, i.e., no off-site discharge, with the pit acting as a closed depression.

3.2.5 Water Balance Parameters

Land use information was derived from previous ecological mapping studies conducted during the Natural Environment studies for the site (refer to Appendix F). Land use for areas of the sub-catchments outside of the site boundary was derived from the Ontario Landcover Compilation v2.0.

Soil information for the site was derived from borehole locations shown on Figure 1. The site is primarily composed of sand deposits at the surface (see published surficial geology on Figure 3). The sand material varies from fine to coarse, and is intercepted by discontinuous layers of silty sand, gravel and silt, as shown in Figure 5. Fine sand was used as the soil type for the proposed extraction pit under operational conditions based on existing borehole results. For the external areas outside the site boundary, soil information was derived from the OMAFRA (Ontario Ministry of Agriculture, Food and Rural Affairs) Soil Survey Complex and Ontario Surficial Geology maps, as shown in Figures 3.

The maximum soil storage is quantified using a Water Holding Capacity (WHC) that is based on guidelines provided in Table 3.1 of the SWM Planning and Design Manual (MECP 2003). The WHC represents the practical maximum amount of water that can be stored in the soil void space and is defined as the difference between the water content at the field capacity and wilting point (the practical maximum and minimum soil water content), respectively.

WHCs are specific to the soil type and land use, whereby values typically range from approximately 10 mm for bedrock to 400 mm for mature forest over silt loam. Surplus water is caused after actual ET has been removed (ET demand is met) and the maximum WHC is exceeded (soil-water storage demand is met).

For the open water areas (flooded pit, Clubhouse Lake, unnamed pond, cattail organic shallow marsh and deciduous swamp), it was assumed surplus equals the difference between the precipitation and PET. For the purposes of this assessment, we are assuming a null (i.e., 0%) infiltration factor adopted for the Clubhouse Lake, the unnamed pond and the deciduous swamp; given the predominantly organic substrate found at their bottom, recognizing that there is possibly some downward seepage from these to the groundwater system. However, for the cattail organic shallow marsh, at the southwestern corner of the site, an estimated infiltration factor was applied owing to the sandy substrate found at its bottom.

WHCs at the site and for the external areas off site were estimated using the values in Table 3.1 of the SWM Planning and Design Manual (MECP, 2003). Existing, Operational and Rehabilitated catchment areas are summarized by land use, WHC, soil type and infiltration coefficient as listed below in Tables 5, 6, and 7 for existing conditions, operational conditions and rehabilitated conditions, respectively.

Table 5: Summary of Catchment Areas, WHCs, Soil Types, and Infiltration Factors – Existing Conditions

Existing Conditions						
Type	WHC	Type of Land Use	Soil Type	Soil Class	Infiltration Factor	Catchment Areas (m^2)
AGRC-H	75 mm	Urban Lawns	Clay**	D	0.28	95
Community/Infrastructure	75 mm	Urban Development	Silty Sand	B	0.79	54
CUM1-1	100 mm	Pasture and Shrubs	Sand (Fine to Medium), Silty Sand, Sandy Silt	A	0.67	92,651
CUT1	100 mm	Pasture and Shrubs	Sand (Fine to Medium), Silty Sand, Sandy Silt	A	0.70	22,559
FOD 3-1	250 mm	Mature Forests	Sand (F to m), Silty Sand	A	0.72	61,723
FOD 3-1	300 mm	Mature Forests	Silty Sand	B	0.71	28,550
FOD 5-2	300 mm	Mature Forests	Silty Sand, Sandy Silt	B	0.73	179,657
FOM 6-2	250 mm	Mature Forests	Loamy Sand**	A	0.91	6,098
MAS2	Precip-PET	Wetland	Organic Matter*	A	0.00	5,357
Mixed Treed	300 mm	Mature Forests	Silty Sand	B	0.91	483
RES/REC	75 mm	Urban Lawns	Sand (f), Silty Sand	A	0.60	6,183
SWD2-2	Precip-PET	Wetland	Silty Sand	B	0.60	1,209
Total	**404,621**					

**Soil information obtained from Ontario Surficial Geology Maps. **Soil information obtained from the OMAFRA Soil Survey Complex.*

Table 6: Summary of Catchment Areas, WHCs, Soil Types, and Infiltration Factors – Operational Conditions

Operational Conditions (Proposed Total Site Area)						
Type	WHC	Type of Land Use	Soil Type	Soil Class	Infiltration Factor	Catchment Areas (m²)
AGRC-H	75 mm	Urban Lawns	Clay*	D	0.28	95
Community/ Infrastructure	75 mm	Urban Development	Silty Sand	B	0.79	54
CUM1-1	100 mm	Pasture and Shrubs	Sand (Fine to Medium), Silty Sand, Sandy Silt	A	0.65	3,311
CUT1	100 mm	Pasture and Shrubs	Sand (Fine to Medium), Silty Sand, Sandy Silt	A	0.65	6,944
FOD 3-1	250 mm	Mature Forests	Sand (F to m), Silty Sand	A	0.72	37,921
FOD 5-2	300 mm	Mature Forests	Silty Sand, Sandy Silt	B	0.90	25,212
FOM 6-2	250 mm	Mature Forests	Loamy Sand[1]	A	0.91	2,223
MAS2	Precip-PET	Wetland	Organic Matter[2]	A	0.00	5,357
Mixed Treed	300 mm	Mature Forests	Silty Sand	B	0.91	483
RES/REC	75 mm	Urban Lawns	Sand (f), Silty Sand	A	0.60	1,852
SWD2-2	Precip-PET	Wetland	Silty Sand	B	0.60	1,209
Extraction Area - Exposed Bedrock	Precip-PET	Bedrock	Rock	D	1.00[3]	193,592
Extraction Area – Below Water	Precip-PET	Water Body	Fine Sand	A	1.00[4]	126,367
Total	**404,621**					

[1]Soil information obtained from the OMAFRA Soil Survey Complex. [2]Soil information obtained from Ontario Surficial Geology Maps. [3]With the bedrock being and impervious surface similar to a water body, the evapotranspiration over it was assumed to be similar. However, no infiltration is assumed to occur, and all precipitation is assumed to runoff to the pit-pond or infiltrate at the western edge.[4]The infiltration factor for the proposed extraction area is 1.0 (i.e., 100% infiltration) as the pit is assumed to be a closed depression with no surface outlet for the purpose of the water balance assessment. Therefore, all available surplus is expected to infiltrate.

Table 7: Summary of Catchment Areas, WHCs, Soil Types, and Infiltration Factors – Rehabilitated Conditions

Rehabilitation Conditions (Proposed Total Site Area)						
Type	WHC	Type of Land Use	Soil Type	Soil Class	Infiltration Factor	Catchment Areas (m^2)
AGRC-H	75 mm	Urban Lawns	Clay*	D	0.28	95
Community/ Infrastructure	75 mm	Urban Development	Silty Sand	B	0.79	54
CUM1-1	100 mm	Pasture and Shrubs	Sand (Fine to Medium), Silty Sand, Sandy Silt	A	0.65	3,311
CUT1	100 mm	Pasture and Shrubs	Sand (Fine to Medium), Silty Sand, Sandy Silt	A	0.65	6,944
FOD 3-1	250 mm	Mature Forests	Sand (F to m), Silty Sand	A	0.72	37,921
FOD 5-2	300 mm	Mature Forests	Silty Sand, Sandy Silt	B	0.90	25,212
FOM 6-2	250 mm	Mature Forests	Loamy Sand*	A	0.91	2,223
MAS2	Precip-PET	Wetland	Organic Matter**	A	0.00	5,357
Mixed Treed	300 mm	Mature Forests	Silty Sand	B	0.91	483
RES/REC	75 mm	Urban Lawns	Sand (f), Silty Sand	A	0.60	1,852
SWD2-2	Precip-PET	Wetland	Silty Sand	B	0.60	1,209
Rehab Area - Grass and Plants	100 mm	Pasture and Shrubs	Fine Sand	A	0.65	43,098
Rehab Area - Woodlot	150 mm	Pasture and Shrubs	Glacial Till, Silty Sand	B	0.69	193,592
Rehab Area – Below Water	Precip-PET	Water Body	Fine Sand	A	1.00***	83,269
Total	**404,621**					

**Soil information obtained from the OMAFRA Soil Survey Complex. **Soil information obtained from Ontario Surficial Geology Maps. ***The infiltration factor for the proposed extraction area is 1.0 (i.e., 100% infiltration) as the pit is assumed to be a closed depression with no surface outlet for the purpose of the water balance assessment. Therefore, all available surplus is expected to infiltrate.*

An infiltration coefficient of 1.0 (indicating 100% infiltration with no runoff) was applied to the pit lake as part of the proposed extraction area during the fully operational and rehabilitated conditions. The pit lake surface area varies as indicated earlier during the fully operational and rehabilitation conditions (see Figures 8 and 9) and has been estimated to be approximately 12.6 ha and 8.3 ha respectively, at a pit lake surface water elevation of 130 mASL.

This infiltration coefficient was used to acknowledge that with no dewatering or surface water outflow (for water balance assessment purposes only), and assuming the amount of water in the pit does not change on an annual basis, the total annual surplus from the pit area must leave the pit through infiltration.

A summary of the catchment areas, WHCs, soil types, and infiltration factors for the external areas can be found in Table E-6 (Appendix E).

3.2.6 Water Balance Results

The following sections present the water balance results and analyses under existing, fully operational and rehabilitation conditions. A discussion of the potential impacts to surface water features as a result of changes to the water balance during pit development is presented in Section 6.2.

3.2.6.1 Existing Conditions

The results from the existing conditions water balance are shown in Table 8.

Table 8: Existing Conditions Water Balance Results

Component	Average Annual Volume – Site Wide	
	mm/yr	m^3/yr
Precipitation (P)	903	365,365
Evapotranspiration (ET)	585	236,690
Surplus (S)	318	128,617
Infiltration (I)	223	90,073
Runoff (R)	95	38,544

The total average annual surplus for the site area under existing conditions was estimated to be approximately 318 mm or 128,617 m^3/yr and the estimated infiltration is approximately 223 mm or 90,073 m^3/yr. Runoff was calculated as the difference between surplus and infiltration and was estimated to be approximately 95 mm or 38,544 m^3/yr.

3.2.6.2 Operational Conditions

The results from the operational conditions water balance are shown in Table 9.

Table 9: Operational Conditions Water Balance Results

Component	Average Annual Volume – Site Wide	
	mm/yr	m^3/yr
Precipitation (P)	903	365,370
Evapotranspiration (ET)	607	245,420
Surplus (S)	296	119,928
Infiltration (I)	278	112,570
Runoff (R)	18	7,358

The total average annual surplus for the proposed extraction area under operational conditions was estimated to be approximately 296 mm or 119,928 m^3/yr and the estimated infiltration is approximately 278 mm or 112,570 m^3/yr. Runoff was calculated as the difference between surplus and infiltration and was estimated to be approximately 18 mm or 7,358 m^3/yr.

3.2.6.3 Rehabilitated Conditions

The results from the rehabilitated conditions water balance are shown below in Table 10.

Table 10: Rehabilitated Conditions Water Balance Results

Component	Average Annual Volume – Site Wide	
	mm/yr	m^3/yr
Precipitation (P)	903	365,370
Evapotranspiration (ET)	582	235,370
Surplus (S)	321	129,978
Infiltration (I)	241	97,386
Runoff (R)	81	32,592

The total average annual surplus for the proposed extraction area under rehabilitated conditions was estimated to be approximately 321 mm or 129,978 m^3/yr and the estimated infiltration is approximately 241 mm or 97,386 m^3/yr. Runoff was calculated as the difference between surplus and infiltration and was estimated to be approximately 81 mm or 32,592 m^3/yr.

3.2.7 Proposed Water Management Mitigation Measures

To help contain the runoff volumes estimated during the fully operational and rehabilitation conditions within the pit lake, i.e., no off-site discharge, and limit the potential for overflow to the southwest wetland upstream from Clubhouse Lake, the following mitigation measures are proposed (see Figures 8 and 9):

- An emergency surface overflow drainage ditch, to be constructed along the site access road to the south; this ditch will direct potential excess flows during unusually large precipitation or snowmelt events around the southwest wetland to Clubhouse Lake.
- A 1.3-m high perimeter berm will be constructed along the south edge of the extraction area at the low point around the pit lake to help retain runoff volumes within the pit lake (see location on Figure 8).

It is assumed that the pit lake will fill to the lowest ground elevation of 130 mASL, due to potential seepage or exfiltration from the extracted areas into the lake. The estimated cumulative annual runoff volumes during the full operational and rehabilitation scenarios are added to the corresponding pit lake storage capacity at the 130 mASL and the total water volumes are approximately 655,144 m^3 and 301,679 m^3, respectively (Tables E-3 and E-4 of Appendix E). These calculated total water volumes are less than the corresponding pit lake storage capacities of 747,051 m^3 and 348,611 m^3 for a pit lake surface water elevation of 130 mASL for the fully operational and rehabilitation conditions, respectively. Hence, they indicate that no off-site discharge is anticipated to occur under average annual water balance conditions.

3.2.8 Hydrological Summary

A summary of the annual water balance considering surplus, infiltration, and runoff for the pre-development existing, fully operational, and rehabilitated conditions is provided in Table E-6 in Appendix E.

Under operational conditions, surplus is anticipated to decrease by approximately 7% from 128,617 to 119,928 m^3/yr. Based on the site layout, approximately 7,358 m^3/yr of runoff will be generated from the site, which is a decrease of approximately 31,186 m^3/yr (approximately 81%) from the existing conditions. This decrease in runoff equates to an increase in infiltration from 90,073 m^3/yr to 112,570 m^3/yr, i.e., about 25%. The reduction in runoff is a direct consequence of the changes in land use from cultivated/forest under existing conditions (surplus of 318 mm) to exposed bedrock/lake form (surplus of 296 mm) which translates into increased losses to evaporation and increased contribution to the groundwater system resulting from increased infiltration. In addition, the consideration of the pit as a closed depression with no outflow off-site results in reduced runoff. It is noteworthy that these percent changes (%) are evaluated within the site footprint; however, the effects on the larger overall catchment will be significantly smaller than those presented here as the area subject to changes in land use represents 19% of the overall Catchment A and 13% of the overall Catchment B.

Under rehabilitated conditions, surplus is anticipated to decrease by approximately 1% from 128,617 to 129,978 m^3/yr. Based on the site layout, approximately 32,592 m3/yr of runoff will be generated from the site, which is a decrease of approximately 5,952 m^3/yr (approximately 15%) from the existing conditions. This decrease in runoff equates to an increase in infiltration from 90,073 m^3/yr to 97,386 m^3/yr, about 8%. The reduction in runoff is a direct consequence of the changes in land use from cultivated/forest under existing conditions (surplus of 318 mm) to woodlot/grassland/lake form (surplus of 321 mm) which translates into increased losses to evaporation and increased contribution to the groundwater system resulting from increased infiltration. In addition, the consideration of the pit as a closed depression with no outflow off-site is the reason for reduced runoff.

The plantings on-site will consist of shrubs/natural growth in the setback area (characterized in the MECP SWM Planning and Design Manual as Pasture and Shrubs); however, for the purpose of this analysis the land uses within the setback allowance area will remain the same as in existing conditions. Therefore, for these areas no difference in annual water balance is estimated between operational and rehabilitation scenarios.

Overall, during the operational and rehabilitated conditions, an increase in evaporative losses is expected to decrease the total annual surplus from the site. The operational and rehabilitated conditions will also result in a decrease in total runoff and an increase in total infiltration.

4.0 RECEPTOR IDENTIFICATION

4.1 Water Supply Wells

The MECP WWIS includes records for four private water supply wells located within 500 metres of the site based on a UTM Reliability Code of 5 (i.e., expected to be found within 300 metres or less of the actual well location). The approximate locations of these wells are shown on Figure 2. In addition, a review of a recent aerial photograph indicates that there are likely additional wells not listed in the MECP WWIS that are located at the Renfrew Golf Club and at the residence/farm located southwest of the site. Assumed well locations were added for these groundwater users (see assumed well locations on Figure 2).

A review of the completion details available for the 4 water supply wells listed in the MECP WWIS is provided in Table 11.

Table 11: Summary of MECP WWIS Wells

Parameter	Range in Values in MECP WWIS Wells
Number of Wells Completed in Bedrock	1
Number of Wells Completed in Overburden	3
Bottom of Well (Depth)	20.4 – 48.2 mbgs
Bottom of Well (Elevation)	79.1 – 118.6 mASL
Uppermost Water-Bearing Zone (Depth)	19.8 – 48.2 mbgs
Uppermost Water-Bearing Zone (Elevation)	79.1 – 119.2 mASL

4.2 Surface Water Features

There are two small streams that flow partially through the proposed licensed site boundary. The larger of the two streams flows by the northeast boundary and has two wetlands along its path adjacent to the site. The smaller stream flows near the southwest boundary and has also two neighboring wetlands; the larger of them lies partially within the site (see Figures 1 and 7). An old beaver dam was observed during site visits along and near the east stream just downstream of SG-2. Also, a small culvert was found near BH21-02 across the stream, diverting part of the flow into the site; and the culvert outflow ultimately appeared to rejoin the stream near BH21-01.

For the stream flowing northeast to the site, its reach upstream of BH21-02 (see Figure 1) is considered upgradient/cross gradient from the site boundary. The reach downstream of BH21-02 to SG-3 is downgradient of the eastern edge of the extraction area boundary, but generally cross gradient from the rest of the extraction area. The wetland downstream of SG-3 is downgradient of the southeast corner of the extraction area, but upgradient of the downstream (south) end of the extraction area, which is the likely water level control for that feature. For the stream flowing southwest to the site, its full reach is downgradient from the southwest site boundary.The Ministry of Natural Resources and Forestry's 'OWIT' tool was used to confirm that surface runoff from the site would drain towards both streams adjacent to the northeast and southwest licensed boundaries. The delineated sub-catchments at the two wetlands (East and West Sub-catchments in Figure 7) indicate there is a natural drainage divide that runs from north to south across the site. Both sub-catchments contribute runoff to the overall catchment area of Clubhouse Lake (i.e., Catchment A in Figure 7). The northwest portion of the site is part of another catchment, Catchment B on Figure 7, that drains towards the west into an unnamed pond. Outflows from both Clubhouse Lake and the unnamed pond flow to small tributaries of Crozier Creek, which discharges to Bonnechere River, the ultimate drainage receptor of the area.

Per WSP Natural Environment Report (WSP 2023), a vernal pool located just north of the Site within the East Sub-catchment in Figure 7 is considered a significantly wildlife habitat (SWH). None of the other wetlands in the Study Area, or Clubhouse Lake, meet the criteria to be considered SWH for breeding amphibians.

Table 12 lists the catchment areas of the two main existing receiving surface water bodies near the site.

Table 12: Catchment Areas of Existing Surface Water Features near the Site

Surface Water Feature	Unnamed Pond	Clubhouse Lake
Catchment Area (ha)	45.7	184.2

Based on the values in Table 12, the site area of 40.5 ha comprises approximately 17.6% of the total catchment area of 229.9 ha for both Clubhouse Lake and the unnamed pond.

5.0 ANALYTICAL GROUNDWATER MODEL

As discussed in Section 1.2, the proposed Renfrew Golf Pit will not be dewatered during operations, but extraction can continue below the groundwater table. Based on the groundwater level data collected at the site, the predicted elevation of the pit lake will be approximately 130 to 131 mASL. This is based on the lowest elevation of the ground surface on the perimeter of the proposed extraction area of 130 mASL (near Clubhouse Lake) and the addition of a 1.3-metre-high berm with an outlet at 131 mASL placed at the low point to minimize outflow from the pit lake.

Following pit development, the surface of the lake in the southern half of the site will be flat at an elevation between 130 to 131 mASL. In areas where the existing groundwater table is in the overburden and is above the estimated elevation of the lake (i.e., in the southern half of the east side of the site – see groundwater elevations at BH21-01 and BH21-02 on Figure 6), drawdown will be observed during and following extraction operations. In areas where the existing groundwater table in the overburden is below the estimated elevation of the lake (i.e., the south end of the site), a minor increase in the groundwater table would be observed. In the northern half of the site, the water table is within the bedrock, and extraction of the overburden material at the site will not result in changes to the groundwater table in the bedrock.

Based on the groundwater table being present in the bedrock on the northern half of the site, and the groundwater table being below the pit lake level in the south/southwest portion of the site, a groundwater drawdown radius of influence associated with the development of the Renfrew Golf Pit is only predicted in the eastern portion of the site in the vicinity of BH21-01 and BH21-02.

The radius of influence can be estimated based on the groundwater elevations measured in the on-site monitoring wells BH21-01 to BH21-02 found on the east side of the site and the hydraulic conductivity of the surficial sediments measured at these wells. The radius of influence can be estimated using the empirical formula developed by Marinelli and Niccoli (2000):

$$h = \sqrt{h_p^2 + \frac{W}{K_h}\left[r_0^2 ln\left(\frac{r}{r_p}\right) - \frac{\left(r^2 - r_p^2\right)}{2}\right]}$$

Where:

h = saturated thickness above the base of the aquifer at a given radius (m)

hp = saturated thickness at the pit wall (m)

W = recharge flux (m/s)

Kh = horizontal hydraulic conductivity (m)

r0 = radius of influence where drawdown is zero (m)

r = radius of influence (m)

rp = effective pit radius (m)

The above analytical solution is based on an equivalent porous medium at the scale of the depressurized zone. Under this scenario, the rate of groundwater flow towards the pit and the extent of depressurization are a function of the hydraulic gradient and the hydraulic conductivity of the hydrogeological units.

5.1 Analytical Model Parameterization

5.1.1 Water Table Decline

At BH21-01, the maximum water table elevation measured was 132.69 mASL. This results in a maximum potential water table decline of 2.69 metres to the lowest potential pit lake elevation of 130 mASL. At BH21-02, the maximum water table elevation (143.12 mASL) is significantly higher than at BH21-01. The difference in the maximum water table elevation between BH21-01 and BH21-02 is 10.43 metres. The distance between BH21-01 and BH21-02 is approximately 310 metres. This results in a gradient of 0.034 m/m between the two monitoring well locations. This is an order of magnitude higher gradient than would be expected in a sand deposit, which suggest the groundwater elevation at BH21-02 may be perched as a result of bedrock present beyond the bottom of BH21-02. In addition, based on the fine-grained silt material found in the bottom half of BH21-02, it is expected that the borehole was completed through lower extent of the sand and gravel deposit at the site and was likely approaching the bedrock surface.

The thickness of the overburden at BH21-02 controls the maximum decline in the groundwater table at this location. Once the bedrock is encountered, there would be no additional decline in the overburden water table. Based on the interpreted perched groundwater table at BH21-02 and the presence of silt in the bottom half of the borehole, it is expected that the bedrock surface would be encountered within 2 to 4 metres below the bottom of BH21-02. However, to remain conservative, during the analytical modelling, it has been assumed that the bedrock surface could be greater than 8 metres below the bottom of BH21-02, and the maximum allowable extraction of 10 metres below the water table occurs within the vicinity of BH21-02. As such, during the analytical modelling, it has been assumed that the worst-case 10-metre decline in the groundwater table occurs in the vicinity of BH21-02.

For the purpose of the analytical modelling, the decline in the groundwater table at BH21-01 will be 2.7 m. It has been assumed that the bottom of the pit in the vicinity of BH21-1 is the maximum 10 metres below the water table.

5.1.2 Equivalent Pit Radius

The empirical formula developed by Marinelli and Niccoli (2000) assumes the pit is circular and uses an equivalent pit radius in the model. Because there is no overburden water table decline over the majority of the pit (i.e., the groundwater table is in the bedrock in the northern half of the site and the groundwater table is below the pit lake level in the south/southwest portion of the site), a 5 hectare portion on the east side of the pit in the vicinity of BH21-01 and BH21-02 where groundwater level drawdown in the overburden can occur was used as the pit area for calculating the equivalent pit radius. This results in an equivalent pit radius of 126 metres.

The following tables provides the parameters used for the analytical modelling to predict the 1-m groundwater drawdown radius of influence in the vicinity of BH21-01 and BH21-02.

Table 13: Analytical Model Parameters for BH21-01

Parameter	**Assigned Value**	**Description**
Horizontal Hydraulic Conductivity ($K_{h;}$ m/s)	1 x 10^{-5}	Measured overburden horizontal hydraulic conductivity during in-situ tests completed at monitoring well BH21-01.
Recharge Flux (W; m/s)	5.5 x 10^{-9}	Assumed 175 mm/yr infiltration to the groundwater table, based on previous experience in near surface materials of similar hydraulic conductivity.
h_o (m)	10	Assumes the pit extraction extends 10 metres below the water table in the vicinity of BH21-01.
h_p (m)	7.3	If the pit is extracted 10 metres below the water table, the elevation of the pit floor will be approximately 122.7 mASL (Water table at BH21-01 132.69 mASL – 10 = 122.69 mASL). The lowest pond elevation would be 130 mASL. This results in a saturated depth at the pit wall of 7.3 metres.
r_p (m)	126	Based on a 5-ha area of the pit in the vicinity of BH21-01 and BH21-02 where a decline in groundwater levels in the overburden can occur.

Table 14: Analytical Model Parameters for BH21-02

Parameter	**Assigned Value**	**Description**
Horizontal Hydraulic Conductivity ($K_{h;}$ m/s)	5 x 10^{-6}	Measured overburden horizontal hydraulic conductivity during in-situ tests completed at monitoring well BH21-02.
Recharge Flux (W; m/s)	5.5 x 10^{-9}	Assumed 175 mm/yr infiltration to the groundwater table, based on previous experience in near surface materials of similar hydraulic conductivity.
h_o (m)	10	Assumes bedrock could be encountered up to 10 metres below the water table measured at BH21-02.
h_p (m)	0.0	Assumed height of seepage face at the pit wall. If bedrock is encountered 10 metres below the water table, the elevation of the bedrock would be at approximately 133.1 mASL. In the vicinity of BH21-02, overburden groundwater will flow over the bedrock surface down towards the pit lake in the southern end of the

		property at elevation 131 mASL. As such, the pit lake depth in the vicinity of BH21-02 will be zero.
r_p (m)	126	Based on a 5-ha area of the pit in the vicinity of BH21-01 and BH21-02 where a decline in groundwater levels in the overburden can occur.

5.1.3 Model Results and Discussion

Based on the parameters assigned in Table 13, the predicted radius of influence (1-metre groundwater drawdown) associated with the development of the Renfrew Golf Pit in the vicinity of BH21-01 is estimated to be 74 metres from the pit boundary (see analytical model results in Appendix H).

Based on the parameters assigned in Table 14, the predicted radius of influence (1-metre groundwater drawdown) associated with the development of the Renfrew Golf Pit in the vicinity of BH21-02 is estimated to be a maximum of 125 metres from the pit boundary based on the worst-case assumption that bedrock is encountered 10 metres below the water table at this location (see analytical model results in Appendix H).

North of BH21-02, the water table is interpreted to be located in the bedrock as was observed during the drilling of TW-3 to the northwest of BH21-02 (see location on Figure 1). Extraction of overburden at the site will not impact the water table in the bedrock. As such, the predicted radius of influence does not extend beyond the below water extraction area of the site that starts just north of BH21-02. At the southern end of the site, because the lowest pit water level is at 130 mASL, the groundwater table will not be lowered beyond this elevation, and the predicted radius of influence cannot extend below the 130 mASL groundwater elevation contour shown on Figure 1. To remain conservative, the worst-case predicted radius of influence (125 metres from the pit edge decreasing to 74 metres from the pit edge in the vicinity of BH21-01) was used during the assessment of potential impacts associated with the development of the pit (see impact assessment in Section 6.0). The predicted worst-case 1-m groundwater drawdown radius of influence is shown on Figure 1 and Figure 2.

6.0 ASSESSMENT OF POTENTIAL IMPACTS OF PROPOSED PIT

Based on the nature of the subsurface materials, the final floor elevation for the pit will vary from 135 mASL to 154 mASL in the north/northwest portion of the site to 120 mASL in the southern portion of the site and will be primarily controlled by the elevation of the bedrock within the extraction area. Only unconsolidated materials (sand, gravel, etc.) will be removed from the site. Any bedrock encountered on the site will remain in place. When the groundwater table is encountered, excavation can occur a maximum of 10 metres below the water table.

Extraction operations below the groundwater table will not involve dewatering of the excavation. Based on the groundwater level data collected at the site, the predicted elevation of the pit lake will be approximately 130 to 131 mASL. This is based on the lowest elevation of the ground surface on the perimeter of the proposed extraction area of 130 mASL (near Clubhouse Lake) and the addition of a 1.3-metre-high berm with an outlet proposed to be constructed upstream of an emergency surface overflow drainage ditch at 131 mASL at the low point to minimize outflow from the pit lake.

6.1 Potential Impact to Groundwater Users

Based on aerial imagery, there are approximately 4 private-well users within 500 metres of the proposed boundary area to be licensed. There are also 4 water wells listed in the MECP WWIS (with a UTM Reliability

Code of 5 or less); however, they are all located along Golf Course Road and likely do not all correspond to the 4 wells seen on aerial imagery. A review of a recent aerial photograph indicates that there are likely additional wells not listed in the MECP WWIS that are located at the Renfrew Golf Club and at the residence/farm located southwest of the site. Assumed well locations were added for these groundwater users for use during the impact assessment (see assumed well locations on Figure 2).

The worst-case estimated 1-metre groundwater drawdown radius of influence associated with the development of the Renfrew Golf Pit is shown on Figure 2. As shown on Figure 2, there are no water supply wells located within the estimated radius of influence. As such, impacts to water supply wells, completed in the overburden or the bedrock as a result of the proposed development of the Renfrew Golf Pit are not predicted.

6.2 Potential Impact to Existing Surface Water Features

6.2.1 Water Balance Assessment

As discussed earlier, Clubhouse Lake and the unnamed pond lie outside of the site boundary and receive drainage from the site both in the form of surface runoff and sub-surface seepage off the embankments through groundwater movements. The total catchment area near the lake mouth is approximately 184.2 ha and near the pond mouth is 45.7 ha (estimated using Ontario Watershed Information Tool, OWIT; see Table 12). The pit excavation will convert approximately 27.4 ha of the catchment area of Clubhouse Lake (approximately 15%) to a depression that will internally drain through shallow groundwater to Clubhouse Lake. Similarly, approximately 4.5 ha of the unnamed pond catchment area (approximately 10%) will also be converted to a depression.

It is more meaningful to assess the potential impacts to the existing water features considering surplus estimates from the water balance analyses, since surplus reflects the combined effect of runoff and infiltration. Also as noted earlier in Section 3.2.3, runoff water intercepted by the pit is anticipated to flow towards Clubhouse Lake and the unnamed pond to the west of the site following infiltration through groundwater movement.

Under operational conditions, surplus volumes to Clubhouse Lake and the unnamed pond are expected to decline by 1% for both water features compared to the estimates under the existing conditions. Under rehabilitation conditions, surplus volume to Clubhouse Lake is expected to remain the same, i.e., no effect compared to the existing conditions, whereas for the unnamed pond, the surplus volume is expected to increase by 0.2% compared to the existing conditions.

East sub-catchment A (see Figure 7) contains an unnamed wetland, to the northeast of the site. The land use under operation conditions will be 3.4 ha of exposed bedrock and 0.6 ha of pit lake. Under, rehabilitated conditions this will change to 3.4 ha of rehabilitated woodlot, 0.1 ha of grassland and 0.5 ha of pit-pond. Conversion of this total 4 ha within the approximately 55 ha sub-catchment is anticipated to result in a change in the surplus to the wetland by -1% and +0.2% during the operational and rehabilitated conditions, respectively. This shows that the rehabilitation conditions improve and bring the difference back closer to the existing conditions.

West sub-catchment A contains another unnamed wetland, in close proximity of Clubhouse Lake. The land use under operational conditions will be 7.5 ha of exposed bedrock and 1.7 ha of pit-pond. Under, rehabilitated conditions this will change to 7.5 ha of rehabilitated woodlot, 0.3 ha of grassland and 1.4 ha of pit-pond. Conversion of this total of 9.2 ha within the approximately 21.4 ha sub-catchment is expected to result in a change in the surplus to the wetland by -3% and +2% during the operation and rehabilitated conditions, respectively.

As discussed in Section 3.2.1.1, based on shallow groundwater and surface water elevation data, the unnamed wetland feature found in west sub-catchment A is interpreted to be an expression of the local shallow water table and is not considered to be primarily surface water fed. As shown in Figure 1, the mouth of the unnamed wetland is fairly close to Clubhouse Lake and based on the elevation contours, it is anticipated that any surface water reaching the wetland will outflow into Clubhouse Lake. Because the operation of the Renfrew Golf Pit will not decrease groundwater levels in the vicinity of this wetland feature, the groundwater table is predicted to slightly increase in this area; it is not anticipated that the loss of surface water catchment will result in a significant decrease in water levels within the wetland. This will be confirmed through the proposed long-term surface water monitoring program for the site which includes daily water level measurement at SG-1 using a datalogger.

Sub-catchment B contains an unnamed wetland located approximately 120 m upstream of the unnamed pond to the west of the Site (see Figure 7). The impacts of the extraction area conversion within sub-catchment B on this wetland were pro-rated from the impacts on the unnamed pond that were estimated earlier based on the results in Appendix E. The catchment area up to the unnamed wetland was delineated using OWIT and found to be approximately 21.5 ha. The pro-rated impacts were based on the ratio of the wetland catchment area to the total area of sub-catchment B, after deducting the portion of the site area within sub-catchment B; this ratio was found to be approx. 38.8%. Insignificant changes in surplus, i.e., runoff and infiltration, to the wetland of -2% and +0.5% during the fully operational and rehabilitation conditions respectively were estimated.

As the pit develops, the overburden material will be extracted to a maximum of 10 metres below the groundwater table. A portion of the excavation area in the southern half of the site will eventually become a pit lake. There will be no dewatering of the pit, so no direct discharge is anticipated to the surrounding environment from the pit. Because the groundwater table is at least 2 metres to 3 metres below ground surface along the edge of the extraction area (over 30 metres below ground surface in the high elevation central portion of the site), the development of the pit will result in a closed depression without a perennial surface outlet to the environment. Although the pit lake is anticipated to not directly contribute a substantial amount of runoff to Clubhouse Lake, the water surplus collected within the pit will infiltrate and flow downgradient as groundwater seepage flow to the southwest wetland and eventually the Clubhouse Lake. Further, to discourage discharge off-site, and encourage further infiltration, a berm is proposed to be constructed at the southern edge of the pit lake boundary at the low point around the pit lake.

Operation of the proposed pit area is also not expected to contribute to flooding problems in the receiving drainage features, as there will be no water discharge from the pit. The southern portion of the pit is expected to operate as a large infiltration basin temporarily detaining storm runoff and moderating flows in the receiving watercourses. The redirection of catchment areas from the north (the unnamed northeastern wetland), from the southeast (Clubhouse Lake), and from the southwest (the other unnamed wetland), and from the west (the unnamed pond) to the pit area thus results in an overall reduction in peak surface flow rates in all directions.

Overall, significant impacts to surface water features within the vicinity of the site resulting from the operation and rehabilitation of the Renfrew Golf Pit are not predicted. The estimated percentage changes in the surplus volumes noted above during the operation and rehabilitated conditions are less than ±5%, which is considered insignificant.

6.2.2 Groundwater Level Drawdown

As shown on Figure 1, a small wetland pocket and a watercourse connected to the wetland pocket located just east of the eastern site boundary are within the predicted 1-metre groundwater drawdown radius of influence for the development of the Renfrew Golf Pit.

Surface water levels within the watercourse located along the eastern boundary of the site are measured at staff gauge location SG-2. Near surface groundwater levels at the same location as SG-2 are measured using a shallow drive-point well at location DP-2 (see location on Figure 1). The surface water and groundwater elevation data for SG-2 and DP-2 are presented on Figure 6. As shown on Figure 6, the shallow groundwater elevation measured at DP-2 is typically 0.25 to 0.3 metres below the surface water elevations measured at SG-2. The available water elevation data confirms that the water feature is consistently perched above the groundwater table and the groundwater is not discharging to the water feature. At the time DP-2 was installed, a fine-grained silt layer was noted at shallow depth below the water feature. This silt layer is interpreted to separate the water feature from the underlying sand and gravel deposit at the site. Based on auger holes completed within the wetland feature within the predicted radius of influence, the wetland is underlain clay soils , and this feature is also interpreted to be perched above the local groundwater table.

The nearest groundwater monitoring well to SG-2 and the wetland is BH21-02 (approximately 80 metres from SG-2 and 120 metres from the wetland). As shown on Figure 6, the groundwater elevation measured at BH21-02 is consistently at least four metres lower than the surface water elevation measure at SG-2. Overall, the water feature and the wetland are interpreted to be surface water fed with no connection to the underlying groundwater table within the sand and gravel deposit at the site. As such, impact to these features as a result of drawdown within the sand and gravel deposit associated with the development of the Renfrew Golf Pit are not predicted.

Ongoing water level monitoring at SG-2 and a new staff gauge to be installed within the wetland feature are included in the long-term monitoring program for the site.

The vernal pool located to the north of the site boundary within east sub-catchment A is considered to be upgradient from the site (see Figures 1 and 7). Because the groundwater flow is interpreted to be from north to south (Figure 1), the site operations are anticipated to have no adverse impacts on the vernal pool.

6.3 Source Water Protection

The proposed Renfrew Golf Pit falls outside of a local conservation authority and there is no source water protection plan established for the region. Therefore, there are no impacts to groundwater quality or quantity related to Wellhead Protection Areas as a result of the proposed development of the Renfrew Golf Pit.

7.0 COMPLAINTS RESPONSE PROGRAM

Based on the results of the groundwater modelling and the review of local water supply wells, it is concluded that water well interference complaints attributable to the development of the Renfrew Golf Pit are unlikely. Water well interference complaints will be responded to in light of the collected monitoring data and under the *Complaints Response Program* described below.

