REPORT

Hydrological Assessments in Support of Aggregate Resources Act Applications for the Port Colborne Proposed Pit 3 Extension, Port Colborne, Ontario

Submitted to:

Port Colborne Quarries Inc.
222 Martindale Road, P.O. Box 1116
St. Catharines, Ontario
L2R 7A3

Submitted by:

Golder Associates Ltd.
6925 Century Avenue, Suite #100 Mississauga, Ontario, L5N 7K2 Canada

+1 905 567 4444

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1.0 INTRODUCTION

Port Colborne Quarries Inc. (PCQ), a division of Rankin Construction Inc. (Rankin) is proposing an extension to Pit 3 of their existing Port Colborne Quarry in order to continue extraction of the aggregate resources.

In order to satisfy the requirements of the Ontario Aggregate Resources Act (ARA) with regard to a Category 2, Class “A” Quarry Below Water license application certain plans and studies are required to identify the effects of the proposed Pit 3 extension and to identify any required mitigation so that established environmental objectives are met. This includes the requirement for a Level 1/ 2 Water Resources Assessment. This report provides the hydrological component of the water resources assessment; the hydrogeological assessment is provided under separate cover.

The existing Port Colborne Quarry is located in the City of Port Colborne within the Regional Municipality of Niagara. The existing quarry is bounded by Second Concession Road to the north, Highway 140 to the west, Main Street East (Highway 3) to the south, and 200 metres west of Carl Road to the east (Figure 1).

The proposed Pit 3 extension (Site) is situated directly east of the existing quarry and remains between Second Concession Road to the north and Highway 3 to the south and extends eastward to Miller Road (see Figure 1). The Site is located in Part of Lots 18 and 19 Concession 2, Humberstone Township, Regional Municipality of Niagara and comprises 106.29 hectares (262.65 acres). The property is bordered by Second Concession Road to the north, Main Street East to the south, the existing Port Colborne quarry to the west and agricultural fields and Humberstone Speedway to the east, and the Carl Road right-of-way (Plan 59R-16702) within the property.

East Wignell Drain (formerly Mitchner Drain) will be realigned around the site boundary as part of the planned City’s drainage modifications. The realignment will include the impact evaluation, channel design and construction; therefore, any effects to the drain as a result of the realignment were not evaluated in this assessment. The realignment is expected to collect the drainage to the north and east of the Pit 3 extension.

1.1 Required Land Use Approvals

In order for extraction to occur on the subject lands, the following approvals are required:

- Amendment to the Region of Niagara Official Plan 2014, to designate the lands as Licensed Pits and Quarries.
- Amendment to the City of Port Colborne Official Plan 2017, to re-designate the lands from Agricultural to Mineral Aggregate Operation.
- Amendment to the City of Port Colborne Zoning By-Law 6575/30/18, to rezone the lands from Agricultural (A) to Mineral Aggregate Operation (MAO).
- Application to the Ministry of Natural Resources, under the Aggregate Resources Act for a Class A Category 2 Licence (Quarry Below Water).

1.1.1 Region of Niagara Official Plan (ROP) 2014

Policy 6.C.13 of the Region of Niagara ROP states: “Where a new pit or quarry or an extension to an existing licensed pit or quarry are to be located outside a Possible Aggregate Area, an amendment to this Plan is required.” As the subject lands are not within a Possible Aggregate Area, a Regional Official Plan Amendment through the Region of Niagara is required to identify the subject lands on Schedule D4 - Mineral Resources.

1.1.2 City of Port Colborne Official Plan (OP) 2017

Policy 10.2 of the City of Port Colborne OP states: “The establishment of a new or an expansion to an existing mineral aggregate operation shall require an amendment to this Plan…” Therefore, an Official Plan Amendment through the City of Port Colborne is required.

1.1.3 City of Port Colborne Zoning By-Law No. 6575/30/18:

The lands are currently zoned (A) Agricultural within the City’s Comprehensive Zoning By-Law. Extraction and related uses are not a permitted use. Therefore, the lands must be rezoned to (MAO) Mineral Aggregate Operations in order to permit extraction and all the permitted accessory uses. This requires an amendment to the City’s Zoning By-Law No. 6575/30/18.

1.1.4 Aggregate Resources Act

In addition to the above Planning Approvals, PCQ also requires approval for a Class A Category 2 (Quarry Below Water) License under the Aggregate Resources Act as processed through the Ministry of Natural Resources and Forestry.

2.0 SITE HYDROLOGY

The full development of the Site will potentially affect local surface water hydrology, via land use changes, surface water drainage alterations and the quarry water management. To identify the surface water features present on the Site (i.e. watercourses, waterbodies, and/or drainage features), historic reports, Ministry of Natural Resources mapping, along with information collected during site visits conducted between September 2017 to November 2019 were reviewed.

To maintain dry working conditions at the existing quarry, the existing extraction area is dewatered with some water being used for aggregate processing and dust suppression. During drier seasons, discharge from the Port Colborne Quarries' sumps is often the only flow within the receiving watercourse (west branch of the Wignell Drain). Current Port Colborne Quarries dewatering facilities consist of 4 quarry sumps within the 3 open pits that collect surface water from the operations area and an open excavation area, as detailed in the Water Management Plan found in Attachment A.

There are several surface water features located on the proposed Pit 3 extension area, including an unnamed tributary that connects with the east branch of the Wignell drain (formerly Mitchner Drain) in the northern and eastern portions of the Site, a pond in the northeast corner, and three more ponds adjacent to the Humberstone Speedway in the southeast corner of the Site.

The east branch of the Wignell Drain will be re-routed around the proposed Pit 3 extension as part of the drain maintenance and realignment to be completed by the City of Port Colborne. Therefore, it is assumed that the drain will be realigned prior to the excavation of the proposed Pit 3 extension area and no analysis to support the drain alignment was completed as part of this study.

North of the proposed extraction area (within the property boundary) there is a wooded wetland feature (deciduous swamp) which maintains standing water or wet conditions for portions of the year. This feature contributes drainage to the upstream end of the East Wignell Drain (formerly Mitchner Drain). The wetland feature may collect surface drainage from north of 2nd Concession Road but does not collect runoff from the extraction area to the south.

2.1 Monitoring

Existing Quarry Monitoring

PCQ conducts monitoring in support of the current Permit to Take Water (PTTW No. 7645-AAYS3Y) and Environmental Compliance Approval (ECA No. 6607-8X7GTZ). To satisfy the PTTW, groundwater monitoring was completed and reported on an annual basis. Similarly, quarry effluent volume and quality monitoring was completed and reported on an annual basis to satisfy ECA requirements. Details for the groundwater monitoring program can be found in Golder's Hydrogeological Assessment, Level 1 / 2 Water Resources Study (2020).

The ECA effluent monitoring consisted of quarterly discharge samples analyzed for hydrogen sulphide, total suspended solids (TSS), and total oil and grease. Field measurements of pH, temperature, conductivity and dissolved oxygen were collected on a biannual basis. Effluent was also visually inspected for floating and settleable solids, and for visible film, sheen or foam. Quarterly samples were taken from Pit 1 discharge, Pit 2 discharge and Pit 3 discharge. Grab samples were collected from the discharge pipe for each of the three Pit samples.

Proposed Pit 3 Extension Baseline Monitoring

Golder visited the Site on September 22, 2017 to confirm the conditions at the proposed Pit 3 extension area and assess the conditions and capacity of the receiving system. The proposed Pit 3 extension area was observed to confirm the soil and land use conditions. The discharge locations and the receiving system (west branch of the Wignell Drain) were inspected to evaluate the potential effect of additional quarry discharge. The east branch of the Wignell Drain (formerly Mitchner Drain) was also visually inspected to evaluate current flow volumes and capacity for a proposed quarry discharge from the proposed Pit 3 extension area.

Surface water monitoring stations were subsequently installed at east and west branches of the Wignell Drain on November 10, 2017 and are still operating at the time of this report. Monitoring station SW-1 is located downstream of the existing quarry discharge along the west branch of the Wignell Drain while SW-2 is located downstream of the proposed Pit 3 extension along the east branch of the Wignell Drain, as shown on Figure 2. The surface water monitors SW-1 and SW-2 each consist of a manual staff gauge and a water level logger. Water level hydrographs (displaying continuous monitoring levels) for each of the stations are provided in Attachment B.

The ranges in water levels seen though the recorded period (i.e. November 2017 to November 2019) are presented in Table 1.

Table 1: Maximum and Minimum Water Levels for Monitoring Stations (November 2017 – November 2019)

Existing Monitors	Maximum Water Level (in meters - local datum)	Minimum Water Level (in meters – local datum)
SW-1	99.801	98.996
SW-2	99.646	98.914

The continuous water level hydrograph at SW-1 experienced many short-lived peak events which were not observed during the field monitoring events. A lower confidence is placed on the magnitude of these peaks and in some cases (particularly in the winter months), a lower confidence is placed on the existence of the peaks as they may be indicative of the transducer being frozen in ice.

The continuous water level record at SW-2 did not experience many peaks events, compared to SW-1. The continuous water levels at SW-2 were generally stable, while the data fluctuated within a 0.1-0.15 m range throughout the record. This fluctuation is likely caused by inconsistencies in the water level logger. However, the water level pattern over the monitoring period is consistent and is considered reliable.

Instantaneous flow measurements were collected at SW-1 and SW-2. Measurements were collected through standard velocity-area methods, using a wading rod and stream velocity meter with velocity measured at 60% of water depth. The field measurements at the east and west branches of the Wignell Drain stations were collected on five occasions in between November 2017 and November 2019, shown in Table 2.

Table 2: Flow Comparison for Monitoring Stations SW-1 and SW-2

Crossing ID	SW-1 (along west branch of the Wignell Drain)		SW-2 (along east branch of the Wignell Drain [formerly Mitchner Drain])	
Date	Discharge (m^3/s)	Water Level (in meters - local datum)	Discharge (m^3/s)	Water Level (in meters - local datum)
10-Nov-2017	0.014	99.16	0.129	99.32
19-Jun-2018	<0.001	99.064	0.070	99.182
13-Dec-2018	0.005	99.15	0.060	99.23
14-Mar-2019	0.036	99.313	0.071	99.222
14-Nov-2019	0.011	99.205	0.050	99.215

The maximum instantaneous flow measurement at SW-1 was observed in March 2019 (0.036 m^3/s) and the lowest measurement was observed in June 2018 (<0.001 m^3/s). The maximum instantaneous flow measurement at SW-2 was observed in November 2017 (0.129 m^3/s) and the lowest measurement was observed in November 2019 (0.050 m^3/s).

Rating Curves

A rating curve is the relationship between the water level and flow rate at a particular cross-section in a stream. Fully developed rating curves are usually one or a series of curves of the form $Q = aY^b$, where Q is the stream flow rate in cubic metres per second, Y is the water depth in metres above the controlling invert, a and b are a fitted coefficient and exponent, respectively. As described, water level records were obtained at stations SW1 and SW2 for the duration of the monitoring period. The rating curves for stations SW-1 and SW-2 detailing the relationship between water level and flow for the in-field measurements collected in 2017 to 2019 are presented on Figures C-1 and C-2, respectively, in Attachment C.

3.0 WATER BALANCE

The purpose of the hydrological assessment was to evaluate the potential implications of quarry operations on surface water flows in the key surface water receptors. Predicted impacts in surplus, infiltration and runoff will be reduced as the analysis extends further downstream. Water balances were developed for both proposed Pit 3 extension and existing licensed areas with results found in Sections 3.5 and 3.6, respectively.

The proposed Pit 3 extension area water balance analysis assesses the differences in surplus, infiltration and runoff for the following scenarios: (1) existing conditions of the Site under approved licensed conditions (i.e. herein referred to as “Existing”); (2) proposed Pit 3 extension operational conditions (i.e. herein referred as “Operational”); (3) proposed rehabilitated conditions following quarry activities of extraction areas under the proposed Pit 3 extension (herein referred as “Rehabilitated”).

3.1 Water Balance Methodology

A water balance analysis was conducted to evaluate the impact under operational and rehabilitated conditions for the key receptor that will receive discharge from the proposed quarry proposed Pit 3 extension. The Meteorological Service Data Analysis and Archive division of Environment Canada (EC) provides monthly water budget summaries for meteorological stations with greater than 20 years of meteorological data. These water budgets include monthly values for all parts of the water budget (rainfall, snowmelt, potential evaporation, etc.) for each of the years in the historic record, as well as average monthly values over the entire record.

The water balance assessment was based on meteorological data from the EC Thornthwaite water budgets (EC Station ID #6136606 Port Colborne, Ontario between 1965 to 2018; as presented in Attachment D - Table D-1), watershed boundaries, land use data, and the existing soil types.

This method describes water flux in a unit area of soil on a monthly basis based on a balance of precipitation (rainfall and snowmelt), evapotranspiration (ET), soil storage, and surplus. The water budget can be summarized as follows:

$$P = S + ET + R + I$$

Where: P = precipitation;

S = change in soil water storage;

ET = evapotranspiration;

R = surface runoff; and,

I = infiltration (groundwater recharge).

The various water budget components associated with catchment areas are typically presented in millimetres (mm) over their respective sub-catchments, and represent the amount of water per unit of watershed area. This amount is related to specific soil properties, including field capacity and wilting point.

Short-term or seasonal changes in soil moisture storage (S) occur as demonstrated by dry conditions in the summer months and relatively saturated conditions in the winter and spring. Long-term changes (e.g., year to year) in soil moisture storage are generally small and assumed to be zero.

Evapotranspiration (ET) refers to water losses from soil surfaces to the atmosphere. The term combines evaporation (i.e., water lost from the soil surface) and transpiration (i.e., water lost from plants and trees) because of the difficulties involved in separating these processes. The potential or maximum ET is estimated, in this case, by the empirical Thornthwaite equation (using average monthly temperature and hours of daylight) and represents the amount of water that would be evaporated or transpired under saturated soil-water scenarios. The actual ET is the total evapotranspiration for the period of study based on evapotranspiration demand, available soil-water storage, and the rate at which soil water is drawn from the ground (as defined by an established drying curve specific to the soil type). The mean annual potential ET for the study site is approximately 663 mm/year based on data (Thornthwaite water budget for Port Colborne) provided by EC.

The water budget model combines accumulated rainfall and snowmelt to estimate total precipitation. Rainfall represents precipitation when monthly mean temperatures are greater than 0°C. Snowmelt is initiated when snow is on the ground and monthly mean temperatures are greater than 0°C. Hence, snowmelt is based on the depletion of snow storage (accumulated precipitation during periods of sub-zero temperatures). Annual water surplus is the difference between the annual precipitation (P) and the annual actual ET and represents the total amount of water, the sum of surface runoff (R) and infiltration (I), that would flow from the catchment area on an annual basis. On a monthly basis, surplus water remains after actual evapotranspiration has been removed from the sum of rainfall and snow-melt and maximum soil storage is exceeded. Maximum soil storage is quantified using a water holding capacity (WHC) specific to the soil type and land use and conceptually represents the difference in water content between the field capacity and the wilting point. The total water surplus is calculated by summing the surplus available from each WHC within the watershed. Precipitation data collected at EC Port Colborne monitoring station (1965 to 2018) indicated a mean annual precipitation (P) of 989 mm/year.

3.2 Catchment Delineation

Site catchment for the proposed Pit 3 extension area was delineated using topographic mapping and site boundary information as illustrated on Figure 3 and summarized in Table 3. The water balance evaluated the catchment area of the proposed Pit 3 extension.

3.3 Water Balance Scenarios

A water balance analysis was completed for the footprint corresponding to the proposed Pit 3 extension area (refer to Figure 3 to 5). The water balance analysis considered three scenarios to assess changes in the water balance for the entire extension area. The simulated scenarios for each assessment considered the assumptions described below:

- Existing conditions analyzed the current land uses of the proposed Pit 3 extension area. The existing conditions at the proposed Site were analysed based on the mapped vegetation found within the proposed Pit 3 extension area. The catchment is composed of mature forest, marsh/swamp and agricultural lands with several built-up areas as seen in Figure 3;
- Operational conditions analyzed the development of the proposed Pit 3 extension area. Under operational conditions, most of the proposed Pit 3 extension area will be excavated to form the proposed quarry leaving a border of land (open pasture) defined by the setback boundary with forested and marsh/swamp areas in the northwest section as seen in Figure 4; and

- Rehabilitated conditions analyzed the effect of rehabilitating the proposed Pit 3 extension area with the quarry extraction area filled in with water, as seen in Figure 5. Rehabilitated conditions were considered in this study to determine the water surplus after excavation operations have ceased and the quarry is decommissioned. The rehabilitated condition considers the quarry filled with water and surplus discharging off-Site.

A quarry water balance was also completed for the current quarry extraction conditions. The results of the water balance assessment were used to estimate seepage rates into the quarry and are presented in Sections 3.5 and 3.6.

3.4 Water Balance Parameters

The site-specific surface water balance was conducted on the proposed Pit 3 extension site. The existing and proposed catchment areas are summarized by land use, WHC, soil type, and infiltration factor in Table 3.

Table 3: Summary of Water Balance Parameters

Existing Conditions					
Type	**WHC (mm)**	**Type of Land Use**	**Soil Type**	**Infiltration Factor (%)**	**Catchment Areas (m^2)**
Wooded	400	Mixed Trees	Silty Clay	0.8	14,563
Agricultural	200	Tilled	Silty Clay	0.6	809,330
Marsh/Swamp	75	Marsh/Swamp	-	0.0	181,582
Built Up Area (Impervious)	10	Roads and Roofs	Roads, Roofs	0	22,973
Built Up Area (Pervious)	75	Gravel Driveways and Parking Lots	Silty Clay	0.6	34,459
Total					**1,062,908**
Operational Conditions (Proposed Pit 3 Extension)					
Type	**WHC (mm)**	**Type of Land Use**	**Soil Type**	**Infiltration Factor (%)**	**Catchment Areas (m^2)**
Mature Forest	400	Wooded	Silty Clay	0.8	14,563
Agricultural	200	Agricultural	Silty Clay	0.6	133,106
Marsh/Swamp	75	Marsh/Swamp	-	0.0	181,582
Built Up Area (Quarry)	10	Quarry Excavation	Bedrock	0.0	711,157
Open Pasture	100	Berm	Silty Clay	0.6	22,500
Total					**1,062,908**

Rehabilitated Conditions					
Type	**WHC (mm)**	**Type of Land Use**	**Soil Type**	**Infiltration Factor (%)**	**Catchment Areas (m^2)**
Mature Forest	400	Wooded	Silty Clay	0.8	14,563
Open Pasture	150	Tilled	Silty Clay	0.6	155,606
Marsh/Swamp	75	Marsh/Swamp	-	0.0	181,582
Open Water	0	Quarry Pond	-	0.0	711,157
Total					**1,062,908**

The water balance analysis considered the following:

- The Water Holding Capacities (WHC) were chosen based on soil type and land use in reference to guidelines provided in Table 3.1 of the MOECC Stormwater Management Planning and Design (SWM) Manual (2003). The soil types were determined using Ontario Quaternary Soils Mapping (see Figure 3) based on the MNRF and LIO data source (2012). Soils at the site are primarily silty clay. Exposed bedrock was assumed to be the operational conditions surface ("soil") type for the proposed Pit 3 extension based on existing borehole results as discussed in (Golder Associates Ltd., 2020). 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. For temperate region watersheds, soil storage is typically relatively stable year-round, remaining at or near field capacity with the exception of 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. Surplus water is generated after actual ET has been removed (ET demand is met) and the maximum WHC is exceeded (soil-water storage demand is met).
- Infiltration rates were estimated using the MOECC Stormwater Management Planning and Design (SWM) Manual (2003) (Table 3.1). There are three main factors that determine the percent infiltration of the total surplus: topography, soil type and ground cover. The sum of the fractions representing the three characteristics establishes the approximate annual percentage of surplus which can be infiltrated in an area with a sufficient downward groundwater gradient.
- The global result of the water balance, referred as 'Total Runoff' is defined according to the following equation:

$$Total\ Runoff = Net\ Surplus - Infiltration \quad [1]$$

3.5 Proposed Pit 3 Extension Area Water Balance Results

The water balance analysis assesses the differences in total runoff for the following scenarios: existing conditions, proposed operational conditions; and proposed rehabilitated conditions. The detailed results for the monthly water balance analysis are presented in Attachment E, Tables E-1 to E-3.