A comprehensive complaints response program has been developed for the purpose of responding to well interference complaints from local water supply well users. Each complaint will be dealt with on a case-by-case basis.

When a complaint is received by Cavanagh, the Complaints Response Program detailed below shall be initiated. As soon as can be arranged, a representative of Cavanagh and/or their agent will visit the site to make an initial assessment of the complaint. This will include a well/system inspection (where accessible) by a licensed pump maintenance contractor to determine the groundwater level, pump depth setting and condition of the well system. The available groundwater level data from the existing on-site monitoring well network will be reviewed by a licensed professional hydrogeologist/engineer to develop an estimate of the potential groundwater level drawdown at the potentially affected well that is the subject of the complaint response. The information obtained by the contractor from the well/well system inspection and the review of the available groundwater level data will be used by the professional hydrogeologist/engineer to prepare an opinion on the likelihood that the well interference complaint is related to pit operation.

If it is concluded that the well interference complaint is most likely attributable to site activities and the water supply is at risk, then a temporary supply will immediately be arranged, and a water supply restoration program will be implemented. The decision as to whether to proceed with the water supply restoration program will be based on a review of groundwater level information by the professional hydrogeologist/engineer and well construction and performance information from the licensed pump maintenance contractor as noted above.

The water supply restoration program consists of the following measures which are applicable for local water supply wells where the operation of the water supply wells may have been compromised by pit operation or based on the analysis of all monitoring data, are assessed to likely be compromised in the near future:

- Well System Rehabilitation – The well system could be rehabilitated by replacement or lowering of pumps, pump lines flushing, well deepening, etc. to improve performance. Where water is unavailable in the shallow bedrock and a well in deeper bedrock is being considered, a water sample(s) would be taken from the existing well for chemical, physical and bacteriological analyses prior to deepening the well to provide a basis of comparison. If the groundwater in the deeper bedrock is found to be of acceptable quality by the homeowner, either directly from the well or with treatment, it will be developed as the domestic supply. Any modifications to a well would be conducted in accordance with *Ontario Regulation 903*.

- Well Replacement or Additional Well(s) – The well could be replaced or augmented with a new well(s) that could be located further from the pit excavation. The feasibility of well replacement would be based on a test drilling program that could include more than one test well. Where water is unavailable in the shallow bedrock/overburden and a well in deeper bedrock (compared to the original water supply well) is being considered, a water sample(s) would be taken from the existing well for chemical, physical and bacteriological analyses to provide a basis of comparison. If the groundwater in the deeper bedrock is found to be of acceptable quality by the homeowner, either directly from the well or with treatment, it will be developed as the domestic supply. Construction of a new well(s) would be conducted in accordance with *Ontario Regulation 903*.

- Water Treatment Considerations – Appropriate water treatment will be incorporated into any restored water supply as discussed above.

Cavanagh would be responsible for all costs associated with the water supply restoration program. It is important to note that water supply restoration activities undertaken to address an adverse effect would be done so in consultation with the affected property owner in order to ensure a mutually agreeable solution is implemented.

8.0 PROPOSED MONITORING PROGRAM

A site-specific water level monitoring program has been developed to measure and evaluate the actual effects on potential receptors associated with long-term development of the proposed Renfrew Golf Pit, and to allow for a comparison of the actual effects measured during the monitoring program and those predicted as part of the impact assessment provided in Section 6.0.

8.1 Proposed Groundwater Level Monitoring Program

The proposed groundwater level monitoring program would include existing on-site monitoring wells. Table 15 includes a description of the monitoring locations proposed for inclusion in the groundwater level monitoring program, as well as the rationale for inclusion. The locations of the proposed monitoring wells are shown on Figure 2.

Table 15: Proposed Groundwater Monitoring Locations

Location	Rationale for Inclusion
BH21-01	Long-term monitoring location to assess changes in groundwater levels in the overburden between the site and the golf course located to the east of the site.
BH21-02	Long-term monitoring location to assess changes in groundwater levels in the overburden between the site and the water features located to the east of the site.
BH21-04	Long-term monitoring location to assess changes in groundwater levels in the overburden in the vicinity of Clubhouse Lake and the residence located to the south of Clubhouse Lake.
TW-1	Monitoring location to assess changes in groundwater levels in the overburden on the western side of the site. This location will ultimately be removed by progressive pit development and will not be replaced.

Water levels at the identified monitoring wells would be measured manually on a monthly basis. The groundwater level monitoring program for the site would be started prior to extraction below the groundwater table.

8.2 Surface Water Monitoring

The proposed surface water level monitoring program will include the existing on-site staff gauges SG-1 and SG-2, and the drive-point piezometers DP-1 and DP-2 plus a new staff gauge identified at SG-3 proposed in the wetland found on the eastern boundary of the site (see proposed location on Figure 1). The collection of water levels at these locations will allow for long-term monitoring of the water levels within the two unevaluated wetlands located along the northeast and southwest portions of the site (see Figure 2).

Water level dataloggers are proposed to be installed at SG-1, SG-2 and SG-3, to record water level measurements at least once per day during pit operation. Water levels at the identified monitoring staff gauge and drive-point piezometer locations would also be measured manually on a monthly basis for verification and quality assurance of the data collected through the loggers. The surface water monitoring program would start when extraction operations begin at the site.

9.0 SUMMARY AND CONCLUSIONS

A Level 1 and 2 Hydrogeological and Hydrological Assessment (Water Report) was completed for the proposed Cavanagh Renfrew Golf Pit located on Part Lots 23, 24 and 25, Concession 1, Horton Township, Renfrew County, Ontario. Based on the results of the investigation, the following summary and conclusions are presented:

The site consists of a 40.5 ha area proposed to be licensed under the ARA, of which the proposed extraction area occupies 31.6 ha. The first lift will extend to the groundwater table, or the bedrock/non-marketable material surface, whichever is encountered first. Usable material identified below the water table will be extracted in the second lift. Extraction below the groundwater table will primarily occur in the southern half of the site and will result in the formation of a pit lake within this area.

Based on the nature of the subsurface materials, the final floor elevation for the pit will vary from 135 mASL to 154 mASL in the north/northwest portion of the site to 120 mASL in the southern portion of the site and will be primarily controlled by the elevation of the bedrock within the extraction area. Only unconsolidated materials (sand, gravel, etc.) will be removed from the site. Any bedrock encountered on the site will remain in place. When the water table is encountered, excavation can occur a maximum of 10 metres below the water table.

The local overburden deposits on the property consist primarily of sand deposits ranging from sand and gravel to sandy silt. The upper bedrock unit in the vicinity of the site consists of Precambrian Bedrock consisting of Carbonate Metasedimentary Rocks (i.e., marble). Immediately southwest of the site, the upper bedrock unit consists of Mafic to Ultramafic Plutonic Rocks. The local depth to bedrock indicated in the WWIS well records vary from 1.2 mbgs to over 48 mbgs. The depth to the bedrock can be highly variable within the vicinity of the site due to uneven Precambrian bedrock surface.

Field investigations were carried out at the site in 2017, 2018 and the current investigation in 2021. The 2017/2018 investigation involved excavation of test pits and boreholes to characterize the resource at the site. The objective of the 2021 field investigation was to install groundwater level monitoring wells to better define the elevation of the groundwater table at the site.

The pre-development groundwater elevations (i.e., background conditions) in the vicinity of the site ranged from a low of 127.1 mASL at BH21-4 in March 2022 to a high of 143.1 mASL at BH21-2 in April 2022. Groundwater depths range from 2.6 (BH21-4) to 33.6 (TW-1) mbgs across the site. Groundwater elevations in all monitoring wells are generally stable (i.e., vary by less than one metre) and display minor seasonal variations. Based on groundwater elevation data collected during the pre-development period, the general groundwater flow direction in the vicinity of the site is influenced by the topography of the site and seasonal groundwater table fluctuations. Groundwater generally flows from northeast to southwest across the site towards Clubhouse Lake.

There are no water supply wells located within the estimated radius of influence associated with the development of the Renfrew Golf Pit. As such, impacts to water supply wells, completed in the overburden or the bedrock as a result of the proposed development of the pit are not predicted.

A staff gauge and drive-point piezometer were installed in the wetland along the southwestern site boundary and in the watercourse along the eastern site boundary, to monitor the surface water levels.

Based on the water balance surplus assessment, significant impacts to Clubhouse Lake, the unnamed pond and the unnamed wetland to the northeast of the site are not predicted. West sub-catchment A contains another unnamed wetland, in close proximity of Clubhouse Lake. The site area within the west sub-catchment A forms approximately 49% of this sub-catchment. Based on shallow groundwater and surface water elevation data, this wetland feature is interpreted to be an expression of the local shallow water table and is not considered to be primarily surface water fed. Also, because of the proximity of this wetland mouth to Clubhouse Lake and based on the elevation contours in Figure 1, it is anticipated that any surface water that might reach this wetland will quickly outflow to Clubhouse Lake. Because the operation of the Renfrew Golf Pit will not decrease groundwater levels in the vicinity of this wetland feature, the groundwater table is predicted to slightly increase in this area, it is not anticipated that the loss of surface water catchment will result in a significant decrease in the water level within the wetland. This will be confirmed through the proposed long-term surface water monitoring program for the site which includes daily water level measurement at SG-1 using a datalogger.

The percentage change in surplus volume estimates for Clubhouse Lake, the unnamed pond and the 2 unnamed wetlands to the northeast and southwest of the site were calculated and found to be within ±5%, which is considered insignificant. Similarly, the percentage changes in surplus volume estimates for the wetland located upstream of the unnamed pond were calculated and found to be approximately -2% and +0.5% during the fully operational and rehabilitation conditions respectively; and these changes are also considered insignificant.

A small wetland pocket and a watercourse connected to the wetland pocket located just east of the eastern site boundary are within the predicted 1-metre groundwater drawdown radius of influence for the development of the Renfrew Golf Pit. The available water elevation data confirms that the watercourse is consistently perched above the groundwater table and the groundwater is not discharging to the water feature. As such, impacts to these features as a result of drawdown within the sand and gravel deposit associated with the development of the Renfrew Golf Pit are not predicted. Ongoing water level monitoring at SG-2 and a new staff gauge (SG-3) to be installed within the wetland feature are included in the long-term monitoring program for the site.

The vernal pool located to the north of the site boundary within east sub-catchment A is considered to be upgradient from the site (see Figures 1 and 7). Because the groundwater flow is interpreted to be from north to south (Figure 1), the site operations are anticipated to have no adverse impacts on the vernal pool.

Operation of the proposed pit area is not expected to contribute to flooding problems in the receiving drainage features, as there will be no water discharge from the pit. The southern portion of the pit is expected to operate as a large infiltration basin temporarily detaining storm runoff and moderating flows in the receiving watercourses.

Based on the findings of this assessment, no significant adverse effects to groundwater and surface water resources and their uses are anticipated as a result of the operation and rehabilitation of the proposed Renfrew Golf Pit.

10.0 RECOMMENDATIONS

Based on the results of the hydrogeological and hydrological assessments for the Renfrew Golf Pit, the following recommendations are provided for inclusion on the site plans:

- The following water level monitoring program shall be implemented by the Licensee.
  - Monthly water levels shall be collected from BH21-01, BH21-02, BH21-04 TW-1, SG-1, DP-1, SG-2, DP-2 and SG-3. A datalogger will be installed at SG-1, SG-2 and SG-3 to record water level measurements at least once per day.

  - The groundwater level monitoring will start prior to extraction below the water table at the site. The surface water monitoring program will start when extraction operations begin at the site.

- In the event of a well interference complaint, the Licensee shall implement the Complaints Response Program outlined in Section 7.0 of this report.

- It is recommended to construct an overflow structure, for example, spillway, broad-crested weir or rock chute at the upstream end of the proposed emergency surface overflow drainage ditch along the west side of the site access road (see Figures 8 and 9). The crest elevation of this overflow structure should be lower than the 131.3 mASL top elevation of the perimeter berm by approximately 0.3 metres, to allow for emergency outflow from the pit lake during extreme storm events without overtopping the berm.

- It is recommended during operations to construct a perimeter ditch along the northeast site boundary within sub-catchment B (see Figure 7), to divert clean surface runoff form the upper part of the sub-catchment around the site boundary and towards the west to eventually reach the unnamed wetland. Similarly, another perimeter ditch flowing to the southeast is recommended to be constructed during operations along the southwest extraction area boundary within sub-catchment B, to prevent site contact water from reaching the unnamed wetland.

11.0 LIMITATIONS AND USE OF REPORT

This report was prepared for the exclusive use of Thomas Cavanagh Construction Limited. The report, which specifically includes all tables, figures and appendices, is based on data and information collected by WSP Canada Inc. and is based solely on the conditions of the properties at the time of the work, supplemented by historical information and data obtained by WSP Canada Inc. 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.

WSP Canada Inc. 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 monitoring locations have been inferred based on conditions observed at monitoring 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. WSP Canada Inc. 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, WSP Canada Inc. should be requested to re-evaluate the conclusions of this report, and to provide amendments as required.

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12.0 CLOSURE

We trust this report meets your current needs. If you have any questions regarding this report, please contact the undersigned.

WSP Canada Inc.

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https://golderassociates.sharepoint.com/sites/145731/project files/6 deliverables/level 1 and 2 water report/21465813-r-reva-renfrew golf water report_dec2023.docx

REFERENCES

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

Golder Associates Ltd., 2003. Renfrew County – Mississippi – Rideau Groundwater Study. Prepared for Mississippi Valley Conservation Authority Study Group. September 2003.

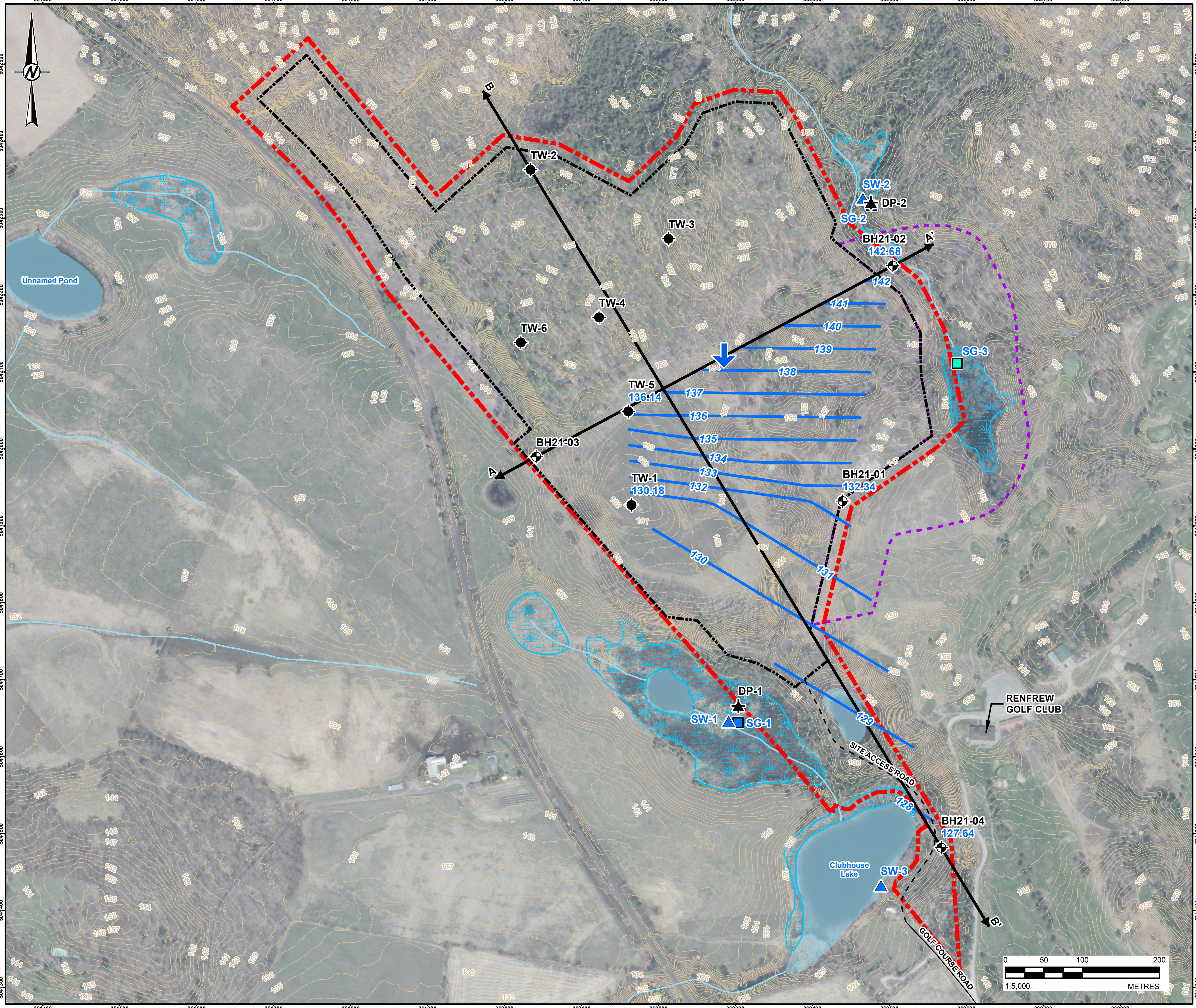
GRI Inc. 2018. Memorandum,17-023 Renfrew Golf Course Test Pits and Review. Report No. MGG172301D, June 13, 2018.

Hvorslev, M.J., 1951. Time lag and soil permeability in groundwater observations. U.S. Army Corp Engrs. Waterways Exp. Sta. Bull. 36, Vicksburg, Miss.

Marinelli, F., and W.L. Niccoli., 2000. Simple analytical equations for estimating groundwater inflow to a mine pit. Groundwater 38, no. 2: 311-314.

Ministry of the Environment. 2003. Stormwater Management Planning and Design Manual, March 2003.

WSP Canada Inc. (WSP). 2023. Natural Environment Report – Proposed Renfrew Golf Pit, Horton Township, Renfrew County, ON. File No. CA-GLD-21465813.



KEY MAP

SCALE 1:200,000

LEGEND

- APPROXIMATE BOREHOLE LOCATION
- APPROXIMATE BOREHOLE LOCATION BY OTHERS
- APPROXIMATE DRIVEPOINT PIEZOMETER LOCATION
- APPROXIMATE SURFACE WATER SAMPLE LOCATION
- APPROXIMATE STAFF GAUGE LOCATION
- PROPOSED STAFF GAUGE LOCATION
- ROADWAY
- TOPOGRAPHIC CONTOUR, metres
- WATERCOURSE
- CROSS-SECTION LOCATION
- WATERBODY
- WETLAND
- PREDICTED 1-METRE GROUNDWATER DRAWDOWN RADIUS OF INFLUENCE
- PROPOSED EXTRACTION BOUNDARY
- PROPOSED LICENSE BOUNDARY
- 9999 GROUNDWATER ELEVATION, mASL (JULY 31, 2021)
- GROUNDWATER ELEVATION CONTOUR, mASL
- INTERPRETED GROUNDWATER FLOW DIRECTION

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. KEY MAP: © OPENSTREETMAP (AND) CONTRIBUTORS, CC-BY-SA COUNTY OF RENFREW
3. BING IMAGERY SUPPLIED BY ESRI AND MICROSOFT © 2020 MICROSOFT CORPORATION AND ITS DATA SUPPLIERS. IMAGERY DATE: 10/10/2016
4. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83, COORDINATE SYSTEM: MTM ZONE 9, VERTICAL DATUM: CGVD28

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
LEVEL 1 AND 2 WATER REPORT, RENFREW GOLF PIT, HORTON TOWNSHIP, ONTARIO

TITLE
SITE PLAN

CONSULTANT

YYYY-MM-DD	2023-08-24
DESIGNED	LB
PREPARED	JEM/BR
REVIEWED	HF
APPROVED	JPAO

PROJECT NO.	CONTROL	REV.	FIGURE
21465813	0003	A	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

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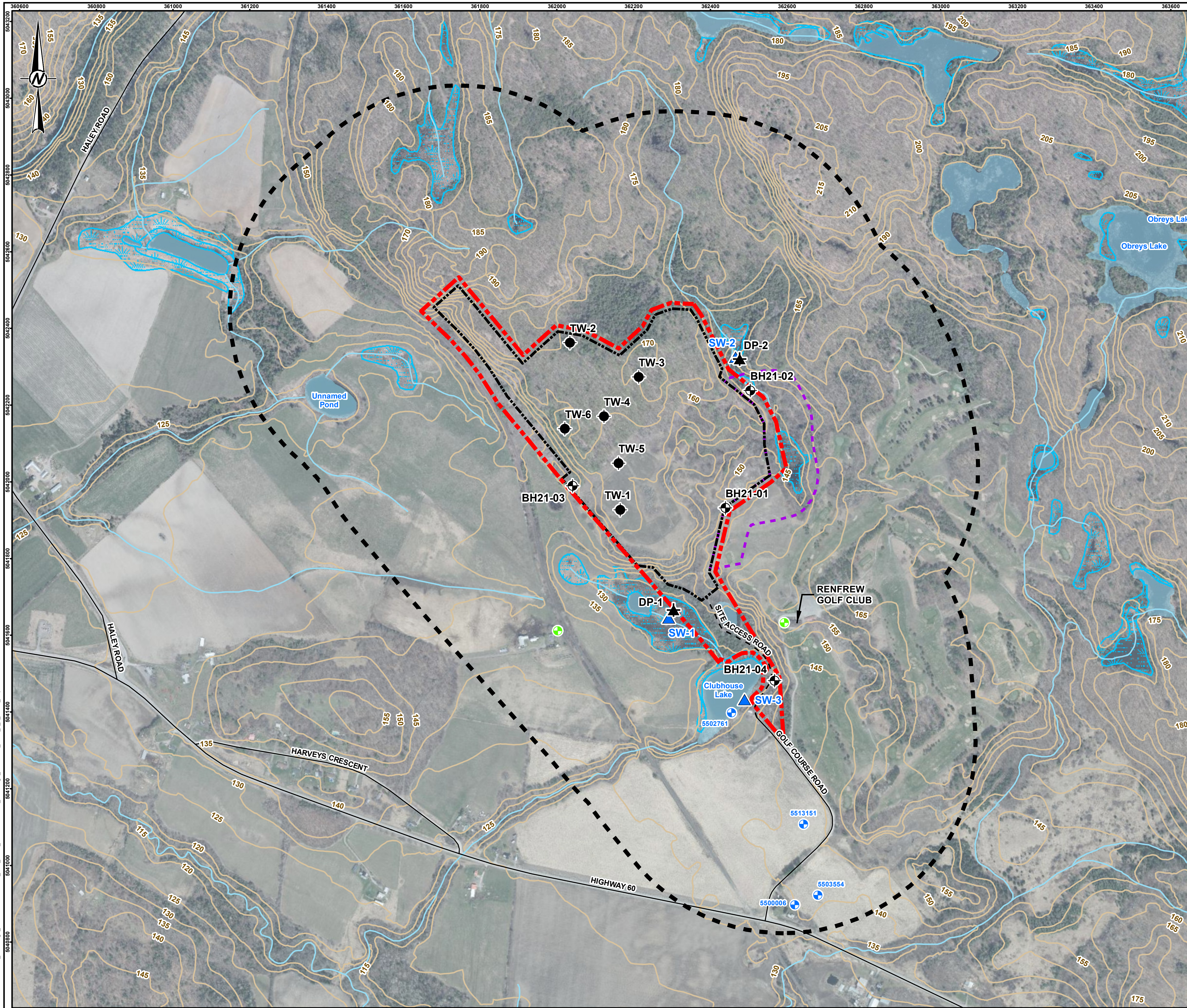

LEGEND

- MECP WWIS WATER WELL LOCATION
- ASSUMED WELL LOCATION
- APPROXIMATE BOREHOLE LOCATION
- APPROXIMATE BOREHOLE LOCATION BY OTHERS
- APPROXIMATE DRIVEPOINT PIEZOMETER LOCATION
- APPROXIMATE SURFACE WATER SAMPLE LOCATION
- ROADWAY
- TOPOGRAPHIC CONTOUR, METRES
- WATERCOURSE
- WATERBODY
- WETLAND
- PREDICTED 1-METRE GROUNDWATER DRAWDOWN RADIUS OF INFLUENCE
- PROPOSED EXTRACTION BOUNDARY
- SITE
- 500 m BUFFER

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
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4. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83, COORDINATE SYSTEM: MTM ZONE 9, VERTICAL DATUM: CGVD28

0 100 200 400
1:10,000 METRES

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
LEVEL 1 AND 2 WATER REPORT, RENFREW GOLF PIT, HORTON TOWNSHIP, ONTARIO

TITLE
WATER SUPPLY WELLS

CONSULTANT

wsp

YYYY-MM-DD	2023-07-05
DESIGNED	LB
PREPARED	JEM/BR
REVIEWED	HF
APPROVED	JPAO

PROJECT NO.	CONTROL	REV.	FIGURE
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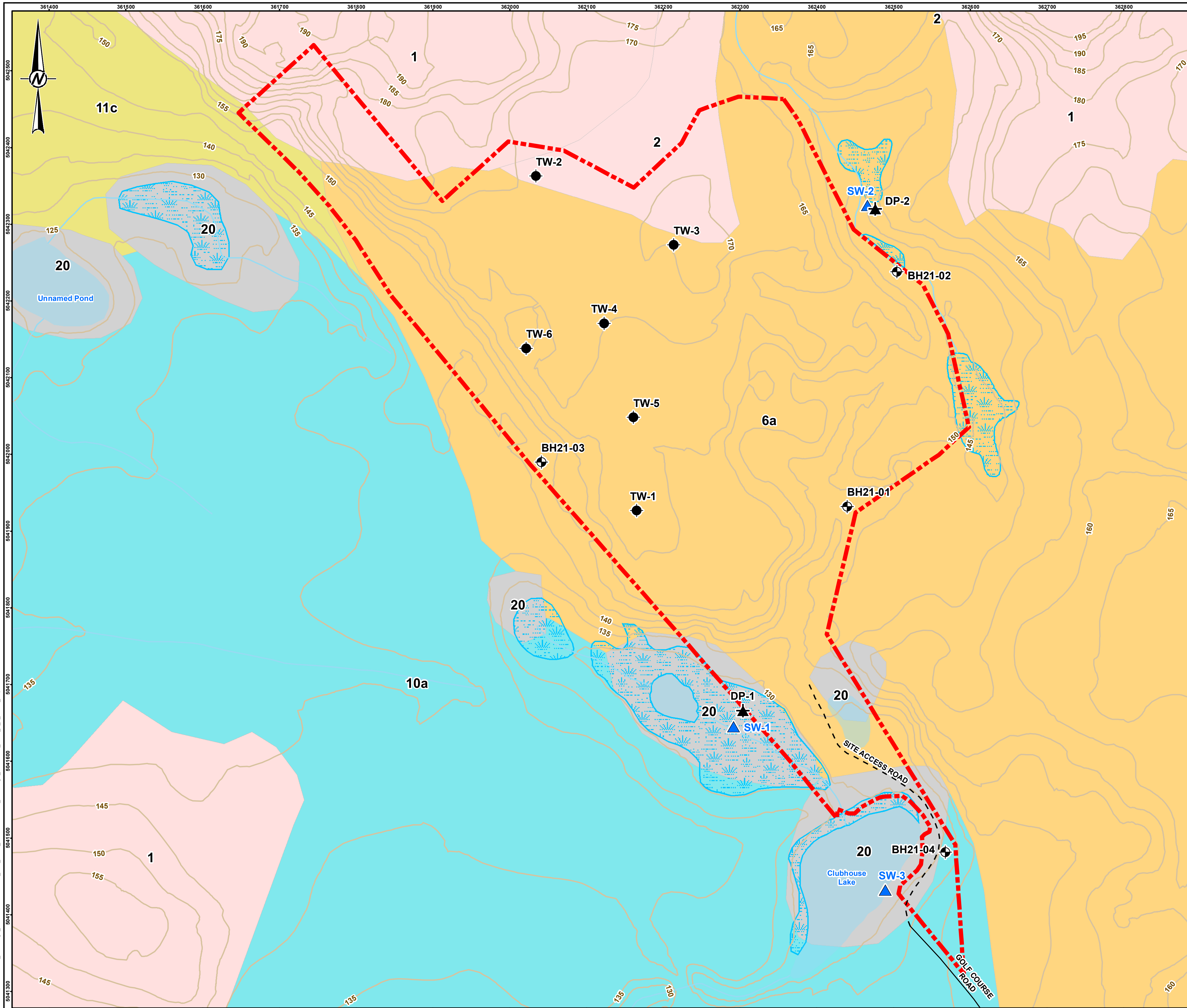


LEGEND

- APPROXIMATE BOREHOLE LOCATION
- APPROXIMATE BOREHOLE LOCATION BY OTHERS
- APPROXIMATE DRIVEPOINT PIEZOMETER LOCATION
- APPROXIMATE SURFACE WATER SAMPLE LOCATION
- ROADWAY
- TOPOGRAPHIC CONTOUR, METRES
- WATERCOURSE
- WATERBODY
- WETLAND
- SITE

OGS SURFICIAL GEOLOGY

- 1. **PRECAMBRIAN BEDROCK**
- 2. **BEDROCK-DRIFT COMPLEX IN PRECAMBRIAN TERRAIN:**
- 6a. **ICE-CONTACT STRATIFIED DEPOSITS:** SAND AND GRAVEL MINOR, SILT, CLAY AND TILL; IN MORAINES, ESKERS, KAMES AND CREVASSE FILLS
- 10a. **FINE-TEXTURED GLACIOMARINE DEPOSITS:** SILT AND CLAY, MINOR SAND AND GRAVEL; MASSIVE TO WELL LAMINATED
- 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 2020
3. KEY MAP:
4. BING IMAGERY SUPPLIED BY ESRI AND MICROSOFT © 2020 MICROSOFT CORPORATION AND ITS DATA SUPPLIERS. IMAGERY DATE: 10/10/2016
4. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83, COORDINATE SYSTEM: MTM ZONE 9, VERTICAL DATUM: CGVD28

0 50 100 200
1:5,000 METRES

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
LEVEL 1 AND 2 WATER REPORT, RENFREW GOLF PIT, HORTON TOWNSHIP, ONTARIO

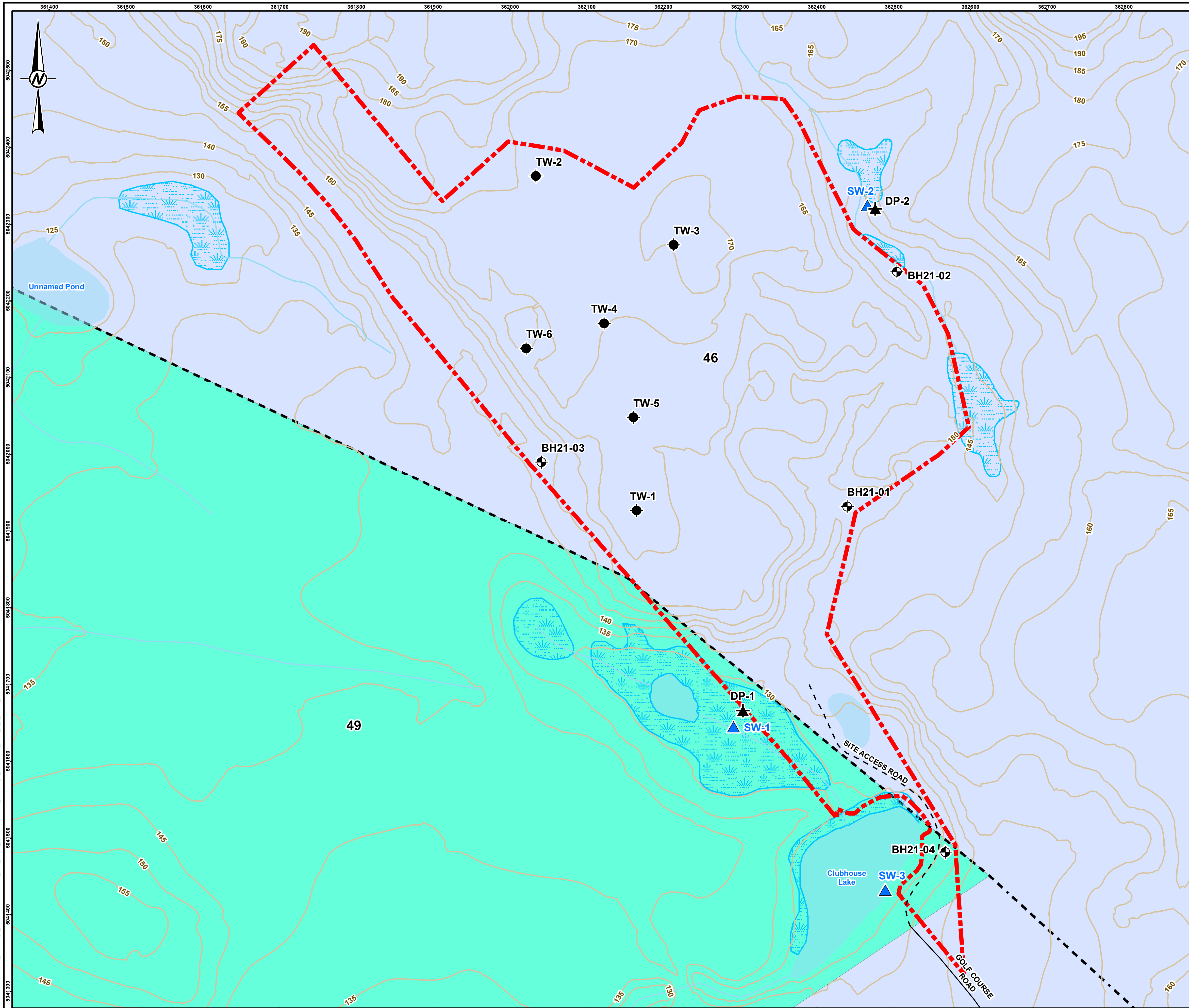
TITLE
SURFICIAL GEOLOGY MAP

CONSULTANT

wsp

YYYY-MM-DD	2023-06-28
DESIGNED	LB
PREPARED	JEM/BR
REVIEWED	HF
APPROVED	JPAO

PROJECT NO.	CONTROL	REV.	FIGURE
21465813	0003	0	3



LEGEND

- APPROXIMATE BOREHOLE LOCATION
- APPROXIMATE BOREHOLE LOCATION BY OTHERS
- APPROXIMATE DRIVEPOINT PIEZOMETER LOCATION
- APPROXIMATE SURFACW WATER SAMPLE LOCATION
- ROADWAY
- TOPOGRAPHIC CONTOUR, METRES
- WATERCOURSE
- WATERBODY
- WETLAND
- SITE
- FAULT LINE
- 49 MAFIC TO ULTRAMAFIC PLUTONIC ROCKS
- 46 CARBONATE METASEDIMENTARY ROCKS

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. ONTARIO GEOLOGICAL SURVEY 2011. 1:250 000 SCALE BEDROCK GEOLOGY OF ONTARIO; ONTARIO GEOLOGICAL SURVEY, MISCELLANEOUS RELEASE–DATA 126 - REVISION 1
2. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2020
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4. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83, COORDINATE SYSTEM: MTM ZONE 9, VERTICAL DATUM: CGVD28

0 50 100 200
1:5,000 METRES

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
LEVEL 1 AND 2 WATER REPORT, RENFREW GOLF PIT, HORTON TOWNSHIP, ONTARIO

TITLE
BEDROCK GEOLOGY MAP

CONSULTANT

wsp

YYYY-MM-DD	2023-06-28
DESIGNED	LB
PREPARED	JEM/BR
REVIEWED	HF
APPROVED	JPAO

PROJECT NO.	CONTROL	REV.	FIGURE
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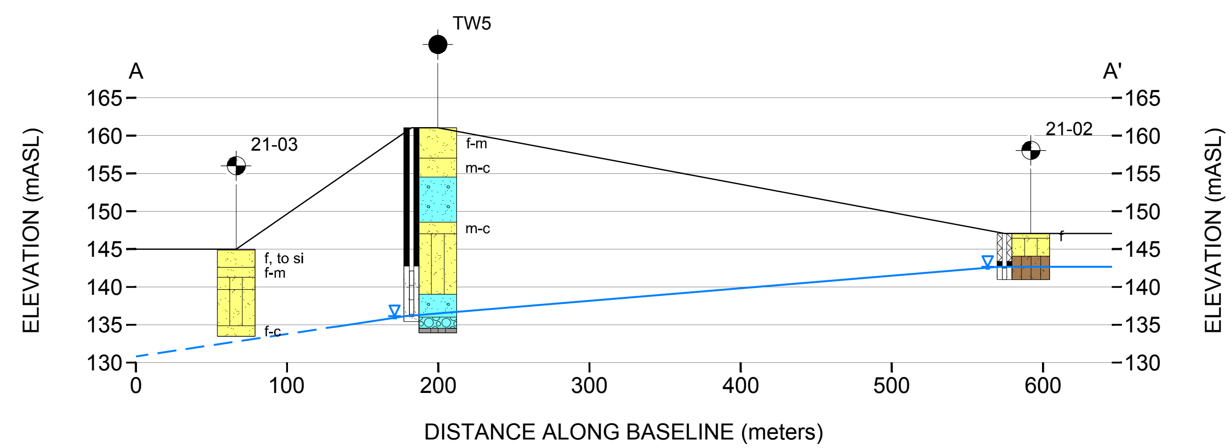
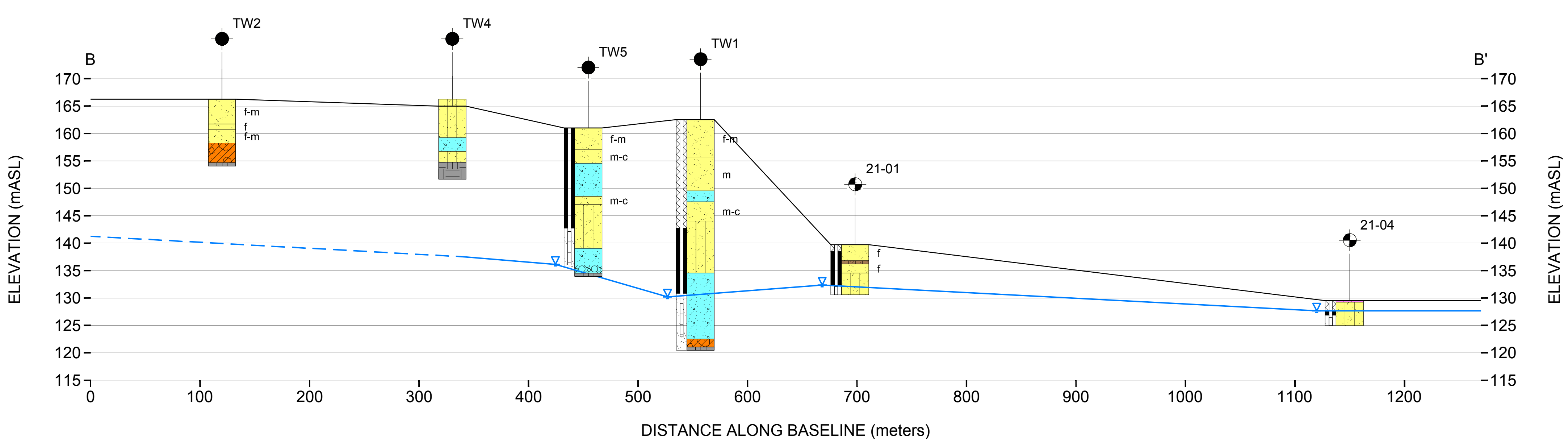
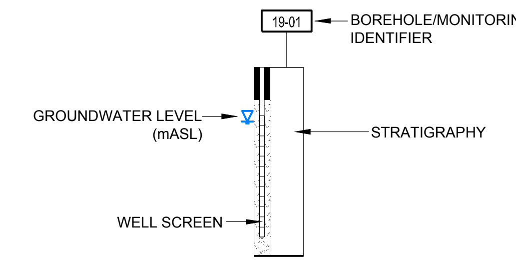