3.5.1 Existing Conditions

The water balance results for the existing conditions are provided in Table 4.

Table 4: Existing Conditions Water Balance Results

Land Use	Area	Estimated Surplus		Estimated Infiltration		Estimated Runoff	
	(m^2)	(mm/yr)	(m^3/yr)	(mm/yr)	(m^3/yr)	(mm/yr)	(m^3/yr)
Wooded	14,563	329	4,791	263	3,833	66	958
Agricultural	809,330	360	291,359	216	174,815	144	116,544
Marsh/Swamp	181,582	436	79,170	0	0	436	79,170
Built Up Area (Impervious)	22,973	501	11,509	0	0	501	11,509
Built Up Area (Pervious)	34,459	436	15,024	262	9,015	174	6,010
TOTAL	**1,062,908**	**378**	**401,853**	**177**	**187,663**	**202**	**214,191**

The total average annual surplus for the catchment area under existing conditions was estimated to be 378 mm or 401,853 m^3 per year and the estimated infiltration is approximately 177 mm or 187,663 m^3 per year. Runoff was calculated as the difference between surplus and infiltration and was estimated to be 202 mm or 214,191 m^3 per year. Based on the assessment, approximately 47% of the annual surplus infiltrates while the remaining 53% is surface runoff under the existing condition.

3.5.2 Operational Conditions

The water balance results for operational conditions are provided in Table 5.

Table 5: Operational Conditions Water Balance Results

Land use	Area	Estimated Surplus		Estimated Infiltration		Estimated Runoff	
	(m^2)	(mm/yr)	(m^3/yr)	(mm/yr)	(m^3/yr)	(mm/yr)	(m^3/yr)
Mature Forest	14,563	329	4,791	263	3,833	66	958
Agricultural	133,106	360	47,918	216	28,751	144	19,167
Marsh/Swamp	181,582	436	79,170	0	0	436	79,170
Built Up Area (Quarry)	711,157	501	356,290	0	0	501	356,290
Open Pasture	22,500	416	9,360	250	5,616	166	3,744
TOTAL	**1,062,908**	**468**	**497,529**	**36**	**38,200**	**432**	**459,329**

Under operational conditions, the total average annual surplus for the proposed Pit 3 extension area would be 497,529 m^3 per year. This represents an increase of approximately 95,676 m^3/year compared to existing conditions (or 24% increase), as a result of land use changes (due to the lower water holding capacity, there is less opportunity for evapotranspiration of water) resulting from quarrying activities. Total Site infiltration is expected to be reduced by 149,463 m^3/year (80%). The total Site runoff is expected to increase by 245,138 m^3/year, which is equivalent to an increment of 114% in comparison to existing conditions.

3.5.3 Rehabilitated Conditions

The water balance results for the rehabilitated conditions are provided in Table 6.

Table 6: Rehabilitated Conditions Water Balance Results

Land use	Area	Estimated Surplus		Estimated Infiltration		Estimated Runoff	
	(m^2)	(mm/yr)	(m^3/yr)	(mm/yr)	(m^3/yr)	(mm/yr)	(m^3/yr)
Mature Forest	14,563	329	4,791	263	3,833	66	958
Open Pasture	155,606	381	59,286	229	35,571	152	23,714
Marsh/Swamp	181,582	436	79,170	0	0	436	79,170
Open Water	711,157	327	232,548	0	0	327	232,548
TOTAL	**1,062,908**	**354**	**375,795**	**37**	**39,404**	**316**	**336,390**

Under rehabilitated conditions, the total annual surplus for the Site would be approximately 375,795 m^3/yr. This represents a decrease of approximately 26,058 m^3/year compared to existing conditions (or 7% decrease). The infiltration would be reduced by approximately 148,259 m^3/year (79%). The total runoff would be increased by approximately 122,199 m^3/year, which is equivalent to an increment of approximately 57% in comparison with existing conditions.

3.5.4 Proposed Pit 3 Extension Water Balance Summary

A summary of the annual water balance considering surplus, infiltration, and runoff for the baseline, operational, and rehabilitated conditions is provided in Table 7.

Table 7: Water Balance Summary

	Existing Condition		Operational Condition		Rehabilitated Condition	
Parameter	**(mm)**	**(m^3/yr)**	**(mm)**	**(m^3/yr)**	**(mm)**	**(m^3/yr)**
Surplus	378	401,853	468	497,529	354	375,795
Infiltration	177	187,663	36	38,200	37	39,404
Runoff	202	214,191	432	459,329	316	336,390

Under operational conditions, surplus is anticipated to increase by approximately 24% from 401,853 to 497,529 m^3/yr – representing the reduced evapotranspiration due to the removal of agricultural land use. All infiltration and runoff amounts shall be conveyed over the quarry floor to a sump(s) and eventually pumped off-Site. Infiltration is expected to decrease by 80% from 187,663 to 38,200 m^3/yr as the operational surplus is greater than existing conditions and the quarry floor will have a low infiltration rate. This will effectively increase the total runoff from the Site to 432 mm/yr (459,329 m^3/yr). This equates to an overall increase in runoff of approximately 114% or 245,138 m^3/yr.

Under rehabilitated conditions, the objective was to restore the Site to a stable condition. Rehabilitated conditions will be largely open water within the quarry footprint, and thus surplus is projected to decrease by 7% to 375,795 m^3/yr, compared to existing conditions. All available runoff from within the rehabilitated quarry footprint will drain by gravity to a discharge channel. This discharge will to be conveyed to the east branch of the Wignell Drain. Some infiltration, which constitutes a minimal amount of the discharge (11%), may eventually report to downstream surface water receivers. The infiltration is expected to decrease by approximately 79% to 37 mm/yr (39,404 m^3/yr) and the runoff will increase by 57% to 316 mm/yr (336,390 m^3/yr), compared to existing conditions.

3.6 Existing Licensed Quarry Water Balance Results

A quarry water balance was also completed for the existing licensed quarry. The quarry water balance was evaluated using the meteorological data from the nearest Environment Canada gauge station (e.g. EC Station ID #6136606 Port Colborne, Ontario between 1965 to 2018).

The water balance was completed with the same methodology as the proposed quarry extraction. Pumping data from the last 7 years (2012 to 2018) was provided by Port Colborne Quarries Inc. (GENIVAR, 2013, and WSP, 2014 – 2019). Based on the collected information, a water budget was estimated on a monthly basis for the years 2012 to 2018 using data retrieved from Environment Canada's Meteorological Service of Canada Thornthwaite water budgets (EC Station ID #6136606 Port Colborne, Ontario between 2012 – 2018). The existing quarry footprint was analyzed for this assessment. The detailed results for the 2012 to 2018 water balance analysis are presented in Attachment F, Table F-1.

Existing quarry runoff was compared against the amount of water pumped out of the quarry through recorded dewatering activities. Runoff was estimated according to equation [1] in Section 3.1. Table 8 shows the results of the quarry water balance.

Table 8: Water Balance Results (m^3/year) for Existing Quarry for the 2012 to 2018 period

Existing Quarry	Area	Estimated Average Annual Surplus [1]	Estimated Average Annual Infiltration [1]	Estimated Average Annual Runoff [1,2]
	(m^2)	(m^3/yr)	(m^3/yr)	(m^3/yr)
Quarry Catchment	1,780,700	828,331	414,165	414,165

Notes:
1. Corresponding to estimated amounts over the 2012 to 2018 period.
2. Estimated total runoff calculated as Total Runoff = Total Surplus - Total Infiltration.

The results show that the average yearly estimated runoff within the existing Site catchment area for the years 2012 to 2018 is approximately 414,165 m^3 per year. The total volume of runoff versus the total volume of water pumped annually for the past 4 years is provided in Table 9.

Table 9: Pumping Results Summary

Year	Estimated Annual Average Runoff (m^3) [1]	Total Annual Pumped (m^3) [2]	Ratio Runoff versus Pumped (m^3)
2015	611,492	1,006,119	0.61
2016	521,567	725,017	0.72
2017	957,126	1,506,598	0.64
2018	1,120,416	1,664,894	0.67
Average	**802,651**	**1,225,657**	**0.66**

Note(s):
1) Annual average runoff values were calculated based on monthly meteorological data from Port Colborne Environment Canada gauge station (#6136606) in relation to the total existing site area: Monthly Surplus (m^3) = Monthly Surplus value per 10 mm Water Holding Capacity (mm) × Overall Site Area (m^2).
2) Total Annual Pumped values are based on a summation of daily water taking values published in annual compliance reports provided by Port Colborne Quarries Inc. (WSP, 2016 – 2019).

Between the years 2015 and 2018, the annual runoff is estimated to be approximately 66% of the annual quarry pumping. However, the earlier years of this period likely had a smaller quarry footprint and would have collected less runoff than estimated. Therefore, the runoff in the earlier years of the period may be over estimated. Based on the calculated annual average runoff and total annual reported pumping, the difference between the estimated runoff to the quarry and the annual pumping volumes represents the estimated groundwater seepage to the quarry, which represents approximately 423,000 m^3 on average per year.

4.0 IMPACT ASSESSMENT

4.1 Potential Impacts to Surface Water Resources

The west branch of the Wignell Drain flows intermittently through the northern side of the existing licensed area and eventually connects with the east branch of the Wignell Drain (formerly Mitchner Drain) downstream of the Site. Similarly, the east branch of the Wignell Drain flows through the proposed Pit 3 extension area before the confluence point with the west branch of the Wignell Drain downstream. Currently, discharge from the Port Colborne Quarry is one of the primary sources of flow through the west branch of the Wignell Drain, particularly during drier seasons. The change from the existing conditions to the proposed Pit 3 extension is expected to have a local effect on stream flows at the east and west branches of the Wignell Drain.

As the extension area is extracted, the quarry discharge is expected to be discharged to the east branch of the Wignell Drain, with the full proposed Pit 3 extension development discharge expected to be split by 30% and 70% to the west and east branches of the Wignell Drain, respectively, as detailed below in Table 10. The discharge from the proposed Pit 3 will be directed to the existing Port Colbourne Quarry discharge to West Wignell Drain and to a proposed discharge location on East Wignell Drain, at the southeast corner of the Site (near the Humberstone Speedway).

Table 10: Proposed Pit 3 Extension Area Water Balance Summary for Subcatchment Divides

	Existing Condition		Operational Condition		Rehabilitated Condition	
Subcatchment	**West Brach of the Wignell Drain**	**East Branch of the Wignell Drain (formerly Mitchner Drain)**	**West Brach of the Wignell Drain**	**East Branch of the Wignell Drain**	**West Brach of the Wignell Drain**	**East Branch of the Wignell Drain**
Parameter	**(m^3/yr)**					
Surplus	120,556	281,297	149,259	348,270	112,739	263,057
Infiltration	56,299	131,364	11,460	26,740	11,821	27,583
Runoff	64,257	149,934	137,799	321,530	100,917	235,473

The Ministry of Natural Resources and Forestry Ontario Flow Assessment Tool (OFAT) in conjunction with GIS mapping was used to determine the approximate subcatchment areas of the west branch of the Wignell Drain (310 ha) and east branch of the Wignell Drain (543 ha), as seen on Figure 6. The proposed Pit 3 extension area lies almost entirely within the east branch of the Wignell Drain catchment and represents approximately 17% of the east branch of the Wignell Drain catchment. The quarry development is expected to increase the annual flows under operational and rehabilitated conditions within the east and west branches of the Wignell Drains, since discharge from the proposed Pit 3 extension area will be directed to both catchments.

According to the Niagara Peninsula Conservation Authority Watershed Explorer interactive GIS mapping service, the Welland Canal (discharging into Lake Ontario) is located approximately 3 km west of the proposed Pit 3 extension. The surface water bodies to the west of the site are not expected to be measurably affected by the proposed quarry extraction operations. Overall, adverse effects on surface water resources and the east branch of the Wignell Drain are not expected. The peak flows within these drains are not expected to increase, due to the quarry sump storage and discharge rate of the quarry sumps, as detailed in the Water Management Plan (Appendix A). The increase to stream flows is expected under the average or low flow conditions when stream flow will be augmented with quarry discharge. For this reason, the risk of erosion within the drains is not expected to increase since the proposed peak flows will be limited to flows similar to those experienced under existing conditions. The catchment areas to the west and east branches of the Wignell Drains are not expected to change, since runoff from the quarry will be directed to the Wignell Drain(s).

The wooded wetland (deciduous swamp) at the north west end of the property is not expected to see a reduction in runoff area and based on the geological data in the area (Golder Associates Ltd., 2020), the wetland is underlain by clayey material to a significant depth which will restrict the seepage as a result of the quarry dewatering. For these reasons, the function of the wooded wetland is not expected to change significantly as a result of the quarry extraction.

All monitoring requirements with respect to the quarry discharges and the receiving system will be regulated by the Industrial Sewage Works Environmental Compliance Approval, to be amended prior to the dewatering of Pit 3 extension.

5.0 CONCLUSIONS

The following conclusions are provided in support of a Level 1 and Level 2 Hydrogeological and Hydrological Assessment application for the Port Colborne Quarries proposed Pit 3 extension property.

1) Compared to existing conditions, average annual surplus over the Site footprint area is expected to increase under operational conditions by approximately 24% and decrease under rehabilitated conditions by approximately 7%.

2) Compared to existing conditions (187,663 m^3/yr), average annual infiltration is expected to decrease over the Site footprint area under operational and rehabilitated conditions to 38,200 m^3/yr and 39,404 m^3/yr, respectively.

3) Compared to existing conditions (214,191 m^3/yr), average annual off-Site runoff is expected to increase under operational and rehabilitated conditions to 459,329 m^3/yr and 336,390 m^3/yr, respectively.

4) The increased runoff under operational and rehabilitated conditions will be directed to the east and west branches of the Wignell Drain, increasing the annual flows within these water features.

Considering the above conclusions, no adverse hydrogeological impacts associated with this licence application are anticipated.

Signature Page

Golder Associates Ltd.

Craig De Vito, PEng
Water Resources Engineer

Kevin MacKenzie, MSc, PEng
Principal, Senior Water Resources Engineer

NP/CDV/KMM/ng/mp

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REFERENCES

GENIVAR Inc. (GENIVAR). 2013. 2012 Annual Compliance Report – Port Colborne Quarries.

Golder Associates Ltd. (Golder). 2020. Hydrogeological Assessment, Level 1 / 2 Water Resources Study.

WSP Canada Inc. (WSP). 2014. Port Colborne Quarries – 2013 Annual Compliance Report.

WSP Canada Inc. (WSP). 2015. Port Colborne Quarries – 2014 Annual Compliance Report.

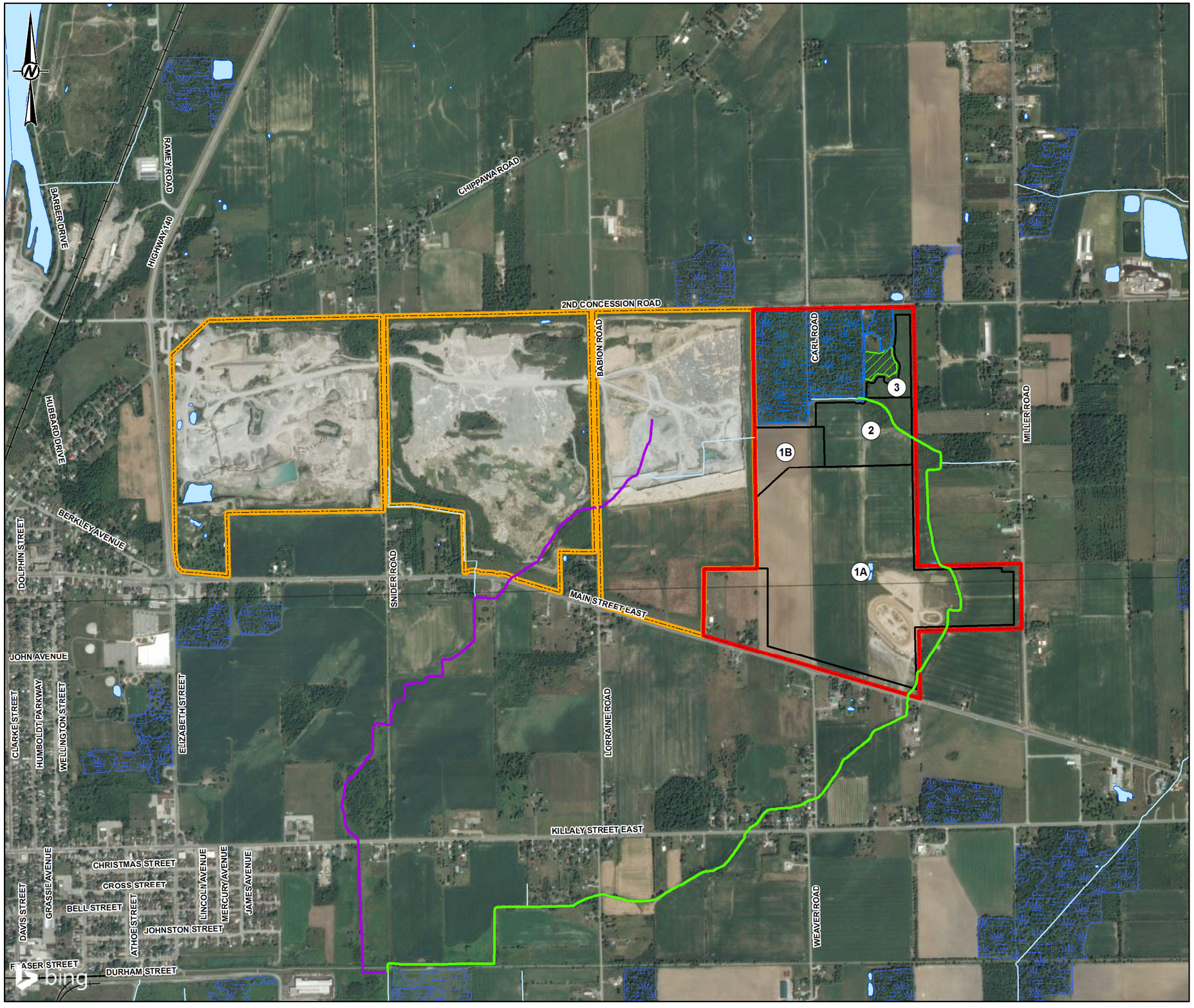
WSP Canada Inc. (WSP). 2016. Port Colborne Quarries – 2015 Annual Compliance Report.

WSP Canada Inc. (WSP). 2017. Port Colborne Quarries – 2016 Annual Compliance Report.

WSP Canada Inc. (WSP). 2018. Port Colborne Quarries – 2017 Annual Compliance Report – Port Colborne Quarries Inc.

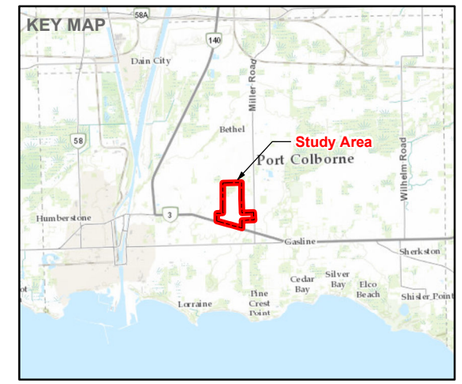
WSP Canada Inc. (WSP). 2019. Port Colborne Quarries – 2018 Annual Compliance Report – Port Colborne Quarries Inc.

FIGURES



LEGEND

- Excavation Phase
- Railway
- Watercourse
- West Branch of the Wignell Drain
- East Branch of the Wignell Drain (formerly Mitchner Drain)
- Waterbody
- Wetland
- Woodland
- Proposed Quarry Extension
- Property Boundary
- Approximate Excavation Phasing Boundary



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CLIENT
RANKIN CONSTRUCTION INC.

PROJECT
PORT COLBORNE QUARRY EXTENSION

TITLE
SITE LOCATION PLAN

CONSULTANT
GOLDER

YYYY-MM-DD	2020-10-29
DESIGNED	PR
PREPARED	PR
REVIEWED	NP
APPROVED	CDV

PROJECT NO.	CONTROL	REV.	FIGURE
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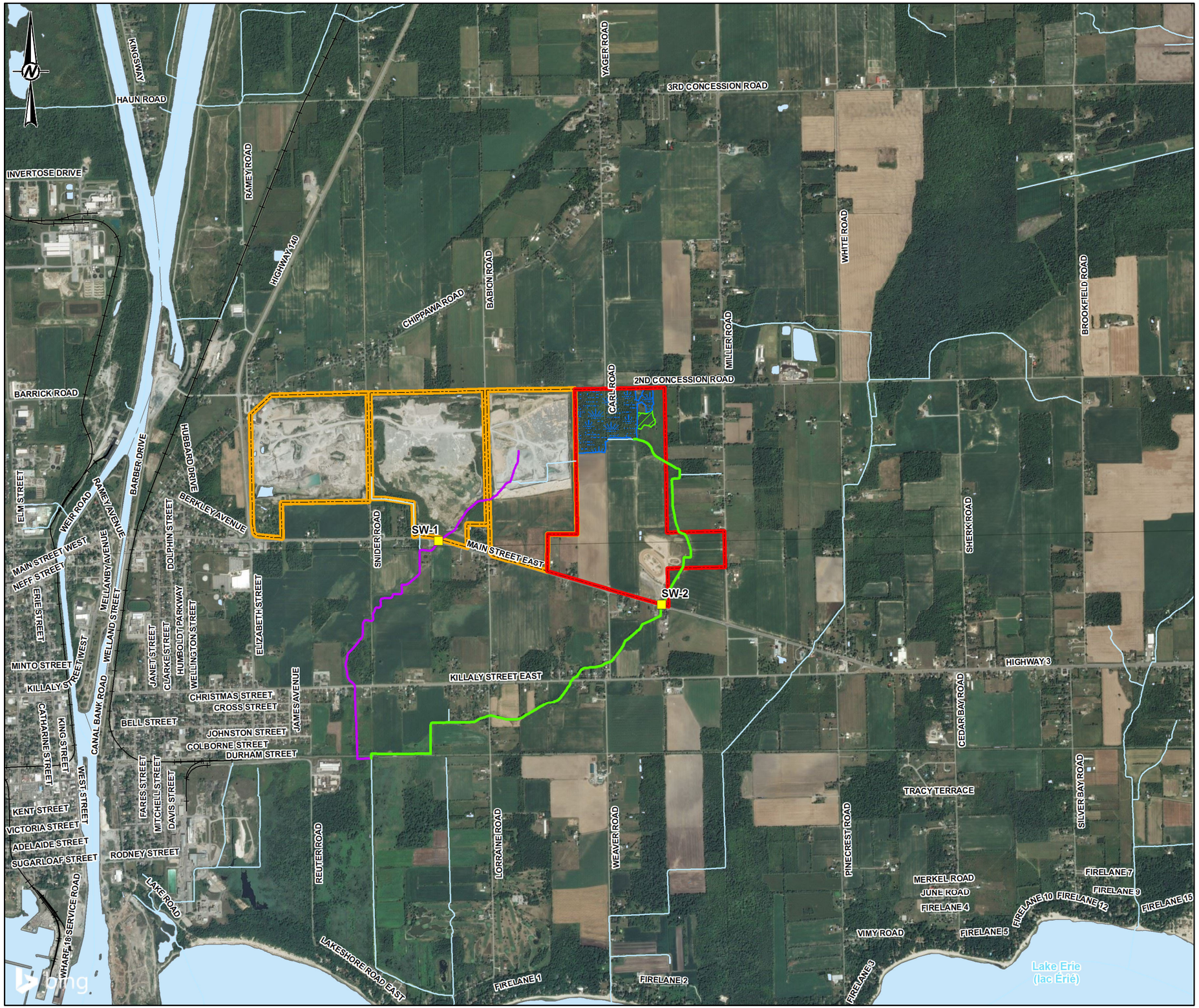

LEGEND

- Surface Water Station
- Railway
- Watercourse
- West Branch of the Wignell Drain
- East Branch of the Wignell Drain (formerly Mitchner Drain)
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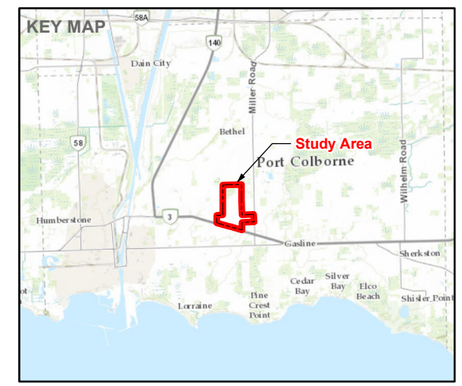
- Property Boundary
- Proposed Quarry Extension



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PROJECT
PORT COLBORNE QUARRY EXTENSION

TITLE
SURFACE WATER MONITORING LOCATIONS

CONSULTANT

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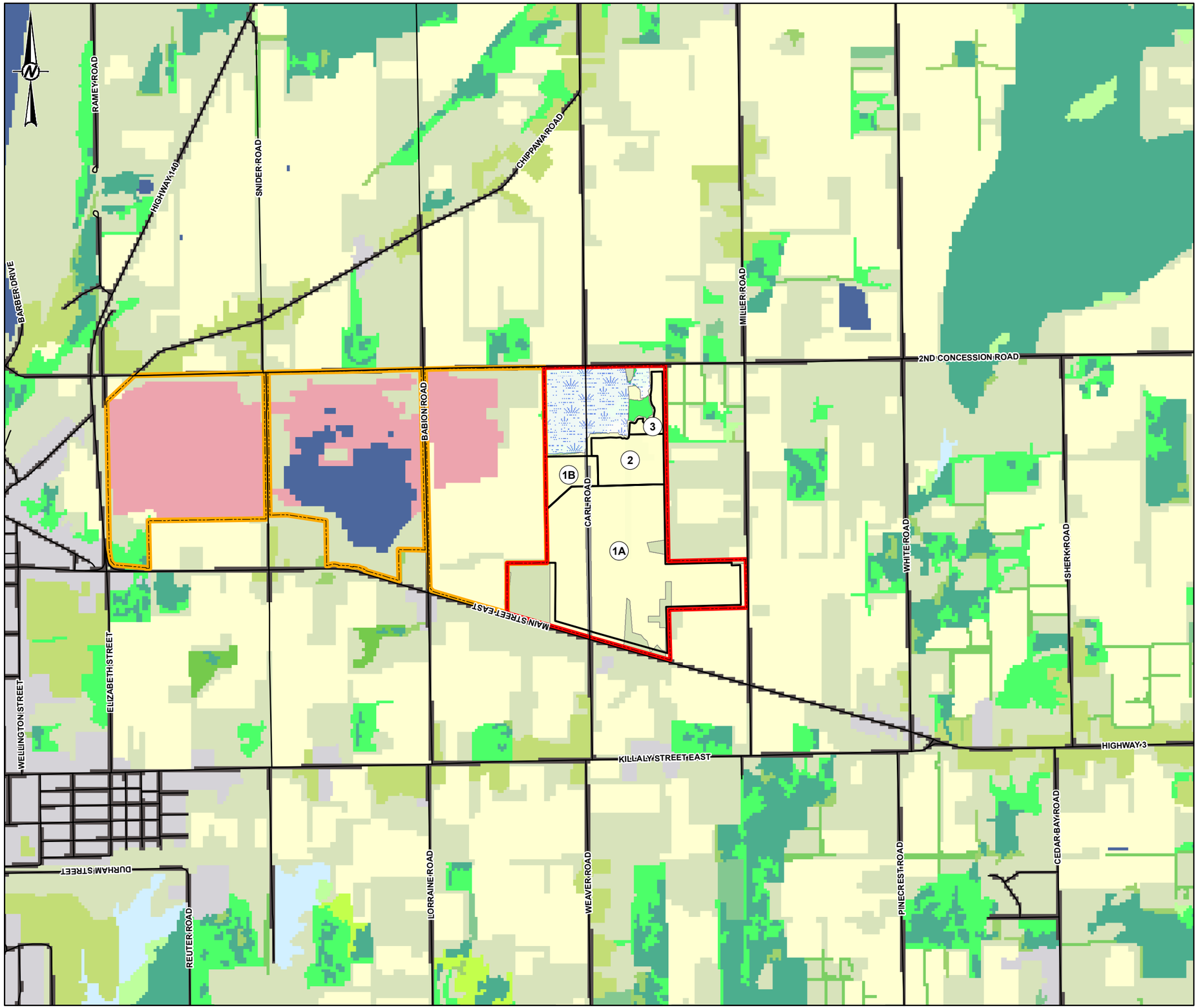

LEGEND

- 1 Excavation Phase
- Roads
- Property Boundary
- Proposed Quarry Extension
- Approximate Excavation Phasing Boundary

Land Use

- 90. Forest
- 91. Coniferous Forest
- 92. Mixed Forest
- 93. Deciduous Forest
- 131. Treed Swamp
- 135. Thicket Swamp
- 160. Marsh
- 170. Open Water
- 191. Plantation
- 192. Hedge Row
- 193. Tilled
- 201. Transportation
- 202. Built Up Area - Pervious
- 203. Built Up Area - Impervious
- 204. Extraction - Aggregate
- 250. Undifferentiated
- Silver Maple Mineral Deciduous Swamp

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CLIENT
RANKIN CONSTRUCTION INC.

PROJECT
PORT COLBORNE QUARRY EXTENSION

TITLE
LAND USE

CONSULTANT
GOLDER

YYYY-MM-DD	2020-09-03
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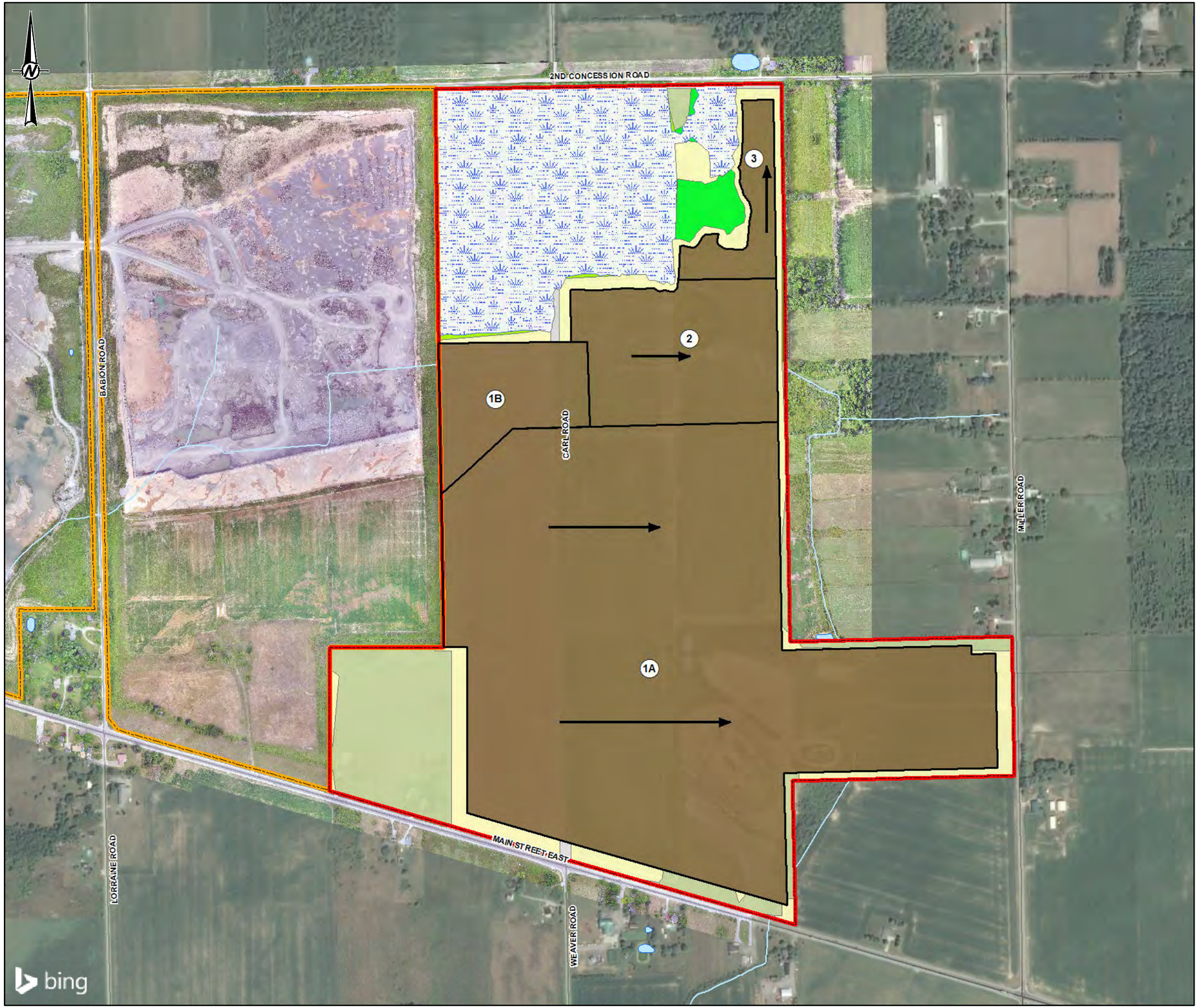

LEGEND

- Excavation Phase
- Excavation Direction Arrow
- Roads
- Watercourse
- Waterbody
- Property Boundary
- Proposed Quarry Extension
- Approximate Excavation Phasing Boundary

Land Use

- Deciduous Forest
- Hedge Row
- Mixed Forest
- Quarry Excavation
- Silver Maple Mineral Deciduous Swamp
- Tilled
- Transportation
- Undifferentiated

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PROJECT
PROPOSED PORT COLBORNE QUARRY EXTENSION

TITLE
LAND USES UNDER OPERATIONAL CONDITIONS

CONSULTANT
GOLDER

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REVIEWED	NP
APPROVED	CDV

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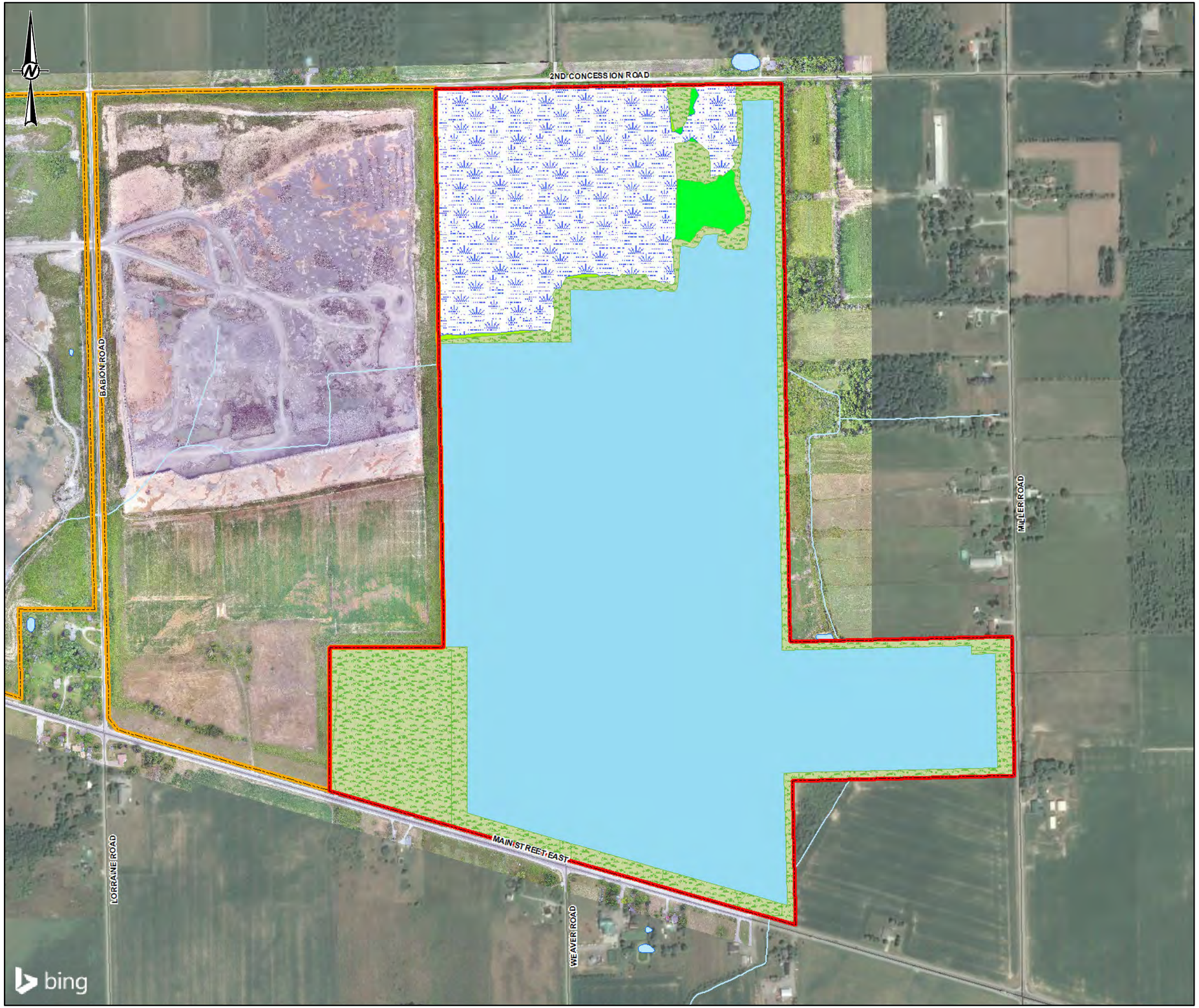

LEGEND

- Roads
- Watercourse
- Property Boundary
- Proposed Quarry Extension

Land Use

- Deciduous Forest
- Mixed Forest
- Open Pasture
- Silver Maple Mineral Deciduous Swamp
- Pond

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PROJECT
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TITLE
LAND USES UNDER REHABILITATED CONDITIONS

CONSULTANT

GOLDER

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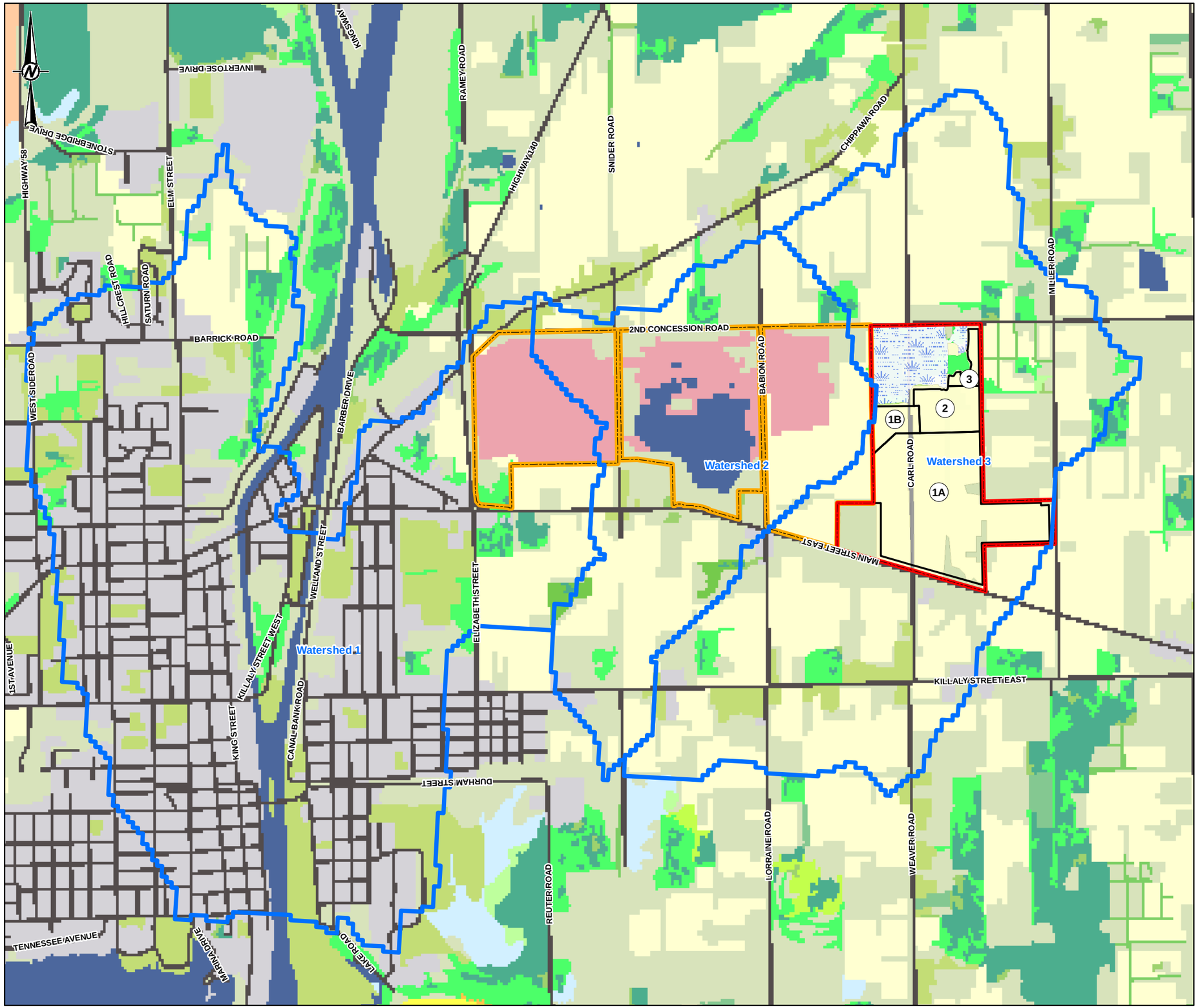

LEGEND

- 1 Excavation Phase
- Proposed Quarry Extension
- Property Boundary
- Approximate Excavation Phasing Boundary
- Watershed

Land Use

- 11. Open Beach/Bar
- 21. Open Sand Dune
- 90. Forest
- 91. Coniferous Forest
- 92. Mixed Forest
- 93. Deciduous Forest
- 131. Treed Swamp
- 135. Thicket Swamp
- 150. Bog
- 160. Marsh
- 170. Open Water
- 191. Plantation
- 192. Hedge Row
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RANKIN CONSTRUCTION INC.