LEGEND

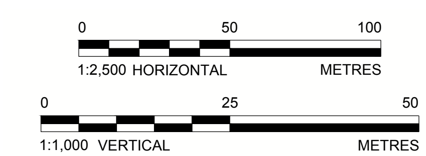
	INTERPRETED POSITION OF GROUNDWATER TABLE, JULY 31, 2021
f	FINE
f-m	FINE TO MEDIUM
f-c	FINE TO COARSE
m-c	MEDIUM TO COARSE
f, to si	FINE TO SILTY
f-c, gr	MEDIUM TO COARSE
m	MEDIUM
	BOREHOLE
	BOREHOLE BY OTHERS



SOIL STRATIGRAPHY

TOPSOIL	SANDY SILT
SAND	SILTY SAND
SAND AND GRAVEL	GLACIAL TILL
GRAVEL	BEDROCK

DRAFT



CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

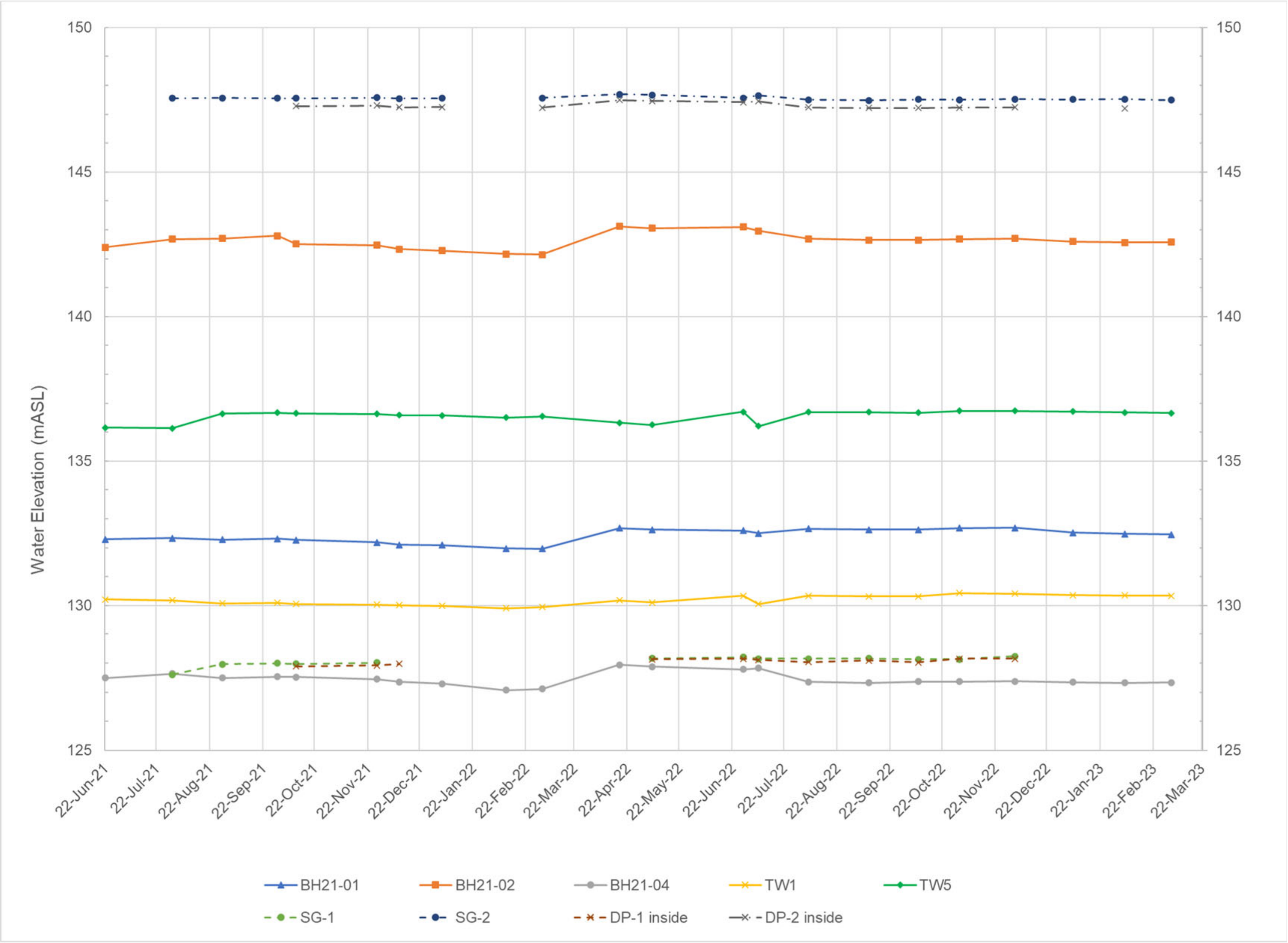
PROJECT
HYDROGEOLOGICAL ASSESSMENT
RENFREW GOLF PIT

TITLE
CROSS-SECTION A-A' AND B-B'

CONSULTANT

YYYY-MM-DD	2023-07-04
DESIGNED	----
PREPARED	ZS
REVIEWED	----
APPROVED	----

PROJECT NO.	CONTROL	REV.	FIGURE
21465813	0003	A	5



CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
LEVEL 1 AND 2 WATER REPORT, RENFREW GOLF PIT, HORTON TOWNSHIP, ONTARIO

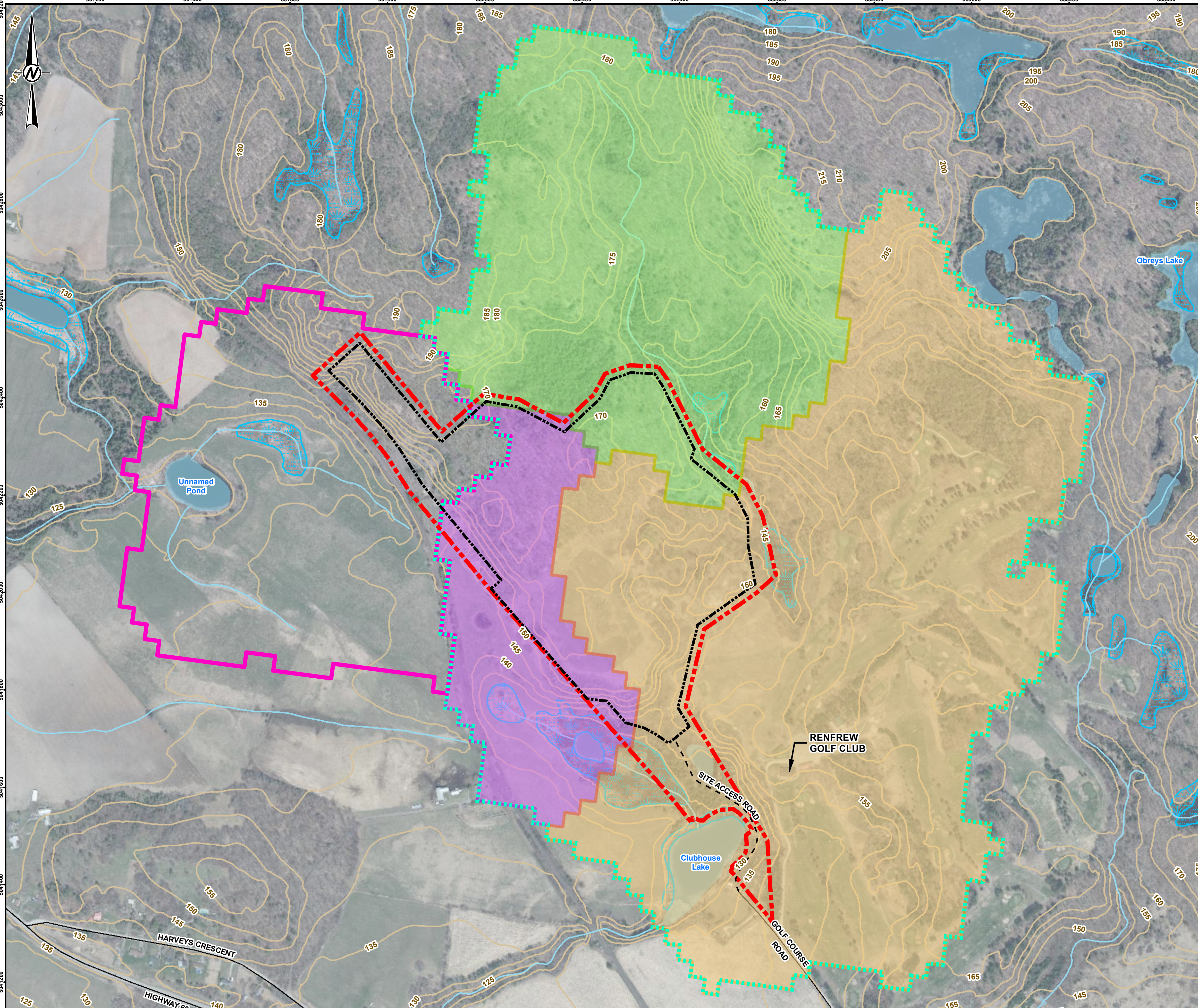
CONSULTANT

wsp

YYYY-MM-DD	2023/04/06
PREPARED	LEB
DESIGN	LEB
REVIEW	JPAO
APPROVED	JPAO

TITLE
GROUNDWATER AND SURFACE WATER ELEVATION DATA (JUNE 2021 TO MARCH 2023)

PROJECT No.	PHASE	Rev.	FIGURE
21465813			6



LEGEND

- ROADWAY
- TOPOGRAPHIC CONTOUR, METRES
- WATERCOURSE
- WATERBODY
- WETLAND
- PROPOSED EXTRACTION LIMIT
- SITE
- CATCHMENT A - 184.16 ha
- CATCHMENT B - 45.73 ha
- MAIN SUB-CATCHMENT - 107.77 ha
- EAST SUB-CATCHMENT - 55.02 ha
- WEST SUB-CATCHMENT - 21.37 ha

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
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4. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83, COORDINATE SYSTEM: MTM ZONE 9, VERTICAL DATUM: CGVD28

0 80 160 320

1:8,000 METRES

CLIENT

THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT

LEVEL 1 AND 2 WATER REPORT, RENFREW GOLF PIT, HORTON TOWNSHIP, ONTARIO

TITLE

SURFACE WATER CATCHMENT AREAS

CONSULTANT

YYYY-MM-DD	2023-08-24
DESIGNED	LB
PREPARED	JEM/BR
REVIEWED	HF
APPROVED	JPAO

PROJECT NO.	CONTROL	REV.	FIGURE
21465813	0003	A	7

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

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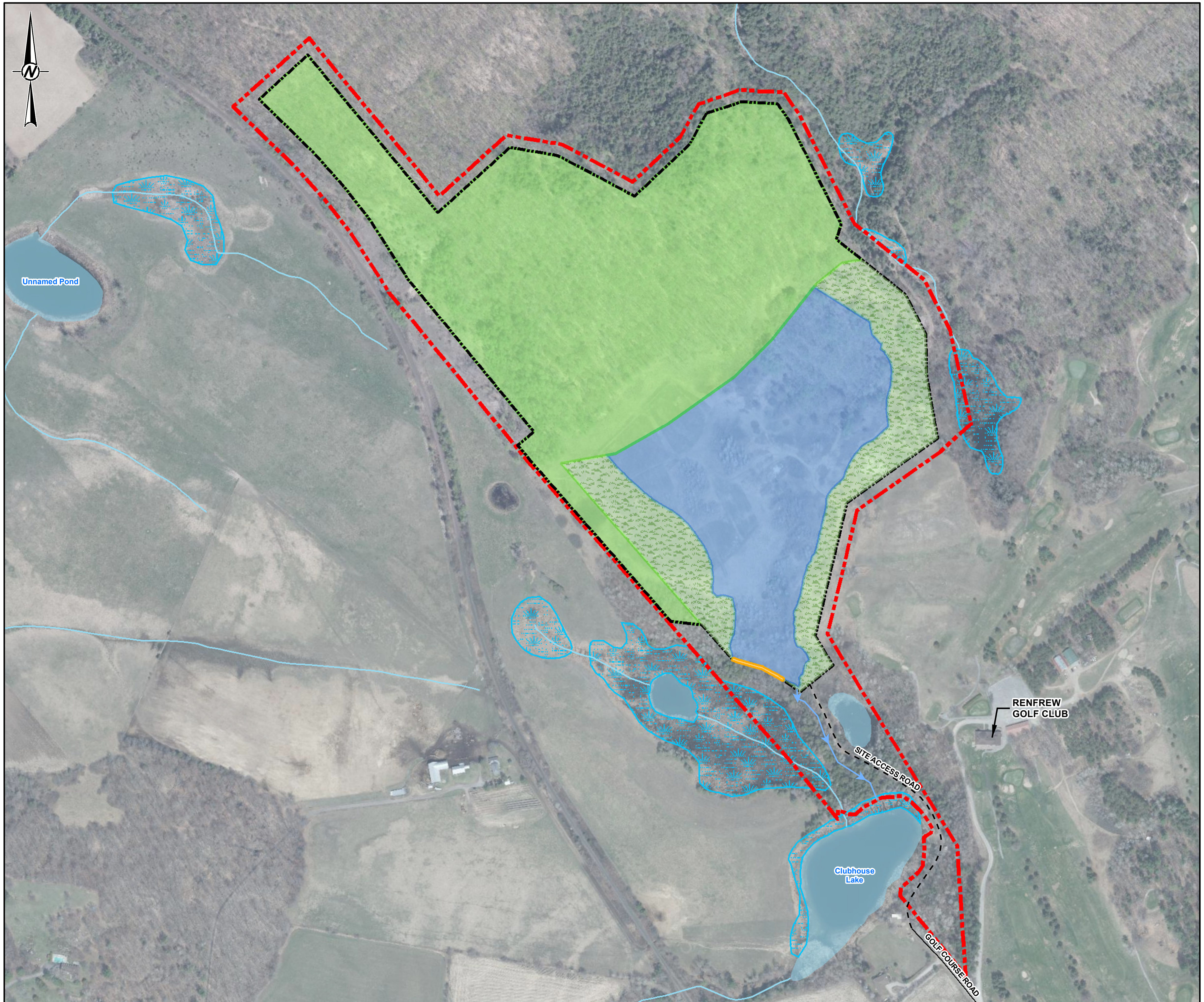

LEGEND

- ROADWAY
- WATERCOURSE
- OVERFLOW DRAINAGE DITCH
- WATERBODY
- WETLAND
- NATIVE SEED MIX OF GRASSES AND PLANTS
- WOODLOT REHABILITATION AREA
- PIT LAKE
- 1.3 m HIGH PERIMETER BERM
- PROPOSED EXTRACTION LIMIT
- PROPOSED LICENSE 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
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4. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83, COORDINATE SYSTEM: MTM ZONE 9, VERTICAL DATUM: CGVD28

0 50 100 200
1:5,000 METRES

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
HYDROGEOLOGICAL ASSESSMENT
RENFREW GOLF PIT

TITLE
REHABILITATION SCENARIO LAND COVERS AND MITIGATION MEASURES

CONSULTANT

wsp

YYYY-MM-DD	2023-08-24
DESIGNED	----
PREPARED	JEM
REVIEWED	HF
APPROVED	JPAO

PROJECT NO.	CONTROL	REV.	FIGURE
21465813	0005	A	9

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 0 25mm

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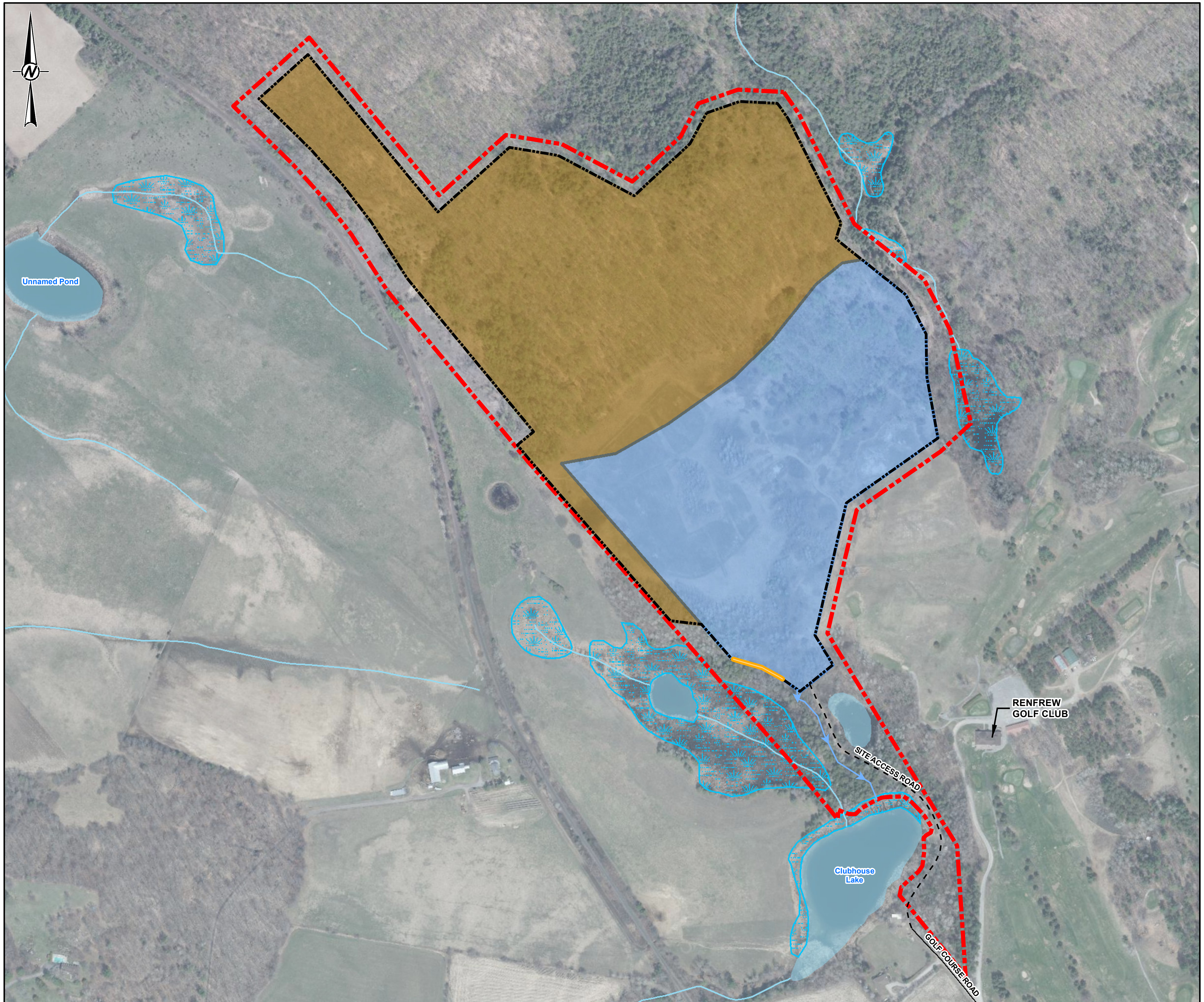

LEGEND

- ROADWAY
- WATERCOURSE
- OVERFLOW DRAINAGE DITCH
- WATERBODY
- WETLAND
- AREA EXTRACTED TO FINAL ELEVATION
- PIT LAKE
- 1.3 m HIGH PERIMETER BERM
- PROPOSED EXTRACTION LIMIT
- PROPOSED LICENSE BOUNDARY

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

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4. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83, COORDINATE SYSTEM: MTM ZONE 9, VERTICAL DATUM: CGVD28

0 50 100 200

1:5,000 METRES

CLIENT

THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT

HYDROGEOLOGICAL ASSESSMENT
RENFREW GOLF PIT

TITLE

OPERATIONAL SCENARIO LAND COVERS AND MITIGATION MEASURES

CONSULTANT

YYYY-MM-DD	2023-08-24
DESIGNED	----
PREPARED	JEM
REVIEWED	HF
APPROVED	JPAO

PROJECT NO.	CONTROL	REV.	FIGURE
21465813	0005	A	8

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APPENDIX A

Qualifications and Experience of the Report Authors

Education

M.Sc. Civil Engineering: Hydrogeology
Queen's University
Kingston, Ontario, 2001

B.Sc. Environmental Science: Earth Sciences Stream, Honours
Brock University
St. Catharines, Ontario
1998

Certifications

Registered Professional Geoscientist Ontario

WSP Canada Inc. – Ottawa

Senior Hydrogeologist

Jaime Oxtobee has over 20 years of broad experience in the field of physical hydrogeology that includes hydrogeological impact assessments in support of the licensing of pits and quarries under the *Aggregate Resources Act*, water supply development and regional scale groundwater studies.

Employment History

Golder Associates Ltd./WSP Canada Inc. – Ottawa
Senior Hydrogeologist (2001 to Present)

Jaime is responsible for project management, technical analysis and reporting for a variety of hydrogeological and environmental projects. Jaime is also often responsible for senior technical review of hydrogeological investigations.

Projects have included groundwater resources studies; hydrogeological investigation programs in support of licensing/permitting pits and quarries and in support of Permit to Take Water applications for local construction dewatering projects, ready-mix concrete plants, golf courses and quarries; communal water supply investigations; wellhead protection studies; contaminated site investigations; and, providing senior review for landfill, pit and quarry monitoring reports.

Queen's University – Kingston, Ontario
Teaching Assistant (2000 to 2001)

Teaching assistant for university courses relating to groundwater flow and contaminant transport in porous media and fractured rock environments.

Phase IV Bedrock Remediation Program – Smithville, Ontario
Project Manager (1999)

Coordinated and conducted a groundwater/surface water interaction study downgradient from the PCB-contaminated site in Smithville, Ontario. The study involved detailed numerical modelling, as well as an extensive field program including stream surveys, stream gauging, construction and installation of mini-piezometers, seepage meters and weirs, fracture mapping, groundwater and surface water sampling.

SELECTED PROJECT EXPERIENCE – AGGREGATE INDUSTRY

Hydrogeological and Hydrological Assessments for Quarry Licensing
Township of Drummond-North Elmsley, Ontario, Canada

Golder (now WSP) carried out the necessary hydrogeological, hydrological ecological and archaeological studies to support an application under the *Aggregate Resource Act* for licensing the extension of an existing quarry. The application was for two new below water quarries on either side of an existing below water quarry. Jaime led the hydrogeological/hydrological assessment component of the project, and was responsible for coordinating the multi-disciplinary team. Jaime was responsible for the development and execution of the hydrogeology field program, development of the site conceptual model and completion of the hydrogeological impact assessment/reporting. Jamie also provided input to the integration of the findings from the multiple disciplines.

Hydrogeological Assessments for Pit Licensing Township of Lanark, Ontario, Canada

Golder (now WSP) carried out the necessary hydrogeological, ecological and archaeological studies to support an application under the *Aggregate Resource Act* for licensing a new pit above the water table. Jaime led the hydrogeological assessment component of the project and was responsible for coordinating the multi-disciplinary team. Jaime was responsible for the development and execution of the hydrogeology field program and preparing the required reporting.

Hydrogeological and Hydrological Assessments for Quarry Licensing
Ramara, Ontario, Canada

Golder (now WSP) carried out the necessary hydrogeological, hydrological and archaeological studies to support an application under the *Aggregate Resource Act* for licensing the extension of an existing quarry. The application was for one new below water quarry adjacent to an existing below water quarry. Jaime led the hydrogeological and hydrological assessment component of the project. Jaime was responsible for development and execution of the hydrogeology field program, development of the site conceptual model and completion of the hydrogeological impact assessment/reporting.

Hydrogeological Assessments for Pit Licensing
Township of Leeds and Thousand Islands, Ontario, Canada

Golder (now WSP) carried out the necessary hydrogeological studies to support an application under the *Aggregate Resource Act* for licensing a new pit below the water table. Jaime led the hydrogeological assessment component of the project. Jaime was responsible for the development and execution of the hydrogeology field program and completing the hydrogeological impact assessment/reporting.

Hydrogeological Assessment for Quarry Permitting
Township of Bomby

Golder (now WSP) carried out the necessary hydrogeological, ecological and archaeological studies to support an application under the *Aggregate Resource Act* for permitting a new quarry. The application was for a below water quarry located on Crown Land. Jaime led the hydrogeological assessment component of the project and was responsible for coordinating the multi-disciplinary team. Jaime was responsible for the development and execution of the hydrogeology field program, development of the site conceptual model and completion of the hydrogeological impact assessment/reporting. Jamie also provided input to the integration of the findings from the multiple disciplines.

Hydrogeological Assessment for Pit Permitting
District of Kenora, Ontario, Canada

Golder (now WSP) carried out the necessary hydrogeological, ecological and archaeological studies to support an application under the *Aggregate Resource Act* for permitting a new pit. The application was for a below water pit located on Crown Land. Jaime provided input to the hydrogeological assessment component of the project and was responsible for coordinating the multi-disciplinary team. Jaime was responsible for the development of the site conceptual model in the vicinity of the pit and completion of the hydrogeological impact
assessment/reporting. Jamie also provided input to the integration of the findings from the multiple disciplines.

Hydrogeological Assessment for Quarry Permitting
District of Kenora, Ontario, Canada

Golder (now WSP) carried out the necessary hydrogeological, ecological and archaeological studies to support an application under the *Aggregate Resource Act* for permitting a new quarry. The application was for a below water quarry located on Crown Land. Jaime provided input to the hydrogeological assessment component of the project and was responsible for coordinating the multi-disciplinary team. Jaime was responsible for the development of the site conceptual model in the vicinity of the quarry and completion of the hydrogeological impact assessment/reporting. Jamie also provided input to the integration of the findings from the multiple disciplines.

Hydrogeological and Hydrological Assessment for Quarry Licensing City of Kawartha Lakes, Ontario, Canada

Golder (now WSP) carried out the necessary hydrogeological, hydrological and ecological studies to support an application under the *Aggregate Resource Act* for licensing a new quarry. The application was for a below water quarry located adjacent to a provincially significant wetland. Jaime provided input to the hydrogeological assessment component of the project, which included the installation of over 80 monitoring intervals and the completing of three pumping tests. Jaime was involved in data analysis and the completion of the impact assessment and reporting for the hydrogeology assessment.

TRAINING

Beyond Data: Conceptual Site Models in Environmental Site Assessments
Golder U, 2011

Critical Thinking in Aquifer Test Interpretation
Golder U, 2011

HydroBench (Proprietary Aquifer Test Interpretation Software)
Golder U, 2011

Project Management
Golder U, 2007

Short course: Environmental Isotopes in Groundwater Resource and Contaminant Hydrogeology
2007

Short course: Hydrogeology of Fractured Rock – Characterization, Monitoring, Assessment and Remediation
2002

PROFESSIONAL AFFILIATIONS

Member, Association of Professional Geoscientist of Ontario Member,

Ottawa Geotechnical Group

PUBLICATIONS

Conference Proceedings

West, A.L., K.A. Marentette and J.P.A. Oxtobee. 2009. *Quantifying Cumulative Effects of Multiple Rock Quarries on Aquifers*. 2009 Joint Assembly, May. Toronto, Canada.

Novakowski, K.S., P.A. Lapcivic, J.P.A. Oxtobee and L. Zanini. 2000. *Groundwater Flow in the Lockport Formation Underlying the Smithville Ontario Area*. 1st IAH-CNC and CGS Groundwater Specialty Conference, October. Montreal, Canada.

Oxtobee, J.P.A. and K.S. Novakowski. 2001. *A Study of groundwater/Surface Water Interaction in a Fractured Bedrock Environment*. Fractured Rock 2001 Conference, March. Toronto, Canada.

Journal Articles

Oxtobee, J.P.A. and K.S. Novakowski. Groundwater/Surface Water Interaction in a Fractured Rock Aquifer. *Journal of Ground Water*, 41(5) (2003), 667-681.

Oxtobee, J.P.A. and K.S. Novakowski. A Field Investigation of Groundwater/Surface Water Interaction in a Fractured Bedrock Environment. *Journal of Hydrology*, 269 (2002), 169-193.

Other

Oxtobee, J.P.A., 1998. Environmental Assessment of Grapeview, Francis and Richardson's Creeks, St. Catharines, Ontario. B.Sc. Thesis, Brock University, Earth Sciences Department pp.119.

HESHAM FOULI, PhD, PEng

Senior Water Resources Engineer, Earth and Environment

Areas of practice

Stormwater Management and Drainage Design in Municipal and Mine Sites Environment; Erosion and Sediment Control Design; Flood Mapping, Mitigation, Hazard and Risk Assessment; Design of Hydraulic Structures.

Languages

Arabic – Fluent

English – Fluent

German - Good

PROFILE

Hesham is a senior water resources engineer with a blend of academic, consulting and operational water resources and management experience obtained through working at different organizations in Canada and abroad. His professional experience of over 10 years comprises: stormwater management and drainage design in municipalities and on aggregate and coal mining sites, erosion and sediment control design, analysis and design of hydraulic structures, flood management and flood hazard assessment studies, and dam design and assessment studies. He has also participated in watershed hydrologic studies.

Having participated in large-profile projects that included multi-disciplinary teams, Hesham has excellent teamwork and communication skills that lead to the successful completion of projects. He has also led multiple committees and teams in different settings where he showed important skills, such as, taking initiatives and responsibility, understanding and caring for clients needs, sharing experience, respect, quality control and assurance, inclusion and integrity, as well as agility and flexibility.

He also has a strong and diverse academic background having worked as a water resources engineering university faculty for almost 10 years, where he taught water-related courses, including fluid mechanics, hydraulics, hydrology, design of hydraulic structures, water supply and drainage, and industry and environment. He has a proven technical writing skills having published many research articles in reputed journals, conference papers and patents. Such experience lends a multitude of skills, including, innovation, excellence, being detail-oriented and accurate.

EDUCATION

PhD, Water Resources Engineering, University of Alberta, Canada	2006
MSc, Water Resources Engineering, University of Karlsruhe, Germany	1998

SAMPLE PROFESSIONAL DEVELOPMENT

Federal and Provincial Flood Studies Update, National Workshop, Canadian Water Resources Association	2021
Flood Mitigation and Special Flood Hazard Areas, RedVector	2020
2D HEC-RAS and Dam Breach Modelling, Australian Water School	2019

SAMPLE AWARDS

Research Award of the College of Engineering at King Saud University. The award was granted due to publishing multiple peer-reviewed articles in reputed journals, including, the Journal of Fluid Mechanics, Water Resources Management, and the Journal of Hydrology, as well as publishing 2 patents at the United States Office of Patents and Technology (UPSTO) and the Saudi Patents Office.	2016
3 Gold Medals at international invention exhibitions (British Inventors Society, Geneva Inventions, and German iENA)	2010, 2011, 2012
Izaak Walton Killam Memorial PhD Scholarship, University of Alberta	2001-2003

HESHAM FOULI, PhD, PEng

Senior Water Resources Engineer, Earth and Environment

PROFESSIONAL ASSOCIATIONS

Professional Engineers of Ontario, since 2023	PEO
Engineers and Geoscientists BC, since 2021	EGBC
Canadian Water Resources Association, since 2018	CWRA
Association of Professional Engineers and Geoscientists of Alberta, since 2008	APEGA

CAREER

Senior Water Resources Engineer, Earth and Environment, WSP	2022 – Present
Water Management Lead, Teck Coal Ltd, Elkview Operations, Sparwood, BC, Canada	2021 – 2022
Senior Water Resources Engineer, Espira Engineering Ltd, Edmonton, AB, Canada	2021 – 2022
Senior Water Resources Engineer, Water Resources Engineering, AECOM, Edmonton, AB, Canada	2018 – 2020
Assistant/Associate Professor, Department of Civil Engineering, King Saud University, Riyadh, Saudi Arabia	2009 – 2018
Hydrotechnical Specialist, Water Resources Engineering, AECOM, Edmonton, AB, Canada	2006 – 2009
Research Associate, Institute of Hydrodynamics, University of Karlsruhe, Germany	1998 - 1999

PROFESSIONAL EXPERIENCE

Aggregate and Coal Mining Water Management, and Environmental Compliance Approvals

- North 40 Quarry Water Management Plan, Iqaluit, NU, Canada (2022): Technical Lead. Developed the water management plan for the quarry operation; reviewed water balance analyses under existing, operational, and rehabilitated conditions, as well as completing effects assessment; and prepared water management best practices including erosion and sediment control measures, and water quality monitoring plan. Client: MHBC Planning Urban Design & Landscape Architecture for the City of Iqaluit.
- Victoria Road Quarry, City of Kawartha Lakes, ON, Canada (2022): Technical Lead. Authored the 2022 Environmental Compliance Approval Report for the site that included updating the quarry water management plan and reporting effluent water quality monitoring program results to the Ministry of Environment, Conservation and Parks. Client: Five W. Farms Inc.
- Water Management Lead, Teck Coal Ltd, Elkview Operations, Sparwood, BC, Canada (2021 -2022). Led over 12 freshet preparedness meetings with multiple crews to ensure readiness of the site for the freshet season; reviewed pit dewatering / pumping plans and guidelines; upgraded water infrastructure maintenance programs; participated in monthly meetings with representatives from regulatory authorities; proposed and maintained various erosion and sediment control measures, which

reduced total suspended solids (TSS) non-compliance on site; and authored annual mine water management and nitrogen source control plans and submitted to regulatory authorities.

- Stittsville Quarry, Township of Goulbourn, City of Ottawa, ON, Canada (2022): Technical Lead. Supported updating the quarry effluent water balance analyses; reviewed the on-site measured flows; and reported the results as part of the annual monitoring program conducted in accordance with the permit to take water (PTTW) for the site. Client: R. W. Tomlinson Ltd.

Flood Hazard Assessment, Flood Mapping and Mitigation Studies

- Flood Mapping and Flood Mitigation Planning Study, City of Kelowna, BC, Canada (2020): Technical Lead. The study included developing a 1D/2D HEC-RAS model of Mission Creek for a length of approximately 45 km. The model includes 5 bridge crossings; in addition to modelling dike breach for critical areas within the city. Developed the model, attended client meetings and conducted field visits and quality assurance. Client: City of Kelowna and Regional District of Central Okanagan.
- Hydrotechnical Assessment and Flood Mitigation Alternatives of Pekisko Creek Floodplain, Bar U Ranch Historical Site, AB, Canada (2019): Senior Reviewer. The study included updating a HEC-RAS model of the creek to protect buildings on the floodplain and two bridges across the creek. The primary focus was to protect the creek banks against scour and erosion; in addition to proposing measures that allow smoother passage of extreme floods in that area. Client: Public Works and Government Services Canada.
- Paddle River Dam Inflow Design Flood Review, AB, Canada (2008): Hydrotechnical Specialist. The study included reviewing and recommending the inflow design flood using the Canadian Dam Association Guidelines, determining the hazard potential for different dam breach scenarios considering loss of life and property damages, and generating flood inundation maps. Tasks included performing the analyses, reviewing the drawings and preparing the technical report. Client: Alberta Infrastructure and Transportation.
- Flood Mitigation Study, Fort McMurray, AB, Canada (2019): Senior Water Resources Engineer. Checked the design of downstream storm sewers and proposed alternatives. Proposed a replacement outfall structure for the existing Gregoire Outfall Structure. Client: Regional Municipality of Wood Buffalo.
- Client: Alberta Environment (multiple projects)
  - Rycroft Flood Hazard Mapping Study, Two Hills Flood Risk Mapping Study and Town of Penhold Flood Risk Mapping Study (2008 - 2009): Water Resources Engineer. Those 3 studies included hydrologic analyses to estimate various flood frequency discharges for the relevant streams in the watersheds; developed HEC-RAS models for those streams that were used for mapping the flood hazards through floodway criteria maps. Used Hyfran to estimate flood frequencies; other tasks included co-authoring the report for the Rycroft Study and assisting in the analyses for the other two studies.