PROJECT
PORT COLBORNE QUARRY EXTENSION

TITLE
SUBCATCHMENT AREAS

CONSULTANT
GOLDER

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APPENDIX A

Stormwater Management Plan

REPORT

Water Management Plan

Port Colborne Quarries

Submitted to:

Port Colborne Quarries Inc.

222 Martindale Road, P.O. Box 1116
St. Catharines, Ontario
L2R 7A3

Submitted by:

Golder Associates Ltd.

6925 Century Avenue, Suite #100 Mississauga, Ontario, L5N 7K2 Canada

+1 905 567 4444

1771656

November 2020

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5.0 PROPOSED SUMP PEAK FLOW AND VOLUME ESTIMATES **3**

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Figure 2: Drainage Features

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by Port Colborne Quarries Inc. (PCQ) to prepare a Water Management Plan for the Port Colborne Quarry proposed Pit 3 extension located at the corner of Chippawa Road and Highway 140 in Port Colborne, Niagara Region, Ontario (the Site). This report discusses the water management of the existing quarry and proposed Pit 3 extension. This water management plan has been developed, for the proposed quarry discharge, to evaluate flooding in the quarry during the spring freshet and large storm events, and to evaluate flooding and erosion potential in the receiving system.

The Site is bordered by Second Concession Road to the north, Miller Road to the east, Main Street East (also known as Highway 3) to the South and Highway 140 to the west. The proposed Pit 3 extension area is located on Part of Lots 18 & 19 Second Concession in the City of Port Colborne and Plan 59R-16702. A key plan showing the location of the existing quarry and proposed Pit 3 extension property is provided on Figure 1.

2.0 EXISTING WATER HANDLING SYSTEM AND OPERATIONS

The existing quarry is composed of 3 open pits occupying an area of approximately 178 hectares (ha) as shown on Figure 1. Current Port Colborne Quarries dewatering facilities consist of 4 discharge locations within the 3 open pits that collect surface water from the operations area and an open excavation area. Pit 1, is approximately 62 ha in area and does not operate under an aggregate licence from the Ministry of Natural Resources and Forestry, but rather is used for aggregate processing and stockpile storage. The pit includes a water collection and sedimentation area, two off-line settling ponds serving an on-site wash plant (operating in a recirculating loop system), and one discharge location directed to a roadside ditch on the east side of Highway 140. Pit 2 is approximately 73 ha in area and is currently inactive, but has a valid aggregate license. The pit is partially used for a water collection and a sedimentation pond where collected water is discharged to the west branch of the Wignell Drain. Pit 3 is approximately 70 ha in area and is a currently used for active extraction. Pit 3 has two sumps that discharge to an internal ditch located on the east side of Babion Road, which connects to the west branch of the Wignell Drain. The existing quarry has a maximum permitted daily withdrawal volume of 8,640,000 litres from the existing quarry under Permit to Take Water (PTTW) No. 7645-AAYS3Y. The total volume pumped from the quarry in 2018 was 1.62 million cubic metres.

To maintain dry working conditions, the quarry is dewatered with some water being used for aggregate processing and dust suppression. During drier seasons, discharge from the Port Colborne Quarry is often the only flow within the receiving watercourse (west branch of the Wignell Drain). Details of the surface water features are shown on Figure 2.

3.0 PROPOSED PIT 3 EXTENSION

The proposed Pit 3 extension will discharge collected water towards the west and east branches of the Wignell Drain, located west and east of the proposed quarry footprint, respectively. The west branch of the Wignell Drain joins the east branch of the Wignell Drain (formerly Mitchner Drain) approximately 1.5 km south of the Site. Discharge from the existing quarry is not released into the east branch of the Wignell Drain (formerly Mitchner Drain). Under existing conditions, all of the proposed Pit 3 extension area drains to the east branch of the Wignell Drain.

4.0 PEAK FLOW AND VOLUME ESTIMATES

The intensity-duration-frequency (IDF) data for the Port Colborne Environment Canada Climate station (Climate ID 6136606, 1965-2018) were used to evaluate existing sump storage requirements under various return periods. The rainfall volumes of the 24-hour duration storm events were evaluated for both the two-year and five-year return periods over the quarry catchment area. Based on the IDF curve values, the total rainfall depth that would be collected during the 24-hour two-year event and the 24-hour five-year event would be approximately 60 mm and 70 mm, respectively. The IDF curve coefficients were provided by the Niagara Peninsula Conservation Authority (2010). The results are provided in Table 1 below.

Table 1: Rainfall Storage Volumes at Quarry Sumps

Sump Name	Catchment Area (m^2)	Rainfall Volume for Return Period (m^3)	
		2 year	5 year
Pit # 1 sump	617,900	35,910	43,100
Pit # 2 sump	582,800	33,870	40,650
Pit # 3 sumps	580,000	33,710	40,450
Totals	**1,780,700**	**103,490**	**124,200**

The total rainfall volume that would be directed to the quarry sumps during the 24-hour five-year event was estimated to be approximately 124,200 cubic meters (m^3). For a 24-hour two-year event, the approximate total rainfall volume would be 103,490 m^3. PCQ provided pumping records as part of the PTTW annual reports for the years 2012 to 2018 inclusive. PCQ maintains a record of all water takings that includes the date, time, rates, and total measured amounts of water pumped per day for each day that water is taken. Available pumping data indicated that each sump dewaters at different flow rates.

The existing quarry discharge rates at Pit 2 and Pit 3 are known and consistent at approximately 0.0475 m^3/s and 0.058 m^3/s respectively during active pumping. The pumping records also include the total volume pumped per sump during this period. Table 2 shows the volumes pumped within each pit sump.

Table 2: Volume Pumped by Port Colborne Quarries Sumps

	Pit 1	Pit 2	Pit 3, Sump 1	Pit 3, Sump 2	All Pits
Total Volume between 2012 and 2018 (m^3)	1,268,173	3,905,754	4,802	2,492,365	**7,671,094**
Percentage of Overall Volume Pumped at Sump (%)	16.5%	50.9%	0.1%	32.5%	**100.0%**

Assuming that the quarry is discharging continuously following a rain event, the associated water would be pumped from the quarry in approximately 8 days for Pit 2 and 6 days for Pit 3 during a two-year return period event. For a five-year return period event, Pit 2 and Pit 3 would take approximately 10 days and 8 days to dewater, respectively.

5.0 PROPOSED SUMP PEAK FLOW AND VOLUME ESTIMATES

The intensity-duration-frequency (IDF) data for the Port Colborne Environment Canada Climate station (Climate ID 6136606, 1965-2018) were used to evaluate sump storage requirements under various return periods at the proposed quarry. The rainfall volumes of the 24-hour duration storm events were evaluated for both the two-year and five-year return periods over the quarry catchment area. Based on the IDF curve values, the total rainfall depth that would be collected during the 24-hour two-year event and the 24-hour five-year event would be approximately 60 mm and 70 mm, respectively. The rainfall volume which would be conveyed to the quarry sump during the twenty-four (24) hour, two (2) year event would be approximately 37,800 m^3. The proposed quarry discharge flow rate is intended to dewater the quarry from a two-year rainfall event within a three-day period. This proposed discharge rate during such an event is 146 L/s (i.e., 37,800 m^3 / 3 days = 12,600 m^3/day). The IDF curve coefficients were provided by the Niagara Peninsula Conservation Authority (2010).

In order to maintain a minimum twenty-four (24) hour residence time with a discharge rate of 146 L/s, the quarry sump will require a permanent volume of at least 12,600 m^3, as seen in Table 3. The proposed depth of the sump will be between 1 and 3 m with side dimensions of approximately 65 m by 195 m (i.e., 12,675 m^3 assuming a minimum depth of 1 m for settling purposes), with recommended sump volume size detailed in Table 3. This provides a length to width ratio of approximately 3:1 (L:W) for settling. These approximate sump dimensions may change based on the depth of the quarry floor, but are sized for pumping out of the quarry over the subsequent dry days.

Table 3: Proposed Volume Pumping for Port Colborne Quarries Proposed Pit 3 Extension Sump

Sump Name	Catchment Area	Rainfall Volume for Return Period (m^3) *(mm)*		Recommended Sump Volume [1]
	m^2	2 year	5 year	m^3
Pit 3 Extension Sump	651,000	37,800 *(58.1)*	45,400 *(69.7)*	12,675

Note(s):
1) Recommended sump volume based on length, width and depth dimensions to maintain a minimum twenty-four (24) hour residence time.

Under average annual conditions the quarry sump will discharge at 58 L/s, which requires a sump volume of approximately 5,010 m^3 to obtain 24 hrs of retention. The typical dewatering rate of the proposed Pit 3 extension area will likely be similar to that of Pit #3 under full extraction. The proposed quarry sump is sufficient for both the average and maximum proposed discharge rates to obtain 24 hours of retention time. The sump design will be based on 146 L/s pump rate and 12,675 m^3 of volume, however dewatering to a lower volume (i.e., 5,010 m^3) may be possible at a lower pumping rate (i.e., 58 L/s). Under storm event conditions large rainfall events would result in minor flooding of the quarry floor. In this situation, the flooded area would be dewatered over a period of a few days after the event.

To reduce the potential for flooding on the quarry floor, areas of the catchment outside of the quarry area could be bermed or redirected away from the quarry. Intense storm events will likely overtop the sump, which is sized to be pumped out during the days after rain events, and flood low lying parts of the quarry floor.

6.0 ASSESSMENT OF RECEIVING SYSTEM

The proposed quarry water balance suggests runoff to the east and west branches of the Wignell Drains are expected to increase under both operational and rehabilitated conditions as a result of the change in land use and reduction in evapotranspiration. The peak flows within these drains are not expected to increase, due to the quarry sump storage and continuous discharge rate of the quarry sumps. The increase to stream flows is expected under the average or low flow conditions when stream flow will be augmented with quarry discharge. For this reason, the risk of erosion within the drains is not expected to increase since the proposed peak flows will be limited to flows similar to those experienced under existing conditions. The catchment areas to the west and east branches of the Wignell Drains are not expected to change, since runoff from the quarry will be directed to the Wignell Drain(s).

The receiving ditches for the sump discharges are well vegetate and have a gentle slope with stable banks and no evidence of erosion. The upstream portion of the drain flows through agricultural land. During field monitoring events, flows within the Mitchner drain were similar to the proposed discharge rate. Based on field observations, the channel has capacity to accommodate flows.

7.0 CONCLUSIONS

Following two-year and five-year return period event, the associated water would be pumped from the proposed quarry in approximately 8 days and 9 days, respectively.

The annual average stream flow in the east and west branches of the Wignell Drain is expected to increase as a result of quarry dewatering and the addition of groundwater seepage, however the risk of erosion is not expected to increase.

8.0 CLOSURE

We trust that this information meets your present requirements. Should any point require clarification, or if we can be of additional assistance in this regard, please contact the undersigned.

Signature Page

Golder Associates Ltd.

Craig De Vito, PEng
Water Resources Engineer

Kevin MacKenzie, MSc, PEng
Principal, Senior Water Resources Engineer

NP/CDV/KMM/ng/mp

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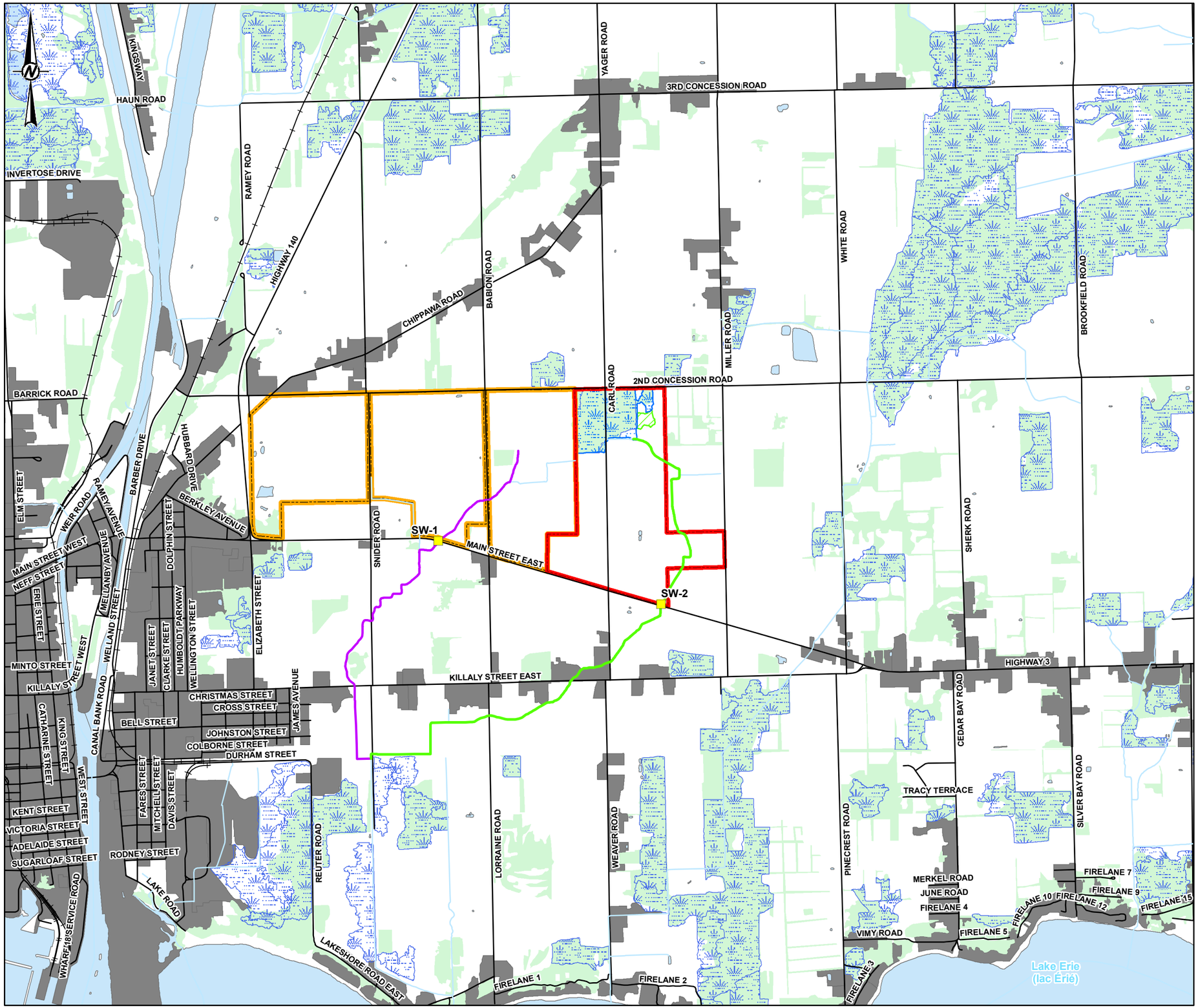
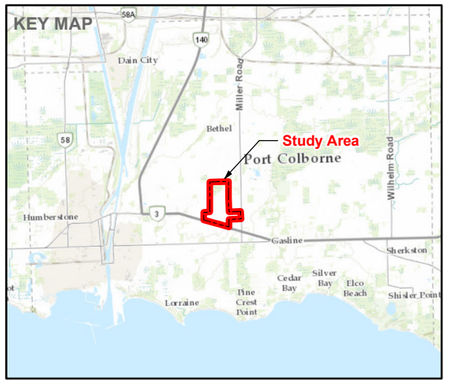
FIGURES



LEGEND

- Surface Water Station
- Roads
- Railway
- Watercourse
- West Branch of the Wignell Drain
- East Branch of the Wignell Drain (formerly Mitchner Drain)
- Wooded Area
- Built Up Area
- Wetland
- Waterbody
- Property Boundary
- Proposed Quarry Extension



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3. PROJECTION: TRANSVERSE MERCATOR NAD 1983 UTM ZONE 17N

CLIENT
RANKIN CONSTRUCTION INC.

PROJECT
STORMWATER MANAGEMENT PLAN

TITLE
SITE LOCATION PLAN AND SURFACE WATER MONITORING LOCATIONS

CONSULTANT

GOLDER

YYYY-MM-DD	2020-10-30
DESIGNED	PR
PREPARED	SO/PR
REVIEWED	NP
APPROVED	CDV

PROJECT NO.	CONTROL	REV.	FIGURE
1771656	0013		A1

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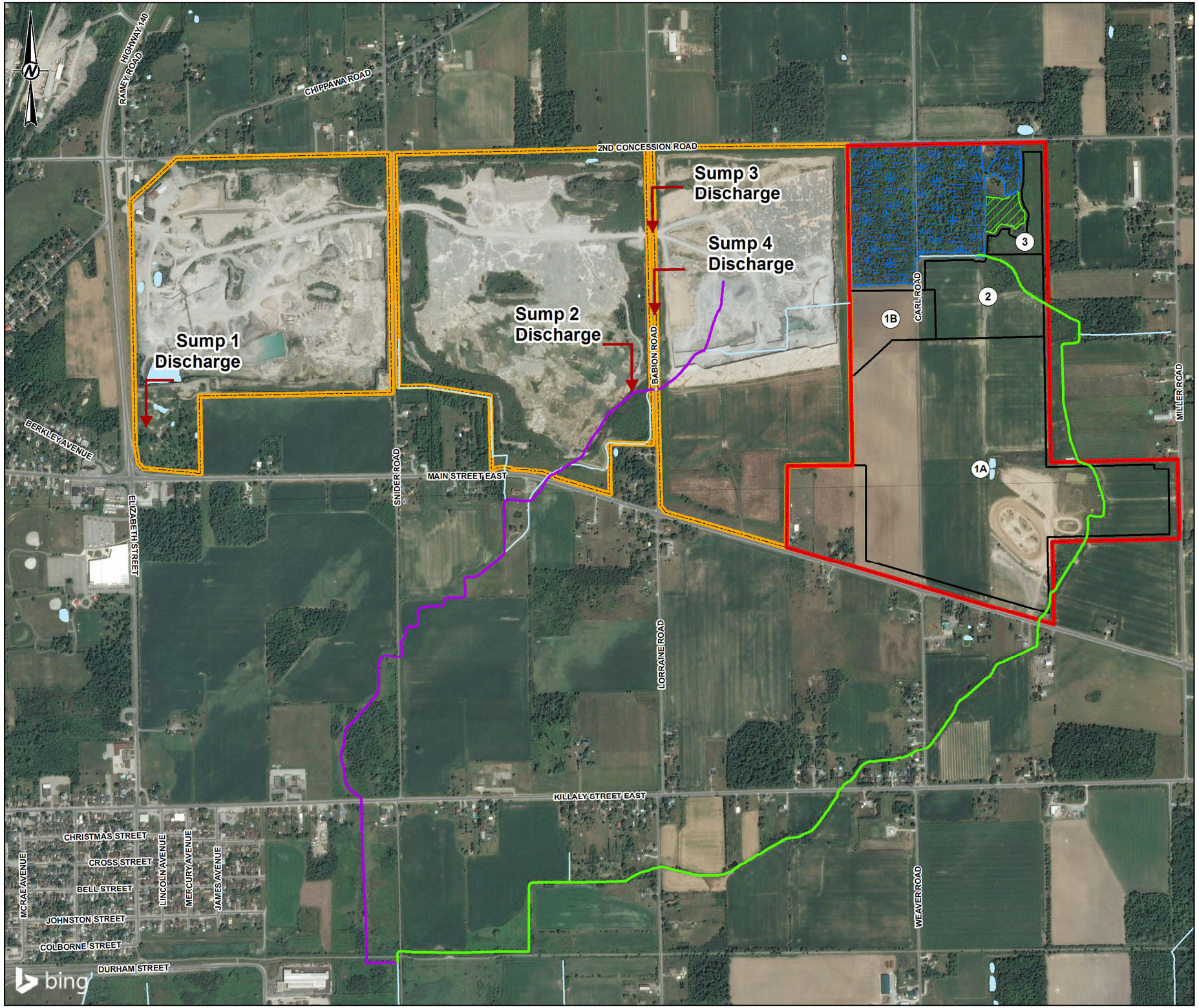
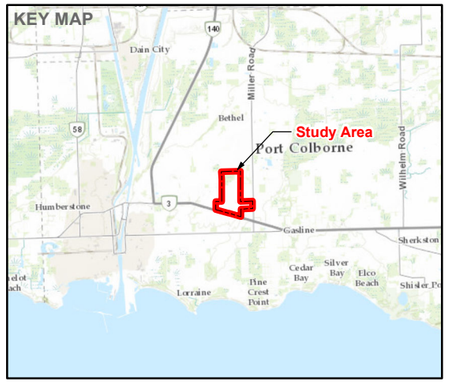


LEGEND

- Excavation Phase
- Watercourse
- East Branch of the Wignell Drain (formerly Mitchner Drain)
- West Branch of the Wignell Drain
- Sump Discharge
- Waterbody
- Wetland
- Woodland
- Property Boundary
- Proposed Quarry Extension
- Approximate Excavation Phasing Boundary



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3. PROJECTION: TRANSVERSE MERCATOR NAD 1983 UTM ZONE 17N

CLIENT
RANKIN CONSTRUCTION INC.

PROJECT
STORMWATER MANAGEMENT PLAN

TITLE
DRAINAGE FEATURES

CONSULTANT

GOLDER

YYYY-MM-DD	2020-10-29
DESIGNED	PR
PREPARED	PR
REVIEWED	NP
APPROVED	CDV

PROJECT NO.	CONTROL	REV.	FIGURE
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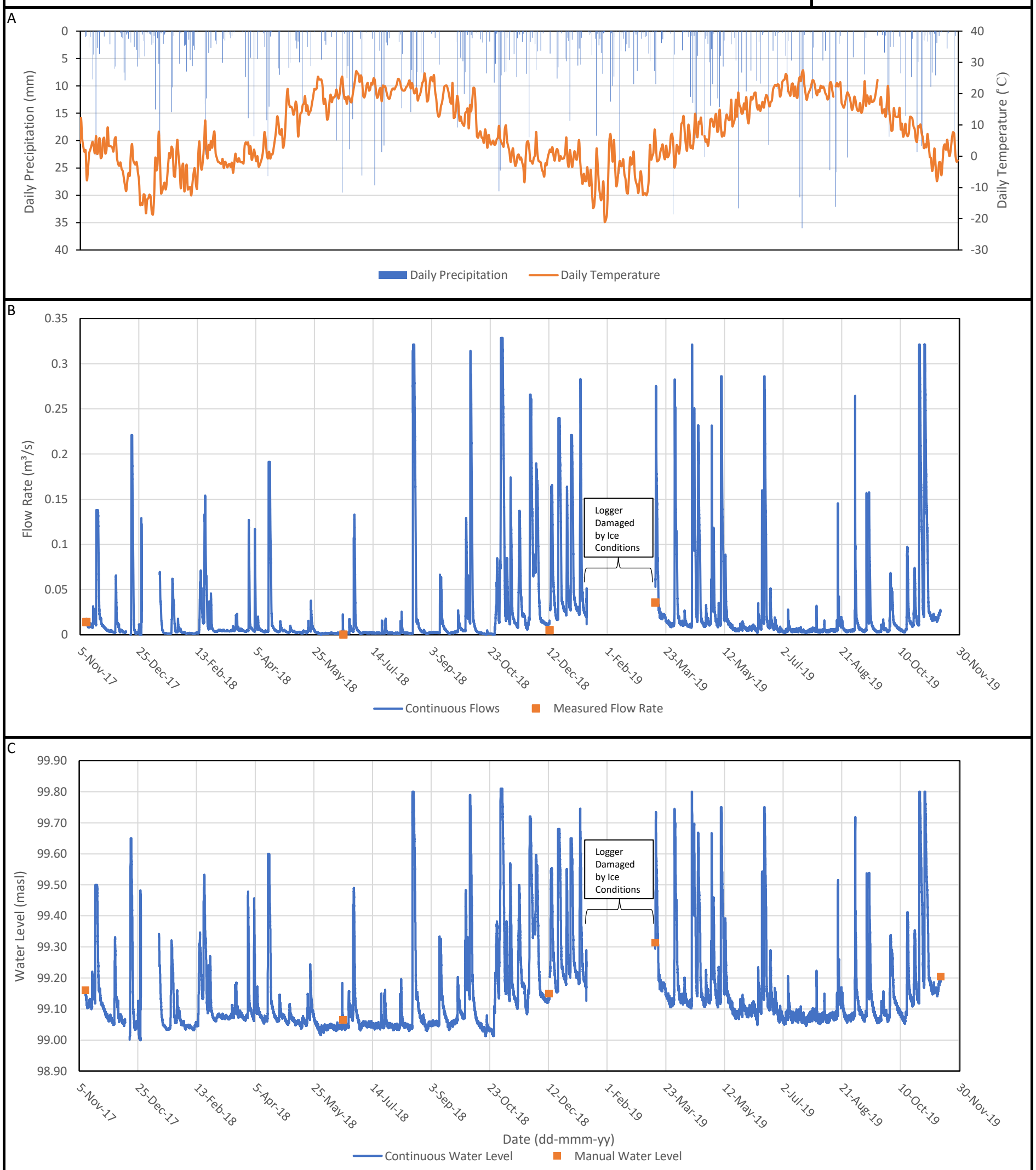
APPENDIX B

Water Level Hydrographs

Surface Water Monitoring at SW1 DRAFT | **FIGURE B-1**



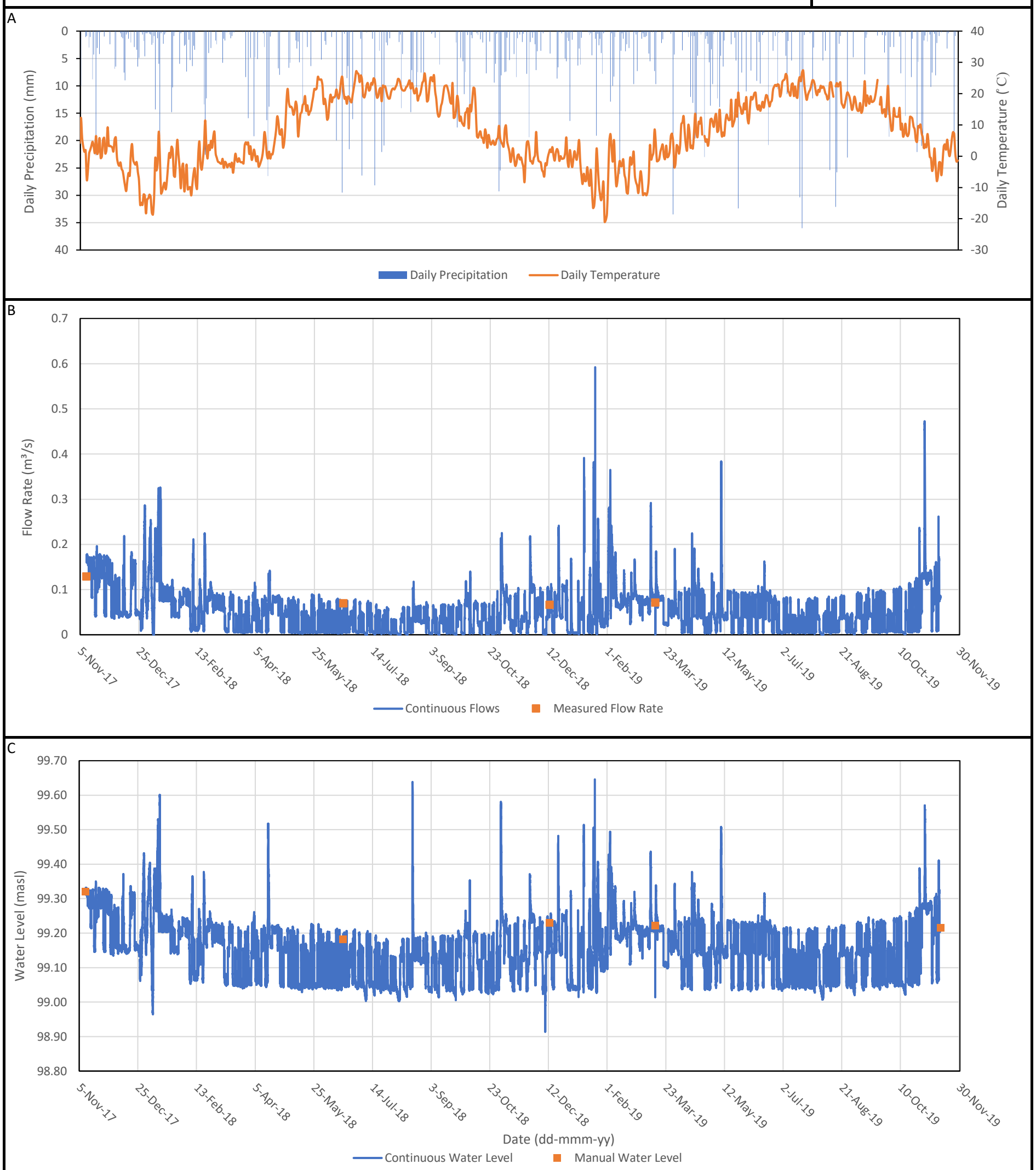
A. Daily Precipitation and Temperature B. Flow Rate C. Water Level

PROJECT: 1664706/3000
DATE: October 2020

GOLDER

DRAWN: NP
CHECK: CDV

Surface Water Monitoring at SW2 DRAFT | **FIGURE B-2**



A. Daily Precipitation and Temperature B. Flow Rate C. Water Level

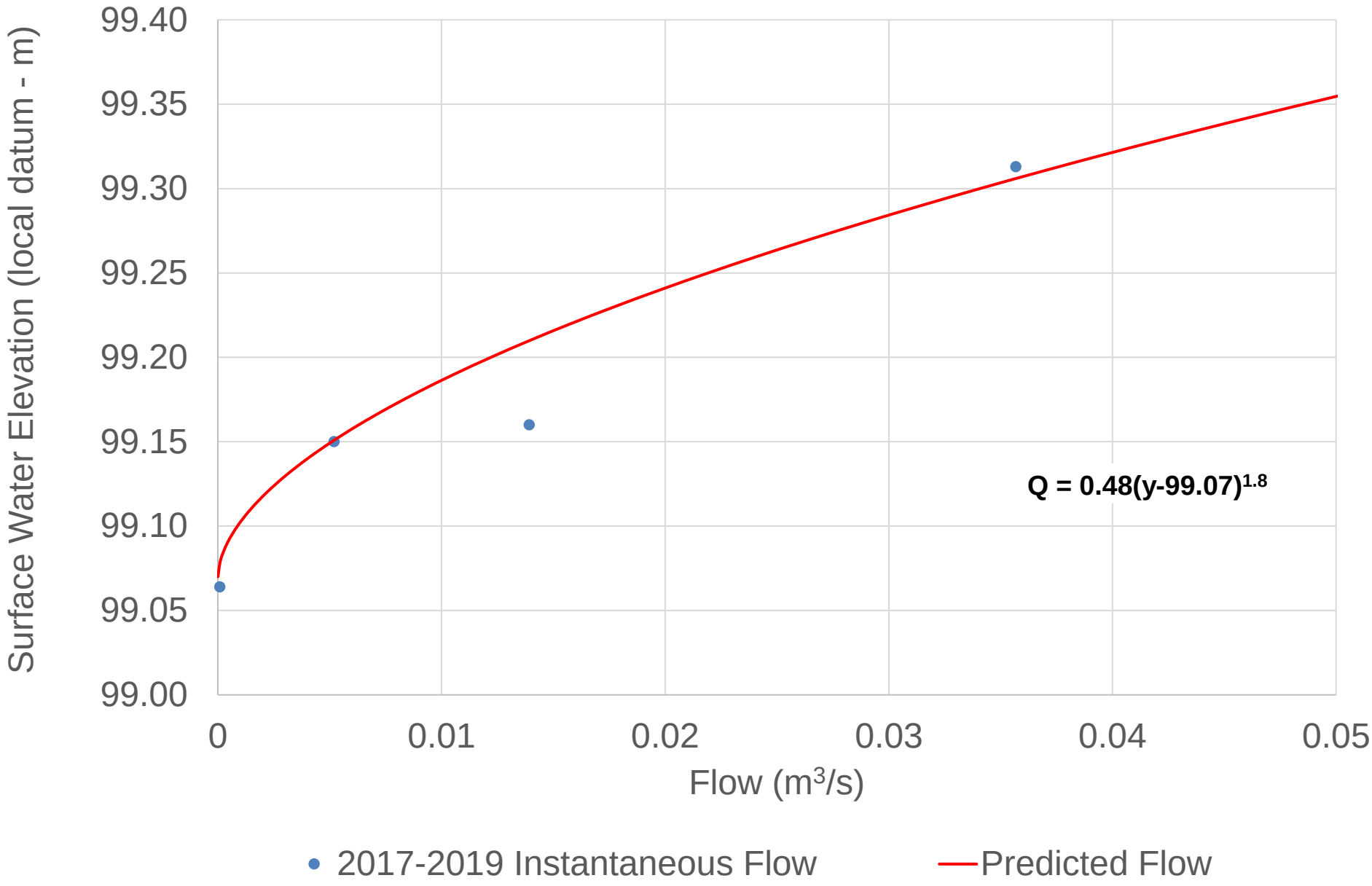
PROJECT: 1664706/3000
DATE: October 2020

GOLDER

DRAWN: NP
CHECK: CDV

APPENDIX C

Rating Curves



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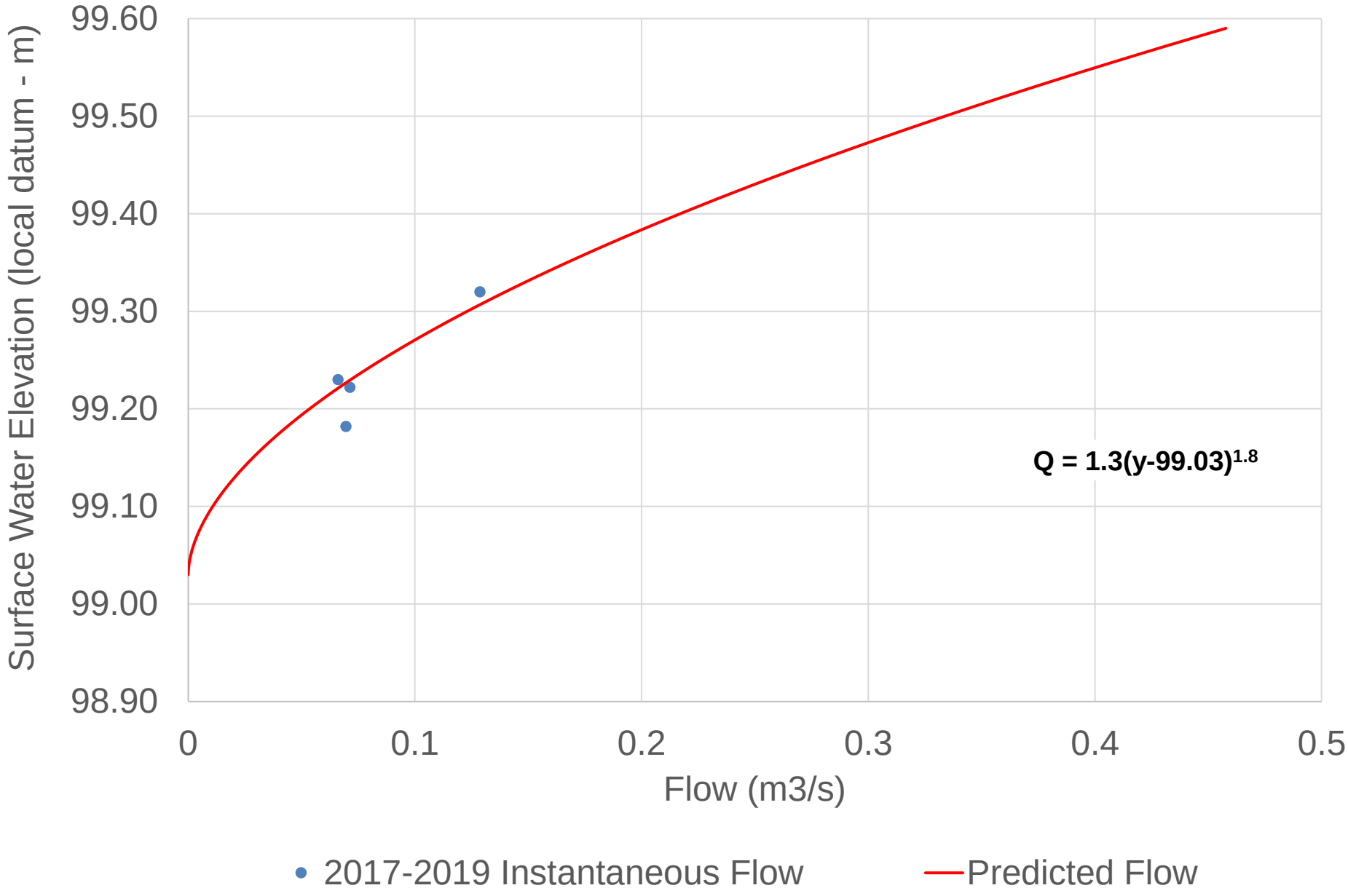
PROJECT	PORT COLBORNE QUARRY EXTENSION
CONSULTANT	GOLDER
YYYY-MM-DD	2020-05-21
PREPARED	NP
DESIGN	NP
REVIEW	-CDV
APPROVED	-KMAC
TITLE	SW1 ESTIMATED FLOW RATING CURVE
PROJECT No.	1771656
Rev.	1
	October 2020

FIGURE C-1



CLIENT	RANKIN CONSTRUCTION INC.
PROJECT	PORT COLBORNE QUARRY EXTENSION
CONSULTANT	GOLDER
YYYY-MM-DD	2020-05-21
PREPARED	NP
DESIGN	NP
REVIEW	-CDV
APPROVED	-KMAC
TITLE	SW2 ESTIMATED FLOW RATING CURVE
PROJECT No.	1771656
Rev.	1
	October 2020

FIGURE C-2

APPENDIX D

Water Budget - Port Colborne 1965 to 2018

Table D-1: Water Budget (Based on Port Colborne EC Monthly Data) - Port Colborne Quarries