Stormwater Management Studies

- Stormwater Management Plan for a Proposed Industrial Development, Township of Springwater, ON, Canada (2022): Project Manager and Technical Lead. Updated a stormwater management plan related to the impacts of an industrial development, in support of the site zoning amendment. Developed a technical memo addressing the review comments of the Town, including assessing the sediment removal efficiency of a settling pond and design of an outflow rock chute, for an interim approval of the development. Client: Western Mechanical.

- Atlantic Coast Pipeline (ACP), VA, USA (2019 – 2020): Senior Water Resources Engineer. Provided engineering support for stormwater drainage and erosion and sediment control along the access roads to the pipeline; tasks included watershed delineations using ArcGIS, culvert and end treatment design, drainage ditch design, and QA/QC of developed drawings. Client: Dominion Energy Inc.
- Redcliff Regional Landfill Design, Redcliff, AB, Canada (2019 – 2020): Senior Water Resources Engineer. Performed stormwater drainage design of two landfill municipal solid waste disposal cells for the landfill design and its closure plans; tasks included design of stormwater ponds and delivering a technical memo. Client: Redcliff Cypress Waste Management Authority.
- Arena Road and 231 St. Upgrades, Edmonton, AB, Canada (2019 – 2020): Senior Water Resources Engineer. Provided stormwater drainage design for the upgraded roads including design of roadside ditches and culvert crossings. Developed drainage specifications for the project and reviewed the generated drawings; participated in meetings with the client. Client: Enoch Cree Nation.
- Highway 2:60 and 2:62 Twinning, Peace River, AB, Canada (2019 2020). Reviewed the design of storm sewers and the west outfall structure. Proposed an alternative outfall design based on the client requirements to resolve a difficulty with the constructability of a previous design. Client: Alberta Transportation.
- Kicking Horse Canyon Project, Town of Golden, BC, Canada (2007 – 2008): Hydrotechnical Specialist. Tasks included drainage design of different bridge and tunnel alternatives per the BC MOT. Reviewed drawings and deliverables as part of Quality Management System (QMS). Client: British Columbia Ministry of Transportation.

Design of Hydraulic Structures

- Petroleum Way Road Widening from 17 Street to Streambank Ave, Strathcona, AB (2019): Senior Water Resources Engineer. Performed design check for a critical drop manhole within the stormwater drainage network to ensure its smooth hydraulic performance during extreme storm events. Provided recommendations for manhole upgrades to avoid chocking flow conditions and air trap. Client: Strathcona County.
- Dams Operation and Maintenance Program, Saudi Arabia (2009 – 2018): Assistant Project Manager. The study involved assessing 230 dams built for different purposes across Saudi Arabia considering hydrologic, hydrogeologic, hydraulic, socio-economic, structural and operational aspects. Tasks included: overseeing site visits and dam inspections, following-up with the different technical teams and reviewing their technical reports, proposing dam operation policies, and periodically presenting results to the client. Demonstrated building a collaborative environment and strong communication skills. This work was done as part of my employment at King Saud University. Client: Saudi Ministry of Environment, Water and Agriculture.
- Client: Alberta Infrastructure and Transportation (multiple projects)
  - Winagami-Girouxville Canal Rehabilitation, AB, Canada (2006 – 2009): Hydrotechnical Specialist. Developed a HEC-RAS model of a 14-km reach of the canal that included multiple bridges, culverts, weirs and drop structures. Performed site visits and assessed the structures; recommended rehabilitation and improvement actions for better hydraulic performance of the canal.

  - McAllistar Creek, Heart River Bridge on Hwy 2-North of Nampa, Hwy 9:02 near the Village of Irricana, and Gregoire River Bridge at Anzac, AB, Canada (2006 – 2009). Those 3 projects included single and multiple-span bridges, Arch Beam Culverts (ABC), Corrugated Steel Pipe (CSP) and other types of culverts. Tasks included inspecting the structures and establishing HEC-RAS models of the different proposed alternative designs. Modelled the natural streams with the existing and the proposed structures considering navigability, fish passage and wildlife requirements. Estimated extreme and low flow conditions, ice thickness, scour depths and designed erosion protection measures.

SAMPLE PUBLICATIONS AND PRESENTATIONS

Publications

- Elgamal, M., Fouli, H. “Sediment removal from dam reservoirs using syphon suction action.” *Arab. J. Geosci. 13, 943*, September 2020, https://doi.org/10.1007/s12517-020-05955-x.
- Tekeli, A.E., Fouli, H. “Evaluation of TRMM satellite-based precipitation indexes for flood forecasting over Riyadh City, Saudi Arabia.” *J. Hydrol.*, 2016, http://dx.doi.org/10.1016/j.jhydrol.2016.01.014
- Fouli, H. and Zhu, David Z. “Interfacial Waves in Two-layer Exchange Flows Downslope of a Bottom Sill.” *Journal of Fluid Mechanics*, 680, pp. 194-224, 2011.
- Fouli, Hesham Rabie et al. “Wave Energy Convertor Using Oscillating Pendulums.” *Patent No. US 9,151,268 B1*, October 2015.
- Fouli, H. and Zhu, David Z. “Transition of Two-layer Stratified Flow from the Slope of Bottom Topography to a Horizontal Channel.” *Journal of Atmosphere-Ocean*, Canadian Meteorological and Oceanographic Society (CMOS), Vol. 46(4), pp. 391-404, 2008.

Presentations

- Bashir, B., Fouli, H., Al-Turbak, A. and Loni, O.A. 2015. “Using GIS and DEM to Identify Suitable Rainwater Harvesting Sites in Riyadh Region of Saudi Arabia.” The European Water Resources Association 9th World Congress - Water Resources Management in a Changing World: Challenges and Opportunities, Istanbul, Turkey. June 10 – 13, 2015.
- Hesham Fouli and David Z. Zhu. 2003. “On Interfacial Waves in Two-Layer Exchange Flows.” Proceedings of the 16th Canadian Hydrotechnical Conference, Burlington, Ontario, Canada
- David Z. Zhu, Yaw A. Okyere and Hesham Fouli. 2000. “Experiments of Exchange Flows Through an Opening.” Proceedings of the Fifth International Symposium on Stratified Flows at the Univ. of British Columbia, Vancouver, Canada, pp. 609-614.

Education

M.Sc. Geology, University of Windsor, Windsor, Ontario, 1988

B.Sc. Geology, Honours, University of Windsor, Windsor, Ontario, 1986

Certifications

Registered Professional Geoscientist, 2002

Languages

English – Fluent

WSP Canada Inc. – Ottawa, Ontario

Employment History

Career Summary

Principal/Senior Hydrogeologist (1997 to Present)

Mr. Kris A. Marentette, M.Sc., P.Geo., is a Principal and Senior Hydrogeologist in the Ottawa office of WSP Canada Inc. (previously Golder Associates), and has 20 years of broad experience in the fields of water supply development, physical hydrogeological characterization studies, regional scale groundwater studies, waste management, contaminated sites assessment /remediation, aggregate resource evaluations and the licensing and permitting of quarry development and expansion projects. Kris is responsible for business development, project management, and senior technical review of hydrogeology, quarry and sand and gravel pit development and expansion, golf course irrigation, site assessment and remediation projects, and waste facility siting, design, operation and environmental compliance monitoring assignments from the Ottawa office.

From 1997 to 2001, Mr. Marentette was Project Manager for Golder Associates' component of one of the largest Environmental Site Assessment (ESA) contracts in Canada which involved the assessment of over 780 sites which were being transferred from Transport Canada to NAV CANADA. Golder Associates completed Phase I ESA of approximately 400 sites of which about 130 sites required Phase II ESA activities. The sites ranged from small antennas towers to large, complex international airports. Project involved considerable logistic planning to mobilize personnel across the country, familiarity with federal and provincial soil and groundwater remediation criteria, development of site-specific remediation options (including permafrost sites), and ongoing interaction with consultant team and Transport Canada/NAV CANADA.

Kris has also been involved as principal consultant or senior reviewer for over 100 Phase I ESAs and over 50 Phase II ESAs completed by the Ottawa office. These projects included industrial, commercial, and residential properties ranging from former coal gasification plants to microcircuit manufacturers. Projects have included an evaluation of permitting requirements related to waste water discharges and air emissions as well as designated substances surveys. Kris has also conducted subsurface investigations at numerous bulk storage, fuel dispensing and pipeline sites; development of groundwater and soil vapour monitoring programs; design and permitting of remedial measures including product recovery and excavation of contaminated soil; supervision and verification of site remediation.

Kris has provided environmental consultation services to many wood product manufacturers in Renfrew County and Lanark County in the context of assessing environmental impacts of wood waste storage and lumber yard and sawmill operations on the natural environment. While working for the wood product manufacturers, Kris established a consistent approach to site investigations and set a focused list of leachate indicator parameters for groundwater and surface water assessments which has met with Ontario Ministry of Environment (MOE) approval.

Kris has been the Golder Associates Project Manager on a number of Ministry of Natural Resources quarry and pit licensing projects for both new operations and expansions to existing operations and has extensive experience in managing these complex, multi-disciplinary projects. Participated in comprehensive aggregate resource evaluations of Paleozoic sedimentary sequences (limestone) and Precambrian marble deposits at quarries in eastern Ottawa for the purpose of developing preferred site development plans to maximize the production of high quality aggregate products. The aggregate resource evaluations have typically included borehole coring, geological core logging, geophysical evaluations and comprehensive laboratory testing programs. Participated in other quarry-related projects associated with the Ministry of Environment Permit to Take Water Program and the issuance of Certificates of Approval (Industrial Sewage Works) under Section 53 of the Ontario Water Resources Act as well as studies undertaken for the purpose of complying with requirements under the Aggregate Resources Act. In the case of the Permit to Take Water approvals and industrial sewage works applications under Sections 34 and 53 of the Ontario Water Resources Act, Kris has consulted with, and interacted extensively, with MOE personnel in both the local District and Regional offices and with key personnel within the Environmental Assessment and Approvals Branch of the MOE in Toronto. Kris was the Project Manager assigned to assist the City of Ottawa in a comprehensive project focused on assisting City staff in understanding the intricate details of the MOE's Permit to Take Water Program. Kris is also well known to the local conservation authorities (Rideau Valley Conservation Authority, Mississippi Valley Conservation Authority and South Nation Conservation) as a result of involvement in water supply and quarry-related projects in the Ottawa area and has interacted with the Ontario Stone, Sand & Gravel Association on various issues related to the aggregate industry (e.g., addressing the MOE concern associated with the potential presence of dinitrotoluene in quarry discharge water, source water protection, etc.). Kris has appeared as an expert witness before the Ontario Municipal Board on quarry-related applications.

Golder Associates Ltd. – Ottawa, Ontario

Hydrogeologist/Senior Hydrogeologist (1988 to 1997)

Responsible for business development and the initiation, implementation and direction of hydrogeological investigations from the Ottawa office. Projects have included test well drilling programs for private services developments; subsurface investigations as related to the installation of subsurface sewage disposal systems; communal water supply investigations; and, regional hydrogeological studies to assist in establishing planning policies for future private services developments and to develop standards for water well construction.

Project manager for numerous hydrogeological studies of existing/proposed landfill sites including the assessment of impacts on water resources and developing and implementing monitoring programs and contingency and remedial action plans. Participated in hydrogeological aspects of waste management studies, preparation and submission of documentation to obtain Emergency Certificates of Approval and Site Interim Expansions of landfill sites under both the Environmental Assessment Act and Environmental Protection Act. Projects have included preparation of landfill site development and operations plans including evaluations of landfill final cover design options. Expert testimony at hearings before the Environmental Assessment Board.

Also responsible for investigation, design and implementation of soil and groundwater remediation programs at hydrocarbons, metals, solvents, and PAH contaminated sites including the risk assessment approach to site management. Projects have included third party peer review of site remediation programs.

Conducted hydrogeological assessments of quarry developments/expansions and pre-acquisition environmental site audits.

PROJECT EXPERIENCE – WATER RESOURCES MANAGEMENT

Village of Winchester Water Supply Project
Ontario, Canada

Project Hydrogeologist for the Village of Winchester Water Supply Expansion Project. This project included the preliminary evaluation of potential target aquifers followed by a comprehensive test well investigation and aquifer characterization program. Participated in the development of a comprehensive Water Resources Protection Strategy.

Rural Subdivision Development
Ontario, Canada

Supervised test well drilling programs for numerous residential, industrial and commercial private services subdivision developments including evaluation and selection of target aquifers, development of site specific well construction requirements, analysis and interpretation of physical hydrogeological data and groundwater chemical data and preparation and submission of detailed hydrogeological reports. Responsible for conducting many subsurface investigations as related to the installation of small and large subsurface septic sewage disposal systems for private services developments including projects subject to the Ontario Ministry of the Environment Reasonable Use Guideline B-7.

Communal / Commercial Water Supply Evaluation
Ontario, Canada

Project Manager for communal water supply investigations for non-profit housing developments in Elgin and Clayton, Ontario and time share condominium development in Cobden, Ontario; responsible for groundwater resource evaluation with respect to project specific water supply requirements. Conducted hydrogeological assessment of the Evergreen Spring Water Site in the Township of Sebastopol, Ontario for Cott Beverages Ltd.; assessment included characterization of geological setting, quantity, quality and age of spring water and evaluation of potential sources of contamination in the vicinity of the spring.

Township of Kingston Planning Study
Ontario

Conducted hydrogeological study and general terrain analysis of rural Kingston Township to characterize the present status of the Township's groundwater resources to assist in establishing planning policies for locating new developments on private services and to provide standards for water well construction within the Municipality.

Land Development Evaluation
Ontario

Conducted a preliminary hydrogeological and terrain evaluation of a 400 acre parcel of land south of the Ottawa International Airport with respect to the feasibility of developing the site as a rural residential subdivision on private services.

PROJECT EXPERIENCE – WASTE MANAGEMENT

Township of Clarence Landfill Buchanan Landfill
Bourget, Ontario/Chalk River, Ontario, Canada

Preparation and submission of documentation to the Ontario Ministry of the Environment to obtain an exemption from the Environmental Assessment Act and approval under the Environmental Protection Act for interim expansions of the Township of Clarence Landfill and Buchanan Landfill. Project involved detailed hydrogeological and geophysical site characterization studies, development of mitigation measures to address existing off-site impacts on groundwater and surface water resources and participation in the preparation of the site development and operations reports, trigger mechanisms, and contingency measures, site closure plans, public participation/presentations, document preparation and representation to regulatory agencies. Expert testimony at the Environmental Assessment Board hearings resulting in successful applications.

Dodge Landfill
Espanola, Ontario, Canada

Project Hydrogeologist responsible for hydrogeological studies of existing landfill in support of an application to the Ontario Ministry of Environment for a long-term site expansion.

Lanark County Waste Management Master Plan City/Township of Kingston Waste Management Master Plan
Ontario, Canada

Hydrogeological consultant on the master plan study teams involving technical aspects and document preparation, Environmental Assessment process, EA level field investigations and evaluation of site-specific engineered containment system requirements at the preferred sites and presentations to the steering committees and the public.

Armbro Mine Landfill Development
Marmora, Ontario, Canada

Project Hydrogeologist as part of the Metro Toronto area landfill site search, for hydrogeological assessment, conceptual design and technical feasibility evaluation of constructing a municipal landfill in the 250 metre deep former open pit iron ore mine.

Township of Clarence Waste Management Planning Study
Ontario, Canada

As part of a multi-disciplinary team, responsible for the hydrogeological aspects of a long term waste management planning study under the Environmental Assessment Act and Environmental Protection Act, including development and evaluation of alternative waste management components and systems, a systematic landfill site selection process and interaction with the Public Liaison Committee, municipal council and the public.

Municipal Waste Management Planning Studies
Ontario, Canada

Participated in hydrogeological aspects of waste management planning studies to identify potentially suitable areas for landfill development to satisfy the long term waste disposal requirements for the Township of Grattan, Township of Pittsburgh and the Townships of Palmerston, North and South Canonto.

Various Landfill Sites
Eastern and Northern Ontario, Canada

Responsible for undertaking and/or managing hydrogeological and waste management studies at in excess of 50 municipal landfill sites. The typical objectives of these studies have been to define the physical and contaminant hydrogeology including use of geophysical methods; undertake site-specific impact assessments on groundwater and surface water resources and gas migration; complete site performance evaluations in terms of current regulatory requirements; develop site-specific remedial action plans; design and implement annual hydrogeological monitoring programs; assist in the preparation of site development, operations and contingency and remedial action plans; and, to assemble the necessary documentation required to apply to the Ontario Ministry of Environment for Certificate of Approval revisions to permit continued disposal. Conducted evaluations of final cover design options using the Hydrologic Evaluation of Landfill Performance (HELP) computer model for the purpose of selecting the most appropriate final cover design for numerous landfills based on hydrogeological considerations, economics and availability of construction materials in the vicinity of the sites.

PROJECT EXPERIENCE – CONTAMINATED SITES INVESTIGATION AND REMEDIATION

Nation-Wide Environmental Site Assessments
Canada

Project Manager for Golder Associates' component of one of the largest environmental site assessment contracts in Canada which involved the assessment of over 780 sites which were being transferred from Transport Canada to NAV CANADA. Golder Associates completed Phase I ESAs of approximately 400 sites of which about 130 sites required Phase II ESA activities. The sites ranged from small antenna towers to large, complex international airports. Project involved considerable logistic planning to mobilize personnel across the country, familiarity with federal and provincial soil and groundwater remediation criteria, development of site-specific remediation options (including permafrost sites), and ongoing interaction with consultant team and Transport Canada/NAV CANADA.

Assessment of Rockcliffe Airbase Lands
Ottawa, Ontario, Canada

Project Manager to participate as part of a multi-disciplinary team assembled to conduct an existing conditions assessment related to potential redevelopment of the Rockcliffe site for residential land use. Completed a review of subsurface environmental investigation reports in terms of identifying potential development constraints associated with soil and groundwater conditions at the site. Presented recommended actions for evaluating issues of potential environmental concern including development of cost estimates to address these concerns.

Environmental Site Assessments
Eastern Ontario, Canada

Senior Reviewer for over 100 Phase I ESAs and over 50 Phase II ESAs completed by the Ottawa office. These projects included industrial, commercial and residential properties ranging from former coal gasification plants to microcircuit manufacturers. Projects have included an evaluation of permitting requirements related to waste-water discharges and air emissions as well as designated substances surveys.

Assessment of Diesel Fuel Release
Smiths Falls, Ontario, Canada

Project Manager for an environmental impact study which focused on a diesel fuel leak at a large industrial site and included the delineation of the areal extent of contamination, assessment with respect to current soil and groundwater remediation criteria and participation in the development and implementation of a site specific monitoring program and evaluation of remedial options.

Petroleum Hydrocarbon Releases
Eastern Ontario, Canada

Conducted subsurface investigations at numerous bulk storage, fuel dispensing and pipeline sites; development of groundwater and soil vapour monitoring programs; design and permitting of remedial measures including product recovery and excavation of contaminated soil; supervision and verification of site remediation.

Investigation of Salt Storage Facilities
Eastern Ontario, Canada

Project Manager for hydrogeological investigation relating to an assessment of poor groundwater quality adjacent to a salt dome near Almonte, Ontario. Project involved an evaluation of existing water quality data, development and implementation of a replacement well drilling program and long term groundwater quality monitoring program; project involved extensive consultation with municipal officials, affected homeowners and representatives from the Ontario Ministry of the Environment. Responsible for hydrogeological impact assessments relating to salt storage facilities near Eganville and Deep River, Ontario. Investigations included reconnaissance level geophysical surveys to characterize general dimension of the contaminant plumes followed by confirmation drilling, monitoring well installation and groundwater sampling programs to delineate the nature and extent of the contaminant plumes originating from the salt storage facilities and to differentiate between groundwater impacts from the salt storage facilities and that from nearby landfill sites.

PROJECT EXPERIENCE – AGGREGATE INDUSTRY

Stittsville Quarry
Township of Goulbourn (Ottawa), Ontario, Canada

Project Manager and Project Hydrogeologist retained by R.W. Tomlinson Limited to provide geoscience and engineering services and to co-ordinate a multi-disciplinary study team in the preparation of the supporting documents, for a submission to the Ontario Ministry of Natural Resources, in support of an application for a Category 2, Class “A” quarry license to extract limestone from below the established groundwater table. Assignment also included preparation and submission of applications to the Ontario Ministry of Environment for approval under Section 34 (Permit to Take Water) and Section 53 (Industrial Sewage Works) of the Ontario Water Resources Act. All required approvals were obtained and the quarry became operational in September 2002. Kris continues to be involved as Project Director on all environmental compliance monitoring requirements associated with the Ministry of Natural Resources aggregate license and the Ministry of Environment approvals under Section 34 and 53 on the Ontario Water Resources Act.

Rideau Road Quarries
City of Gloucester (Ottawa), Ontario, Canada

In 2003, Golder Associates was retained by R.W. Tomlinson Limited to provide geoscience and engineering services and to co-ordinate a multi-disciplinary study team in the preparation of the supporting documents, for a submission to the Ontario Ministry of Natural Resources, in support of an application for a Category 2, Class “A” quarry license for a parcel of land adjacent to Tomlinson’s existing quarry operations. The quarry was designed to extract limestone from below the established groundwater table for the production of high quality aggregate suitable for all types of asphalt pavements. Kris was Project Director and Project Hydrogeologist for this assignment and Golder Associates’ primary responsibilities included preparation of Level 1 and Level 2 Hydrogeological studies and Natural Environment evaluations of the property. Of particular significant for this project was the innovative approach develop by Golder Associates (in consultation with the Ministry of Natural Resources) for the purpose of addressing the presence of the American ginseng plant species and butternut trees on the property. The aggregate license was issued by the Ministry of Natural Resources in 2006.

Tatlock Quarry
Township of Lanark Highlands, Ontario, Canada

Project Director and Project Hydrogeologist retained in 2002 by Omya Canada Inc. to conduct Level 1 and Level 2 hydrogeological studies in support of an application to the Ministry of Natural Resources for a Category 2, Class “A” license for the extraction of calcitic marble (crystalline limestone) at the Omya Tatlock Quarry located northwest of Perth, Ontario. Golder Associates was also responsible for the preparation of an application for an industrial sewage works approval under Section 53 of the Ontario Water Resources Act. The quarry license application was issued by the Ministry of Natural Resources in April 2006 and the industrial sewage works approval was issued by the Ministry of Environment in March 2006. Kris continues to advise Omya Canada Inc. on matters related to environmental compliance monitoring and other issues pertaining to Ministry of Natural Resources aggregate license and the Ministry of Environment approvals under Section 34 and 53 on the Ontario Water Resources Act.

Dunvegan Quarry
Township of North Glengarry, Ontario, Canada

Project Hydrogeologist retained by the Township of North Glengarry to conducted a peer review of the hydrogeological aspects of the Cornwall Gravel Company Ltd. Dunvegan Quarry license application. The peer review focused on developing an opinion as to whether the Hydrogeological Assessment Report addressed the various components specified as part of a Hydrogeological Level 1 study and Hydrogeological Level 2 study in the context of a Category 2, Class “A” Quarry Below Water.

Klock Quarry
Aylmer, Quebec, Canada

Golder Associates was retained by Lafarge Canada Inc. to conduct the hydrogeological and natural environment assessments associated with obtaining approval for the extraction of limestone from a property situated adjacent to the existing Klock Quarry. Kris is responsible for overall project co-ordination and direction of a multi-disciplinary team.

Brechin Quarry
City of Kawartha Lakes,
Ontario, Canada

Project Manager and Project Hydrogeologist retained by R.W. Tomlinson Limited to complete the necessary hydrogeological, hydrological and ecological studies to support an application under the Aggregate Resources Act. The proposed Brechin Quarry is located in the former Township of Carden within the City of Kawartha Lakes, Ontario. The assignment involves a comprehensive assessment of the potential effects of quarry development on private water supply wells and an adjacent Provincially Significant Wetland and other natural environment (biological) features as well as consideration of the potential cumulative impacts associated with multiple quarry developments in the area of the proposed Tomlinson Brechin Quarry. This project involves extensive municipal and public consultation as well as interaction with representatives of the Ontario Ministry of Natural Resources and Ontario Ministry of Environment. The aggregate license was issued by the Ministry of Natural Resources in 2009.

TRAINING

Ministry of Environment Approvals Reform and Air Emission Summary and Dispersion Modelling Report Workshop
Ministry of the Environment, 1998

Site Specific Risk Assessment Seminar
Ottawa, 1998

Contaminated and Hazardous Waste Site Management
1997

Occupational Health and Safety Course
1989, 1995

Groundwater Protection in Ontario Conference
Toronto, 1991

Short Course in Dense, Immiscible Phase Liquid Contaminants (DNAPLs) in Porous and Fractured Media
Waterloo Centre for Groundwater Research, 1990

PROFESSIONAL AFFILIATIONS

Associate Member, Ontario Stone Sand and Gravel Association (OSSGA)

Member, Association of Groundwater Scientists and Engineers (N.G.W.A.)

Member, International Association of Hydrogeologists

Member, Ottawa Geotechnical Group, The Canadian Geotechnical Society

Member, Ontario Water Well Association

APPENDIX B

Borehole Logs (Current Investigation)

PROJECT: 21465813

RECORD OF BOREHOLE: 21-01

SHEET 1 OF 1

LOCATION: N 5041932.3 ;E 362439.4

BORING DATE: June 17, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

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

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE	139.72					
0	TOPSOIL	0.05					
	(SP) SAND, fine, some silt; light brown to brown; non-cohesive, moist, loose		1	SS	2		Cuttings
1			2	SS	5		
2			3	SS	7		
			4	SS	8		
3	(ML) sandy SILT; dark brown; non-cohesive, wet, loose	136.82 / 2.90	5	SS	3		
	(SP) SAND, fine, some silt; brown to light brown; non-cohesive, moist, loose	136.21 / 3.51					
4			6	SS	7		Bentonite Seal
5			7	SS	7		
	(SM) SILTY SAND, fine; light brown; non-cohesive, moist to wet, compact	134.54 / 5.18	8	SS	12	M	
6			9	SS	17		
7			10	SS	16		Silica Sand
8			11	SS	13		51 mm Diam. PVC #10 Slot Screen
			12	SS	10		
9	End of Borehole	130.58 / 9.14					

Note(s):

1. Water level measured in screen at elev. 132.34 m (7.38 mbgs) on July 31, 2021

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

RECORD OF BOREHOLE: 21-02

PROJECT: 21465813

SHEET 1 OF 1

LOCATION: N 5042238.2 ;E 362504.5

BORING DATE: June 17, 2021

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	147.05					
0	Power Auger, 200 mm Diam. (Hollow Stem)	(SP) SAND, fine, some silt; brown, contains rootlets; non-cohesive, moist, loose	0.00	1	SS	6		
		(SM/ML) SILTY SAND, fine to SILT, some sand; brown, mottled, contains organics; non-cohesive, moist, loose	146.44 / 0.61					
1				2	SS	3		
		- alternating moist and wet layers		3	SS	6	M	Cuttings and Bentonite
2				4	SS	5		
3		(ML) sandy SILT; brown grey; non-cohesive, wet, loose	144.08 / 2.97	5	SS	1	M	
4		- 100 mm clay layer		6	SS	2		Bentonite Seal
								Silica Sand
5				7	SS	1		51 mm Diam. PVC #10 Slot Screen
				8	SS	1		
6		End of Borehole	140.95 / 6.10					

Note(s):

1. Water level measured in screen at elev. 142.68 m (4.37 mbgs) on July 31, 2021

Chart columns (no data plotted): 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)

DEPTH SCALE 1 : 50

WSP GOLDER

LOGGED: JS

CHECKED: LEB

MIS-BHS 001 21465813.GPJ GAL-MIS.GDT 6/28/23 JEM

PROJECT: 21465813

RECORD OF BOREHOLE: 21-03

SHEET 1 OF 2

LOCATION: N 5041990.0 ;E 362041.0

BORING DATE: June 16, 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

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

Elev. / Depth (m)	Description
145.00	GROUND SURFACE
0.00	TOPSOIL - (SP) SAND, fine some silt; dark brown, contains organics; non-cohesive, moist, loose
0.15	(SP/SM) SAND, fine, some silt to SILTY SAND; brown; non-cohesive, moist, loose
142.56 / 2.44	(SP) SAND, fine to medium; light brown; non-cohesive, moist, compact
141.27 / 3.73	(SM) SILTY SAND, fine to coarse, trace gravel; light brown; non-cohesive, moist, compact - trace silt
139.67 / 5.33	(SM/ML) SILTY SAND, fine to fine SAND and SILT; light brown; non-cohesive, moist, compact - occasional layers of (SW) SAND, fine to coarse

Number	Type	Blows/0.30m	Additional Lab. Testing
1	SS	5	
2	SS	5	
3	SS	6	
4	SS	13	
5	SS	14	
6	SS	21	
7	SS	21	M
8	SS	26	
9	SS	26	
10	SS	30	
11	SS	43	M
12	SS	40	
13	SS	35	
14	SS	>50	

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50

WSP GOLDER

LOGGED: JS

CHECKED: LEB

PROJECT: 21465813

RECORD OF BOREHOLE: 21-03

LOCATION: N 5041990.0 ;E 362041.0

BORING DATE: June 16, 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
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	Power Auger 200 mm Diam. (Hollow Stem)			134.87	14	SS	>50				
		(SW) SAND, fine to coarse, some gravel; light brown, contains cobbles and boulders; non-cohesive, moist, dense		10.13							
11					15	SS	41				
				133.47	16	SS	>50				
		End of Borehole Auger Refusal		11.53							
12											
13											
14											
15											
16											
17											
18											
19											
20											

DEPTH SCALE

1 : 50

WSP GOLDER

LOGGED: JS

CHECKED: LEB

PROJECT: 21465813

RECORD OF BOREHOLE: 21-04

SHEET 1 OF 1

LOCATION: N 5041481.9 ;E 362567.5

BORING DATE: June 17, 2021

DATUM: Geodetic

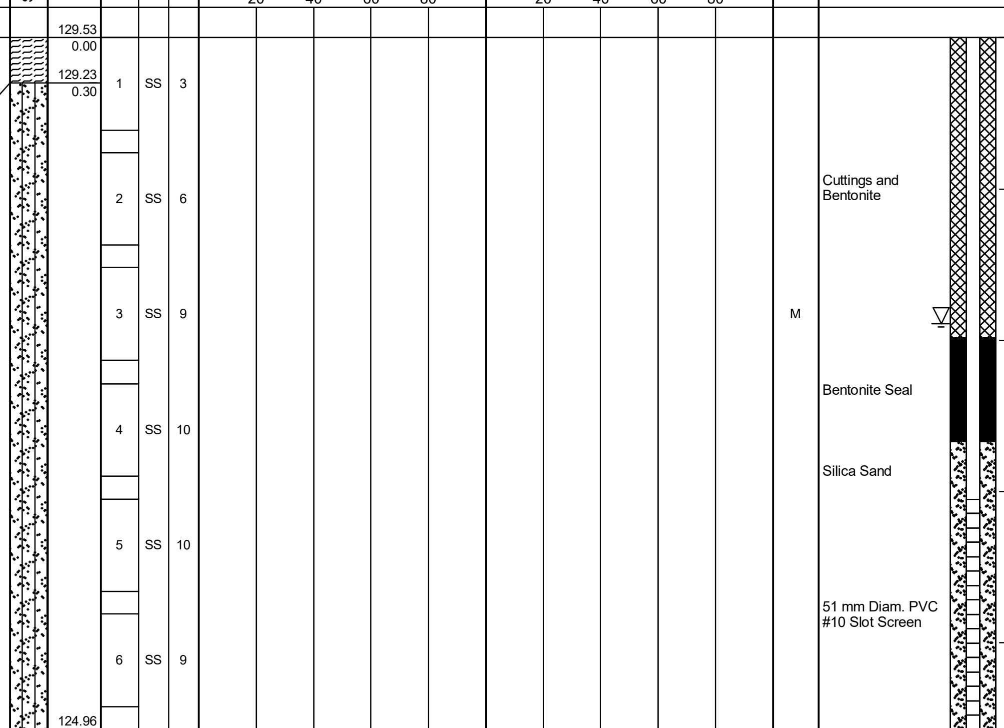
SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	129.53					
0	Power Auger, 200 mm Diam. (Hollow Stem)	TOPSOIL - (SP) SAND, fine, some silt; dark brown, contains organics; non-cohesive, moist, loose	0.00					Cuttings and Bentonite
		(SM/ML) SILTY SAND, fine to fine SAND and SILT; brown; non-cohesive, moist to wet, loose to compact	129.23 / 0.30	1	SS	3		
1				2	SS	6		
2		- wet		3	SS	9	M	
				4	SS	10		Bentonite Seal
3				5	SS	10		Silica Sand; 51 mm Diam. PVC #10 Slot Screen
4				6	SS	9		
		End of Borehole	124.96 / 4.57					

Note(s):

1. Water level measured in screen at elev. 127.64 m (1.89 mbgs) on July 31, 2021



DEPTH SCALE 1 : 50

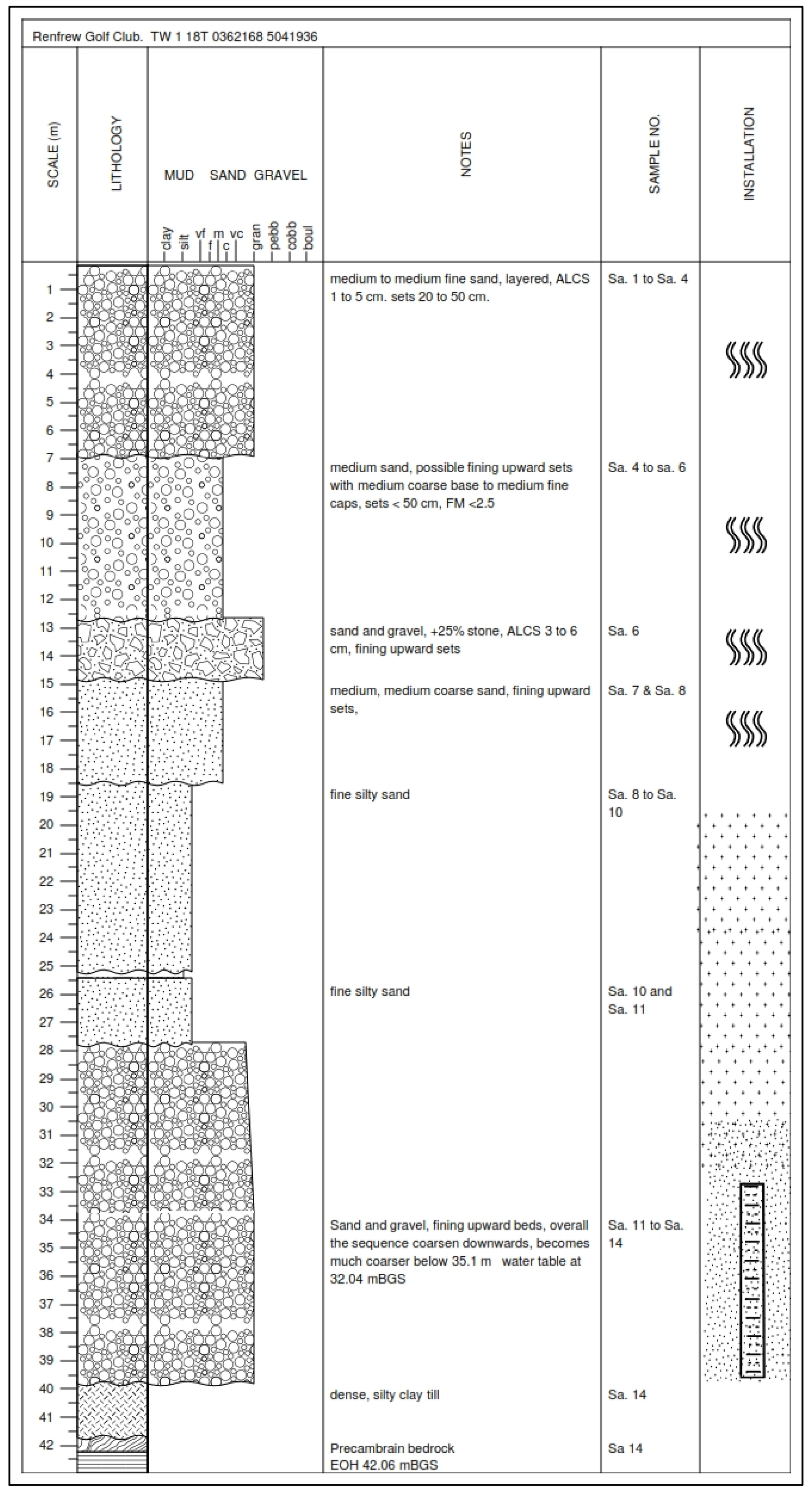
WSP GOLDER

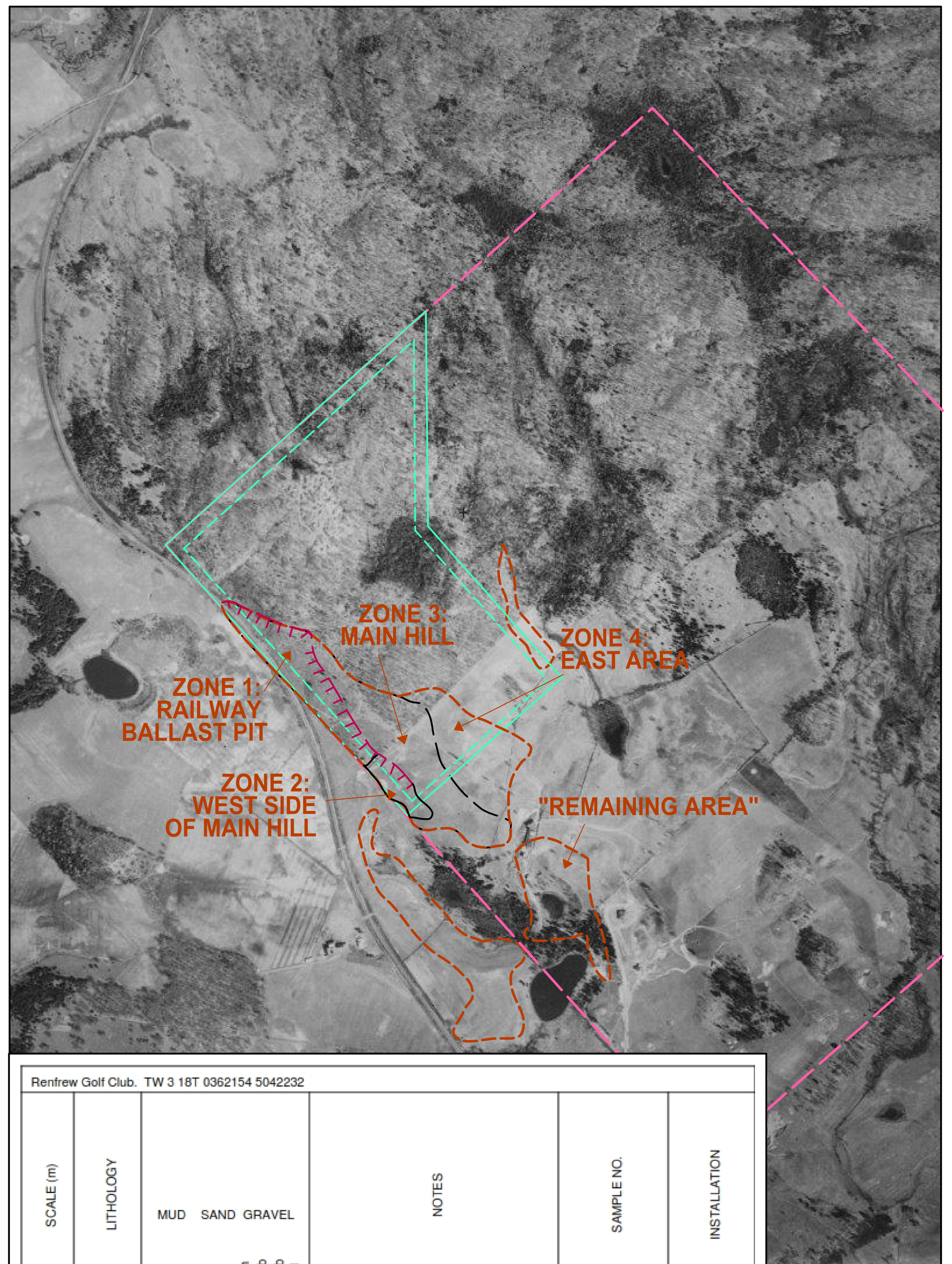
LOGGED: JS

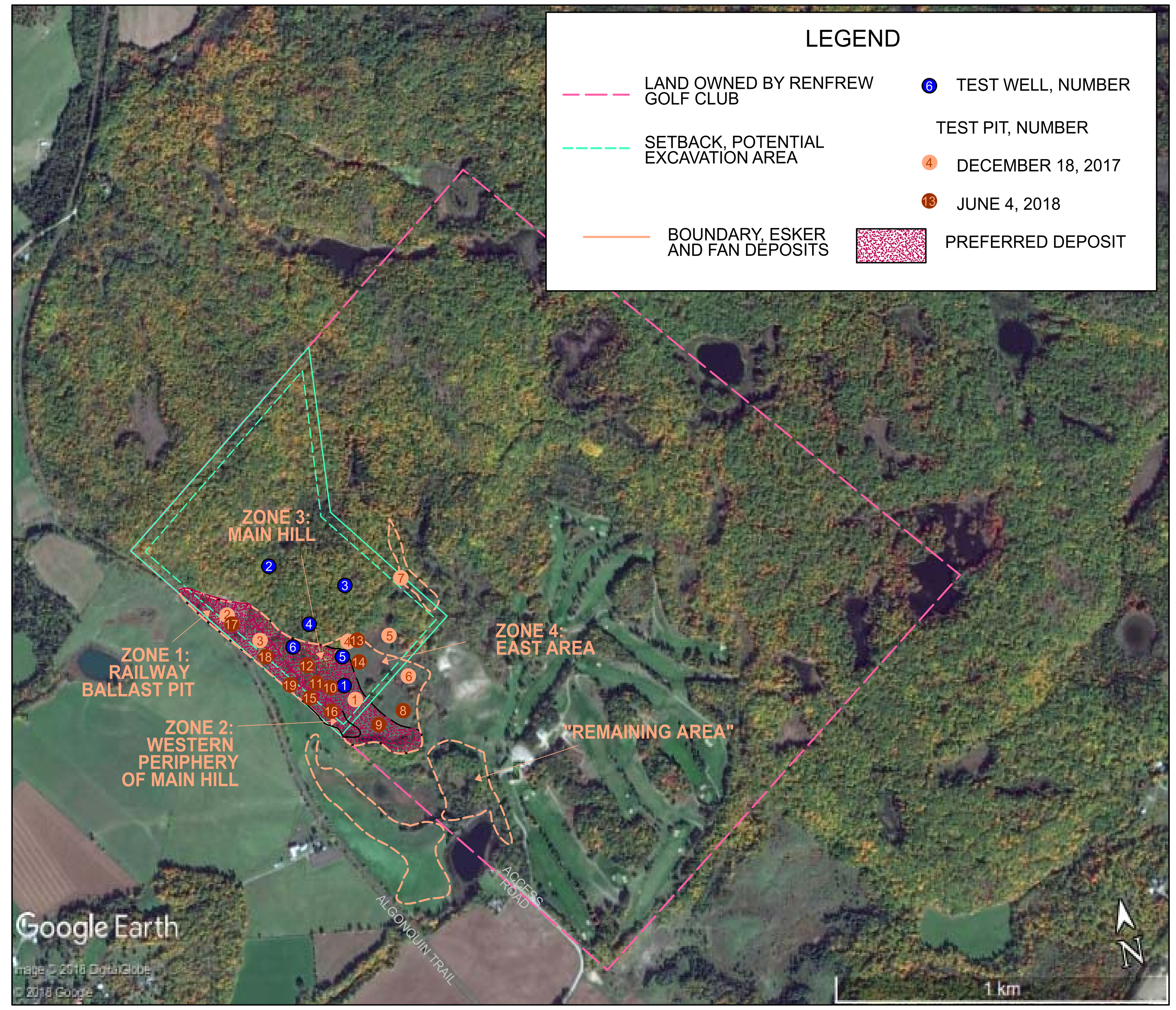
CHECKED: LEB

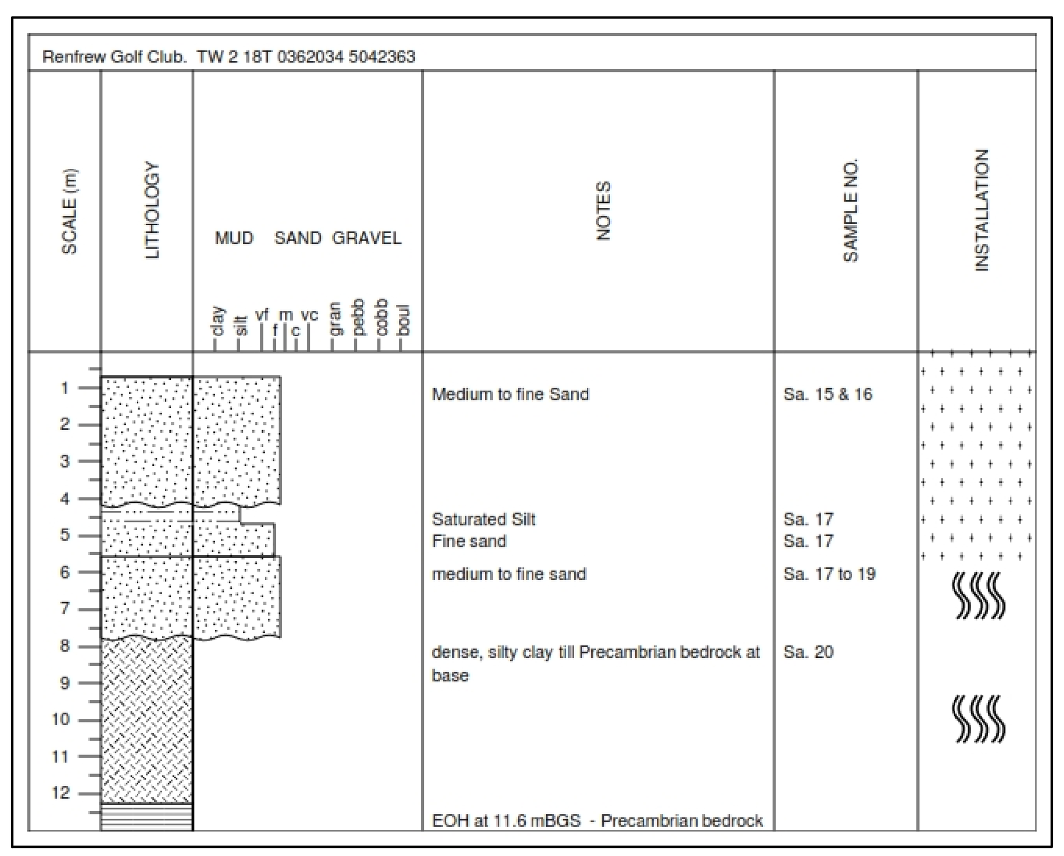
APPENDIX C

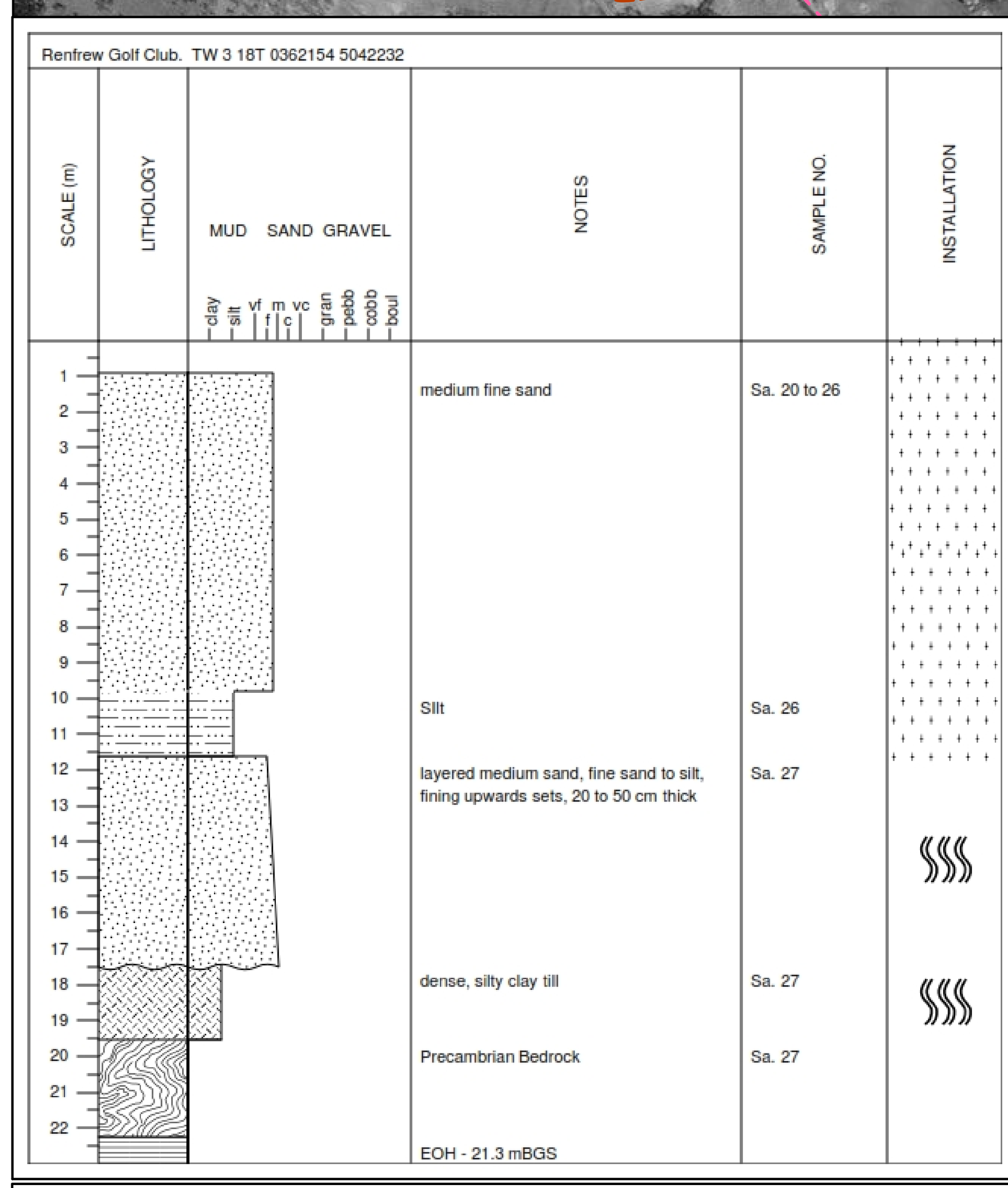
Borehole Logs and Test Pit Logs (GRI Inc. 2018)

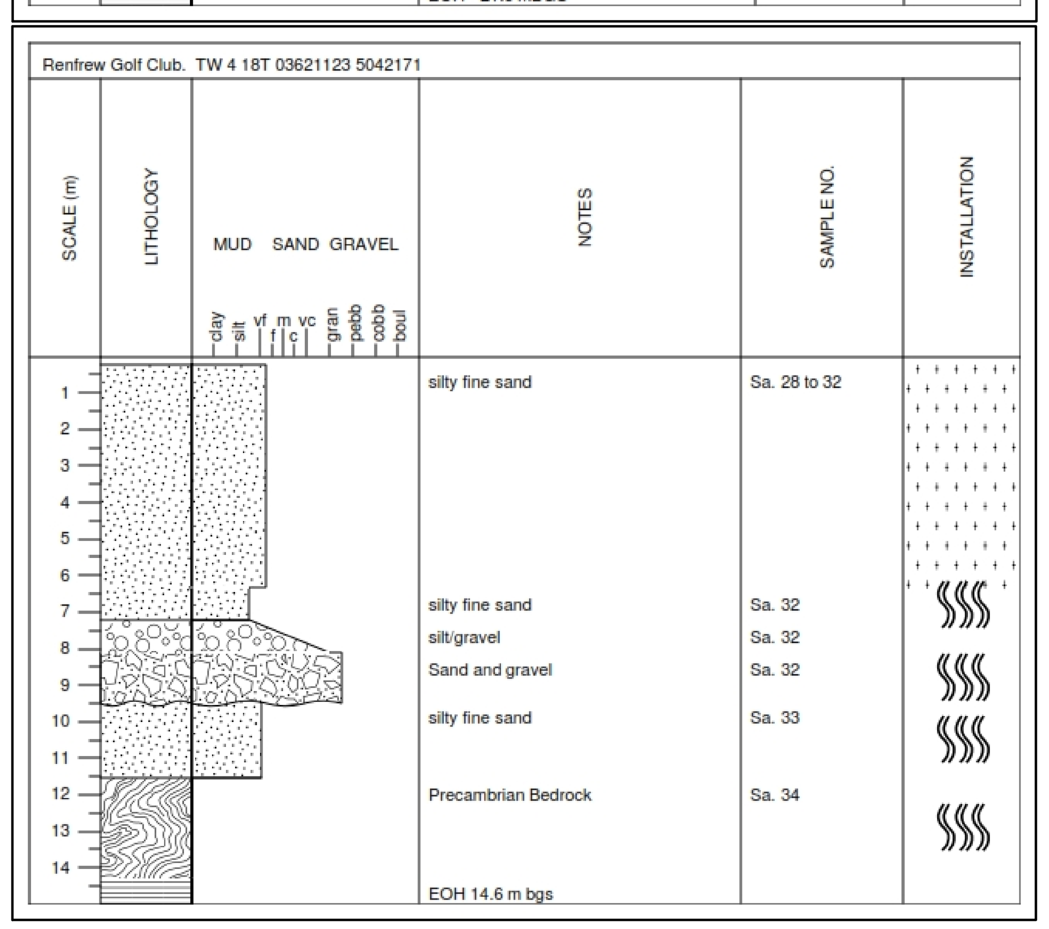


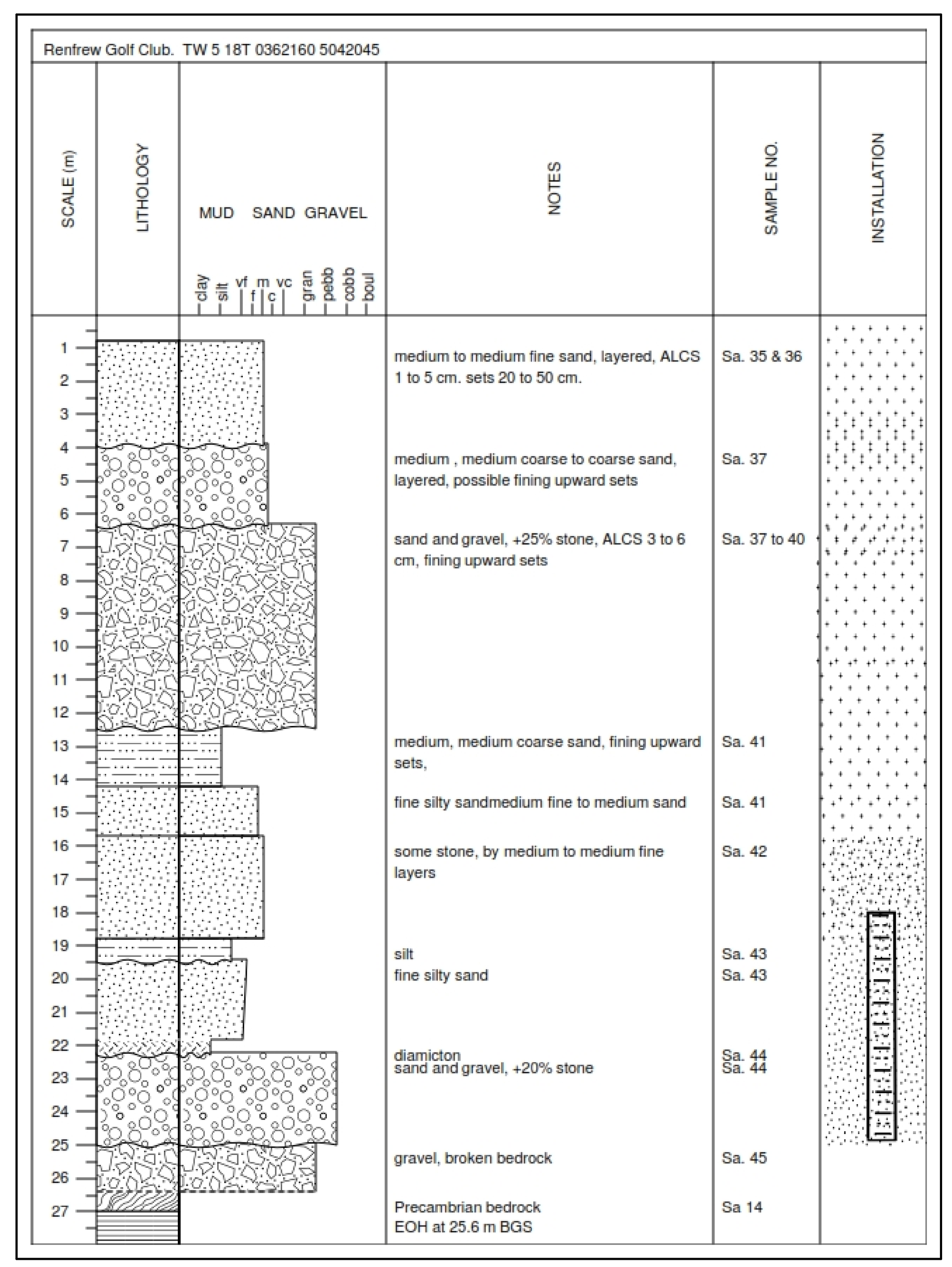


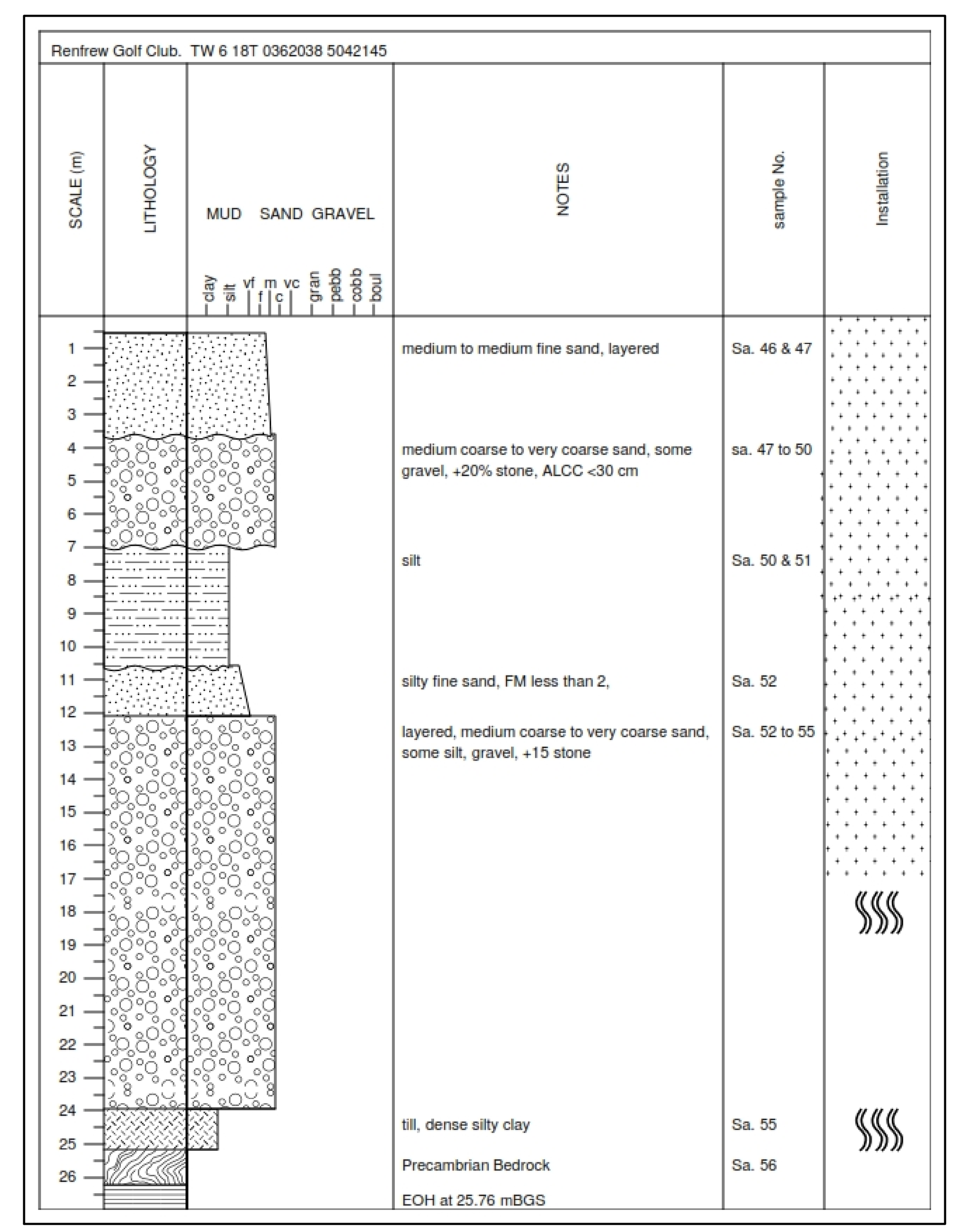












TEST PIT DETAILS

December 18, 2017 Test Pits

TEST PIT 1 - 0352167 5041941 S.E. 157 mASL

0 to 0.91 topsoil, medium dark brown, medium fine sand

0.91 to 5.79 sand, stone gravel, medium brown to grey, material is in layers/beds which are 0.5 to 1.7 m thick, FM 1 to 4, <20% stone, average large clast size (ALCS) <5 cm, Sample 1

TEST PIT 2 - 0361883 5042206 S.E. 161 mASL

-5.5 to 0 +30% stone, ALCS 10 to 15 cm, medium coarse to very coarse sand FM estimated to be well above 3, material is in foreset beds, Sample 2

0 to 5.5 hole excavated at base of pit face, +20% stone, medium coarse to coarse sand, ALCS <10 cm, FM 2 to 3, Sample 3

TEST PIT 3 - 0361967 5042124 S.E. 160 mASL

0 to 6.1 medium brown, medium to coarse sand, gravel, ALCS <15 cm, FM 1.5 to >3. Sample 4

TEST PIT 4 - 0362182 5042091 S.E. 167 mASL

0 to 6.01 medium brown, medium to fine sand, FM estimated <1.5. Appears to coarsen downwards. Sample 5

TEST PIT 5 - 0362327 5042078 S.E. 155 mASL

0 to 6.1 medium brown to grey, fine silty sand, FM <1.5, Sample 6

TEST PIT 6 - 0362345 5041977 S.E. 153 m ASL

0 to 6.1 medium brown to grey, fine silty sand, FM <1.5, Sample 7

TEST PIT 7 - 0362477 5042221 S.E. 154 mASL

0 to 8.0 layers of fine, medium, coarse to very coarse sand, gravel, pebbles and cobbles, layers 1- to 2.5 m thick, ALCS 10 to 20 cm, FM 1.5 to greater than 3.

June 4, 2018

TEST PIT 8 - 03623327 5041888

Test Pit 8 was excavated on the crest of the eastern hill, next to the road entering the site

0 to 6.0 layers of fine to silty fine sand, sampled; Sample 1

TEST PIT 9- 036640 5041862

Test Pit 9 was excavated on the southern periphery of the main hill

0 to 2.2 medium fine to very fine sand, oxidized
2.2 to 5.8 medium to medium coarse sand, pebbles, sampled; Sample 2

TEST PIT 10 - 0362147 5041959

Test Pit 10 was excavated at the top of the main hill. Excavated north of TW 1 and Test Pit 1

0 to 0.45 Topsoil
0.45 to 6.0 medium coarse to very coarse sand, pebbles, cobbles and boulders, ALCS 0.25, largest clast 0.92 m, sampled; Sample 3

TEST PIT 11 - 0362121 5042038

Test pit 11 was drilled north of Test Pit 10 just south of the tree line in the sumacs

0 to 0.60 Topsoil, red sand
0.60 to 5.5 medium to medium fine sand, coarsen below 4.8 m; sampled - Sample 4

TEST PIT 12 - 0362068 5042107

Test Pit 12 was dug between TW 5 and TW 6

0 to 5 fine silty sand
6 to 6.4 medium coarse to coarse sand, gravel - pebbles and cobbles, ALCS 2 to 7 cm, sampled - Sample 5

TEST PIT 13 - 0362171 5042105

Test Pit 13 was dug in same spot as TP 4

0 to 5 fine sand, sampled, Sample 6

TEST PIT 14 - 0362221 5042062

Test Pit 14 was excavated south of Test Pit 13, and is on the height of land

0 to 5 fine silty sand, sample; Sample 7

TEST PIT 15 - 0362128 5041926

Test Pit 15 was excavated west of TP 3 and was excavated on the western side of the main hill

0 to 5.5 +30% sand and gravel, cobbles and boulders. ALCS 20 cm; largest clast 1.5 m, sampled, Sample 8

TEST PIT 16 - 0362144 5041887

Test Pit 16 was excavated south of Test Pit 15, and is on the western side of the main hill

0 to 5.5 +30% sand and gravel, cobbles and boulders, ALCS 20 cm, largest clast 1.2 m, sampled; Sample 9

TEST PIT 17 - 0361896 5042178

Test Pit 17 was excavated 15 m south of TP 2 and is on the floor of old ballast pit

0 to 4.8 fine silty sand
4.8 to 6.5 sand and gravel, +30% stone, medium coarse sand matrix, ALCS 10 cm, largest clast 40 cm, sampled, Sample 10

FIGURE 1:

SITE CHARACTERISTICS

CLIENT: MILLER GROUP INC.
PROJ. NO.: 17-023
DATE: JUNE 2018

GRI Inc.
Oxford Mills, ON K0G 1S0
T - (613) 258-2954

APPENDIX D

Well Response Test Analyses

HVORSLEV SLUG TEST ANALYSIS
FALLING HEAD TEST 21-01

INTERVAL (metres below ground surface)

Top of Interval = **7.62**
Bottom of Interval = **9.14**

$$K = \frac{r_c^2}{2L_e} ln\left[\frac{L_e}{2R_e} + \sqrt{1 + \left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$

where K = (m/sec)

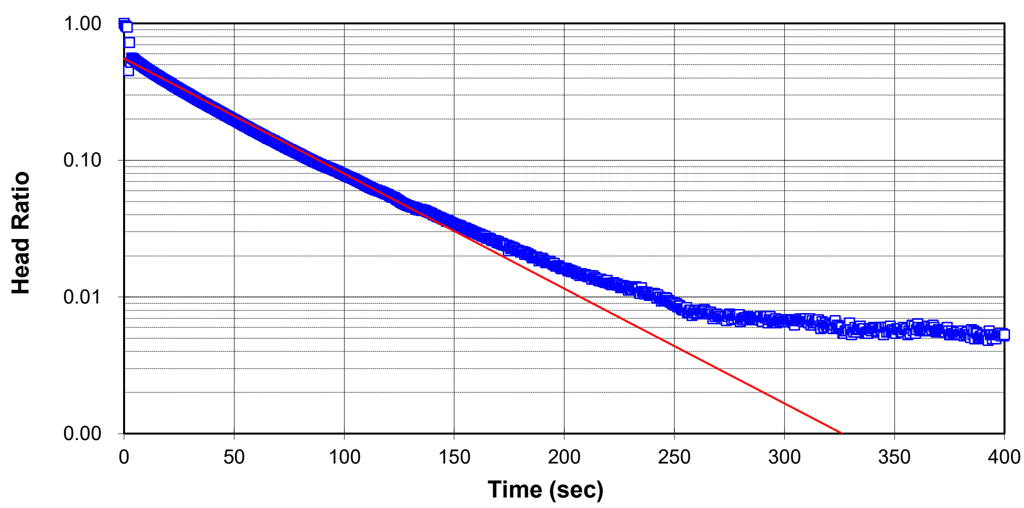
where:
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS

r_c =	0.025
R_e =	0.10
L_e =	1.5
t_1 =	3.5
t_2 =	114
h_1/h_0 =	0.52
h_2/h_0 =	0.06

RESULTS

K=	1E-05	m/sec
K=	1E-03	cm/sec



Project Name: Renfrew
Project No.: 21465813
Test Date: 2021-06-23

Analysis By: SPS
Checked By: LEB
Analysis Date: 2021-06-24

Golder Associates Ltd.

HVORSLEV SLUG TEST ANALYSIS
FALLING HEAD TEST 21-02

INTERVAL (metres below ground surface)

Top of Interval =	**4.57**
Bottom of Interval =	**6.10**

$$K = \frac{r_c^2}{2L_e} ln\left[\frac{L_e}{2R_e} + \sqrt{1 + \left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$

where K = (m/sec)

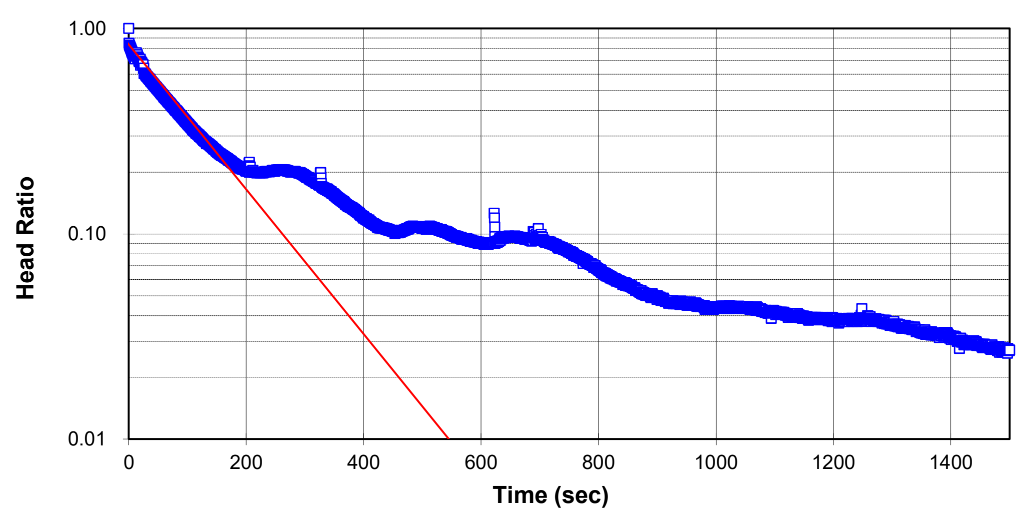
where:
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS

r_c =	0.025
R_e =	0.10
L_e =	1.5
t_1 =	1
t_2 =	143.5
h_1/h_0 =	0.83
h_2/h_0 =	0.26

RESULTS

K=	5E-06	m/sec
K=	5E-04	cm/sec



Project Name: Renfrew
Project No.: 21465813
Test Date: 2021-06-23

Analysis By: SPS
Checked By: LEB
Analysis Date: 2021-06-24

Golder Associates Ltd.