Month	Mean Temperature (°C)	Rainfall (mm)	Precipitation (mm)	Potential Evapotrans-piration (mm)	Actual Evapotranspiration (mm)									Surplus (mm)									
					3 mm	10 mm	75 mm	100 mm	150 mm	200 mm	250 mm	300 mm	400 mm	3 mm	10 mm	75 mm	100 mm	150 mm	200 mm	250 mm	300 mm	400 mm	Precip -PET
January	-4	34	77	2	2	2	2	2	2	2	2	2	2	56	56	55	54	52	49	45	41	39	75
February	-4	30	62	2	2	2	2	2	2	2	2	2	2	60	60	60	60	60	58	55	53	51	60
March	1	52	70	9	9	9	9	9	9	9	9	9	9	90	90	90	90	90	90	90	88	86	61
April	7	78	80	32	32	32	32	32	32	32	32	32	32	51	51	51	51	51	51	51	51	51	48
May	13	83	83	77	62	65	77	77	77	77	77	77	77	22	22	22	22	22	22	22	22	22	6
June	19	81	81	116	76	79	105	110	115	116	116	116	116	7	6	6	6	6	6	6	6	6	-35
July	22	76	76	140	74	75	98	109	125	134	137	139	140	2	2	0	0	0	0	0	0	0	-64
August	21	86	86	127	80	80	84	88	100	109	116	120	124	6	5	2	2	1	0	0	0	0	-41
September	18	98	98	88	73	73	74	74	75	77	80	82	85	24	21	6	5	4	4	4	4	4	10
October	11	91	91	47	46	46	46	46	46	46	47	47	47	44	42	16	12	7	7	7	6	6	44
November	5	91	95	18	18	18	18	18	18	18	18	18	18	75	74	58	45	29	24	23	22	21	77
December	0	59	91	5	5	5	5	5	5	5	5	5	5	72	72	70	69	59	49	45	44	43	86
Total		859	990	663	479	486	552	572	606	627	641	649	657	509	501	436	416	381	360	348	337	329	327

Notes:

Climatic Water Budget: Water Budget Means for the Period 1965-2018 (Port Colborne, Climate ID: 6136606). Data gaps infilled with data from EC stations Welland-Pelham (Climate ID: 6139449), and Fort Erie (Climate ID: 6132470)

APPENDIX E

Proposed Pit 3 Extension Water Balance

Table E-1: Water Balance Existing Condition - Port Colborne Quarries

					Wooded			Agricultural			Swamp			Built Up Area (Impervious)			Built Up Area (Pervious)									
					WHC	400 mm		WHC	200 mm		WHC	75 mm		WHC	10 mm		WHC	75 mm								
					Total Area (m^2)	14,563		Total Area (m^2)	809,330		Total Area (m^2)	181,582		Total Area (m^2)	22,973		Total Area (m^2)	34,459								
					Infiltration Factor	0.8		Infiltration Factor	0.6		Infiltration Factor	0.0		Infiltration Factor	0.0		Infiltration Factor	0.6								
Month	Days	Temp	Precipitation	Potential Evapotranspiration	Actual Evapotranspiration Wooded Areas	Surplus		Actual Evapotranspiration Agricultural Areas	Surplus		Actual Evapotranspiration Swamp Areas	Surplus		Actual Evapotranspiration Built Up Area (Impervious) Areas	Surplus		Actual Evapotranspiration Built Up Area (Pervious) Areas	Surplus		Net Surplus	Total Surplus (Runoff and Infiltration)		Total Infiltration		Total Runoff	
		(°C)	(mm)	(mm)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(m^3)	(L/s)	(L/min)	(m^3)	(L/s)	(m^3)	(L/s)
January	31	-3.9	77.0	2	2	39	568	2	49	39,657	2	55	9,987	2	56	1,286	2	55	1,895	53,394	19.9	1,196	25,386	9.5	28,008	10.46
February	28	-3.6	62.0	2	2	51	743	2	58	46,941	2	60	10,895	2	60	1,378	2	60	2,068	62,025	25.6	1,538	29,896	12.4	32,129	13.28
March	31	0.7	70.0	9	9	86	1,252	9	90	72,840	9	90	16,342	9	90	2,068	9	90	3,101	95,603	35.7	2,142	45,946	17.2	49,657	18.54
April	30	6.6	80.0	32	32	51	743	32	51	41,276	32	51	9,261	32	51	1,172	32	51	1,757	54,208	20.9	1,255	27,220	10.5	26,988	10.41
May	31	13.2	83.0	77	77	22	320	77	22	17,805	77	22	3,995	65	22	505	77	22	758	23,384	8.7	524	11,994	4.5	11,390	4.25
June	30	18.6	81.0	116	116	6	87	116	6	4,856	105	6	1,089	79	6	138	105	6	207	6,377	2.5	148	3,438	1.3	2,939	1.13
July	31	21.8	76.0	140	140	0	0	134	0	0	98	0	0	75	2	46	98	0	0	46	0.0	1	124	0.0	-78	-0.03
August	31	21.4	86.0	127	124	0	0	109	0	0	84	2	363	80	5	115	84	2	69	547	0.2	12	0	0.0	547	0.20
September	30	17.6	98.0	88	85	4	58	77	4	3,237	74	6	1,089	73	21	482	74	6	207	5,074	2.0	117	2,030	0.8	3,044	1.17
October	31	11.2	91.0	47	47	6	87	46	7	5,665	46	16	2,905	46	42	965	46	16	551	10,174	3.8	228	3,593	1.3	6,581	2.46
November	30	5.3	95.0	18	18	21	306	18	24	19,424	18	58	10,532	18	74	1,700	18	58	1,999	33,960	13.1	786	12,230	4.7	21,730	8.38
December	31	-0.4	91.0	5	5	43	626	5	49	39,657	5	70	12,711	5	72	1,654	5	70	2,412	57,060	21.3	1,278	25,494	9.5	31,566	11.79
Total			***990.0***	***663.0***	***657***	***329***	***4,791***	***627***	***360***	***291,359***	***552***	***436***	***79,170***	***486***	***501***	***11,509***	***552***	***436***	***15,024***	***401,854***	***154***	***9,225***	***187,353***	***71.7***	***214,501***	**82.05**
Average		***9.0***																			***23.7***			***11.0***		***12.6***

Notes:

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

P = ET + R + I + S

Table E-2: Water Balance Operational Condition - Port Colborne Quarries

					Mature Forest			Agricultural			Marsh/Swamp			Built Up Area (Quarry)			Open Pasture									
					WHC	400 mm		WHC	200 mm		WHC	75 mm		WHC	10 mm		WHC	100 mm								
					Total Area (m^2)	14,563		Total Area (m^2)	133,106		Total Area (m^2)	181,582		Total Area (m^2)	711,157		Total Area (m^2)	22,500								
					Infiltration Factor	0.8		Infiltration Factor	0.6		Infiltration Factor	0.0		Infiltration Factor	0.0		Infiltration Factor	0.6								
Month	Days	Temp	Precipitation	Potential Evapotranspiration	Actual Evapotranspiration Mature Forest Areas	Surplus		Actual Evapotranspiration Agricultural Areas	Surplus		Actual Evapotranspiration Marsh/Swamp Areas	Surplus		Actual Evapotranspiration Built Up Area (Quarry) Areas	Surplus		Actual Evapotranspiration Open Pasture Areas	Surplus		Total Surplus	Total Surplus (Runoff and Infiltration)		Total Infiltration		Total Runoff	
		(°C)	(mm)	(mm)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(m^3)	(L/s)	(L/min)	(m^3)	(L/s)	(m^3)	(L/s)
January	31	-3.9	77.0	2	2	39	568	2	49	6,522	2	55	9,987	2	56	39,825	2	54	1,215	58,117	21.7	1,302	5,097	1.9	53,020	19.80
February	28	-3.6	62.0	2	2	51	743	2	58	7,720	2	60	10,895	2	60	42,669	2	60	1,350	63,377	26.2	1,572	6,036	2.5	57,341	23.70
March	31	0.7	70.0	9	9	86	1,252	9	90	11,980	9	90	16,342	9	90	64,004	9	90	2,025	95,603	35.7	2,142	9,405	3.5	86,199	32.18
April	30	6.6	80.0	32	32	51	743	32	51	6,788	32	51	9,261	32	51	36,269	32	51	1,148	54,208	20.9	1,255	5,356	2.1	48,853	18.85
May	31	13.2	83.0	77	77	22	320	77	22	2,928	77	22	3,995	65	22	15,645	77	22	495	23,384	8.7	524	2,310	0.9	21,074	7.87
June	30	18.6	81.0	116	116	6	87	116	6	799	105	6	1,089	79	6	4,267	110	6	135	6,377	2.5	148	630	0.2	5,747	2.22
July	31	21.8	76.0	140	140	0	0	134	0	0	98	0	0	75	2	1,422	109	0	0	1,422	0.5	32	0	0.0	1,422	0.53
August	31	21.4	86.0	127	124	0	0	109	0	0	84	2	363	80	5	3,556	88	2	45	3,964	1.5	89	27	0.0	3,937	1.47
September	30	17.6	98.0	88	85	4	58	77	4	532	74	6	1,089	73	21	14,934	74	5	113	16,727	6.5	387	434	0.2	16,293	6.29
October	31	11.2	91.0	47	47	6	87	46	7	932	46	16	2,905	46	42	29,869	46	12	270	34,063	12.7	763	791	0.3	33,272	12.42
November	30	5.3	95.0	18	18	21	306	18	24	3,195	18	58	10,532	18	74	52,626	18	45	1,013	67,670	26.1	1,566	2,769	1.1	64,901	25.04
December	31	-0.4	91.0	5	5	43	626	5	49	6,522	5	70	12,711	5	72	51,203	5	69	1,553	72,615	27.1	1,627	5,346	2.0	67,269	25.12
Total			***990.0***	***663.0***	***657***	***329***	***4,791***	***627***	***360***	***47,918***	***552***	***436***	***79,170***	***486***	***501***	***356,290***	***572***	***416***	***9,360***	***497,529***	***190***	***11,406***	***38,200***	***14.6***	***459,329***	***175.48***
Average		***9.0***																			***29.2***			***2.2***		***27.0***

Notes:

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

P = ET + R + I + S

Table E-3: Water Balance Rehabilitated Condition - Port Colborne Quarries

					Open Pasture			Open Water			Mature Forest			Marsh/Swamp									
					WHC	150 mm		WHC	0 mm		WHC	400 mm		WHC	75 mm								
					Total Area (m^2)	155,606		Total Area (m^2)	711,157		Total Area (m^2)	14,563		Total Area (m^2)	181,582								
					Infiltration Factor	0.6		Infiltration Factor	0.0		Infiltration Factor	0.8		Infiltration Factor	0.0								
Month	Days	Temp	Precipitation	Potential Evapotranspiration	Actual Evapotranspiration Open Pasture Areas	Surplus		Actual Evapotranspiration Open Water Areas	Surplus		Actual Evapotranspiration Mature Forest Areas	Surplus		Actual Evapotranspiration Marsh/Swamp Areas	Surplus		Total Surplus	Total Surplus (Runoff and Infiltration)		Total Infiltration		Total Runoff	
		(°C)	(mm)	(mm)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(mm)	(mm)	(m^3)	(m^3)	(L/s)	(L/min)	(m^3)	(L/s)	(m^3)	(L/s)
January	31	-3.9	77.0	2	2	52	8,091	2	75	53,337	2	39	568	2	55	9,987	71,983	27	1,613	5,309	2.0	66,674	25
February	28	-3.6	62.0	2	2	60	9,336	2	60	42,669	2	51	743	2	60	10,895	63,643	26	1,578	6,196	2.6	57,447	24
March	31	0.7	70.0	9	9	90	14,005	9	61	43,381	9	86	1,252	9	90	16,342	74,980	28	1,680	9,405	3.5	65,575	24
April	30	6.6	80.0	32	32	51	7,936	32	48	34,136	32	51	743	32	51	9,261	52,075	20	1,205	5,356	2.1	46,719	18
May	31	13.2	83.0	77	77	22	3,423	77	6	4,267	77	22	320	77	22	3,995	12,005	4	269	2,310	0.9	9,695	4
June	30	18.6	81.0	116	115	6	934	116	-35	-24,890	116	6	87	105	6	1,089	-22,780	-9	-527	630	0.2	-23,410	-9
July	31	21.8	76.0	140	125	0	0	140	-64	-45,514	140	0	0	98	0	0	-45,514	-17	-1,020	0	0.0	-45,514	-17
August	31	21.4	86.0	127	100	1	156	127	-41	-29,157	124	0	0	84	2	363	-28,639	-11	-642	93	0.0	-28,732	-11
September	30	17.6	98.0	88	75	4	622	88	10	7,112	85	4	58	74	6	1,089	8,882	3	206	420	0.2	8,462	3
October	31	11.2	91.0	47	46	7	1,089	47	44	31,291	47	6	87	46	16	2,905	35,373	13	792	723	0.3	34,649	13
November	30	5.3	95.0	18	18	29	4,513	18	77	54,759	18	21	306	18	58	10,532	70,109	27	1,623	2,952	1.1	67,157	26
December	31	-0.4	91.0	5	5	59	9,181	5	86	61,160	5	43	626	5	70	12,711	83,677	31	1,874	6,009	2.2	77,668	29
Total			***990.0***	***663.0***	***606***	***381***	***59,286***	***663***	***327***	***232,548***	***657***	***329***	***4,791***	***552***	***436***	***79,170***	***375,795***	***144***	***8,652***	***39,404***	***15***	***336,391***	***129***
Average		***9.0***																			***2.3***		

Notes:

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

P = ET + R + I + S

APPENDIX F

Existing Quarry Water Balance

Table F-1: Water Balance Rehabilitated Condition - Port Colborne Quarries

Quarry	
WHC	10 mm
Total Area (m^2)	1,780,700
Infiltration Factor	0.5

Date	Days	Temp	Precipitation	Potential Evapotranspiration	Actual Evapotranspiration Quarry Areas	Surplus		Total Surplus		Quarry - Monthly Volume Pumped (1)		Difference (Pumped vs. Surplus)	Total Surplus (Runoff and Infiltration)		Total Infiltration		Total Runoff	
		(°C)	(mm)	(mm)	(mm)	(mm)	(m^3)	(m^3)	(L)	(m^3)	(L)	(m^3)	(L/s)	(L/min)	(m^3)	(L/s)	(m^3)	(L/s)
Jan-12	31	-0.2	82.2	5	5	77	137,114	**137,114**	137,113,900	**97,774**	97,774,208	**-39,340**	51.2	3,072	68,557	25.6	68,557	25.60
Feb-12	29	0.2	44.8	3	3	42	74,255	**74,255**	74,255,190	**77,503**	77,502,832	**3,248**	29.6	1,778	37,128	14.8	37,128	14.82
Mar-12	31	7.3	74.6	35	35	40	70,338	**70,338**	70,337,650	**102,088**	102,087,889	**31,750**	26.3	1,576	35,169	13.1	35,169	13.13
Apr-12	30	7.2	66.7	33	33	33	59,475	**59,475**	59,475,380	**48,470**	48,470,038	**-11,005**	22.9	1,377	29,738	11.5	29,738	11.47
May-12	31	17.4	25.9	104	36	0	0	**0**	0	**61,212**	61,212,201	**61,212**	0.0	0	0	0.0	0	0.00
Jun-12	30	20.0	72.4	123	72	0	0	**0**	0	**58,129**	58,129,040	**58,129**	0.0	0	0	0.0	0	0.00
Jul-12	31	24.4	39.7	157	40	0	0	**0**	0	**13,782**	13,782,191	**13,782**	0.0	0	0	0.0	0	0.00
Aug-12	31	22.3	26.0	132	26	0	0	**0**	0	**5,548**	5,548,344	**5,548**	0.0	0	0	0.0	0	0.00
Sep-12	30	18.0	102.2	90	90	2	3,383	**3,383**	3,383,330	**9,434**	9,433,801	**6,050**	1.3	78	1,692	0.7	1,692	0.65
Oct-12	31	12.1	173.2	52	52	122	216,533	**216,533**	216,533,120	**54,210**	54,209,589	**-162,324**	80.8	4,851	108,267	40.4	108,267	40.42
Nov-12	30	4.6	19.0	15	15	4	6,945	**6,945**	6,944,730	**60,829**	60,828,536	**53,884**	2.7	161	3,472	1.3	3,472	1.34
Dec-12	31	2.7	95.2	10	10	66	117,526	**117,526**	117,526,200	**63,523**	63,523,428	**-54,003**	43.9	2,633	58,763	21.9	58,763	21.94
TOTAL			***821.9***	***759.8***	***418***	***385***	***685,570***	***685,570***	***685,569,500***	***652,502***	***652,502,097***	***-33,067***	***259***	***15,525***	***342,785***	***129***	***342,785***	***129***
Jan-13	31	-1.3	61	5.5	5.5	75.1	133,731	**133,731**	133,730,570	**48,979**	48,979,152	**-84,751**	49.9	2,996	66,865	25.0	66,865	24.96
Feb-13	28	-3.3	93	0.7	0.7	75.6	134,621	**134,621**	134,620,920	**74,222**	74,221,552	**-60,399**	55.6	3,339	67,310	27.8	67,310	27.82
Mar-13	31	0.7	9	7.0	7.0	18.4	32,765	**32,765**	32,764,880	**71,332**	71,332,046	**38,567**	12.2	734	16,382	6.1	16,382	6.12
Apr-13	30	7.3	93	35.3	35.3	57.3	102,034	**102,034**	102,034,110	**71,843**	71,842,978	**-30,191**	39.4	2,362	51,017	19.7	51,017	19.68
May-13	31	16	106	94.3	94.3	11.6	20,656	**20,656**	20,656,120	**65,758**	65,758,033	**45,102**	7.7	463	10,328	3.9	10,328	3.86
Jun-13	30	18.3	189	110.8	110.8	77.7	138,360	**138,360**	138,360,390	**136,376**	136,376,054	**-1,984**	53.4	3,203	69,180	26.7	69,180	26.69
Jul-13	31	22.6	96	143.9	105.6	0.0	0	**0**	0	**95,202**	95,202,206	**95,202**	0.0	0	0	0.0	0	0.00
Aug-13	31	21.1	92	123.2	91.8	0.0	0	**0**	0	**99,865**	99,864,792	**99,865**	0.0	0	0	0.0	0	0.00
Sep-13	30	17.3	101	85.6	85.6	5.6	9,972	**9,972**	9,971,920	**94,814**	94,813,778	**84,842**	3.8	231	4,986	1.9	4,986	1.92
Oct-13	31	13	196	57.0	57.0	138.9	247,339	**247,339**	247,339,230	**152,640**	152,640,245	**-94,699**	92.3	5,541	123,670	46.2	123,670	46.17
Nov-13	30	4.2	68	16.8	16.8	46.8	83,337	**83,337**	83,336,760	**124,983**	124,983,249	**41,646**	32.2	1,929	41,668	16.1	41,668	16.08
Dec-13	31	-1.3	115	4.3	4.3	111.9	199,260	**199,260**	199,260,330	**55,853**	55,852,884	**-143,407**	74.4	4,464	99,630	37.2	99,630	37.20
TOTAL			***1,217***	***684***	***615***	***619***	***1,102,075***	***1,102,075***	***1,102,075,230***	***1,091,867***	***1,091,866,969***	***-10,208***	***421***	***25,260***	***551,038***	***211***	***551,038***	***211***
Jan-14	31	-6.4	64	1.3	1.3	47.7	84,939	**84,939**	84,939,390	**46,814**	46,813,919	**-38,125**	31.7	1,903	42,470	15.9	42,470	15.86
Feb-14	28	-6.6	63	0.7	0.7	49.8	88,679	**88,679**	88,678,860	**34,261**	34,261,406	**-54,417**	36.7	2,199	44,339	18.3	44,339	18.33
Mar-14	31	-2.9	40	3.8	3.8	65.9	117,348	**117,348**	117,348,130	**131,310**	131,309,687	**13,962**	43.8	2,629	58,674	21.9	58,674	21.91
Apr-14	30	6.7	136	31.7	31.7	104.5	186,083	**186,083**	186,083,150	**199,283**	199,283,128	**13,200**	71.8	4,307	93,042	35.9	93,042	35.90
May-14	31	13.3	112	76.5	76.5	35.6	63,393	**63,393**	63,392,920	**188,442**	188,441,532	**125,049**	23.7	1,420	31,696	11.8	31,696	11.83
Jun-14	30	20.5	64	126.3	73.7	0.0	0	**0**	0	**151,549**	151,548,702	**151,549**	0.0	0	0	0.0	0	0.00
Jul-14	31	20.8	109	130.1	108.9	0.0	0	**0**	0	**87,980**	87,980,353	**87,980**	0.0	0	0	0.0	0	0.00
Aug-14	31	21.4	27	124.9	26.9	0.0	0	**0**	0	**86,861**	86,861,322	**86,861**	0.0	0	0	0.0	0	0.00
Sep-14	30	18.2	51	90.7	51.1	0.0	0	**0**	0	**35,266**	35,265,979	**35,266**	0.0	0	0	0.0	0	0.00
Oct-14	31	12.1	127	51.8	51.8	65.2	116,102	**116,102**	116,101,640	**49,180**	49,179,900	**-66,922**	43.3	2,601	58,051	21.7	58,051	21.67
Nov-14	30	3.7	57	15.0	15.0	41.6	74,077	**74,077**	74,077,120	**46,302**	46,302,197	**-27,775**	28.6	1,715	37,039	14.3	37,039	14.29
Dec-14	31	1.1	45	5.5	5.5	39.0	69,447	**69,447**	69,447,300	**43,710**	43,709,849	**-25,737**	25.9	1,556	34,724	13.0	34,724	12.96
TOTAL			***893***	***658***	***447***	***449***	***800,069***	***800,069***	***800,068,510***	***1,100,958***	***1,100,957,974***	***300,889***	***305***	***18,330***	***400,034***	***153***	***400,034***	***153***
Jan-15	31	-6	79	0.6	0.6	52.7	93,843	**93,843**	93,842,890	**35,159**	35,158,585	**-58,684**	35.0	2,102	46,921	17.5	46,921	17.52
Feb-15	28	-11.1	80	0.0	0.0	0.0	0	**0**	0	**3,410**	3,410,460	**3,410**	0.0	0	0	0.0	0	0.00
Mar-15	31	-1.3	56	3.6	3.6	143.8	256,065	**256,065**	256,064,660	**83,119**	83,119,067	**-172,946**	95.6	5,736	128,032	47.8	128,032	47.80
Apr-15	30	6.8	84	31.7	31.7	66.5	118,417	**118,417**	118,416,550	**131,925**	131,925,368	**13,509**	45.7	2,741	59,208	22.8	59,208	22.84
May-15	31	15.9	60	93.4	70.0	0.0	0	**0**	0	**110,071**	110,071,177	**110,071**	0.0	0	0	0.0	0	0.00
Jun-15	30	18.2	134	110.2	110.2	13.5	24,039	**24,039**	24,039,450	**119,340**	119,340,173	**95,301**	9.3	556	12,020	4.6	12,020	4.64
Jul-15	31	21.8	51	137.9	60.8	0.0	0	**0**	0	**167,394**	167,394,111	**167,394**	0.0	0	0	0.0	0	0.00
Aug-15	31	21.1	77	123.4	77.1	0.0	0	**0**	0	**72,331**	72,330,582	**72,331**	0.0	0	0	0.0	0	0.00
Sep-15	30	20.6	91	104.6	91.4	0.0	0	**0**	0	**79,191**	79,190,548	**79,191**	0.0	0	0	0.0	0	0.00
Oct-15	31	11.5	87	48.6	48.6	28.6	50,928	**50,928**	50,928,020	**92,889**	92,888,645	**41,961**	19.0	1,141	25,464	9.5	25,464	9.51
Nov-15	30	8.9	29	31.6	31.6	0.0	0	**0**	0	**90,321**	90,321,129	**90,321**	0.0	0	0	0.0	0	0.00
Dec-15	31	5.8	59	18.5	18.5	38.3	68,201	**68,201**	68,200,810	**20,969**	20,968,834	**-47,232**	25.5	1,528	34,100	12.7	34,100	12.73
TOTAL			***888***	***704***	***544***	***343***	***611,492***	***611,492***	***611,492,380***	***1,006,119***	***1,006,118,679***	***394,626***	***230***	***13,805***	***305,746***	***115***	***305,746***	***115***
Jan-16	31	-1.9	35	2.7	2.7	31.9	56,804	**56,804**	56,804,330	**52,534**	52,533,560	**-4,271**	21.2	1,272	28,402	10.6	28,402	10.60
Feb-16	29	-1.1	77	5.4	5.4	71.2	126,786	**126,786**	126,785,840	**109,642**	109,641,700	**-17,144**	50.6	3,036	63,393	25.3	63,393	25.30
Mar-16	31	3.8	81	18.7	18.7	62.5	111,294	**111,294**	111,293,750	**132,889**	132,889,280	**21,596**	41.6	2,493	55,647	20.8	55,647	20.78
Apr-16	30	6.1	38	31.2	31.2	6.6	11,753	**11,753**	11,752,620	**87,353**	87,353,020	**75,600**	4.5	272	5,876	2.3	5,876	2.27
May-16	31	14.7	20	86.1	30.2	0.0	0	**0**	0	**47,457**	47,457,000	**47,457**	0.0	0	0	0.0	0	0.00
Jun-16	30	19.7	54	121.0	53.6	0.0	0	**0**	0	**35,854**	35,854,040	**35,854**	0.0	0	0	0.0	0	0.00
Jul-16	31	23.4	48	149.6	48.2	0.0	0	**0**	0	**9,420**	9,420,300	**9,420**	0.0	0	0	0.0	0	0.00
Aug-16	31	24.4	62	146.1	62.4	0.0	0	**0**	0	**16,288**	16,288,080	**16,288**	0.0	0	0	0.0	0	0.00
Sep-16	30	20.2	76	102.5	75.6	0.0	0	**0**	0	**22,629**	22,628,546	**22,629**	0.0	0	0	0.0	0	0.00
Oct-16	31	13.1	81	57.4	57.4	13.6	24,218	**24,218**	24,217,520	**57,524**	57,524,120	**33,307**	9.0	543	12,109	4.5	12,109	4.52
Nov-16	30	7.7	70	26.5	26.5	43.2	76,926	**76,926**	76,926,240	**78,136**	78,135,640	**1,209**	29.7	1,781	38,463	14.8	38,463	14.84
Dec-16	31	0.4	69	4.7	4.7	63.9	113,787	**113,787**	113,786,730	**75,292**	75,291,520	**-38,495**	42.5	2,549	56,893	21.2	56,893	21.24
TOTAL			***710***	***752***	***417***	***293***	***521,567***	***521,567***	***521,567,030***	***725,017***	***725,016,806***	***203,450***	***199***	***11,946***	***260,784***	***100***	***260,784***	***100***
Jan-17	31	-0.2	60	5.4	5.4	46.2	82,268	**82,268**	82,268,340	**117,606**	117,606,020	**35,338**	30.7	1,843	41,134	15.4	41,134	15.36
Feb-17	28	1.6	62	8.8	8.8	61.0	108,623	**108,623**	108,622,700	**130,190**	130,189,594	**21,567**	44.9	2,694	54,311	22.5	54,311	22.45
Mar-17	31	1.1	103	12.7	12.7	89.8	159,907	**159,907**	159,906,860	**190,796**	190,796,403	**30,890**	59.7	3,582	79,953	29.9	79,953	29.85
Apr-17	30	10.2	124	50.2	50.2	74.2	132,128	**132,128**	132,127,940	**266,936**	266,935,521	**134,808**	51.0	3,059	66,064	25.5	66,064	25.49
May-17	31	13.6	141	79.7	79.7	61.3	109,157	**109,157**	109,156,910	**230,015**	230,015,487	**120,859**	40.8	2,445	54,578	20.4	54,578	20.38
Jun-17	30	19.5	55	121.9	65.1	0.0	0	**0**	0	**66,575**	66,574,676	**66,575**	0.0	0	0	0.0	0	0.00
Jul-17	31	22.1	57	142.7	56.9	0.0	0	**0**	0	**67,096**	67,095,528	**67,096**	0.0	0	0	0.0	0	0.00
Aug-17	31	21.1	74	125.2	74.0	0.0	0	**0**	0	**61,562**	61,562,314	**61,562**	0.0	0	0	0.0	0	0.00
Sep-17	30	19.3	26	96.6	26.0	0.0	0	**0**	0	**37,940**	37,940,124	**37,940**	0.0	0	0	0.0	0	0.00
Oct-17	31	15	134	65.9	65.9	58.2	103,637	**103,637**	103,636,740	**86,757**	86,757,406	**-16,879**	38.7	2,322	51,818	19.3	51,818	19.35
Nov-17	30	5.6	107	18.9	18.9	88.2	157,058	**157,058**	157,057,740	**206,792**	206,792,336	**49,735**	60.6	3,636	78,529	30.3	78,529	30.30
Dec-17	31	-2.8	82	3.7	3.7	58.6	104,349	**104,349**	104,349,020	**44,332**	44,332,401	**-60,017**	39.0	2,338	52,175	19.5	52,175	19.48
TOTAL			***1,025***	***732***	***467***	***538***	***957,126***	***957,126***	***957,126,250***	***1,506,598***	***1,506,597,810***	***549,472***	***365***	***21,918***	***478,563***	***183***	***478,563***	***183***
Jan-18	31	-3.9	59	3.6	3.6	72.6	129,279	**129,279**	129,278,820	**179,739**	179,738,731	**50,460**	48.3	2,896	64,639	24.1	64,639	24.13
Feb-18	28	-0.9	61	5.4	5.4	58.1	103,459	**103,459**	103,458,670	**184,500**	184,499,790	**81,041**	42.8	2,566	51,729	21.4	51,729	21.38
Mar-18	31	0.2	24	3.9	3.9	20.5	36,504	**36,504**	36,504,350	**120,112**	120,111,993	**83,608**	13.6	818	18,252	6.8	18,252	6.81
Apr-18	30	3.6	74	17.8	17.8	56.6	100,788	**100,788**	100,787,620	**157,330**	157,329,546	**56,542**	38.9	2,333	50,394	19.4	50,394	19.44
May-18	31	16.2	58	97.5	67.6	0.0	0	**0**	0	**109,674**	109,673,696	**109,674**	0.0	0	0	0.0	0	0.00
Jun-18	30	19.9	83	125.1	83.1	0.0	0	**0**	0	**74,725**	74,724,589	**74,725**	0.0	0	0	0.0	0	0.00
Jul-18	31	23.8	56	155.9	56.3	0.0	0	**0**	0	**64,015**	64,014,589	**64,015**	0.0	0	0	0.0	0	0.00
Aug-18	31	23.6	347	142.0	142.0	195.4	347,949	**347,949**	347,948,780	**122,319**	122,318,975	**-225,630**	129.9	7,795	173,974	65.0	173,974	64.95
Sep-18	30	19.9	77	101.1	86.8	0.0	0	**0**	0	**151,776**	151,776,265	**151,776**	0.0	0	0	0.0	0	0.00
Oct-18	31	11	111	47.0	47.0	53.8	95,802	**95,802**	95,801,660	**134,530**	134,529,690	**38,728**	35.8	2,146	47,901	17.9	47,901	17.88
Nov-18	30	2.8	118	10.5	10.5	107.5	191,425	**191,425**	191,425,250	**188,729**	188,729,496	**-2,696**	73.9	4,431	95,713	36.9	95,713	36.93
Dec-18	31	1.2	70	5.3	5.3	64.7	115,211	**115,211**	115,211,290	**177,447**	177,446,586	**62,235**	43.0	2,581	57,606	21.5	57,606	21.51
TOTAL			***1,139***	***715***	***529***	***629***	***1,120,416***	***1,120,416***	***1,120,416,440***	***1,664,894***	***1,664,893,946***	***544,478***	***426***	***25,565***	***560,208***	***213***	***560,208***	***213***
Sum Total			***6693***	***5005***	***3437***	***3256***	***5798315***	***5798315***	***5798315340***	***7747954***	***7747954281***	***1949639***	***2206***	***132348***	***2899158***	***1103***	***2899158***	***1103***
Overall Avg		***10.0***	***80***	***-***	***-***	***39***	***69,028***	***69,028***	***69,027,564***	***92,238***	***92,237,551***	***23,210***	***26***	***1,576***	***34,514***	***13***	***34,514***	***13***
								828,331	828,330,763	1,106,851	1,106,850,612	278,520	315	18,907	414,165	158	414,165	158

Notes:

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

P = ET + R + I + S

APPENDIX G

Curriculum Vitae

Education

M.Sc. (Eng.) Water Resource Engineering, University of Guelph, Guelph, 1995

B.Sc. (Eng.) Water Resource Engineering, Minor: Environmental Engineering, University of Guelph, Guelph, 1993

Languages

English – Fluent

Golder Associates Ltd. – Cambridge

Employment History

Golder Associates Ltd. – Cambridge, Ontario
Water Resources Engineer, Principal (1997 to Present)

Responsible for management of water resources assessments including hydrology, hydraulics, upland and in stream erosion, water quality and water management for a wide variety of government, power generation, industrial, mining and aggregate producing clients. Being part of a comprehensive client service team for aggregate producers in Ontario has facilitated an excellent understanding of the aggregate business and how water management affects their operations. Water resources assessments have been completed in support of Environmental Assessments (EA) and Permitting and Approvals under Federal, provincial and international regulations. Peer reviewer for two Ontario Source Water Protection projects and water resources sections of a new international airport in Quito, Ecuador. Responsible for managing and implementing field data collection studies, including stream flow monitoring, meteorology and water quality. Other abilities include assessments of upland soil erosion, natural channel design and fluvial geomorphology.

University of Guelph – Guelph, Ontario
Hydrologist (1996 to 1996)

Responsible for collection and analysis of four large databases of rural hydrology parameters in Southern Ontario. Frequency distributions were found for event, daily and yearly runoff coefficients and detailed daily water budgets were synthesised for the duration of each record. Estimated evapo-transpiration in the absence of meteorological data required for the Penman equation.

University of Guelph – Guelph, Ontario
Research Assistant (1994 to 1996)

Responsible for designing and performing experiments concerning soil erosion by rainfall. Erosion rates from single drop impacts and 1.0 m^2 erosion plots were quantified and related to rainfall intensity and energy flux rate. A model of the inter-rill detachment process was developed for use in future large-scale erosion models.

University of Guelph – Guelph, Ontario
Teaching Assistant (1994 to 1996)

Taught weekly seminars on engineering mechanics (statics and dynamics) and on engineering design and report writing. Emphasis was placed on three-dimensional vector analysis and excellence in communicating technical information through text and verbal presentations.

PROJECT EXPERIENCE – LINEAR INFRASTRUCTURE

Trans Canada Pipelines Vaughan Mainline Expansion Vaughan, Ontario, Canada	Senior technical advisor for baseline hydrology studies, effects assessments and permitting, in support of the environmental and socio-economic assessment (ESA) under the National Energy Board (NEB) filing process and construction planning and design for a ~12 km pipeline expansion in the Greater Toronto Area.
Trans Canada Pipelines Eastern Mainline Expansion Ontario, Canada	Senior technical advisor for baseline hydrology studies, effects assessments and permitting in support of the environmental and socio-economic assessment (ESA) under the National Energy Board (NEB) filing for the Eastern Mainline Expansion in Ontario (~260 km long gas pipeline through central and eastern Ontario).
Trans Canada Pipelines Parkway West Connection Vaughan, Ontario, Canada	Senior technical advisor for baseline hydrology studies, effects assessments and permitting, in support of the environmental and socio-economic assessment (ESA) under the National Energy Board (NEB) filing process for a local service connection in the Greater Toronto Area.
Trans Canada Pipelines Kings North Connection Ontario, Canada	Surface water discipline lead for the Kings North Connection Project, including baseline hydrology studies and effects assessments in support of the environmental and socio-economic assessment (ESA) under the National Energy Board (NEB) process. Scour assessments, sag-bend setback recommendations and permitting were also completed to support construction activities.
Pipeline Corridor Investigations Timmins, Ontario	A pipeline was proposed to slurry tailing from the Kidd Metallurgical Site to the Kidd Mine, approximately 35 km away. The tailings are to be used for paste back-filling of depleted areas of the underground mine. An environmental review of water resources along the proposed pipeline corridor was completed. Larger watercourse crossings were mapped, and directional drilling was proposed to mitigate environmental effects.
Trans Canada Pipelines Borer's Creek Modelling and Restoration Design Dundas, Ontario	HEC-RAS modelling and assessment of a failing reach of Borer's Creek that threatened to expose a high pressure natural gas pipeline. Design of remedial measures for failing banks and restoration of the affected reach. Coordinated regulatory approvals. The project was successfully implemented before the spring freshet and significantly reduced the risk of damage to the pipeline.

PROJECT EXPERIENCE – CLIMATE CHANGE

Goldcorp Sudbury Integrated Nickel Operations – East End Water Management
Sudbury, Ontario

Senior review and technical advisor for an assessment of potential climate change effects and vulnerabilities on a multi-site water management system including eight reservoirs, flooded underground mine works, an active smelter complex, a water treatment plant and associated dams and infrastructure. A Goldsim model of the water management system was constructed and validated. Ensemble Global Circulation Model (GCM) results, from approximately ninety model runs, were obtained for the 2050 horizon. Monte Carlo simulations were used to simulate daily weather patterns constrained by the GCM results and the same daily weather patterns were used to model a potential future range of water management scenarios using the Goldsim water management model.

Goldcorp Sudbury Integrated Nickel Operations – East End Infrastructure Assessment
Sudbury, Ontario

Evaluated climate change risks to several small flow conveyance structures including culverts, pipes and flow measurement structures. Peak flows from small sub-catchments are typically sensitive to short duration intense precipitation events. A trend analysis and curve fitting exercise was completed on observed maximum annual events, over recent site history, for a range of event durations ranging up to 24 hours. The trend analysis was used to estimate potential changes to Intensity-Duration-Frequency statistics at the 2050 horizon. This information was used to assess the capacity of existing flow conveyance infrastructure in small sub-catchments.

Meteorological Service of Canada – Environment Canada
Ottawa and across Canada

Participated on a national research team studying the effects of climate change on hydrological variables. Contribution to the study was to complete a regionalization study based on measured hydrologic variables from the Reference Hydrometric Basin Network (RHBN) including mean annual flow, lowest annual daily flow and peak annual daily flow. The data series were grouped according to their similarity using a cluster analysis routine. The homogeneous hydrologic regions identified by this method were compared to hydrologic regions identified in previous studies using meteorological and physiographic variables. Cluster analysis results consistently identified three homogeneous regions in the British Columbia mountains as well as several regions in Ontario, the Maritimes and along the St. Lawrence. The study demonstrated a significant lack of RHBN coverage in the northern part of the Prairie Provinces and the North West Territories, such that homogenous regions, if they exist in these areas, could not be identified by cluster analysis.

Infrastructure Ontario (Ontario Realty Corp.) – Infrastructure Climate Risk Assessment
Ontario

Completed the water resources and drainage components of a climate risk assessment on three typical buildings owned by Infrastructure Ontario. Risk was assessed using guidance provided in Engineers Canada's PIEVC protocol. Co-led focus group workshops with building operators and subject matter experts to assess potential future risk.

Iqaluit Water Supply
Nunavut

Senior technical reviewer for a climate risk investigation of the Town of Iqaluit's water supply. A Goldsim model was developed for the lake-based water supply. Various scenarios were investigated to assess the vulnerability of the supply to climate change.

BHP Billiton
Elliot Lake, Ontario

Technical advisor for applying climate change projections to extreme precipitation events used to assess potential climate change implications for tailings storage facilities and water management ponds. This work was completed as a part of the Dam Safety Surveillance and Management program at BHP Billiton's closed Canadian and U.S. sites.

PROJECT EXPERIENCE – SOURCE WATER PROTECTION

Source Water Protection: Midland and Penetanguishene Tier 3
Midland, Ontario

Surface water lead for the Midland and Penetanguishene Tier 3 water budget and water quantity risk level assessment. This study involved implementation of a combined surface and groundwater model using MIKE-SHE. The modelled recharge distribution was applied to a groundwater model developed by Golder using FEFLOW in order to further refine drawdown effects in close proximity to wells and surface water features. The study area included the whole of the Midland Peninsula and areas of provincially significant wetlands in close proximity to municipal wells with GUDI designation. Groundwater and surface water interactions, both recharge and discharge areas were significant in spatial scale and an important part of this project.

Source Water Protection: Peer Reviewer York Region Tier 3
York Region, Ontario

Peer reviewer for the surface water components of the ongoing York Region Tier 3 water budget and water quantity risk level assessment for the area between and surrounding Aurora and Stouffville. The project team is proposing to use GSFLOW to model both the surface and groundwater systems. GSFLOW is an integrated surface and groundwater hydrology model developed by the US Geological Survey, based on MODFLOW and PRMS components. The study area is complex as it includes the southern flank of the Oak Ridges Moraine and straddles the divide between Lake Ontario and Lake Simcoe. Stouffville is in the headwaters of the Rouge River watershed.