HVORSLEV SLUG TEST ANALYSIS
RISING HEAD TEST 21-04

INTERVAL (metres below ground surface)

Top of Interval = 3.05
Bottom of Interval = 4.57

$$K = \frac{r_c^2}{2L_e} ln\left[\frac{L_e}{2R_e} + \sqrt{1 + \left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$

where K = (m/sec)

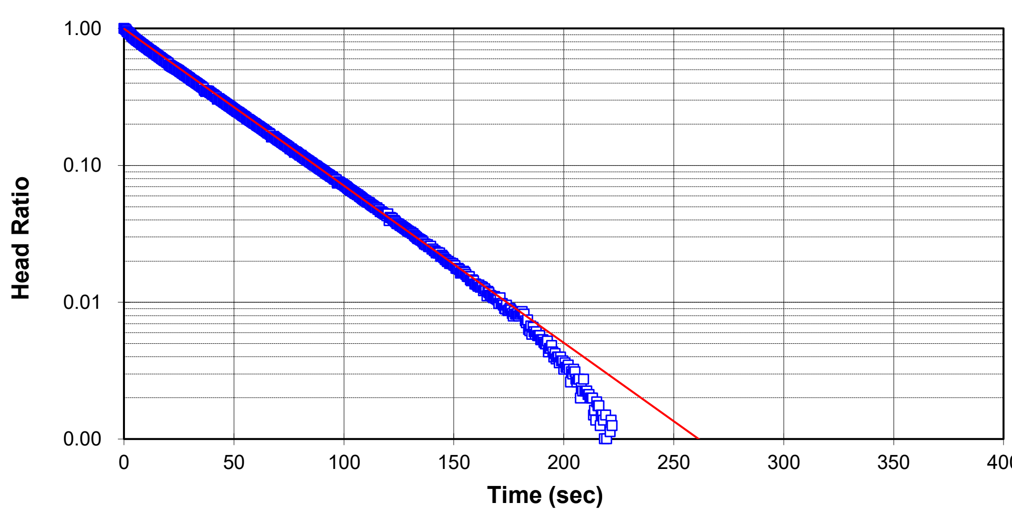
where:
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS

r_c =	0.025
R_e =	0.10
L_e =	1.5
t_1 =	0
t_2 =	150
h_1/h_0 =	1.00
h_2/h_0 =	0.02

RESULTS

K=	2E-05	m/sec
K=	2E-03	cm/sec



Project Name: Renfrew
Project No.: 21465813
Test Date: 2021-06-23

Analysis By: SPS
Checked By: LEB
Analysis Date: 2021-06-24

APPENDIX E

Water Balance Calculations

WATER HOLDING CAPACITY...75 MM												
Ottawa IntlAWATERBUDGETMEANSFORTHEPERIOD1939-2019DC20492												
LAT.... 45.32	WATER HOLDING CAPACITY...100 MM			HEAT INDEX... 36.68								
LONG... 75.67	LOWER ZONE............... 60 MM			A............ 1.079								
DATE		TEMP (C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31	1	-10.7	62	11	14	0	0	0	24	84	74	295
28	2	-9	56	11	16	1	1	0	26	113	74	350
31	3	-2.9	65	31	77	5	5	0	102	70	75	416
30	4	5.7	73	68	75	31	31	0	112	0	75	490
31	5	13.1	76	76	0	80	80	0	14	0	57	566
30	6	18.3	85	85	0	116	107	-9	5	0	30	651
31	7	20.9	88	88	0	136	104	-32	3	0	11	739
31	8	19.6	84	84	0	118	83	-34	1	0	11	823
30	9	14.8	82	82	0	75	65	-10	4	0	24	905
31	10	8.3	77	77	0	37	36	-1	14	0	51	77
30	11	1.2	76	59	8	10	10	0	38	9	70	154
31	12	-6.9	79	26	14	1	1	0	36	48	74	233
AVE		6	904	698	204	610	523	-86	379			

WATER HOLDING CAPACITY...100 MM												
Ottawa IntlAWATERBUDGETMEANSFORTHEPERIOD1939-2019DC20492												
LAT.... 45.32	WATER HOLDING CAPACITY...100 MM			HEAT INDEX... 36.68								
LONG... 75.67	LOWER ZONE............... 60 MM			A............ 1.079								
DATE		TEMP (C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31	1	-10.7	62	11	14	0	0	0	24	84	98	295
28	2	-9	56	11	16	1	1	0	26	113	98	350
31	3	-2.9	65	31	77	5	5	0	101	70	100	416
30	4	5.7	73	68	75	31	31	0	112	0	100	490
31	5	13.1	76	76	0	80	80	0	14	0	81	566
30	6	18.3	85	85	0	116	112	-4	5	0	49	651
31	7	20.9	88	88	0	136	114	-22	3	0	20	739
31	8	19.6	84	84	0	118	87	-31	1	0	16	823
30	9	14.8	82	82	0	75	65	-10	3	0	30	905
31	10	8.3	77	77	0	37	36	-1	9	0	63	77
30	11	1.2	76	59	8	10	10	0	31	9	89	154
31	12	-6.9	79	26	14	1	1	0	32	48	97	233
AVE		6	904	698	204	610	542	-68	361			

WATER HOLDING CAPACITY...150 MM												
Ottawa IntlAWATERBUDGETMEANSFORTHEPERIOD1939-2019DC20492												
LAT.... 45.32	WATER HOLDING CAPACITY...150 MM			HEAT INDEX... 36.68								
LONG... 75.67	LOWER ZONE............... 90 MM			A............ 1.079								
DATE		TEMP (C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31	1	-10.7	62	11	14	0	0	0	21	84	142	295
28	2	-9	56	11	16	1	1	0	24	113	144	350
31	3	-2.9	65	31	77	5	5	0	98	70	149	416
30	4	5.7	73	68	75	31	31	0	111	0	150	490
31	5	13.1	76	76	0	80	80	0	14	0	131	566
30	6	18.3	85	85	0	116	116	0	5	0	96	651
31	7	20.9	88	88	0	136	127	-9	3	0	54	739
31	8	19.6	84	84	0	118	98	-20	1	0	39	823
30	9	14.8	82	82	0	75	67	-8	2	0	52	905
31	10	8.3	77	77	0	37	36	-1	7	0	86	77
30	11	1.2	76	59	8	10	10	0	20	9	123	154
31	12	-6.9	79	26	14	1	1	0	24	48	139	233
AVE		6	904	698	204	610	572	-38	330			

WATER HOLDING CAPACITY...250 MM												
Ottawa IntlAWATERBUDGETMEANSFORTHEPERIOD1939-2019DC20492												
LAT.... 45.32	WATER HOLDING CAPACITY...250 MM			HEAT INDEX... 36.68								
LONG... 75.67	LOWER ZONE............... 150 MM			A............ 1.079								
DATE		TEMP (C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31	1	-10.7	62	11	14	0	0	0	17	84	230	295
28	2	-9	56	11	16	1	1	0	21	113	235	350
31	3	-2.9	65	31	77	5	5	0	91	70	247	416
30	4	5.7	73	68	75	31	31	0	109	0	250	490
31	5	13.1	76	76	0	80	80	0	14	0	231	566
30	6	18.3	85	85	0	116	116	0	5	0	196	651
31	7	20.9	88	88	0	136	135	-1	3	0	146	739
31	8	19.6	84	84	0	118	111	-7	1	0	118	823
30	9	14.8	82	82	0	75	72	-4	2	0	127	905
31	10	8.3	77	77	0	37	37	0	6	0	161	77
30	11	1.2	76	59	8	10	10	0	16	9	202	154
31	12	-6.9	79	26	14	1	1	0	18	48	224	233
AVE		6	904	698	204	610	599	-12	303			

WATER HOLDING CAPACITY...300 MM												
Ottawa IntlAWATERBUDGETMEANSFORTHEPERIOD1939-2019DC20492												
LAT.... 45.32		WATER HOLDING CAPACITY...300 MM				HEAT INDEX... 36.68						
LONG... 75.67		LOWER ZONE............... 180 MM			A............ 1.079							
DATE		TEMP (C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31	1	-10.7	62	11	14	0	0	0	16	84	276	295
28	2	-9	56	11	16	1	1	0	20	113	282	350
31	3	-2.9	65	31	77	5	5	0	89	70	296	416
30	4	5.7	73	68	75	31	31	0	108	0	300	490
31	5	13.1	76	76	0	80	80	0	14	0	281	566
30	6	18.3	85	85	0	116	116	0	5	0	246	651
31	7	20.9	88	88	0	136	136	0	3	0	195	739
31	8	19.6	84	84	0	118	114	-4	1	0	164	823
30	9	14.8	82	82	0	75	73	-3	2	0	171	905
31	10	8.3	77	77	0	37	37	0	6	0	205	77
30	11	1.2	76	59	8	10	10	0	16	9	247	154
31	12	-6.9	79	26	14	1	1	0	17	48	269	233
AVE		6	904	698	204	610	604	-7	297			

						AGRC-H			Community/Infrastructure			CUM1-1			CUT1		
						WHC	75 mm		WHC	75 mm		WHC	100 mm		WHC	100 mm	
						Total Area (m^2)	95		Total Area (m^2)	54		Total Area (m^2)	92651		Total Area (m^2)	22559	
						Infiltration Factor	0.28		Infiltration Factor	0.79		Infiltration Factor	0.67		Infiltration Factor	0.70	
	Month	Days	Temp	Precipitation	Potential Evapotranspiration	Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus	
			(°C)	(mm)	(mm)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)
1	January	31	-10.7	62	0	1	24	2	1	24	1	1	24	2,224	1	24	541
2	February	28	-9.0	56	1	1	26	2	1	26	1	1	26	2,409	1	26	587
3	March	31	-2.9	65	5	5	102	10	5	102	6	5	101	9,358	5	101	2,278
4	April	30	5.7	73	31	31	112	11	31	112	6	31	112	10,377	31	112	2,527
5	May	31	13.1	76	80	80	14	1	80	14	1	80	14	1,297	80	14	316
6	June	30	18.3	85	116	107	5	0	107	5	0	112	5	463	112	5	113
7	July	31	20.9	88	136	104	3	0	104	3	0	114	3	278	114	3	68
8	August	31	19.6	84	118	83	1	0	83	1	0	87	1	93	87	1	23
9	September	30	14.8	82	75	65	4	0	65	4	0	65	3	278	65	3	68
10	October	31	8.3	77	37	36	14	1	36	14	1	36	9	834	36	9	203
11	November	30	1.2	76	10	10	38	4	10	38	2	10	31	2,872	10	31	699
12	December	31	-6.9	79	1	1	36	3	1	36	2	1	32	2,965	1	32	722
	Total			***903***	***610***	***524***	***379***	***36***	***524***	***379***	***21***	***543***	***361***	***33,447***	***543***	***361***	***8,144***
	Average		***6.0***														

Note: The Surplus values in (mm) are calculated using rainfall, melt and Actual Evapotranspiration

P = ET + R + I + S

FOD 3-1			FOD 3-1			FOD 5-2			FOM 6-2			MAS2			Mixed Treed		
WHC	250 mm		WHC	300 mm		WHC	300 mm		WHC	250 mm		WHC	Precip-PET		WHC	300 mm	
Total Area (m^2)	61723		Total Area (m^2)	28550		Total Area (m^2)	179657		Total Area (m^2)	6098		Total Area (m^2)	5357		Total Area (m^2)	483	
Infiltration Factor	0.72		Infiltration Factor	0.71		Infiltration Factor	0.73		Infiltration Factor	0.91		Infiltration Factor	0.00		Infiltration Factor	0.91	
Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus	
(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)
1	17	1,049	1	16	457	1	16	2,875	1	17	104	0	62	332	1	16	8
1	21	1,296	1	20	571	1	20	3,593	1	21	128	1	55	295	1	20	10
5	91	5,617	5	89	2,541	5	89	15,989	5	91	555	5	60	321	5	89	43
31	109	6,728	31	108	3,083	31	108	19,403	31	109	665	31	42	225	31	108	52
80	14	864	80	14	400	80	14	2,515	80	14	85	80	-4	-21	80	14	7
116	5	309	116	5	143	116	5	898	116	5	30	116	-31	-166	116	5	2
135	3	185	136	3	86	136	3	539	135	3	18	136	-48	-257	136	3	1
111	1	62	114	1	29	114	1	180	111	1	6	118	-34	-182	114	1	0
72	2	123	73	2	57	73	2	359	72	2	12	75	7	37	73	2	1
37	6	370	37	6	171	37	6	1,078	37	6	37	37	40	214	37	6	3
10	16	988	10	16	457	10	16	2,875	10	16	98	10	66	354	10	16	8
1	18	1,111	1	17	485	1	17	3,054	1	18	110	1	78	418	1	17	8
600	***303***	***18,702***	***605***	***297***	***8,479***	***605***	***297***	***53,358***	***600***	***303***	***1,848***	***610***	***293***	***1,570***	***605***	***297***	***144***

RES/REC			SWD2-2								
WHC	75 mm		WHC	Precip-PET							
Total Area (m^2)	6183		Total Area (m^2)	1209							
Infiltration Factor	0.60		Infiltration Factor	0.60							
Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Total Surplus	Cummulative Surplus	Total Surplus (Runoff and Infiltration)		Total Infiltration	
(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(m^3)	(m^3)	(L/s)	(L/min)	(m^3)	(L/s)
1	24	148	0	62	75	**7,816**	**7,816**	2.9	175	5,276	2.0
1	26	161	1	55	66	**9,119**	**16,935**	3.8	226	6,240	2.6
5	102	631	5	60	73	**37,421**	**54,357**	14.0	838	26,317	9.8
31	112	693	31	42	51	**43,820**	**98,176**	16.9	1,014	30,976	12.0
80	14	87	80	-4	-5	**5,547**	**103,723**	2.1	124	3,960	1.5
107	5	31	116	-31	-37	**1,787**	**105,510**	0.7	41	1,393	0.5
104	3	19	136	-48	-58	**879**	**106,389**	0.3	20	814	0.3
83	1	6	118	-34	-41	**175**	**106,564**	0.1	4	258	0.1
65	4	25	75	7	8	**970**	**107,533**	0.4	22	656	0.3
36	14	87	37	40	48	**3,047**	**110,581**	1.1	68	1,991	0.7
10	38	235	10	66	80	**8,670**	**119,250**	3.3	201	5,826	2.2
1	36	223	1	78	94	**9,195**	**128,446**	3.4	206	6,157	2.3
524	***379***	***2,343***	***610***	***293***	***354***	***128,446***		***49***	***2,941***	***89,865***	***34***

Total Runoff		Cummulative Runoff	Pit Volume	Comment
(m^3)	(L/s)	(m^3)	(m^3)	
2,540	0.95	**2,540**	**0**	Volume of Operations Pit Lake at 130 mASL
2,879	1.19	**5,419**	**0**	Volume of Operations Pit Lake between 130 and 131 mASL
11,104	4.15	**16,523**	**0**	Volume of Operations Pit Lake at 131 mASL
12,844	4.96	**29,367**		
1,587	0.59	**30,954**		
394	0.15	**31,348**		
65	0.02	**31,412**		
-84	-0.03	**31,329**		
313	0.12	**31,642**		
1,056	0.39	**32,699**		
2,843	1.10	**35,542**		
3,039	1.13	**38,581**		
38,581	***15***			

						AGRC-H			Community/Infrastructure			CUM1-1		
						WHC	75 mm		WHC	75 mm		WHC	100 mm	
						Total Area (m^2)	95		Total Area (m^2)	54		Total Area (m^2)	3311	
						Infiltration Factor	0.28		Infiltration Factor	0.79		Infiltration Factor	0.65	
	Month	Days	Temp	Precipitation	Potential Evapotranspiration	Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus	
			(°C)	(mm)	(mm)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)
1	January	31	-10.7	62	0	1	24	2	1	24	1	1	24	79
2	February	28	-9.0	56	1	1	26	2	1	26	1	1	26	86
3	March	31	-2.9	65	5	5	102	10	5	102	6	5	101	334
4	April	30	5.7	73	31	31	112	11	31	112	6	31	112	371
5	May	31	13.1	76	80	80	14	1	80	14	1	80	14	46
6	June	30	18.3	85	116	107	5	0	107	5	0	112	5	17
7	July	31	20.9	88	136	104	3	0	104	3	0	114	3	10
8	August	31	19.6	84	118	83	1	0	83	1	0	87	1	3
9	September	30	14.8	82	75	65	4	0	65	4	0	65	3	10
10	October	31	8.3	77	37	36	14	1	36	14	1	36	9	30
11	November	30	1.2	76	10	10	38	4	10	38	2	10	31	103
12	December	31	-6.9	79	1	1	36	3	1	36	2	1	32	106
	Total			***903***	***610***	***524***	***379***	***36***	***524***	***379***	***21***	***543***	***361***	***1,195***
	Average		***6.0***											

Note: The Surplus values in (mm) are calculated using rainfall, melt and Actual Evapotranspiration
P = ET + R + I + S

CUT1			FOD 3-1			FOD 5-2			FOM 6-2			MAS2			Mixed Treed		
WHC	100 mm		WHC	250 mm		WHC	300 mm		WHC	250 mm		WHC	Precip-PET		WHC	300 mm	
Total Area (m^2)	6944		Total Area (m^2)	37921		Total Area (m^2)	25212		Total Area (m^2)	2223		Total Area (m^2)	5357		Total Area (m^2)	483	
Infiltration Factor	0.65		Infiltration Factor	0.72		Infiltration Factor	0.90		Infiltration Factor	0.91		Infiltration Factor	0.00		Infiltration Factor	0.91	
Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus	
(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)
1	24	167	1	17	645	1	16	403	1	17	38	0	62	332	1	16	8
1	26	181	1	21	796	1	20	504	1	21	47	1	55	295	1	20	10
5	101	701	5	91	3,451	5	89	2,244	5	91	202	5	60	321	5	89	43
31	112	778	31	109	4,133	31	108	2,723	31	109	242	31	42	225	31	108	52
80	14	97	80	14	531	80	14	353	80	14	31	80	-4	-21	80	14	7
112	5	35	116	5	190	116	5	126	116	5	11	116	-31	-166	116	5	2
114	3	21	135	3	114	136	3	76	135	3	7	136	-48	-257	136	3	1
87	1	7	111	1	38	114	1	25	111	1	2	118	-34	-182	114	1	0
65	3	21	72	2	76	73	2	50	72	2	4	75	7	37	73	2	1
36	9	62	37	6	228	37	6	151	37	6	13	37	40	214	37	6	3
10	31	215	10	16	607	10	16	403	10	16	36	10	66	354	10	16	8
1	32	222	1	18	683	1	17	429	1	18	40	1	78	418	1	17	8
543	***361***	***2,507***	***600***	***303***	***11,490***	***605***	***297***	***7,488***	***600***	***303***	***673***	***610***	***293***	***1,570***	***605***	***297***	***144***

RES/REC			SWD2-2			Extraction Area - Exposed Bedrock			Extraction Area - Below Water						
WHC	75 mm		WHC	Precip-PET		WHC	Precip-PET		WHC	Precip-PET					
Total Area (m^2)	1852		Total Area (m^2)	1209		Total Area (m^2)	193592		Total Area (m^2)	126367					
Infiltration Factor	0.60		Infiltration Factor	0.60		Infiltration Factor	1.00		Infiltration Factor	1.00					
Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Total Surplus	Cummulative Surplus	Total Surplus (Runoff and Infiltration)	
(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(m^3)	(m^3)	(L/s)	(L/min)
1	24	44	0	62	75	0	62	12,003	0	62	7,835	**21,632**	**21,632**	8.1	485
1	26	48	1	55	66	1	55	10,648	1	55	6,950	**19,634**	**41,267**	8.1	487
5	102	189	5	60	73	5	60	11,616	5	60	7,582	**26,771**	**68,038**	10.0	600
31	112	207	31	42	51	31	42	8,131	31	42	5,307	**22,238**	**90,276**	8.6	515
80	14	26	80	-4	-5	80	-4	-774	80	-4	-505	**-213**	**90,063**	-0.1	-5
107	5	9	116	-31	-37	116	-31	-6,001	116	-31	-3,917	**-9,732**	**80,331**	-3.8	-225
104	3	6	136	-48	-58	136	-48	-9,292	136	-48	-6,066	**-15,439**	**64,892**	-5.8	-346
83	1	2	118	-34	-41	118	-34	-6,582	118	-34	-4,296	**-11,024**	**53,869**	-4.1	-247
65	4	7	75	7	8	75	7	1,355	75	7	885	**2,456**	**56,325**	0.9	57
36	14	26	37	40	48	37	40	7,744	37	40	5,055	**13,576**	**69,901**	5.1	304
10	38	70	10	66	80	10	66	12,777	10	66	8,340	**22,998**	**92,899**	8.9	532
1	36	67	1	78	94	1	78	15,100	1	78	9,857	**27,029**	**119,928**	10.1	605
524	***379***	***702***	***610***	***293***	***354***	***610***	***293***	***56,722***	***610***	***293***	***37,025***	***119,928***		***46***	***2,762***

Total Infiltration		Total Runoff		Cummulative Runoff	Pit Volume	Comment
(m^3)	(L/s)	(m^3)	(L/s)	(m^3)	(m^3)	
20,939	7.8	693	0.26	**648,479**	**647,786**	Volume of Operations Pit Lake at 130 mASL
18,920	7.8	714	0.30	**649,193**	**99,265**	Volume of Operations Pit Lake between 130 and 131 mASL
24,762	9.2	2,009	0.75	**651,203**	**747,051**	Volume of Operations Pit Lake at 131 mASL
20,042	7.7	2,195	0.85	**653,398**		
-438	-0.2	226	0.08	**653,624**		
-9,640	-3.7	-92	-0.04	**653,532**		
-15,212	-5.7	-227	-0.08	**653,305**		
-10,843	-4.0	-181	-0.07	**653,124**		
2,374	0.9	82	0.03	**653,206**		
13,219	4.9	358	0.13	**653,563**		
22,256	8.6	742	0.29	**654,305**		
26,190	9.8	838	0.31	**655,144**		
112,570	***43***	***7,358***	***3***			

Table E-4
Rehabilitation Condition Calculation

						AGRC-H			Community/Infrastructure			CUM1-1		
						WHC	75 mm		WHC	75 mm		WHC	100 mm	
						Total Area (m^2)	95		Total Area (m^2)	54		Total Area (m^2)	3311	
						Infiltration Factor	0.28		Infiltration Factor	0.79		Infiltration Factor	0.65	
	Month	Days	Temp	Precipitation	Potential Evapotranspiration	Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus	
			(°C)	(mm)	(mm)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)
1	January	31	-10.7	62	0	1	24	2	1	24	1	1	24	79
2	February	28	-9.0	56	1	1	26	2	1	26	1	1	26	86
3	March	31	-2.9	65	5	5	102	10	5	102	6	5	101	334
4	April	30	5.7	73	31	31	112	11	31	112	6	31	112	371
5	May	31	13.1	76	80	80	14	1	80	14	1	80	14	46
6	June	30	18.3	85	116	107	5	0	107	5	0	112	5	17
7	July	31	20.9	88	136	104	3	0	104	3	0	114	3	10
8	August	31	19.6	84	118	83	1	0	83	1	0	87	1	3
9	September	30	14.8	82	75	65	4	0	65	4	0	65	3	10
10	October	31	8.3	77	37	36	14	1	36	14	1	36	9	30
11	November	30	1.2	76	10	10	38	4	10	38	2	10	31	103
12	December	31	-6.9	79	1	1	36	3	1	36	2	1	32	106
	Total			***903***	***610***	***524***	***379***	***36***	***524***	***379***	***21***	***543***	***361***	***1,195***
	Average		***6.0***											

Note: The Surplus values in (mm) are calculated using rainfall, melt and Actual Evapotranspiration
P = ET + R + I + S

CUT1			FOD 3-1			FOD 5-2			FOM 6-2			MAS2			Mixed Treed		
WHC	100 mm		WHC	250 mm		WHC	300 mm		WHC	250 mm		WHC	Precip-PET		WHC	300 mm	
Total Area (m^2)	6944		Total Area (m^2)	37921		Total Area (m^2)	25212		Total Area (m^2)	2223		Total Area (m^2)	5357		Total Area (m^2)	483	
Infiltration Factor	0.65		Infiltration Factor	0.72		Infiltration Factor	0.90		Infiltration Factor	0.91		Infiltration Factor	0.00		Infiltration Factor	0.91	
Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus	
(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)
1	24	167	1	17	645	1	16	403	1	17	38	0	62	332	1	16	8
1	26	181	1	21	796	1	20	504	1	21	47	1	55	295	1	20	10
5	101	701	5	91	3,451	5	89	2,244	5	91	202	5	60	321	5	89	43
31	112	778	31	109	4,133	31	108	2,723	31	109	242	31	42	225	31	108	52
80	14	97	80	14	531	80	14	353	80	14	31	80	-4	-21	80	14	7
112	5	35	116	5	190	116	5	126	116	5	11	116	-31	-166	116	5	2
114	3	21	135	3	114	136	3	76	135	3	7	136	-48	-257	136	3	1
87	1	7	111	1	38	114	1	25	111	1	2	118	-34	-182	114	1	0
65	3	21	72	2	76	73	2	50	72	2	4	75	7	37	73	2	1
36	9	62	37	6	228	37	6	151	37	6	13	37	40	214	37	6	3
10	31	215	10	16	607	10	16	403	10	16	36	10	66	354	10	16	8
1	32	222	1	18	683	1	17	429	1	18	40	1	78	418	1	17	8
543	***361***	***2,507***	***600***	***303***	***11,490***	***605***	***297***	***7,488***	***600***	***303***	***673***	***610***	***293***	***1,570***	***605***	***297***	***144***

RES/REC			SWD2-2			Rehab Area - Grass and Plants			Rehab Area - Woodlot			Rehab Area - Below Water				
WHC	75 mm		WHC	Precip-PET		WHC	100 mm		WHC	150 mm		WHC	Precip - PET			
Total Area (m^2)	1852		Total Area (m^2)	1209		Total Area (m^2)	43098		Total Area (m^2)	193592		Total Area (m^2)	83269			
Infiltration Factor	0.60		Infiltration Factor	0.60		Infiltration Factor	0.65		Infiltration Factor	0.69		Infiltration Factor	1.00			
Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Actual Evapotranspiration	Surplus		Total Surplus	Cummulative Surplus
(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(m^3)	(m3)
1	24	44	0	62	75	1	61	2,629	1	61	11,809	0	62	5,163	**21,396**	**21,396**
1	26	48	1	55	66	1	55	2,370	1	55	10,648	1	55	4,580	**19,634**	**41,030**
5	102	189	5	60	73	5	60	2,586	5	60	11,616	5	60	4,996	**26,771**	**67,801**
31	112	207	31	42	51	31	42	1,810	31	42	8,131	31	42	3,497	**22,238**	**90,039**
80	14	26	80	-4	-5	80	-4	-172	80	-4	-774	80	-4	-333	**-213**	**89,826**
107	5	9	116	-31	-37	112	-27	-1,164	116	-31	-6,001	116	-31	-2,581	**-9,559**	**80,267**
104	3	6	136	-48	-58	114	-26	-1,121	127	-39	-7,550	136	-48	-3,997	**-12,748**	**67,519**
83	1	2	118	-34	-41	87	-3	-129	98	-14	-2,710	118	-34	-2,831	**-5,816**	**61,703**
65	4	7	75	7	8	65	17	733	67	15	2,904	75	7	583	**4,436**	**66,138**
36	14	26	37	40	48	36	41	1,767	36	41	7,937	37	40	3,331	**13,813**	**79,952**
10	38	70	10	66	80	10	66	2,844	10	66	12,777	10	66	5,496	**22,998**	**102,950**
1	36	67	1	78	94	1	78	3,362	1	78	15,100	1	78	6,495	**27,029**	**129,978**
524	***379***	***702***	***610***	***293***	***354***	***543***	***360***	***15,515***	***573***	***330***	***63,885***	***610***	***293***	***24,398***	***129,978***	

Total Surplus (Runoff and Infiltration)		Total Infiltration		Total Runoff		Cummulative Runoff	Pit Volume	Comment
(L/s)	(L/min)	(m^3)	(L/s)	(m^3)	(L/s)	(m3)	(m^3)	
8.0	479	16,122	6.0	5,274	1.97	**274,360**	**269,087**	Volume of Rehab Pit Lake at 130 mASL
8.1	487	14,790	6.1	4,845	2.00	**279,205**	**79,524**	Volume of Rehab Pit Lake between 130 and 131 mASL
10.0	600	20,256	7.6	6,515	2.43	**285,720**	**348,611**	Volume of Rehab Pit Lake at 131 mASL
8.6	515	16,888	6.5	5,349	2.06	**291,070**		
-0.1	-5	-138	-0.1	-75	-0.03	**290,995**		
-3.7	-221	-7,200	-2.8	-2,360	-0.91	**288,635**		
-4.8	-286	-9,789	-3.7	-2,960	-1.11	**285,676**		
-2.2	-130	-4,750	-1.8	-1,066	-0.40	**284,610**		
1.7	103	3,198	1.2	1,238	0.48	**285,848**		
5.2	309	10,376	3.9	3,437	1.28	**289,285**		
8.9	532	17,299	6.7	5,699	2.20	**294,983**		
10.1	605	20,333	7.6	6,696	2.50	**301,679**		
50	***2,989***	***97,386***	***37***	***32,592***	***12***			

Main Subcatchment A									
Existing Phase									
Type	WHC	Type of Land Use	Soil Group	Dominant Soil Types	Infiltration Factor (%)				Catchment Areas (m^2)
					Topo	Soils	Cover	Total	
AGRC-H	75 mm	Urban Lawns	D	Clay[2]	0.1	0.1	0.08	0.28	29,353
Agricultural and Undifferenti	75 mm	Moderately Rooted Crops	A	Loamy Sand[2]	0.15	0.41	0.1	0.66	364,811
Clear Open Water	Precip-PET	Water Body	D	Clay[2]	*0*	*0*	*0*	*1*	18,300
Community/Infrastructure	75 mm	Urban Development	B	Silty Sand	0.3	0.41	0.08	0.79	819
Coniferous Treed	250 mm	Mature Forests	A	Loamy Sand[2]	0.15	0.41	0.2	0.76	11,041
CUM1-1	100 mm	Pasture and Shrubs	A	Sand (Fine to Medium), Silty Sand, Sandy Silt	0.1	0.42	0.15	0.67	1,670
Deciduous Treed	250 mm	Mature Forests	A	Loamy Sand[2]	0.1	0.41	0.2	0.71	215,521
FOD 3-1	250 mm	Mature Forests	A	Sand (F to m), Silty Sand	0.1	0.42	0.2	0.72	22,649
FOD 5-2	300 mm	Mature Forests	B	Silty Sand, Sandy Silt	0.1	0.4	0.2	0.7	39,770
MAS2	Precip-PET	Wetland	A	Sand (m)	0.3	0.42	0.08	0.8	10,869
Mixed Treed	300 mm	Mature Forests	B	Silty Sand	0.1	0.41	0.2	0.71	26,422
RES/REC	75 mm	Urban Lawns	A	Sand (f), Silty Sand	0.1	0.41	0.08	0.59	86,527
Swamp	Precip-PET	Wetland	A	Loamy Sand[2]	0.3	0.41	0.08	0.79	48,151
SWD2-2	Precip-PET	Wetland	B	Silty Sand	0.3	0.41	0.08	0.79	6,164
Treed Upland	250 mm	Mature Forests	A	Loamy Sand[2]	0.3	0.41	0.2	0.91	3,309
									885,375

[2] Obtained from OGS Surficial Geology Maps and OMAFRA Soil Survey Complex

East Subcatchment A									
Existing Phase									
Type	WHC	Type of Land Use	Soil Group	Dominant Soil Types	Infiltration Factor (%)				Catchment Areas (m2)
					Topo	Soils	Cover	Total	
Agricultural and Undifferenti	75 mm	Moderately Rooted Crops	A	Loamy Sand[2]	0.1	0.41	0.1	0.61	9,636
Deciduous Treed	250 mm	Mature Forests	A	Loamy Sand[2]	0.1	0.41	0.2	0.71	205,934
Deciduous Treed	300 mm	Mature Forests	B	Sandy Loam[2]	0.15	0.4	0.2	0.75	126,839
FOD 5-2	300 mm	Mature Forests	B	Silty Sand, Sandy Silt	0.1	0.4	0.2	0.7	61,052
FOM 6-2	250 mm	Mature Forests	A	Loamy Sand[2]	0.3	0.41	0.2	0.91	39,379
Mixed Treed	300 mm	Mature Forests	A	Loamy Sand[2]	0.1	0.41	0.2	0.71	10,565
Swamp	Precip-PET	Wetland	A	Loamy Sand[2]	0.15	0.41	0.08	0.64	45,619
									499,025

[2] Obtained from OGS Surficial Geology Maps and OMAFRA Soil Survey Complex

Table E-5
External Drainage Areas

West Subcatchment A										
Existing Phase										
Type	WHC	Type of Land Use	Soil Group	Dominant Soil Types	Infiltration Factor (%)					Catchment Areas (m^2)
					Topo	Soils	Cover	Total		
AGRC-H	75 mm	Urban Lawns	D	Clay[2]	0.1	0.1	0.08	0.28		38,070
Agricultural and Undifferenti	75 mm	Moderately Rooted Crops	A	Loamy Sand[2]	0.1	0.41	0.1	0.61		46,672
CUM1-1	100 mm	Pasture and Shrubs	A	Sand (Fine to Medium), Silty Sand, Sandy Silt	0.1	0.42	0.15	0.67		2,815
CUT1	100 mm	Pasture and Shrubs	A	Sand (Fine to Medium), Silty Sand, Sandy Silt	0.3	0.42	0.15	0.87		33
FOD 3-1	250 mm	Mature Forests	A	Sand (F to m), Silty Sand	0.1	0.4	0.2	0.7		5,761
FOD 5-2	300 mm	Mature Forests	B	Silty Sand, Sandy Silt	0.3	0.4	0.2	0.9		174
FOM 6-2	250 mm	Mature Forests	A	Loamy Sand[2]	0.3	0.41	0.2	0.91		487
Marsh	Precip-PET	Wetland	D	Clay[2]	0.3	0.1	0.08	0.48		25
MAS2	Precip-PET	Wetland	A	Sand (m)	0.3	0.42	0.08	0.8		15,904
										109,941

[2] Obtained from OGS Surficial Geology Maps and OMAFRA Soil Survey Complex

Subcatchment B										
Existing Phase										
Type	WHC	Type of Land Use	Soil Group	Dominant Soil Types	Infiltration Factor (%)					Catchment Areas (m^2)
					Topo	Soils	Cover	Total		
AGRC-H	75 mm	Urban Lawns	D	Clay[2]	0.1	0.1	0.08	0.28		68,941
Agricultural and Undifferenti	75 mm	Moderately Rooted Crops	D	Clay[2]	0.15	0.1	0.1	0.35		259,102
Clear Open Water	Precip-PET	Water Body	D	Clay[2]	0	0	0	1		10,710
Coniferous Treed	250 mm	Mature Forests	D	Clay[2]	0.1	0.1	0.2	0.4		2,954
CUT1	100 mm	Pasture and Shrubs	A	Sand (Fine to Medium), Silty Sand, Sandy Silt	0.3	0.42	0.15	0.87		289
Deciduous Treed	250 mm	Mature Forests	D	Clay[2]	0.1	0.1	0.2	0.4		7,929
FOD 5-2	300 mm	Mature Forests	B	Silty Sand, Sandy Silt	0.1	0.4	0.2	0.7		41,525
Marsh	Precip-PET	Wetland	D	Clay[2]	0.3	0.1	0.08	0.48		8,259
Mixed Treed	300 mm	Mature Forests	D	Clay[2]	0.3	0.1	0.2	0.6		360
										400,068

[2] Obtained from OGS Surficial Geology Maps and OMAFRA Soil Survey Complex

Table E-6
Water Balance Summary

Existing Conditions (40.45 ha) - Estimated Annual Average Water Balance

Land Use	Soil	WHC	Area	Precipitation		ET		Surplus		Infiltration		Runoff	
			(m^2)	(mm/a)	Volume (m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)
AGRC-H	Clay2	75	95	903	85	524	50	379	36.12	106	10.11	273	26.01
Community/Infrastructure	Silty Sand	75	54	903	50	524	30	379	20.63	299	16.3	80	4.33
CUM1-1	Sand (Fine to Medium), Silty Sand, Sandy Silt	100	92,651	903	83665	543	50310	361	33447.03	242	22385.6	119	11061.42
CUT1	Sand (Fine to Medium), Silty Sand, Sandy Silt	100	22,559	903	20370	543	12,250	361	8143.89	252	5688.13	109	2455.76
FOD 3-1	Sand (F to m), Silty Sand	250	61,723	903	55735	600	37030	303	18702.19	218	13465.58	85	5236.61
FOD 3-1	Silty Sand	300	28,550	903	25780	600	17,130	303	8650.67	218	6228.49	85	2422.19
FOD 5-2	Silty Sand, Sandy Silt	300	179,657	903	162230	605	108690	297	53358.05	216	38848.25	81	14509.8
FOM 6-2	Loamy Sand2	250	6,098	903	5505	600	3660	303	1847.76	276	1681.47	27	166.3
MAS2	Organic Matter1	Precip-PET	5,357	903	4835	610	3270	293	1569.64	0	0	293	1569.64
Mixed Treed	Silty Sand	300	483	903	435	605	290	297	143.59	270	130.67	27	12.92
RES/REC	Sand (f), Silty Sand	75	6,183	903	5585	524	3240	379	2343.42	227	1406.05	152	937.37
SWD2-2	Silty Sand	Precip-PET	1,209	903	1090	610	740	293	354.09	176	212.46	117	141.64
		TOTAL	404,621	903	365,365	585	236,690	318	128,617	223	90,073	95	38,544

Operation Conditions (40.45 ha) - Estimated Annual Average Water Balance

Land Use	Soil	WHC	Area	Precipitation		ET		Surplus		Infiltration		Runoff	
			(m^2)	(mm/a)	Volume (m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)
AGRC-H	Clay2	75	95	903	85	524	50	379	36.12	106	10.11	273	26.01
Community/Infrastructure	Silty Sand	75	54	903	50	524	30	379	20.63	299	16.3	80	4.33
CUM1-1	Sand (Fine to Medium), Silty Sand, Sandy Silt	100	3,311	903	2990	543	1800	361	1195.24	235	776.9	126	418.33
CUT1	Sand (Fine to Medium), Silty Sand, Sandy Silt	100	6,944	903	6270	543	3,770	361	2506.68	235	1629.34	126	877.34
FOD 3-1	Sand (F to m), Silty Sand	250	37,921	903	34245	600	22750	303	11490.19	218	8272.94	85	3217.25
FOD 5-2	Silty Sand, Sandy Silt	300	25,212	903	22765	605	15,250	297	7488.06	267	6739.25	30	748.81
FOM 6-2	Loamy Sand2	250	2,223	903	2005	600	1330	303	673.48	276	612.87	27	60.61
MAS2	Organic Matter1	Precip-PET	5,357	903	4835	610	3270	293	1569.64	0	0	293	1569.64
Mixed Treed	Silty Sand	300	483	903	435	605	290	297	143.59	270	130.67	27	12.92
RES/REC	Sand (f), Silty Sand	75	1,852	903	1675	524	970	379	701.98	227	421.19	152	280.79
SWD2-2	Silty Sand	Precip-PET	1,209	903	1090	610	740	293	354.09	176	212.46	117	141.64
Extraction Area - Exposed Bedrock	Rock	Precip-PET	193,592	903	174815	610	118090	293	56722.39	293	56722.39	0	0
Extraction Area - Below Water	Fine Sand	Precip-PET	126,367	903	114110	610	77080	293	37025.49	293	37025.49	0	0
		TOTAL	404,621	903	365,370	607	245,420	296	119,928	278	112,570	18	7,358

Rehabilitation Conditions (40.45 ha) - Estimated Annual Average Water Balance

Land Use	Soil	WHC	Area	Precipitation		ET		Surplus		Infiltration		Runoff	
			(m^2)	(mm/a)	Volume (m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)
AGRC-H	Clay2	75	95	903	85	524	50	379	36.12	106	10.11	273	26.01
Community/Infrastructure	Silty Sand	75	54	903	50	524	30	379	20.63	299	16.3	80	4.33
CUM1-1	Sand (Fine to Medium), Silty Sand, Sandy Silt	100	3,311	903	2990	543	1800	361	1195.24	235	776.9	126	418.33
CUT1	Sand (Fine to Medium), Silty Sand, Sandy Silt	100	6,944	903	6270	543	3,770	361	2506.68	235	1629.34	126	877.34
FOD 3-1	Sand (F to m), Silty Sand	250	37,921	903	34245	600	22750	303	11490.19	218	8272.94	85	3217.25
FOD 5-2	Silty Sand, Sandy Silt	300	25,212	903	22765	605	15,250	297	7488.06	267	6739.25	30	748.81
FOM 6-2	Loamy Sand2	250	2,223	903	2005	600	1330	303	673.48	276	612.87	27	60.61
MAS2	Organic Matter1	Precip-PET	5,357	903	4835	610	3270	293	1569.64	0	0	293	1569.64
Mixed Treed	Silty Sand	300	483	903	435	605	290	297	143.59	270	130.67	27	12.92
RES/REC	Sand (f), Silty Sand	75	1,852	903	1675	524	970	379	701.98	227	421.19	152	280.79
SWD2-2	Silty Sand	Precip-PET	1,209	903	1090	610	740	293	354.09	176	212.46	117	141.64
Rehab Area - Grass and Plants	Fine Sand	100	43,098	903	38920	543	23400	360	15515.32	234	10084.96	126	5430.36
Rehab Area - Woodlot	Glacial Till, Silty Sand	150	193,592	903	174815	573	110930	330	63885.28	228	44080.85	102	19804.44
Rehab Area - Below Water	Fine Sand	Precip - PET	83,269	903	75190	610	50790	293	24397.74	293	24397.74	0	0
		TOTAL	404,621	903	365,370	582	235,370	321	129,978	241	97,386	81	32,592

Main Subcatchment A (88.54 ha) - Estimated Annual Average Water Balance													
Land Use	Soil	WHC	Area	Precipitation		ET		Surplus		Infiltration		Runoff	
			(m^2)	(mm/a)	Volume (m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)
AGRC-H	Clay2	75	29,353	903	26505	524	15380	379	11124.75	106	3114.93	273	8009.82
Agricultural and Undifferentiated Rural Land Use	Loamy Sand2	75	364,811	903	329425	524	191160	379	138263.37	250	91253.82	129	47009.55
Clear Open Water	Clay2	Precip-PET	18,300	903	16525	610	11160	293	5362.02	293	5362.02	0	0
Community/Infrastructure	Silty Sand	75	819	903	740	524	430	379	310.37	299	245.19	80	65.18
Coniferous Treed	Loamy Sand2	250	11,041	903	9970	600	6620	303	3345.4	230	2542.5	73	802.9
CUM1-1	Sand (Fine to Medium), Silty Sand, Sandy Silt	100	1,670	903	1510	543	910	361	602.85	242	403.91	119	198.94
CUT1	Sand (Fine to Medium), Silty Sand, Sandy Silt	100	0	903	0	543	0	361	0	0	0	361	0
Deciduous Treed	Loamy Sand2	250	215,521	903	194615	600	129310	303	65302.8	215	46364.99	88	18937.81
FOD 3-1	Sand (F to m), Silty Sand	250	22,649	903	20450	600	13590	303	6862.5	218	4941	85	1921.5
FOD 5-2	Silty Sand, Sandy Silt	300	39,770	903	35910	605	24,060	297	11811.69	208	8268.18	89	3543.51
FOM 6-2	Loamy Sand2	250	0	903	0	600	0	303	0	0	0	303	0
Marsh	0.00	Precip-PET	0	903	0	610	0	293	0	0	0	293	0
MAS2	Sand (m)	Precip-PET	10,869	903	9815	610	6630	293	3184.68	234	2547.74	59	636.94
Mixed Treed	Silty Sand	300	26,422	903	23860	605	15990	297	7847.2	211	5571.52	86	2275.69
RES/REC	Sand (f), Silty Sand	75	86,527	903	78135	524	45340	379	32793.73	224	19348.3	155	13445.43
Swamp	Loamy Sand2	Precip-PET	48,151	903	43480	0	0	903	43480.04	713	34349.23	190	9130.81
SWD2-2	Silty Sand	Precip-PET	6,164	903	5565	610	3760	293	1806.08	231	1426.8	62	379.28
Treed Upland	Loamy Sand2	250	3,309	903	2990	600	1990	303	1002.7	276	912.46	27	90.24
		TOTAL	885,375	903	799,495	527	466,330	376	333,100	256	226,653	120	106,448

East Subcatchment A(49.90 ha) - Estimated Annual Average Water Balance													
Land Use	Soil	WHC	Area	Precipitation		ET		Surplus		Infiltration		Runoff	
			(m^2)	(mm/a)	Volume (m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)
AGRC-H	Clay2	75	0	903	0	524	0	379	0	106	0	273	0
Agricultural and Undifferentiated Rural Land Use	Loamy Sand2	75	9,636	903	8700	524	5050	379	3652.15	250	2410.42	129	1241.73
Clear Open Water	0.00	100	0	903	0	610	0	293	0	293	0	0	0
Community/Infrastructure	Silty Sand	75	0	903	0	524	0	379	0	299	0	80	0
Coniferous Treed	0.00	100	0	903	0	600	0	303	0	230	0	73	0
CUM1-1	Sand (Fine to Medium), Silty Sand, Sandy Silt	100	0	903	0	543	0	361	0	242	0	119	0
CUT1	Sand (Fine to Medium), Silty Sand, Sandy Silt	100	0	903	0	543	0	361	0	0	0	361	0
Deciduous Treed	Loamy Sand2	250	205,934	903	185960	600	123560	303	62398	215	44302.58	88	18095.42
Deciduous Treed	Sandy Loam2	300	126,839	903	114535	600	76100	303	38432.22	215	27286.87	88	11145.34
FOD 5-2	Silty Sand, Sandy Silt	300	61,052	903	55130	605	36,940	297	18132.59	208	12692.81	89	5439.78
FOM 6-2	Loamy Sand2	250	39,379	903	35560	600	23630	303	11931.77	0	0	303	11931.77
Marsh	0.00	Precip-PET	0	903	0	610	0	293	0	0	0	293	0
MAS2	Sand (m)	Precip-PET	0	903	0	610	0	293	0	234	0	59	0
Mixed Treed	Loamy Sand2	300	10,565	903	9540	605	6390	297	3137.77	211	2227.82	86	909.95
RES/REC	Sand (f), Silty Sand	75	0	903	0	524	0	379	0	224	0	155	0
Swamp	Loamy Sand2	Precip-PET	45,619	903	41195	0	0	903	41194.1	713	32543.34	190	8650.76
SWD2-2	Silty Sand	Precip-PET	0	903	0	610	0	293	0	231	0	62	0
Treed Upland	Loamy Sand2	250	0	903	0	600	0	303	0	276	0	27	0
		TOTAL	499,025	903	450,620	544	271,670	358	178,879	243	121,464	115	57,415

Table E-6

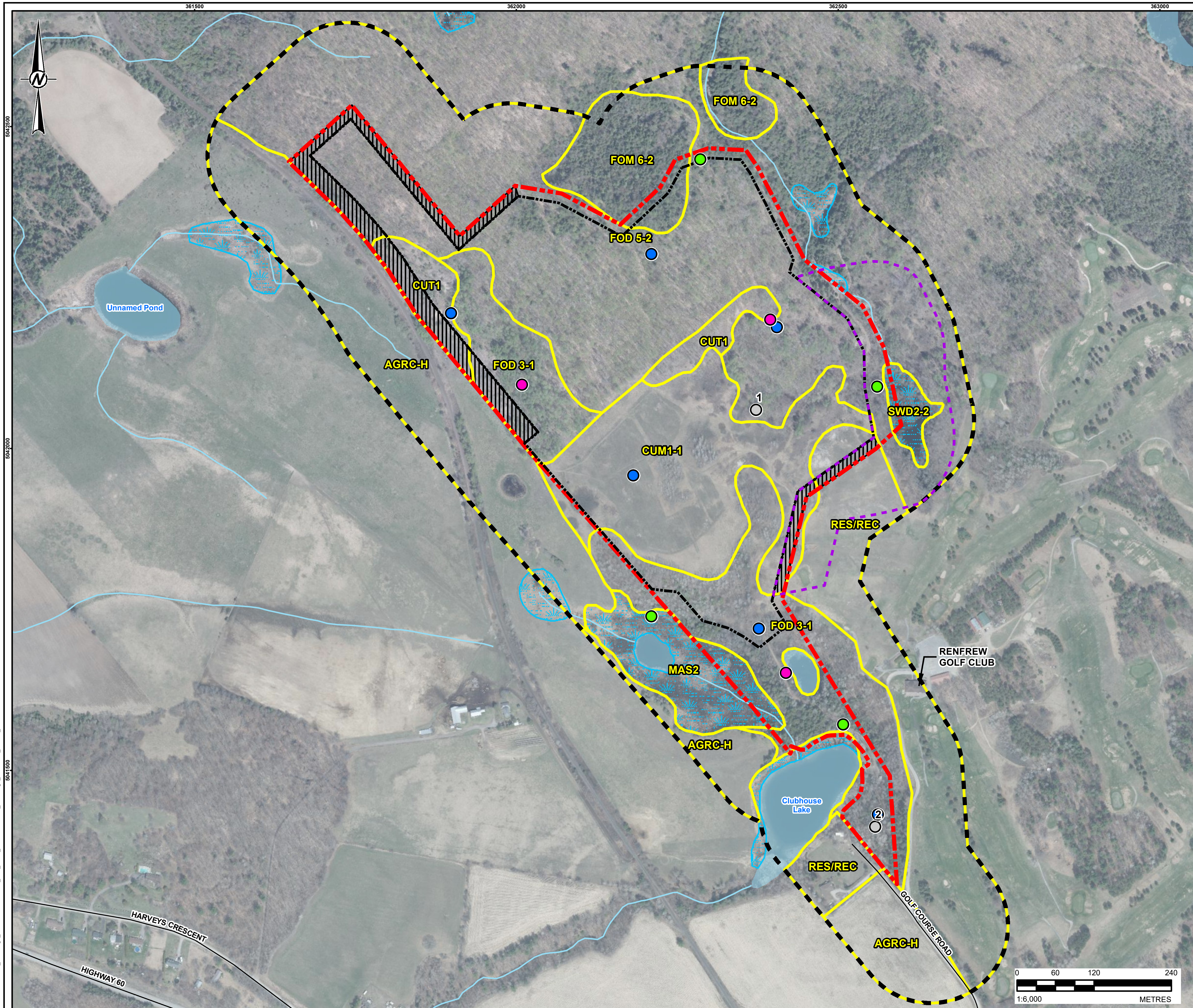
Water Balance Summary

West Subcatchment A (10.99 ha)- Estimated Annual Average Water Balance													
Land Use	Soil	WHC	Area	Precipitation		ET		Surplus		Infiltration		Runoff	
			(m^2)	(mm/a)	Volume (m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)
AGRC-H	Clay2	75	38,070	903	34375	524	19950	379	14428.51	106	4039.98	273	10388.53
Agricultural and Undifferentiated Rural Land Use	Loamy Sand2	75	46,672	903	42145	524	24460	379	17688.59	250	11674.47	129	6014.12
Clear Open Water	Clay2	Precip-PET	0	903	0	610	0	293	0	293	0	0	0
Community/Infrastructure	Silty Sand	75	0	903	0	524	0	379	0	299	0	80	0
Coniferous Treed	Loamy Sand2	250	0	903	0	600	0	303	0	230	0	73	0
CUM1-1	Sand (Fine to Medium), Silty Sand, Sandy Silt	100	2,815	903	2540	543	1,530	361	1016.23	242	680.87	119	335.36
CUT1	Sand (Fine to Medium), Silty Sand, Sandy Silt	100	33	903	30	543	20	361	11.88	0	0	361	11.88
Deciduous Treed	Loamy Sand2	250	0	903	0	600	0	303	0	215	0	88	0
FOD 3-1	Sand (F to m), Silty Sand	250	5,761	903	5200	600	3460	303	1745.54	218	1256.79	85	488.75
FOD 5-2	Silty Sand, Sandy Silt	300	174	903	155	605	110	297	51.8	208	36.26	89	15.54
FOM 6-2	Loamy Sand2	250	487	903	440	600	290	303	147.58	0	0	303	147.58
Marsh	Clay2	Precip-PET	25	903	20	610	20	293	7.29	0	0	293	7.29
MAS2	Sand (m)	Precip-PET	15,904	903	14360	610	9700	293	4659.88	234	3727.91	59	931.98
Mixed Treed	Silty Sand	300	0	903	0	605	0	297	0	211	0	86	0
RES/REC	Sand (f), Silty Sand	75	0	903	0	524	0	379	0	224	0	155	0
Swamp	Loamy Sand2	Precip-PET	0	903	0	0	0	903	0	713	0	190	0
SWD2-2	Silty Sand	Precip-PET	0	903	0	610	0	293	0	231	0	62	0
Treed Upland	Loamy Sand2	250	0	903	0	600	0	303	0	276	0	27	0
		TOTAL	109,941	903	99,265	541	59,540	362	39,757	195	21,416	167	18,341

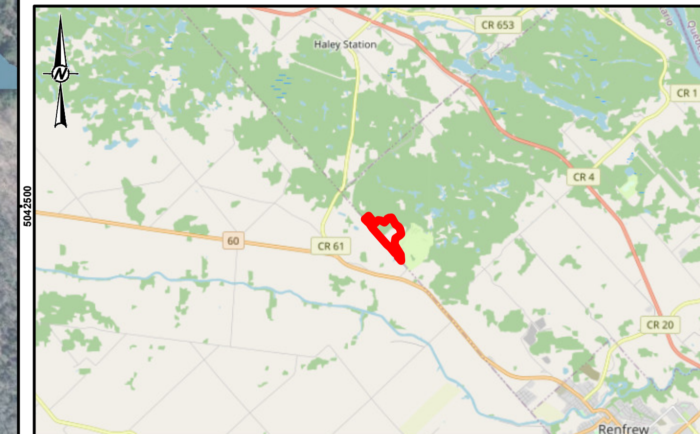
Subcatchemnt B (40.0 ha) - Estimated Annual Average Water Balance													
Land Use	Soil	WHC	Area	Precipitation		ET		Surplus		Infiltration		Runoff	
			(m^2)	(mm/a)	Volume (m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)	(mm/a)	(m^3)
AGRC-H	Clay2	75	68,941	903	62255	524	36130	379	26128.61	106	7316.01	273	18812.6
Agricultural and Undifferentiated Rural Land Use	Clay2	75	259,102	903	233970	524	135770	379	98199.49	250	64811.66	129	33387.83
Clear Open Water	Clay2	Precip-PET	10,710	903	9670	610	6530	293	3138.07	293	3138.07	0	0
Community/Infrastructure	Silty Sand	75	0	903	0	524	0	379	0	299	0	80	0
Coniferous Treed	Clay2	250	2,954	903	2670	600	1770	303	895.21	230	680.36	73	214.85
CUM1-1	Sand (Fine to Medium), Silty Sand, Sandy Silt	100	0	903	0	543	0	361	0	242	0	119	0
CUT1	Sand (Fine to Medium), Silty Sand, Sandy Silt	100	289	903	260	543	160	361	104.21	0	0	361	104.21
Deciduous Treed	Clay2	250	7,929	903	7160	600	4760	303	2402.39	215	1705.7	88	696.69
FOD 3-1	Sand (F to m), Silty Sand	250	0	903	0	600	0	303	0	218	0	85	0
FOD 5-2	Silty Sand, Sandy Silt	300	41,525	903	37495	605	25,120	297	12333	208	8633.1	89	3699.9
FOM 6-2	Loamy Sand2	250	0	903	0	600	0	303	0	0	0	303	0
Marsh	Clay2	Precip-PET	8,259	903	7460	610	5040	293	2419.94	0	0	293	2419.94
MAS2	Sand (m)	Precip-PET	0	903	0	610	0	293	0	234	0	59	0
Mixed Treed	Clay2	300	360	903	325	605	220	297	106.79	211	75.82	86	30.97
RES/REC	Sand (f), Silty Sand	75	0	903	0	524	0	379	0	224	0	155	0
Swamp	Loamy Sand2	Precip-PET	0	903	0	0	0	903	0	713	0	190	0
SWD2-2	Silty Sand	Precip-PET	0	903	0	610	0	293	0	231	0	62	0
Treed Upland	Loamy Sand2	250	0	903	0	600	0	303	0	276	0	27	0
		TOTAL	400,068	903	361,265	539	215,500	364	145,728	216	86,361	148	59,367

APPENDIX F

Ecological Land Classification Figure



KEY MAP



SCALE 1:200,000

LEGEND

- EASTERN WHIP-POOR-WILL STATION
- BREEDING BIRD STATION
- NOCTURNAL ANURAN STATION
- BAT DETECTOR STATION
- ROADWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- PROPOSED EXTRACTION LIMIT
- SITE
- 120 m STUDY AREA
- PREDICTED 1-METRE GROUNDWATER DRAWDOWN RADIUS OF INFLUENCE
- PROPOSED BERM LOCATIONS
- ECOLOGICAL LAND CLASSIFICATION

AGRC-H: GRAMINOID HAYFIELD
CUM1-1: MIXED MEADOW
CUT1: DECIDUOUS THICKET
FOD3-1: DRY TO FRESH POPLAR/MIXED HARDWOOD DECIDUOUS FOREST
FOD5-2: RECENTLY LOGGED DRY TO FRESH SUGAR MAPLE – BEECH DECIDUOUS FOREST
FOM6-2:FRESH TO MOIST HEMLOCK: HARDWOOD MIXED FOREST
MAS2: SHALLOW CATTAIL-SEDGE MINERAL MARSH
RES/REC: RESIDENTIAL/RECREATIONAL
SWD2-2: GREEN ASH MINERAL DECIDUOUS SWAMP

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. KEY MAP: © OPENSTREETMAP (AND) CONTRIBUTORS, CC-BY-SA
COUNTY OF RENFREW
3. BING IMAGERY SUPPLIED BY ESRI AND MICROSOFT © 2020 MICROSOFT CORPORATION AND ITS DATA SUPPLIERS. IMAGERY DATE: 10/10/2016
4. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83, COORDINATE SYSTEM: MTM ZONE 9, VERTICAL DATUM: CGVD28

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
RENFREW GOLF CLUB NATURAL ENVIRONMENT REPORT

TITLE
ECOLOGICAL LAND CLASSIFICATION AND SURVEY STATIONS

CONSULTANT

YYYY-MM-DD	2023-12-11
DESIGNED	----
PREPARED	JEM
REVIEWED	GW
APPROVED	HM

PROJECT NO.	CONTROL	REV.	FIGURE
21465813	0001	0	1

APPENDIX G

Surface Water Quality Results

Sample Location Sample Date Parameter	Unit	SW-1	SW-2	SW-3
			2022-06-27	
General Chemistry				
Alkalinity (Total as CaCO3)	µg/L	220,000	190,000	190,000
Total Ammonia-N	mg/L	<0.050	<0.050	<0.050
Ammonia, unionized	µg/L	0.692	0.961	0.761
Ammonia Nitrogen	µg/L	<50	<50	<50
Chloride	µg/L	3,000	<1,000	3,000
Conductivity (Field)	µS/cm	466	360	438
Dissolved Organic Carbon	µg/L	4,600	2,700	5,300
Hardness, Calcium Carbonate	µg/L	230,000	190,000	200,000
Nitrate as N	µg/L	610	<100	140
Nitrite as N	µg/L	12	<10	10
Nitrate + Nitrite (N)	µg/L	630	<100	150
Nitrogen, Total Kjeldahl	µg/L	610	110	430
pH (Field)	-	7.61	7.82	7.62
Phosphorus	µg/L	12	10	15
Sulphate	µg/L	23,000	9,100	20,000
Temperature (Field)	° C	18	16	19
Total Dissolved Solids	µg/L	275,000	200,000	225,000
Total Suspended Solids	µg/L	<10,000	<10,000	<10,000
Turbidity	NTU	2.1	0.5	0.9
Metals				
Dissolved (0.2u) Aluminum (Al)	µg/L	<5	<5	<5
Total Aluminum (Al)	µg/L	40	32	16
Total Antimony (Sb)	µg/L	<0.50	<0.50	<0.50
Total Arsenic (As)	µg/L	<1.0	<1.0	<1.0
Total Barium (Ba)	µg/L	67	41	57
Total Beryllium (Be)	µg/L	<0.40	<0.40	<0.40
Total Bismuth (Bi)	µg/L	<1.0	<1.0	<1.0
Total Boron (B)	µg/L	29	<10	31
Total Cadmium (Cd)	µg/L	<0.090	<0.090	<0.090
Total Calcium (Ca)	µg/L	71000	60000	62000
Total Chromium (Cr)	µg/L	<5.0	<5.0	<5.0
Total Cobalt (Co)	µg/L	<0.50	<0.50	<0.50
Total Copper (Cu)	µg/L	<0.90	<0.90	<0.90
Total Iron (Fe)	µg/L	**350**	<100	170
Total Lead (Pb)	µg/L	<0.50	<0.50	<0.50
Total Lithium (Li)	µg/L	<5.0	<5.0	<5.0
Total Magnesium (Mg)	µg/L	18,000	13,000	16,000
Total Manganese (Mn)	µg/L	540	49	42
Total Molybdenum (Mo)	µg/L	1.3	<0.50	0.92
Total Nickel (Ni)	µg/L	<1.0	<1.0	<1.0
Total Potassium (K)	µg/L	3,100	1,700	2,800
Total Selenium (Se)	µg/L	<2.0	<2.0	<2.0
Total Silicon (Si)	µg/L	5,400	4,600	3,200
Total Silver (Ag)	µg/L	<0.090	<0.090	<0.090
Total Sodium (Na)	µg/L	3700	1200	3300
Total Strontium (Sr)	µg/L	180	140	160
Total Tellurium (Te)	µg/L	<1.0	<1.0	<1.0
Total Thallium (Tl)	µg/L	<0.050	<0.050	<0.050
Total Tin (Sn)	µg/L	<1.0	<1.0	<1.0
Total Titanium (Ti)	µg/L	<5.0	<5.0	<5.0
Total Tungsten (W)	µg/L	<1.0	<1.0	<1.0
Total Uranium (U)	µg/L	2.1	0.49	1.5
Total Vanadium (V)	µg/L	0.83	0.58	<0.50
Total Zinc (Zn)	µg/L	<5.0	<5.0	<5.0
Total Zirconium (Zr)	µg/L	<1.0	<1.0	<1.0
Petroleum Hydrocarbons				
Oil & Grease - Animal/Vegetable	mg/L	<0.5	<0.5	3.1
Oil & Grease - Mineral/Synthetic	mg/L	<0.5	<0.5	<0.5
Oil & Grease, Total Rec	mg/L	<0.5	<0.5	3.1

Footnotes:

	Tables should be read in conjunction with the accompanying document.
<	Indicates parameter not detected above laboratory method detection limit.
>	Indicates parameter detected above equipment analytical range.
--	Chemical not analyzed or criteria not defined.
Value	Provincial Water Quality Objective (PWQO) and {Interim PWQO} exceedances are highlighted in grey.
(1)	Provincial Water Quality Objectives (PWQO) (July 1994, reprinted February 1999).
(2)	Alkalinity should not be decreased by more than 25% of the natural concentration.
(3)	Current scientific evidence is insufficient to develop a firm Objective at this time. Accordingly, the following phosphorus concentrations should be considered as general guidelines which should be supplemented by site-specific studies: To avoid nuisance concentrations of algae in lakes, average total phosphorus concentrations for the ice-free period should not exceed 20 µg/L; A high level of protection against aesthetic deterioration will be provided by a total phosphorus concentration for the ice-free period of 10 µg/L or less. This should apply to all lakes naturally below this value; Excessive plant growth in rivers and streams should be eliminated at a total phosphorus concentration below 30 µg/L.
(4)	(1) General: The natural thermal regime of any body of water shall not be altered so as to impair the quality of the natural environment. In particular, the diversity, distribution and abundance of plant and animal life shall not be significantly changed. (2) Waste Heat Discharge: (a) Ambient Temperature Changes: The temperature at the edge of a mixing zone shall not exceed the natural ambient water temperature at a representative control location by more than 10°C (18°F). However, in special circumstances, local conditions may require a significantly lower temperature difference than 10°C (18°F). Potential dischargers are to apply to the MOEE for guidance as to the allowable temperature rise for each thermal discharge. This ministry will also specify the nature of the mixing zone and the procedure for the establishment of a representative control location for temperature recording on a case-by-case basis. (b) Discharge Temperature Permitted: The maximum temperature of the receiving body of water, at any point in the thermal plume outside a mixing zone, shall not exceed 30°C (86°F) or the temperature of a representative control location plus 10°C (18°F) or the allowed temperature difference, which ever is the lesser temperature. These maximum temperatures are to be measured on a mean daily basis from continuous records. (c) Taking and Discharging of Cooling Water: Users of cooling water shall meet both the Objectives for temperature outlined above and the "Procedures for the Taking and Discharge of Cooling Water" as outlined in the MOEE publication Deriving Receiving-Water Based, Point-Source Effluent Requirements for Ontario Waters(1994).
(5)	Suspended matter should not be added to surface water in concentrations that will change the natural Secchi disc reading by more than 10 percent.
(6)	At pH 4.5 to 5.5 the Interim PWQO is 15 µg/L based on inorganic monomeric aluminum measure in clay-free samples; At pH > 5.5 to 6.5, no condition should be permitted which would increase the acid soluble inorganic aluminum concentration in clay-free samples to more than 10% above natural background concentrations for waters representative of that geological area of the Province that are unaffected by man-made inputs. At pH > 6.5 to 9.0, the Interim PWQO is 75 µg/L based on total aluminum measured in clay-free samples. If natural background aluminum concentrations in water bodies unaffected by man-made inputs are greater than the numerical Interim PWQO (above), no condition is permitted that would increase the aluminum concentration in clay-free samples by more than 10% of the natural background level. Note: pH values of < 6.5 and > 8.5 are outside the range considered acceptable by the PWQO for pH. See the Scientific Criteria Document for Development of Provincial Water Quality Objectives and Guidelines - Aluminum for a discussion of analytical procedures.
(7)	See Section 1.2.3. of PWQO. This Interim PWQO was set for emergency purposes based on the best information readily available. Employ due caution when applying this value.
(8)	Adopted from Canadian Council of Ministers of the Environment (CCME) 1998 Guidelines.
(9)	Oil or petrochemicals should not be present in concentrations that can be detected as a visible film, sheen, or discolouration on the surface; or can be detected by odour; or can cause tainting of edible aquatic organisms; or can form deposits on shorelines and bottom sediments that are detectable by sight or odour, or are deleterious to resident aquatic organisms.
(10)	Prohibited pesticides under *Regulation 914* of the *Pesticides Act*.
(11)	An interim PWQO of {0.003 µg/L} is listed for only Total Endosulfan.
(12)	PWQO of 0.001 µg/L is listed for only Total Heptachlor.
(13)	PWQO of 0.001 µg/L is listed for Total PCBs that include this parameter.

Your Project #: 21465813
Site Location: RENFREW PIT
Your C.O.C. #: 884606-01-01

Attention: Jaime Oxtobee

Golder Associates Ltd
1931 Robertson Rd
Ottawa, ON
CANADA K2H 5B7

Report Date: 2022/07/08
Report #: R7201850
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C2I1681
Received: 2022/06/29, 11:25

Sample Matrix: Surface Water
Samples Received: 3

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Dissolved Aluminum (0.2 u, clay free) (1)	3	N/A	2022/07/04	CAM SOP-00447	EPA 6020B m
Alkalinity (1)	2	N/A	2022/07/01	CAM SOP-00448	SM 23 2320 B m
Alkalinity (1)	1	N/A	2022/07/04	CAM SOP-00448	SM 23 2320 B m
Chloride by Automated Colourimetry (1)	3	N/A	2022/07/04	CAM SOP-00463	SM 23 4500-Cl E m
Dissolved Organic Carbon (DOC) (1, 2)	2	N/A	2022/07/04	CAM SOP-00446	SM 23 5310 B m
Dissolved Organic Carbon (DOC) (1, 2)	1	N/A	2022/07/05	CAM SOP-00446	SM 23 5310 B m
Hardness (calculated as CaCO3) (1)	3	N/A	2022/07/07	CAM SOP 00102/00408/00447	SM 2340 B
Total Metals Analysis by ICPMS (1)	3	N/A	2022/07/06	CAM SOP-00447	EPA 6020B m
Total Ammonia-N (1)	2	N/A	2022/07/06	CAM SOP-00441	USGS I-2522-90 m
Total Ammonia-N (1)	1	N/A	2022/07/07	CAM SOP-00441	USGS I-2522-90 m
Nitrate & Nitrite as Nitrogen in Water (1, 3)	3	N/A	2022/07/04	CAM SOP-00440	SM 23 4500-NO3I/NO2B
Animal and Vegetable Oil and Grease (1)	3	N/A	2022/07/05	CAM SOP-00326	EPA1664B m,SM5520B m
Total Oil and Grease (1)	3	2022/07/05	2022/07/05	CAM SOP-00326	EPA1664B m,SM5520B m
OC Pesticides (Selected) & PCB (1, 4)	3	2022/07/05	2022/07/06	CAM SOP-00307	EPA 8081A/8082B m
OC Pesticides Summed Parameters (1)	3	N/A	2022/06/30	CAM SOP-00307	EPA 8081A/8082B m
Sulphate by Automated Colourimetry (1)	3	N/A	2022/07/05	CAM SOP-00464	EPA 375.4 m
Total Dissolved Solids (1)	3	2022/07/04	2022/07/05	CAM SOP-00428	SM 23 2540C m
Total Kjeldahl Nitrogen in Water (1)	3	2022/07/05	2022/07/06	CAM SOP-00938	OMOE E3516 m
Total Phosphorus (Colourimetric) (1)	3	2022/07/05	2022/07/07	CAM SOP-00407	SM 23 4500 P B H m
Mineral/Synthetic O & G (TPH Heavy Oil) (1, 5)	3	2022/07/05	2022/07/05	CAM SOP-00326	EPA1664B m,SM5520F m
Total Suspended Solids (1)	3	2022/07/04	2022/07/06	CAM SOP-00428	SM 23 2540D m
Turbidity (1)	3	N/A	2022/06/30	CAM SOP-00417	SM 23 2130 B m

Remarks:

Bureau Veritas is accredited to ISO/IEC 17025 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Bureau Veritas are based upon recognized Provincial, Federal or US method compendia such as CCME, MELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Bureau Veritas' profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Bureau Veritas in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported; unless indicated otherwise, associated sample data are not blank corrected. Where applicable, unless otherwise noted, Measurement Uncertainty has not been accounted for when stating conformity to the referenced standard.

BUREAU VERITAS

Your Project #: 21465813
Site Location: RENFREW PIT
Your C.O.C. #: 884606-01-01

Attention: Jaime Oxtobee

Golder Associates Ltd
1931 Robertson Rd
Ottawa, ON
CANADA K2H 5B7

Report Date: 2022/07/08
Report #: R7201850
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C2I1681
Received: 2022/06/29, 11:25

Bureau Veritas liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Bureau Veritas has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Bureau Veritas, unless otherwise agreed in writing. Bureau Veritas is not responsible for the accuracy or any data impacts, that result from the information provided by the customer or their agent.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested. When sampling is not conducted by Bureau Veritas, results relate to the supplied samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix “m” indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
(1) This test was performed by Bureau Veritas Mississauga, 6740 Campobello Rd , Mississauga, ON, L5N 2L8
(2) Dissolved Organic Carbon (DOC) present in the sample should be considered as non-purgeable DOC.
(3) Values for calculated parameters may not appear to add up due to rounding of raw data and significant figures.
(4) Chlordane (Total) = Alpha Chlordane + Gamma Chlordane
(5) Note: TPH (Heavy Oil) is equivalent to Mineral / Synthetic Oil & Grease

Encryption Key Katherine Szozda

Katherine Szozda
Project Manager
08 Jul 2022 14:16:33

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Katherine Szozda, Project Manager
Email: Katherine.Szozda@bureauveritas.com
Phone# (613)274-0573 Ext:7063633
==
Bureau Veritas has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports.
For Service Group specific validation please refer to the Validation Signature Page.

Bureau Veritas Job #: C2I1681
Report Date: 2022/07/08

Golder Associates Ltd
Client Project #: 21465813
Site Location: RENFREW PIT
Sampler Initials: CA

OIL & GREASE - A/V/M/T (SURFACE WATER)

Bureau Veritas ID		TAV998	TAV999	TAW000		
Sampling Date		2022/06/27 09:00	2022/06/27 09:00	2022/06/27 09:00		
	UNITS	**SW-1**	**SW-2**	**SW-3**	**RDL**	**QC Batch**
Calculated Parameters						
Total Animal/Vegetable Oil and Grease	mg/L	<0.50	<0.50	3.1	0.50	8084268
Petroleum Hydrocarbons						
Total Oil & Grease	mg/L	<0.50	<0.50	3.1	0.50	8091150
Total Oil & Grease Mineral/Synthetic	mg/L	<0.50	<0.50	<0.50	0.50	8091153

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Bureau Veritas 100 – 36 Antares Dr. Nepean, ON, K2E 7W5 Phone: 613-274-0573 Website: www.bvna.com

Bureau Veritas Job #: C2I1681
Report Date: 2022/07/08

Golder Associates Ltd
Client Project #: 21465813
Site Location: RENFREW PIT
Sampler Initials: CA

RESULTS OF ANALYSES OF SURFACE WATER

Bureau Veritas ID		TAV998		TAV999			TAV999		
Sampling Date		2022/06/27 09:00		2022/06/27 09:00			2022/06/27 09:00		
	UNITS	**SW-1**	**QC Batch**	**SW-2**	**RDL**	**QC Batch**	**SW-2 Lab-Dup**	**RDL**	**QC Batch**
Calculated Parameters									
Hardness (CaCO3)	mg/L	230	8088176	190	1.0	8088176			
Inorganics									
Total Ammonia-N	mg/L	<0.050	8088340	<0.050	0.050	8088600			
Total Dissolved Solids	mg/L	275	8088559	200	10	8088559			
Total Kjeldahl Nitrogen (TKN)	mg/L	0.61	8090576	0.11	0.10	8090576	0.15	0.10	8090576
Dissolved Organic Carbon	mg/L	4.6	8084485	2.7	0.40	8086831			
Total Phosphorus	mg/L	0.012	8090097	0.010	0.004	8090097			
Total Suspended Solids	mg/L	<10	8087160	<10	10	8087160			
Dissolved Sulphate (SO4)	mg/L	23	8085413	9.1	1.0	8085413			
Turbidity	NTU	2.1	8085095	0.5	0.1	8085095	0.6	0.1	8085095
Alkalinity (Total as CaCO3)	mg/L	220	8085174	190	1.0	8084944			
Dissolved Chloride (Cl-)	mg/L	3.0	8085400	<1.0	1.0	8085400			
Nitrite (N)	mg/L	0.012	8085459	<0.010	0.010	8085459			
Nitrate (N)	mg/L	0.61	8085459	<0.10	0.10	8085459			
Nitrate + Nitrite (N)	mg/L	0.63	8085459	<0.10	0.10	8085459			

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate

Bureau Veritas Job #: C2I1681
Report Date: 2022/07/08

Golder Associates Ltd
Client Project #: 21465813
Site Location: RENFREW PIT
Sampler Initials: CA

RESULTS OF ANALYSES OF SURFACE WATER

Bureau Veritas ID		TAW000		
Sampling Date		2022/06/27 09:00		
	UNITS	**SW-3**	**RDL**	**QC Batch**
Calculated Parameters				
Hardness (CaCO3)	mg/L	200	1.0	8088176
Inorganics				
Total Ammonia-N	mg/L	<0.050	0.050	8088340
Total Dissolved Solids	mg/L	225	10	8088559
Total Kjeldahl Nitrogen (TKN)	mg/L	0.43	0.10	8090576
Dissolved Organic Carbon	mg/L	5.3	0.40	8086831
Total Phosphorus	mg/L	0.015	0.004	8090097
Total Suspended Solids	mg/L	<10	10	8087160
Dissolved Sulphate (SO4)	mg/L	20	1.0	8085413
Turbidity	NTU	0.9	0.1	8085095
Alkalinity (Total as CaCO3)	mg/L	190	1.0	8084944
Dissolved Chloride (Cl-)	mg/L	3.0	1.0	8085400
Nitrite (N)	mg/L	0.010	0.010	8085459
Nitrate (N)	mg/L	0.14	0.10	8085459
Nitrate + Nitrite (N)	mg/L	0.15	0.10	8085459

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

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Bureau Veritas Job #: C2I1681
Report Date: 2022/07/08

Golder Associates Ltd
Client Project #: 21465813
Site Location: RENFREW PIT
Sampler Initials: CA

ELEMENTS BY ATOMIC SPECTROSCOPY (SURFACE WATER)

Bureau Veritas ID		TAV998	TAV999	TAW000			TAW000		
Sampling Date		2022/06/27 09:00	2022/06/27 09:00	2022/06/27 09:00			2022/06/27 09:00		
	UNITS	SW-1	SW-2	SW-3	RDL	QC Batch	SW-3 Lab-Dup	RDL	QC Batch
Metals									
Dissolved (0.2u) Aluminum (Al)	ug/L	<5	<5	<5	5	8084514			
Total Aluminum (Al)	ug/L	40	32	18	4.9	8091152	16	4.9	8091152
Total Antimony (Sb)	ug/L	<0.50	<0.50	<0.50	0.50	8091152	<0.50	0.50	8091152
Total Arsenic (As)	ug/L	<1.0	<1.0	<1.0	1.0	8091152	<1.0	1.0	8091152
Total Barium (Ba)	ug/L	67	41	57	2.0	8091152	57	2.0	8091152
Total Beryllium (Be)	ug/L	<0.40	<0.40	<0.40	0.40	8091152	<0.40	0.40	8091152
Total Bismuth (Bi)	ug/L	<1.0	<1.0	<1.0	1.0	8091152	<1.0	1.0	8091152
Total Boron (B)	ug/L	29	<10	30	10	8091152	31	10	8091152
Total Cadmium (Cd)	ug/L	<0.090	<0.090	<0.090	0.090	8091152	<0.090	0.090	8091152
Total Calcium (Ca)	ug/L	71000	60000	60000	200	8091152	62000	200	8091152
Total Chromium (Cr)	ug/L	<5.0	<5.0	<5.0	5.0	8091152	<5.0	5.0	8091152
Total Cobalt (Co)	ug/L	<0.50	<0.50	<0.50	0.50	8091152	<0.50	0.50	8091152
Total Copper (Cu)	ug/L	<0.90	<0.90	<0.90	0.90	8091152	<0.90	0.90	8091152
Total Iron (Fe)	ug/L	350	<100	170	100	8091152	170	100	8091152
Total Lead (Pb)	ug/L	<0.50	<0.50	<0.50	0.50	8091152	<0.50	0.50	8091152
Total Lithium (Li)	ug/L	<5.0	<5.0	<5.0	5.0	8091152	<5.0	5.0	8091152
Total Magnesium (Mg)	ug/L	18000	13000	16000	50	8091152	16000	50	8091152
Total Manganese (Mn)	ug/L	540	49	43	2.0	8091152	42	2.0	8091152
Total Molybdenum (Mo)	ug/L	1.3	<0.50	0.96	0.50	8091152	0.92	0.50	8091152
Total Nickel (Ni)	ug/L	<1.0	<1.0	<1.0	1.0	8091152	<1.0	1.0	8091152
Total Potassium (K)	ug/L	3100	1700	2800	200	8091152	2800	200	8091152
Total Selenium (Se)	ug/L	<2.0	<2.0	<2.0	2.0	8091152	<2.0	2.0	8091152
Total Silicon (Si)	ug/L	5400	4600	3200	50	8091152	3200	50	8091152
Total Silver (Ag)	ug/L	<0.090	<0.090	<0.090	0.090	8091152	<0.090	0.090	8091152
Total Sodium (Na)	ug/L	3700	1200	3200	100	8091152	3300	100	8091152
Total Strontium (Sr)	ug/L	180	140	160	1.0	8091152	160	1.0	8091152
Total Tellurium (Te)	ug/L	<1.0	<1.0	<1.0	1.0	8091152	<1.0	1.0	8091152
Total Thallium (Tl)	ug/L	<0.050	<0.050	<0.050	0.050	8091152	<0.050	0.050	8091152
Total Tin (Sn)	ug/L	<1.0	<1.0	<1.0	1.0	8091152	<1.0	1.0	8091152
Total Titanium (Ti)	ug/L	<5.0	<5.0	<5.0	5.0	8091152	<5.0	5.0	8091152
Total Tungsten (W)	ug/L	<1.0	<1.0	<1.0	1.0	8091152	<1.0	1.0	8091152
Total Uranium (U)	ug/L	2.1	0.49	1.5	0.10	8091152	1.5	0.10	8091152
Total Vanadium (V)	ug/L	0.83	0.58	<0.50	0.50	8091152	<0.50	0.50	8091152
Total Zinc (Zn)	ug/L	<5.0	<5.0	<5.0	5.0	8091152	<5.0	5.0	8091152

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate

Bureau Veritas Job #: C2I1681
Report Date: 2022/07/08

Golder Associates Ltd
Client Project #: 21465813
Site Location: RENFREW PIT
Sampler Initials: CA

ELEMENTS BY ATOMIC SPECTROSCOPY (SURFACE WATER)

Bureau Veritas ID		TAV998	TAV999	TAW000			TAW000		
Sampling Date		2022/06/27 09:00	2022/06/27 09:00	2022/06/27 09:00			2022/06/27 09:00		
	UNITS	**SW-1**	**SW-2**	**SW-3**	**RDL**	**QC Batch**	**SW-3 Lab-Dup**	**RDL**	**QC Batch**
Total Zirconium (Zr)	ug/L	<1.0	<1.0	<1.0	1.0	8091152	<1.0	1.0	8091152

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Bureau Veritas Job #: C2I1681
Report Date: 2022/07/08

Golder Associates Ltd
Client Project #: 21465813
Site Location: RENFREW PIT
Sampler Initials: CA

ORGANOCHLORINATED PESTICIDES BY GC-ECD (SURFACE WATER)

Bureau Veritas ID		TAV998	TAV999			TAV999			TAW000		
Sampling Date		2022/06/27 09:00	2022/06/27 09:00			2022/06/27 09:00			2022/06/27 09:00		
	UNITS	SW-1	SW-2	RDL	QC Batch	SW-2 Lab-Dup	RDL	QC Batch	SW-3	RDL	QC Batch
Calculated Parameters											
Aldrin + Dieldrin	ug/L	<0.005	<0.005	0.005	8084273				<0.005	0.005	8084273
Chlordane (Total)	ug/L	<0.005	<0.005	0.005	8084273				<0.005	0.005	8084273
DDT+ Metabolites	ug/L	<0.005	<0.005	0.005	8084273				<0.005	0.005	8084273
Heptachlor + Heptachlor epoxide	ug/L	<0.005	<0.005	0.005	8084273				<0.005	0.005	8084273
o,p-DDD + p,p-DDD	ug/L	<0.005	<0.005	0.005	8084273				<0.005	0.005	8084273
o,p-DDE + p,p-DDE	ug/L	<0.005	<0.005	0.005	8084273				<0.005	0.005	8084273
o,p-DDT + p,p-DDT	ug/L	<0.005	<0.005	0.005	8084273				<0.005	0.005	8084273
Total Endosulfan	ug/L	<0.005	<0.005	0.005	8084273				<0.005	0.005	8084273
Total PCB	ug/L	<0.05	<0.05	0.05	8084273				<0.05	0.05	8084273
Pesticides & Herbicides											
Aldrin	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
Dieldrin	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
a-Chlordane	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
g-Chlordane	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
o,p-DDD	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
p,p-DDD	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
o,p-DDE	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
p,p-DDE	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
o,p-DDT	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
p,p-DDT	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
Lindane	ug/L	<0.003	<0.003	0.003	8092077	<0.003	0.003	8092077	<0.003	0.003	8092077
Endosulfan I (alpha)	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
Endosulfan II (beta)	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
Endrin	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
Heptachlor	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
Heptachlor epoxide	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
Hexachlorobenzene	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
Methoxychlor	ug/L	<0.01	<0.01	0.01	8092077	<0.01	0.01	8092077	<0.01	0.01	8092077
Aroclor 1016	ug/L	<0.05	<0.05	0.05	8092077	<0.05	0.05	8092077	<0.05	0.05	8092077
Aroclor 1221	ug/L	<0.05	<0.05	0.05	8092077	<0.05	0.05	8092077	<0.05	0.05	8092077
Aroclor 1232	ug/L	<0.05	<0.05	0.05	8092077	<0.05	0.05	8092077	<0.05	0.05	8092077
Aroclor 1242	ug/L	<0.05	<0.05	0.05	8092077	<0.05	0.05	8092077	<0.05	0.05	8092077
Aroclor 1248	ug/L	<0.05	<0.05	0.05	8092077	<0.05	0.05	8092077	<0.05	0.05	8092077
Aroclor 1254	ug/L	<0.05	<0.05	0.05	8092077	<0.05	0.05	8092077	<0.05	0.05	8092077

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Bureau Veritas 100 – 36 Antares Dr. Nepean, ON, K2E 7W5 Phone: 613-274-0573 Website: www.bvna.com

Bureau Veritas Job #: C2I1681
Report Date: 2022/07/08

Golder Associates Ltd
Client Project #: 21465813
Site Location: RENFREW PIT
Sampler Initials: CA

ORGANOCHLORINATED PESTICIDES BY GC-ECD (SURFACE WATER)

Bureau Veritas ID		TAV998	TAV999			TAV999			TAW000		
Sampling Date		2022/06/27 09:00	2022/06/27 09:00			2022/06/27 09:00			2022/06/27 09:00		
	UNITS	SW-1	SW-2	RDL	QC Batch	SW-2 Lab-Dup	RDL	QC Batch	SW-3	RDL	QC Batch
Aroclor 1260	ug/L	<0.05	<0.05	0.05	8092077	<0.05	0.05	8092077	<0.05	0.05	8092077
alpha-BHC	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
beta-BHC	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
delta-BHC	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
Endosulfan sulfate	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
Endrin aldehyde	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
Endrin ketone	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
Mirex	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
Octachlorostyrene	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
Oxychlordane	ug/L	<0.005	<0.005	0.005	8092077	<0.005	0.005	8092077	<0.005	0.005	8092077
Toxaphene	ug/L	<0.2	<0.2	0.2	8092077	<0.2	0.2	8092077	<0.2	0.2	8092077
Surrogate Recovery (%)											
2,4,5,6-Tetrachloro-m-xylene	%	69	82		8092077	85		8092077	73		8092077
Decachlorobiphenyl	%	101	106		8092077	106		8092077	91		8092077

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Lab-Dup = Laboratory Initiated Duplicate

Bureau Veritas Job #: C2I1681
Report Date: 2022/07/08

Golder Associates Ltd
Client Project #: 21465813
Site Location: RENFREW PIT
Sampler Initials: CA

TEST SUMMARY

Bureau Veritas ID: TAV998
Sample ID: SW-1
Matrix: Surface Water

Collected: 2022/06/27
Shipped:
Received: 2022/06/29

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Dissolved Aluminum (0.2 u, clay free)	ICP/MS	8084514	N/A	2022/07/04	Arefa Dabhad
Alkalinity	AT	8085174	N/A	2022/07/04	Surinder Rai
Chloride by Automated Colourimetry	KONE	8085400	N/A	2022/07/04	Alina Dobreanu
Dissolved Organic Carbon (DOC)	TOCV/NDIR	8084485	N/A	2022/07/05	Nimarta Singh
Hardness (calculated as CaCO3)		8088176	N/A	2022/07/07	Automated Statchk
Total Metals Analysis by ICPMS	ICP/MS	8091152	N/A	2022/07/06	Arefa Dabhad
Total Ammonia-N	LACH/NH4	8088340	N/A	2022/07/06	Amanpreet Sappal
Nitrate & Nitrite as Nitrogen in Water	LACH	8085459	N/A	2022/07/04	Chandra Nandlal
Animal and Vegetable Oil and Grease	BAL	8084268	N/A	2022/07/05	Automated Statchk
Total Oil and Grease	BAL	8091150	2022/07/05	2022/07/05	Maulik Jashubhai Patel
OC Pesticides (Selected) & PCB	GC/ECD	8092077	2022/07/05	2022/07/06	Li Peng
OC Pesticides Summed Parameters	CALC	8084273	N/A	2022/06/30	Automated Statchk
Sulphate by Automated Colourimetry	KONE	8085413	N/A	2022/07/05	Alina Dobreanu
Total Dissolved Solids	BAL	8088559	2022/07/04	2022/07/05	Shaneil Hall
Total Kjeldahl Nitrogen in Water	SKAL	8090576	2022/07/05	2022/07/06	Massarat Jan
Total Phosphorus (Colourimetric)	LACH/P	8090097	2022/07/05	2022/07/07	Shivani Shivani
Mineral/Synthetic O & G (TPH Heavy Oil)	BAL	8091153	2022/07/05	2022/07/05	Maulik Jashubhai Patel
Total Suspended Solids	BAL	8087160	2022/07/04	2022/07/06	Shaneil Hall
Turbidity	AT	8085095	N/A	2022/06/30	Roya Fathitil

Bureau Veritas ID: TAV999
Sample ID: SW-2
Matrix: Surface Water

Collected: 2022/06/27
Shipped:
Received: 2022/06/29

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Dissolved Aluminum (0.2 u, clay free)	ICP/MS	8084514	N/A	2022/07/04	Arefa Dabhad
Alkalinity	AT	8084944	N/A	2022/07/01	Surinder Rai
Chloride by Automated Colourimetry	KONE	8085400	N/A	2022/07/04	Alina Dobreanu
Dissolved Organic Carbon (DOC)	TOCV/NDIR	8086831	N/A	2022/07/04	Nimarta Singh
Hardness (calculated as CaCO3)		8088176	N/A	2022/07/07	Automated Statchk
Total Metals Analysis by ICPMS	ICP/MS	8091152	N/A	2022/07/06	Arefa Dabhad
Total Ammonia-N	LACH/NH4	8088600	N/A	2022/07/06	Amanpreet Sappal
Nitrate & Nitrite as Nitrogen in Water	LACH	8085459	N/A	2022/07/04	Chandra Nandlal
Animal and Vegetable Oil and Grease	BAL	8084268	N/A	2022/07/05	Automated Statchk
Total Oil and Grease	BAL	8091150	2022/07/05	2022/07/05	Maulik Jashubhai Patel
OC Pesticides (Selected) & PCB	GC/ECD	8092077	2022/07/05	2022/07/06	Li Peng
OC Pesticides Summed Parameters	CALC	8084273	N/A	2022/06/30	Automated Statchk
Sulphate by Automated Colourimetry	KONE	8085413	N/A	2022/07/05	Alina Dobreanu
Total Dissolved Solids	BAL	8088559	2022/07/04	2022/07/05	Shaneil Hall
Total Kjeldahl Nitrogen in Water	SKAL	8090576	2022/07/05	2022/07/06	Massarat Jan
Total Phosphorus (Colourimetric)	LACH/P	8090097	2022/07/05	2022/07/07	Shivani Shivani
Mineral/Synthetic O & G (TPH Heavy Oil)	BAL	8091153	2022/07/05	2022/07/05	Maulik Jashubhai Patel
Total Suspended Solids	BAL	8087160	2022/07/04	2022/07/06	Shaneil Hall
Turbidity	AT	8085095	N/A	2022/06/30	Roya Fathitil

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Bureau Veritas Job #: C2I1681
Report Date: 2022/07/08

Golder Associates Ltd
Client Project #: 21465813
Site Location: RENFREW PIT
Sampler Initials: CA

TEST SUMMARY

Bureau Veritas ID: TAV999 Dup
Sample ID: SW-2
Matrix: Surface Water

Collected: 2022/06/27
Shipped:
Received: 2022/06/29

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
OC Pesticides (Selected) & PCB	GC/ECD	8092077	2022/07/05	2022/07/06	Li Peng
Total Kjeldahl Nitrogen in Water	SKAL	8090576	2022/07/05	2022/07/06	Massarat Jan
Turbidity	AT	8085095	N/A	2022/06/30	Roya Fathitil

Bureau Veritas ID: TAW000
Sample ID: SW-3
Matrix: Surface Water

Collected: 2022/06/27
Shipped:
Received: 2022/06/29

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Dissolved Aluminum (0.2 u, clay free)	ICP/MS	8084514	N/A	2022/07/04	Arefa Dabhad
Alkalinity	AT	8084944	N/A	2022/07/01	Surinder Rai
Chloride by Automated Colourimetry	KONE	8085400	N/A	2022/07/04	Alina Dobreanu
Dissolved Organic Carbon (DOC)	TOCV/NDIR	8086831	N/A	2022/07/04	Nimarta Singh
Hardness (calculated as CaCO3)		8088176	N/A	2022/07/07	Automated Statchk
Total Metals Analysis by ICPMS	ICP/MS	8091152	N/A	2022/07/06	Arefa Dabhad
Total Ammonia-N	LACH/NH4	8088340	N/A	2022/07/07	Amanpreet Sappal
Nitrate & Nitrite as Nitrogen in Water	LACH	8085459	N/A	2022/07/04	Chandra Nandlal
Animal and Vegetable Oil and Grease	BAL	8084268	N/A	2022/07/05	Automated Statchk
Total Oil and Grease	BAL	8091150	2022/07/05	2022/07/05	Maulik Jashubhai Patel
OC Pesticides (Selected) & PCB	GC/ECD	8092077	2022/07/05	2022/07/06	Li Peng
OC Pesticides Summed Parameters	CALC	8084273	N/A	2022/06/30	Automated Statchk
Sulphate by Automated Colourimetry	KONE	8085413	N/A	2022/07/05	Alina Dobreanu
Total Dissolved Solids	BAL	8088559	2022/07/04	2022/07/05	Shaneil Hall
Total Kjeldahl Nitrogen in Water	SKAL	8090576	2022/07/05	2022/07/06	Massarat Jan
Total Phosphorus (Colourimetric)	LACH/P	8090097	2022/07/05	2022/07/07	Shivani Shivani
Mineral/Synthetic O & G (TPH Heavy Oil)	BAL	8091153	2022/07/05	2022/07/05	Maulik Jashubhai Patel
Total Suspended Solids	BAL	8087160	2022/07/04	2022/07/06	Shaneil Hall
Turbidity	AT	8085095	N/A	2022/06/30	Roya Fathitil

Bureau Veritas ID: TAW000 Dup
Sample ID: SW-3
Matrix: Surface Water

Collected: 2022/06/27
Shipped:
Received: 2022/06/29

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Total Metals Analysis by ICPMS	ICP/MS	8091152	N/A	2022/07/06	Arefa Dabhad

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	5.0°C

Results relate only to the items tested.

Bureau Veritas Job #: C2I1681
Report Date: 2022/07/08

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 21465813
Site Location: RENFREW PIT
Sampler Initials: CA

			Matrix Spike		SPIKED BLANK		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
8092077	2,4,5,6-Tetrachloro-m-xylene	2022/07/06	85	50 - 130	82	50 - 130	64	%				
8092077	Decachlorobiphenyl	2022/07/06	114	50 - 130	123	50 - 130	98	%				
8084485	Dissolved Organic Carbon	2022/07/04	97	80 - 120	98	80 - 120	<0.40	mg/L	1.4	20		
8084514	Dissolved (0.2u) Aluminum (Al)	2022/07/04	104	80 - 120	100	80 - 120	<5	ug/L	0.35	20		
8084944	Alkalinity (Total as CaCO3)	2022/06/30			97	85 - 115	<1.0	mg/L	0.33	20		
8085095	Turbidity	2022/06/30			94	85 - 115	<0.1	NTU	9.2	20		
8085174	Alkalinity (Total as CaCO3)	2022/07/04			96	85 - 115	<1.0	mg/L	0.58	20		
8085400	Dissolved Chloride (Cl-)	2022/07/04	82	80 - 120	103	80 - 120	<1.0	mg/L	0.75	20		
8085413	Dissolved Sulphate (SO4)	2022/07/05	NC	75 - 125	102	80 - 120	<1.0	mg/L	1.3	20		
8085459	Nitrate (N)	2022/07/04	98	80 - 120	97	80 - 120	<0.10	mg/L	7.4	20		
8085459	Nitrite (N)	2022/07/04	93	80 - 120	103	80 - 120	<0.010	mg/L	1.7	20		
8086831	Dissolved Organic Carbon	2022/07/04	90	80 - 120	96	80 - 120	<0.40	mg/L	2.1	20		
8087160	Total Suspended Solids	2022/07/06					<10	mg/L	NC	25	95	85 - 115
8088340	Total Ammonia-N	2022/07/06	97	75 - 125	99	80 - 120	<0.050	mg/L	NC	20		
8088559	Total Dissolved Solids	2022/07/05					<10	mg/L	3.8	25	100	90 - 110
8088600	Total Ammonia-N	2022/07/06	96	75 - 125	98	80 - 120	<0.050	mg/L	NC	20		
8090097	Total Phosphorus	2022/07/07	96	80 - 120	101	80 - 120	<0.004	mg/L	4.9	20	97	80 - 120
8090576	Total Kjeldahl Nitrogen (TKN)	2022/07/06	104	80 - 120	103	80 - 120	<0.10	mg/L	NC	20	100	80 - 120
8091150	Total Oil & Grease	2022/07/05			99	85 - 115	<0.50	mg/L	0.51	25		
8091152	Total Aluminum (Al)	2022/07/06	104	80 - 120	103	80 - 120	<4.9	ug/L	8.6	20		
8091152	Total Antimony (Sb)	2022/07/06	108	80 - 120	107	80 - 120	<0.50	ug/L	NC	20		
8091152	Total Arsenic (As)	2022/07/06	100	80 - 120	100	80 - 120	<1.0	ug/L	NC	20		
8091152	Total Barium (Ba)	2022/07/06	102	80 - 120	102	80 - 120	<2.0	ug/L	0.58	20		
8091152	Total Beryllium (Be)	2022/07/06	103	80 - 120	100	80 - 120	<0.40	ug/L	NC	20		
8091152	Total Bismuth (Bi)	2022/07/06	100	80 - 120	98	80 - 120	<1.0	ug/L	NC	20		
8091152	Total Boron (B)	2022/07/06	96	80 - 120	94	80 - 120	<10	ug/L	4.3	20		
8091152	Total Cadmium (Cd)	2022/07/06	103	80 - 120	102	80 - 120	<0.090	ug/L	NC	20		
8091152	Total Calcium (Ca)	2022/07/06	NC	80 - 120	102	80 - 120	<200	ug/L	4.0	20		
8091152	Total Chromium (Cr)	2022/07/06	93	80 - 120	95	80 - 120	<5.0	ug/L	NC	20		
8091152	Total Cobalt (Co)	2022/07/06	99	80 - 120	100	80 - 120	<0.50	ug/L	NC	20		
8091152	Total Copper (Cu)	2022/07/06	100	80 - 120	98	80 - 120	2.1, RDL=0.90	ug/L	NC	20		
8091152	Total Iron (Fe)	2022/07/06	101	80 - 120	102	80 - 120	<100	ug/L	0.58	20		

Bureau Veritas Job #: C2I1681
Report Date: 2022/07/08

QUALITY ASSURANCE REPORT(CONT'D)

Golder Associates Ltd
Client Project #: 21465813
Site Location: RENFREW PIT
Sampler Initials: CA

			Matrix Spike		SPIKED BLANK		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
8091152	Total Lead (Pb)	2022/07/06	101	80 - 120	102	80 - 120	<0.50	ug/L	NC	20		
8091152	Total Lithium (Li)	2022/07/06	98	80 - 120	96	80 - 120	<5.0	ug/L	NC	20		
8091152	Total Magnesium (Mg)	2022/07/06	96	80 - 120	104	80 - 120	<50	ug/L	0.26	20		
8091152	Total Manganese (Mn)	2022/07/06	100	80 - 120	102	80 - 120	<2.0	ug/L	0.82	20		
8091152	Total Molybdenum (Mo)	2022/07/06	101	80 - 120	100	80 - 120	<0.50	ug/L	4.8	20		
8091152	Total Nickel (Ni)	2022/07/06	95	80 - 120	97	80 - 120	<1.0	ug/L	NC	20		
8091152	Total Potassium (K)	2022/07/06	105	80 - 120	107	80 - 120	<200	ug/L	1.0	20		
8091152	Total Selenium (Se)	2022/07/06	100	80 - 120	101	80 - 120	<2.0	ug/L	NC	20		
8091152	Total Silicon (Si)	2022/07/06	104	80 - 120	100	80 - 120	<50	ug/L	0.90	20		
8091152	Total Silver (Ag)	2022/07/06	100	80 - 120	98	80 - 120	<0.090	ug/L	NC	20		
8091152	Total Sodium (Na)	2022/07/06	101	80 - 120	102	80 - 120	<100	ug/L	3.1	20		
8091152	Total Strontium (Sr)	2022/07/06	97	80 - 120	99	80 - 120	<1.0	ug/L	0.43	20		
8091152	Total Tellurium (Te)	2022/07/06	102	80 - 120	99	80 - 120	<1.0	ug/L	NC	20		
8091152	Total Thallium (Tl)	2022/07/06	103	80 - 120	103	80 - 120	<0.050	ug/L	NC	20		
8091152	Total Tin (Sn)	2022/07/06	106	80 - 120	105	80 - 120	<1.0	ug/L	NC	20		
8091152	Total Titanium (Ti)	2022/07/06	99	80 - 120	99	80 - 120	<5.0	ug/L	NC	20		
8091152	Total Tungsten (W)	2022/07/06	104	80 - 120	104	80 - 120	<1.0	ug/L	NC	20		
8091152	Total Uranium (U)	2022/07/06	105	80 - 120	103	80 - 120	<0.10	ug/L	1.3	20		
8091152	Total Vanadium (V)	2022/07/06	96	80 - 120	97	80 - 120	<0.50	ug/L	NC	20		
8091152	Total Zinc (Zn)	2022/07/06	99	80 - 120	103	80 - 120	<5.0	ug/L	NC	20		
8091152	Total Zirconium (Zr)	2022/07/06	100	80 - 120	99	80 - 120	<1.0	ug/L	NC	20		
8091153	Total Oil & Grease Mineral/Synthetic	2022/07/05			97	85 - 115	<0.50	mg/L	1.0	25		
8092077	a-Chlordane	2022/07/06	102	50 - 130	113	50 - 130	<0.005	ug/L	NC	30		
8092077	Aldrin	2022/07/06	117	50 - 130	115	50 - 130	<0.005	ug/L	NC	30		
8092077	alpha-BHC	2022/07/06	92	30 - 130	100	30 - 130	<0.005	ug/L	NC	40		
8092077	Aroclor 1016	2022/07/06					<0.05	ug/L	NC	30		
8092077	Aroclor 1221	2022/07/06					<0.05	ug/L	NC	30		
8092077	Aroclor 1232	2022/07/06					<0.05	ug/L	NC	30		
8092077	Aroclor 1242	2022/07/06					<0.05	ug/L	NC	30		
8092077	Aroclor 1248	2022/07/06					<0.05	ug/L	NC	30		
8092077	Aroclor 1254	2022/07/06					<0.05	ug/L	NC	30		
8092077	Aroclor 1260	2022/07/06					<0.05	ug/L	NC	30		

QUALITY ASSURANCE REPORT(CONT'D)

			Matrix Spike		SPIKED BLANK		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
8092077	beta-BHC	2022/07/06	79	30 - 130	94	30 - 130	<0.005	ug/L	NC	40		
8092077	delta-BHC	2022/07/06	93	30 - 130	105	30 - 130	<0.005	ug/L	NC	40		
8092077	Dieldrin	2022/07/06	117	50 - 130	125	50 - 130	<0.005	ug/L	NC	30		
8092077	Endosulfan I (alpha)	2022/07/06	92	50 - 130	103	50 - 130	<0.005	ug/L	NC	30		
8092077	Endosulfan II (beta)	2022/07/06	97	50 - 130	106	50 - 130	<0.005	ug/L	NC	30		
8092077	Endosulfan sulfate	2022/07/06	113	30 - 130	126	30 - 130	<0.005	ug/L	NC	40		
8092077	Endrin aldehyde	2022/07/06	68	30 - 130	95	30 - 130	<0.005	ug/L	NC	40		
8092077	Endrin ketone	2022/07/06	125	30 - 130	130	30 - 130	<0.005	ug/L	NC	40		
8092077	Endrin	2022/07/06	123	50 - 130	119	50 - 130	<0.005	ug/L	NC	30		
8092077	g-Chlordane	2022/07/06	105	50 - 130	111	50 - 130	<0.005	ug/L	NC	30		
8092077	Heptachlor epoxide	2022/07/06	103	50 - 130	116	50 - 130	<0.005	ug/L	NC	30		
8092077	Heptachlor	2022/07/06	102	50 - 130	104	50 - 130	<0.005	ug/L	NC	30		
8092077	Hexachlorobenzene	2022/07/06	92	50 - 130	95	50 - 130	<0.005	ug/L	NC	30		
8092077	Lindane	2022/07/06	90	50 - 130	101	50 - 130	<0.003	ug/L	NC	30		
8092077	Methoxychlor	2022/07/06	102	50 - 130	111	50 - 130	<0.01	ug/L	NC	30		
8092077	Mirex	2022/07/06	114	30 - 130	112	30 - 130	<0.005	ug/L	NC	40		
8092077	o,p-DDD	2022/07/06	103	50 - 130	118	50 - 130	<0.005	ug/L	NC	30		
8092077	o,p-DDE	2022/07/06	95	50 - 130	102	50 - 130	<0.005	ug/L	NC	30		
8092077	o,p-DDT	2022/07/06	109	50 - 130	120	50 - 130	<0.005	ug/L	NC	30		
8092077	Octachlorostyrene	2022/07/06	98	30 - 130	104	30 - 130	<0.005	ug/L	NC	40		
8092077	Oxychlordane	2022/07/06	96	30 - 130	107	30 - 130	<0.005	ug/L	NC	30		
8092077	p,p-DDD	2022/07/06	105	50 - 130	115	50 - 130	<0.005	ug/L	NC	30		
8092077	p,p-DDE	2022/07/06	89	50 - 130	100	50 - 130	<0.005	ug/L	NC	30		
8092077	p,p-DDT	2022/07/06	111	50 - 130	117	50 - 130	<0.005	ug/L	NC	30		

Bureau Veritas Job #: C2I1681
Report Date: 2022/07/08

QUALITY ASSURANCE REPORT(CONT'D)

Golder Associates Ltd
Client Project #: 21465813
Site Location: RENFREW PIT
Sampler Initials: CA

			Matrix Spike		SPIKED BLANK		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
8092077	Toxaphene	2022/07/06					<0.2	ug/L	NC	40		

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

Surrogate: A pure or isotopically labeled compound whose behavior mirrors the analytes of interest. Used to evaluate extraction efficiency.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference <= 2x RDL).

Bureau Veritas Job #: C2I1681
Report Date: 2022/07/08

Golder Associates Ltd
Client Project #: 21465813
Site Location: RENFREW PIT
Sampler Initials: CA

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by:

Eva Pranjic CHARTERED CHEMIST

Ewa Pranjic, M.Sc., C.Chem, Scientific Specialist

Bureau Veritas has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Bureau Veritas 100 – 36 Antares Dr. Nepean, ON, K2E 7W5 Phone: 613-274-0573 Website: www.bvna.com

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Bureau Veritas
6740 Campobello Road, Mississauga, Ontario Canada L5N 2L8 Tel (905) 817-5700 Toll-free 800-563-6266 Fax (905) 817-5777 www.bvna.com

CHAIN OF CUSTODY RECORD

INVOICE TO:		REPORT TO:		PROJECT INFORMATION:		Laboratory Use Only:	
Company Name:	#14090 Golder Associates Ltd	Company Name:		Quotation #:	C22487	Bureau Veritas Job #:	Bottle Order #:
Attention:	Central Accounting	Attention:	~~Dale Holtze~~ J. Oxtobee	P.O. #:			884606
Address:	1931 Robertson Rd	Address:		Project:	~~20412072A~~ 21465813	COC #:	Project Manager:
	Ottawa ON K2H 5B7			Project Name:	Renfrew Pit	C#884606-01-01	Katherine Szozda
Tel:	(613) 592-9600 Fax: (613) 592-9601	Tel:	Fax:	Site #:			
Email:	gld.CanadaAccountsPayableInvoices@wsp.com	Email:	~~Dale_Holtze@golder.com~~	Sampled By:	C. Albert		

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE BUREAU VERITAS DRINKING WATER CHAIN OF CUSTODY

Regulation 153 (2011)	Other Regulations	Special Instructions
☐ Table 1 ☐ Res/Park ☐ Medium/Fine	☐ CCME ☐ Sanitary Sewer Bylaw	
☐ Table 2 ☐ Ind/Comm ☐ Coarse	☐ Reg 558 ☐ Storm Sewer Bylaw	
☐ Table 3 ☐ Agri/Other ☐ For RSC	☐ MISA Municipality	
☐ Table	☒ PWQO ☐ Reg 406 Table	
	☐ Other	

Include Criteria on Certificate of Analysis (Y/N)? ______

ANALYSIS REQUESTED (PLEASE BE SPECIFIC)

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Field Filtered (please circle): Metals / Hg / Cr VI	Standard SW Sample Analysis	# of Bottles	Comments
1		SW-1	Jun 27/22	9Am	SW	/	✓		
2		SW-2	↓	↓	↓	/	✓		
3		SW-3	↓	↓	↓	/	✓		
4									
5									
6									
7									
8									
9									
10									

Turnaround Time (TAT) Required:
Please provide advance notice for rush projects

Regular (Standard) TAT: ☒
(will be applied if Rush TAT is not specified):
Standard TAT = 5-7 Working days for most tests.
Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.

Job Specific Rush TAT (if applies to entire submission)
Date Required: ______ Time Required: ______
Rush Confirmation Number: ______ (call lab for #)

RECEIVED IN OTTAWA

29-Jun-22 11:25
Katherine Szozda
C2I1681
SBS ENV-951
ON Ice

* RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted	Time Sensitive	Laboratory Use Only
C. Albert	22/06/29	9Am		22/06/29	11:25			Temperature (°C) on Recei: 6, 6, 7
				2022/06/30	0800			Custody Seal Present / Intact: Yes ✓ / No

* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO BUREAU VERITAS'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT WWW.BVNA.COM/TERMS-AND-CONDITIONS.

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

** SAMPLE CONTAINER, PRESERVATION, HOLD TIME AND PACKAGE INFORMATION CAN BE VIEWED AT WWW.BVNA.COM/RESOURCES/CHAIN-OF-CUSTODY-FORMS.

SAMPLES MUST BE KEPT COOL (< 10° C) FROM TIME OF SAMPLING UNTIL DELIVERY TO BUREAU VERITAS

White: Bureau Veritas Yellow: Client

2/4/3

APPENDIX H

Analytical Modelling Results

Based on Equations by Marinelli and Niccoli (2000)

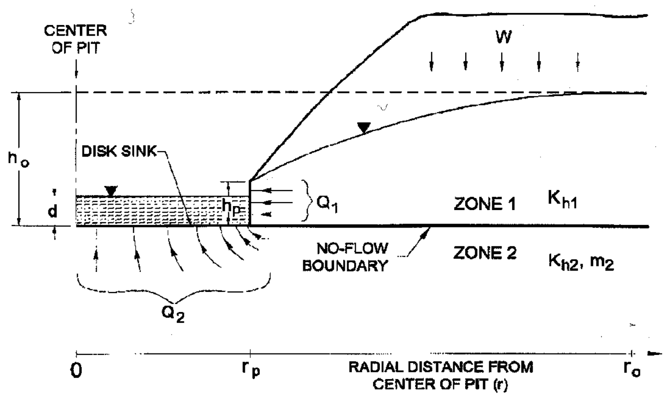

Figure 2. Pit inflow analytical model.

Marinelli, F., and W. L. Niccoli. 2000. Simple analytical equations for estimating ground water inflow to a mine pit. Ground Water 38, no. 2: 311-314.

(A) $$h_o = \sqrt{{h_p}^2 + \frac{W}{K_{h1}}\left[r_o^2 \ln\left(\frac{r_o}{r_p}\right) - \frac{\left(r_o^2 - r_p^2\right)}{2}\right]}$$

(A1) $$h = \sqrt{{h_p}^2 + \frac{W}{K_{h1}}\left[r_o^2 \ln\left(\frac{r}{r_p}\right) - \frac{\left(r^2 - r_p^2\right)}{2}\right]},$$

(B) $$Q_1 = W\pi\left(r_o^2 - r_p^2\right),$$

(C) $$Q_2 = 4r_p\left(\frac{K_{h2}}{m_2}\right)(h_0 - d)$$

(D) $$m_2 = \sqrt{\frac{K_{h2}}{K_{v2}}}$$

Input Parameters

W (m/s)	5.5E-09	recharge flux
Kh1 (m/s)	1.E-05	horizontal hydraulic conductivity in Zone 1 - K at BH21-01
Kh2 (m/s)	1.E-05	horizontal hydraulic conductivity in Zone 2 - K at BH21-01
Kv2 (m/s)	1.E-05	vertical hydraulic conductivity in Zone 2 - K at BH21-01
ho (m)	10.0	initial saturated thickness above the base of Zone 1
hp (m)	7.3	saturated thickness at the pit wall
rp (m)	126.0	effective pit radius
d (m)	7.3	depth of the pit lake

Based on Equations by Marinelli and Niccoli (2000)

One Metre Radius of Influence

r (m)	199.9	radius of influence calculated by iterating equation A1

(known h)		(h calculated using eq. A1)
9.0	=	9.0

Pit Area

	Area (ha)	Area (m2)	R (m)	Radius of Influence at 1 metre drawdown	Radius of Influence beyond Pit Boundary (m)
Operations	5	50000	126	199.9	74

Based on Equations by Marinelli and Niccoli (2000)

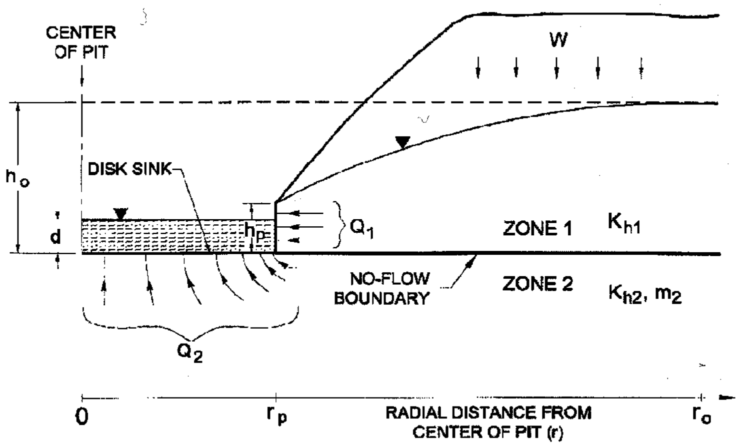

Figure 2. Pit inflow analytical model.

Marinelli, F., and W. L. Niccoli. 2000. Simple analytical equations for estimating ground water inflow to a mine pit. Ground Water 38, no. 2: 311-314.

(A) $$h_o = \sqrt{{h_p}^2 + \frac{W}{K_{h1}}\left[r_o^2 \ln\left(\frac{r_o}{r_p}\right) - \frac{\left(r_o^2 - r_p^2\right)}{2}\right]}$$

(A1) $$h = \sqrt{{h_p}^2 + \frac{W}{K_{h1}}\left[r_o^2 \ln\left(\frac{r}{r_p}\right) - \frac{\left(r^2 - r_p^2\right)}{2}\right]},$$

(B) $$Q_1 = W\pi\left(r_o^2 - r_p^2\right),$$

(C) $$Q_2 = 4r_p\left(\frac{K_{h2}}{m_2}\right)(h_0 - d)$$

(D) $$m_2 = \sqrt{\frac{K_{h2}}{K_{v2}}}$$

Input Parameters BH21-02

W (m/s)	5.5E-09	recharge flux
Kh1 (m/s)	5.E-06	horizontal hydraulic conductivity in Zone 1 - K at BH21-02
Kh2 (m/s)	1.0E-07	horizontal hydraulic conductivity in Zone 2 (Precambian bedrock - typical value)
Kv2 (m/s)	1.0E-07	horizontal hydraulic conductivity in Zone 2 (Precambian bedrock - typical value)
ho (m)	10.0	initial saturated thickness above the base of Zone 1
hp (m)	0.0	saturated thickness at the pit wall
rp (m)	126.0	effective pit radius
d (m)	0.0	depth of the pit lake

Based on Equations by Marinelli and Niccoli (2000)

One Metre Radius of Influence

r (m)	251.6	radius of influence calculated by iterating equation A1

(known h)		(h calculated using eq. A1)
9.0	=	9.0

Pit Area

	Area (ha)	Area (m2)	R (m)	Radius of Influence at 1 metre drawdown	Radius of Influence Beyond the Pit Boundary (m)
Operations	5	50000	126	251.6	125