Source Water Protection: Peer Reviewer Halton Hills Tier 3
Halton, Ontario

Peer reviewer for the surface water components of the ongoing Halton Region Tier 3 water budget and water quantity risk level assessment for the Georgetown and Acton areas. The project team used MIKE-SHE to model surface and groundwater hydrology and applied the modelled recharge distribution to FEFLOW to provide further discretization around key areas of interest including wells and surface water features. The study area is complex as it includes the Niagara Escarpment, the Acton re-entrant valley and several buried bedrock valleys which are believed to play and important role in delivering groundwater to the area. The study area also straddles the divide between the Grand River and Credit River watersheds.

Source Water Protection: Peer Reviewer Orangeville Tier 3
Orangeville, Ontario

Peer reviewer for the surface water components of the ongoing Orangeville, Mono and Amaranth Pilot Tier 3 water budget and water quantity risk level assessment. The project team is using HSPF and MODFLOW to model surface and groundwater hydrology respectively. The study area is complex as it includes the Niagara Escarpment and the Oak Ridges Moraine. The study area also straddles the divides between the Grand River, Credit River and Nottawasaga River watersheds.

Source Water Protection: Peer Reviewer CTC Tier 1 and Tier 2
Southern Ontario

Peer reviewer for the surface water components of the Tier 1 and Tier 2 water quantity stress assessments for the CTC Source Protection Region, which includes the Credit River (CVC), Toronto Region (TRCA) and Central Lake Ontario (CLOCA) watersheds. Data availability and modelling approaches used by the different conservation authorities and their consultants varied across the CTC region.

Source Water Protection: Lower Speed River (Guelph) Tier 3
Guelph, Ontario

Golder Associates teamed with AquaResource to complete a Tier 3 water budget and water quantity risk level assessment for the Lower Speed River watershed. The study area includes the City of Guelph, part of Cambridge and contributing drainage and recharge areas located north and east of Guelph. An extensive baseflow survey was conducted across the study. Baseflow was measured at thirty-two locations during the spring, summer and autumn of 2008. This information was used to estimate varying groundwater discharge and recharge rates to support definition of boundary conditions for the groundwater model.

Source Water Protection: Nickel District CA Valley East Tier 3
Sudbury, Ontario

Senior technical advisor for the Valley East Tier 2 and Tier 3 water quantity stress assessment. The City of Sudbury draws drinking water from several wells located in the Valley East area. Worked with project team to identify a modelling approach that would make the best use of, sometimes limited, existing data. The Tier 2 results led to the initiation of the Tier 3 Local Area Water Budget for the groundwater supply in Valley East.

Source Water Protection: Ramsay Lake Tier 1 and Tier 2
Sudbury, Ontario

Senior technical advisor for the Ramsay Lake Tier 3 water budget and water quantity risk level assessment. The City of Sudbury draws water directly from Ramsay Lake for part of its drinking water supply. Ramsay Lake and its contributing drainage areas are being modelled using HEC-HMS (Hydraulic Engineering Corps – Hydrological Modelling System). Based on existing information, it appears that the hydrology of Ramsay Lake is dominated by surface water inputs and as such, there is no plan to include groundwater modelling at this time. HEC-HMS will be used to complete the risk level assessments. Additional field data collection has been initiated to fill existing data gaps regarding key inflows to the lake and the outflow adjacent to Science North.

Source Water Protection: Bronte Creek
Halton, Ontario

Golder Associates were commissioned to undertake a Threats Assessment of a potential intake at Bronte Creek. Mr. MacKenzie directed the project for Golder. The intake, intended to deliver surface water to a small water treatment plant, was identified as one potential alternative for providing a drinking water supply to nearby residential properties possibly affected through the construction of an adjacent quarry. The Threats Assessment identified eleven water quality issues at the potential intake location, attributing causes to a number of likely contaminant sources throughout the watershed. In accordance with MOE Draft Guidance Modules, the work undertaken as part of this assessment included stakeholder liaison, hydraulic modelling, IPZ delineation, vulnerability analysis, the compilation of issues and threats inventories and a description of data knowledge gaps. Should surface water abstraction from Bronte Creek be identified as the preferred alternative for providing long-term drinking water supply, this Threats Assessment report will provide the basis for the Tier 2 assessment.

Source Water Protection: Timmins IPZ Study
Timmins, Ontario

An Intake Protection Zone (IPZ) and the vulnerability scores for the City of Timmins drinking water treatment plant on the Mattagami River were assessed. The delineation of the IPZ included the consideration of river flow conditions, influences of dam operation, location of significant potential upstream sources of contamination, local transportation routes, storm sewer drainage patterns and the behaviour of spills in the river. The project also included the collection of site-specific data through a field program. The field program used non-conventional methods to measure travel time due to restrictions on the use of dye tracers in the river because of the presence of private drinking water intakes. The field program collected detailed velocity data that was used to estimate dispersion and to calibrate a HEC-RAS model that was used to predict the travel time under various flow conditions.

PROJECT EXPERIENCE – HYDROLOGY/HYDRAULICS

Moira River Flood Mitigation Alternatives Assessment
Foxboro, Ontario

Reviewed and updated floodplain mapping for the Foxboro area, identified several alternative flood mitigation alternatives ranging from floodways and hydraulic controls to lot level flood proofing. Alternatives were assessed and compared based on triple bottom line scores. Triple bottom line analysis considered detailed economic analysis using regions specific flood damage curves developed by Golder's project partner.

Garson Mine Water Management and Inundation Study
Sudbury, Ontario

Senior review and technical advice for flood inundation study downstream of the Vale Garson Mine near Sudbury Ontario. The study included an options assessment, development of improved water management operating practices and conceptual design of reservoir retrofits.

International Falls Dam Rule Curve Cultural Study
Rainy River, Ontario

The effects of a recently updated operating rule curve at the International Falls Dam on water levels in Rainy River and the potential for changed water levels to affect locations of cultural significance are being investigated on behalf of the International Joint Commission on the Great Lakes.

Credit River Floodline Mapping
Mississauga, Ontario

Golder completed the most recent comprehensive update of the flood risk investigation and floodline mapping for the Credit River between Old Derry Road and Lake Ontario. This reach alternately flows through an entrenched bedrock valley and remnant beach plains adjacent to Lake Ontario in the most urbanised part of Mississauga. Mr. MacKenzie served as project staff on this project.

Water Quality Forecasting and Infrastructure
Annapolis Basin, Nova Scotia

Golder was part of a project team working with the Atlantic Innovation Fund / Applied Geomatics Research Group to develop a complex water quality forecasting tool for use by the shell fishing industry in the Digby Gut area. Real time weather forecasts were used to drive real time hydrology and database scenario models of runoff, water quality (bacteriological) and Bay of Fundy tidal fluctuations and their effects on contaminant movement in the Digby Gut. Hydrodynamic modelling was used to estimate contaminant movement and exposure of shell fishing areas to contamination. This information was packaged for use by shell fishers in order to minimize harvests of contaminated shellfish, thereby protecting the resource and minimizing post-harvest dupurification costs. Mr. MacKenzie was the hydrology and hydrometry technical lead for Golder on this project.

Brookfield Homes – Channel Rehabilitation
Brantford, Ontario

Assisted a channel rehabilitation/stabilization assessment and associated 'field fit' design for Brookfield at a tributary of Fairchild Creek to address debris removal and channel instability - responsible for field investigations and construction supervision/inspections.

River Diversion Design
Northern Ontario

Technical advisor for baseline channel hydraulics and fluvial geomorphic studies in support of a major mine development project in Northern Ontario to characterize baseline conditions at several stream channels, as well as to advance a conceptual design for a proposed diversion channel.

Borer's Creek Modelling and Restoration Design
Dundas, Ontario

HEC-RAS modelling and assessment of a failing reach of Borer's Creek that threatened to expose a high-pressure natural gas pipeline. Design of remedial measures for failing banks and restoration of the affected reach. Coordinated regulatory approvals. The project was successfully implemented before the spring freshet and significantly reduced the risk of damage to the pipeline.

Voisey's Bay Nickel Mine
Voisey's Bay, Labrador

A theoretical tailings dam breach was investigated using DAMBREAK to quantify potential impacts on an environmentally sensitive creek. Flood passage downstream of the breach was complicated by several small ponds and alternating sub and supercritical river reaches. Proposed mining operations at the Voisey's Bay nickel deposit require extensive management of surface waters. Five small dams were considered to safely convey clean water around the proposed tailings facility and to contain and treat tailings water. Modelling and design of the reservoirs and outflow structures was completed using GAWSER.

Plains Midstream – Dechlorination and Approval
Sarnia, Ontario

Technical advisor for the design and permitting of a dechlorination system for the Plains Midstream fractionation plant in Sarnia, Ontario. The system is being designed to reduce the free chlorine concentration in the wastewater discharge. Golder is also preparing the ECA (Industrial Sewage Works) amendment package for the facility, to include additional Limited Operational Flexibility (LOF) for the facility for the additional of the dechlorination system, and future sewage work modifications. LOF for the facility will grant future modifications to the works through the appropriate MOE reporting progress, if a professional engineer can demonstrate the modifications will not alter the process discharge quantity and quality limits established for the facility.

Channel Restoration Design
Algonquin Park, Ontario

Technical advisor for the hydraulic design of a stream re-alignment with associated grade controls at an historic train derailment site. Contaminated materials will be removed from the stream bed and banks and adjacent railway embankment. Removal of the contaminated materials will result in a net loss of stream substrate and a change to the fluvial geomorphology of the reach. Grade and stream bank controls were designed to minimize the risks of mobilizing residual contaminants and of significant channel migration.

Omya – Stormwater Management Design and Approvals
Perth, Ontario

A review of existing stormwater management infrastructure was completed for an industrial mineral processing site near Perth Ontario. As a result of incremental development of the site, parts of the stormwater management infrastructure were found to be inadequate. Additional stormwater management works were conceptualized and submitted to MOE for approval. Following approval, Golder provided liaison with the local Conservation Authority, completed basic design drawings suitable for design-build and applied for permitting under the Conservation Authorities Act.

OSSGA Carden Plain Cumulative Impact Assessment
Carden, Ontario

Due to the increased level of aggregate extraction activity in the Carden Plain area, the Ontario Ministry of the Environment (MOE) requested a multidisciplinary study and impact assessment to evaluate the potential cumulative impacts of quarry dewatering at multiple sites on groundwater, surface water and ecological receptors. Golder was retained by the Ontario Stone, Sand & Gravel Association to complete the required study. The project included extensive interaction with the MOE and the Ministry of Natural Resources (MNR). The objectives of the study were to screen out areas where cumulative impacts are unlikely, identify areas where cumulative impacts are likely, and to provide a preliminary assessment of the potential magnitude of predicted cumulative impacts. For the purpose of this study, a cumulative impact was defined as the additive effect of multiple quarry dewatering operations on groundwater, surface water and/or natural environment features. Golder was responsible for all aspects of this project including the development of the final field programs in consultation with personnel from the MOE. Mr. MacKenzie was the surface water lead for the project and participated in the public consultation aspects of the project.

Technical Reviewer Contaminated Site Channel Design Mississauga, Ontario

Golder was retained to review an options analysis and remedial channel design for a PCB contaminated channel in Mississauga. The remedial design included removal of the most contaminated material and design of a hardened channel lining to secure residual contaminants in-situ. Mr. MacKenzie reviewed the hydraulic channel analysis and design and provided a technical review report for consideration by the municipality and the channel designer.

Contaminated Site Channel Stability Analysis
Welland, Ontario

Golder recently completed Phase IV of an assessment of 12 sites in the Niagara River Area of Concern that were identified in the RAP Stage 1 Update as requiring further assessment. The Phase IV study is a detailed assessment of remedial alternatives for the site including passive and intervention options.
In support of the passive treatment options, Golder completed a detailed investigation of the complicated stream and wetland hydraulics of one of the sites on Lyon's Creek. In the intervening years since the historic contamination, the site had developed into a wetland, which provided habitat for threatened plant and animal species. The hydraulic conditions were evaluated using one- and two-dimensional hydraulic models (HEC-RAS and RIVER-2D) to identify areas that are at risk for re-suspension of contaminated sediments and areas that are likely to accumulate new un-contaminated sediment with time. The results supported the passive treatment alternative. Mr. MacKenzie led the hydraulic investigation component of the Lyon's Creek study.

Confidential Mine Site Closure
Eastern Ontario

Technical advisor for comprehensive surface water investigations in support of a risk assessment at two former uranium mines near Bancroft, Ontario. The studies included meteorology and flow monitoring, water column profiling with a particular focus on lake stratification and turnover, and water quality sampling.

Confidential Mine Site Closure
Northern Ontario

Technical advisor for surface water investigations, including streamflow studies, lake column profiling and water quality sampling, at a former nickel mine near Kenora, Ontario.

OPG Atikokan – Environmental Compliance Approval Northern Ontario

Technical advisor for the Environmental Compliance Approval ('ECA') Sewage (including Stormwater) amendment application for the Atikokan GS Biomass Conversion project. The study included a review of existing sewage works and associated ECA and MISA conditions. Implications from the proposed site changes to the sewage works, consisting of process streams (Furnace Ash Treatment Plant, Condenser Cooling Water), sanitary sewage system/lagoons and the coal pile runoff pond, along with their associated ECA conditions.

Confidential Manufacturing Client
Norval, Ontario

Baseline characterisation and impact assessment modelling of a proposed shale quarry in order to quantify and where necessary mitigate potential flow, water quality and thermal effects of the quarry on nearby watercourse and wetlands. Included conceptual design of mitigation measures and preparation of application materials for re-zoning and license under the Ontario Aggregate Resources Act.

Big Bay Point Water Balance
Barrie, Ontario

Monthly and annual water budgets were prepared using the Thornthwaite Water Budget method. This water budget assessment was performed to determine the rate of marina water pumping required from the proposed development area at Big Bay Point, to the golf course and Environmental Protection Area in support of detailed design of stormwater management facilities to meet post-development peak flow targets. Mr. MacKenzie provided technical advice and senior review for this project.

Baseline Hydrology Study for Proposed Mine
Ring of Fire, Northern Ontario

Technical advisor for baseline hydrology studies and effects evaluations in support of a major mine development project in Northern Ontario. Assessments were prepared as part of a multi-disciplinary Environmental Impact Statement (EIS) and Environmental Assessment (EA) under the Canadian Environmental Assessment Act (CEAA).

Quarry License Expansion
Flamborough, Ontario

A level II hydrogeology study was completed in support of a rock quarry license expansion application. The surface water component of the study included establishment of eight continuous stream flow gauges and associated baseflow separation analysis. The baseflow separations were used to estimate mean annual recharge to groundwater. This information was provided to Golder hydrogeologists for use in estimating boundary conditions for the FEFLOW groundwater model. In addition, monthly and annual surface water balances were modelled using the Thornthwaite Water Budget method coupled to a GIS procedure. The fraction of surplus water that infiltrates was estimated using GIS and the method outlined in MOE 2003. The infiltration estimates were initially assumed to equal recharge. The resulting modelled groundwater levels were reviewed to identify areas of upward gradient or minimal downward gradient. This information was used in subsequent iterations to adjust the recharge estimates.

Quarry License Expansion
Northern Ontario

A level II hydrogeology study is underway in support of a rock quarry license expansion application. Surface water features in the area are characterized by shallow intermittent streams flowing on top of bedrock above a small escarpment running through the site. Below the escarpment, there is a line of small watercourses connecting a series of small lakes. The surface water study includes monitoring of several of the small intermittent watercourses and the outlet of two of the small lakes. Surface hydrological. The results of this analysis will form input to the groundwater modelling discipline. Recharge will initially be assumed to equal infiltration in the groundwater model; however, we expect this will cause mounding in parts of the model. Further iterations will be used to calibrate the recharge estimates subject to a mass balance at the surface.

Aggregate Site Water Use Study
Southern Ontario

Participated in a “typical water use” study for the aggregate industry. The study was initiated by the Aggregate Producers Association of Ontario (now the Ontario Stone Sand and Gravel Association) in preparation for planned changes, by the MOE, to the Permit to Take Water application process. Changes to the process were anticipated to include charges for water taking or use. The MOE was simultaneously working on new Source Water Protection legislation. As a result, the APAO felt it would be prudent to quantify actual water use versus maximum permitted water taking rate and to illustrate typical water use at aggregate sites.

Aggregate Site Permitting and Approvals
Southern Ontario

Application packages including MOE application forms and supporting studies and reports have been prepared for numerous aggregate sites across Southern Ontario. Applications have been completed for Permits to Take Water (PTTW) to allow quarry dewatering and for Environmental Compliance Approvals (ECA) under Section 53 of the Ontario Water Resources Act to allow offsite discharge of quarry and storm water.

Simcoe County Groundwater Studies
Simcoe County, Ontario

A base flow survey was conducted to quantify groundwater discharge in a series of watershed in Simcoe County. The project was conducted in two phases, one for North Simcoe and one for South Simcoe. Water budget and average annual infiltration calculations were completed in support of groundwater modelling. Surface-groundwater interactions were estimated throughout the region to provide a water balance.

Hydrology Studies for Quarry Developments
Ottawa Region, Ontario

A series of water resources investigations were completed for aggregate producing clients in the Ottawa area. The studies were completed in support of Certificate of Approval applications made under Section 53 of the Water Resources Act. Each study included a water balance analysis for the quarry and an estimate of future quarry discharge rates. These data were used to estimate the effects of quarry development on downstream water resources.

Water Supply Studies
Sudbury, Ontario

Two municipal water supplies were investigated as Groundwater Under Direct Influence of surface water (GUDI). Surficial water resources were investigated, and a water balance was prepared in support of groundwater modelling studies.

Hydrological Effects Assessment
Hagersville, Ontario

A long-term field monitoring programme was designed and implemented to track changes in flow regime resulting from closure of an underground Gypsum mine. Part of the mine was closed and allowed to flood. Three flow monitoring stations were established in Boston Creek, which flows over the mine. The stations were selected to represent background conditions upstream of the mines influence, conditions above the mine and downstream of the mine influence. Data loggers and transducers were installed to continuously (hourly) record water levels and flows in the creek.

GORO Nickel Mine
New Caledonia

The GORO Nickel mine is located in an area of extreme precipitation. Hydrological and preliminary erosion assessments were completed in support of mine development planning and design. These data were used, by the multi-disciplinary project team, to design tailing basin capacities, diversion ditches and dams.

Round Lake Water Level Control Study
Engelhart, Ontario

Flow exiting Round Lake flows down several kilometres of a very mild sloped reach of the Blanche River before cascading down a set of rapids at a rock outcrop. The rock outcrop was historically blasted to facilitate log driving practices. This modification has caused large fluctuations in water levels in Round Lake and the Blanche River. A hydrological and hydraulic study of the river and lake were completed and a fish-friendly rock-fill weir was designed to stabilise water levels.

Bruce Nuclear Generating Station
Bruce County, Ontario

Participated in background water quality assessments in the surrounding environment. This work included water quality sampling in Baie du D'Or and Lake Huron. The data were used to assess potential effects of the generating station on the quality of surrounding water resources.

Pickering-A Nuclear Generating Station
Pickering, Ontario

A multi-disciplinary environmental assessment was completed for the re-start of four CANDU reactors at the Pickering A generating station. A comprehensive review of existing water quantity and quality data was completed. Potential effects, of operating the station, on surrounding water resources were identified and evaluated.

Falconbridge Smelter Area Closure
Falconbridge, Ontario

Performing a detailed analysis of water quantity and quality to address potential long-term impacts of the closure on the watersheds of Coniston and Emery Creeks. A daily water budget and reservoir routing model was implemented on a spreadsheet to investigate the efficiency of a variety of different closure scenarios. Also involved in hydrometry, automated water level monitoring, water quality sampling, hydrologic modelling.

Fire Water Intake
Blind River, Ontario

Alternative designs for a fire water intake structure modification were assessed to minimise maintenance and sediment deposition and increase safety. Two-dimensional finite element flow modelling of the intake environment and one dimensional, coupled, unsteady, sediment and hydraulic modelling of the river reach was completed. Modelling results indicated that relocating the intake structure would reduce the risk of failure resulting from sediment accumulation.

Brimley Road Slope Failure
Toronto, Ontario

Detailed statistical analysis of the rainfall amounts in the 30 days prior to a major slope failure. Historical records of rainfall and snowmelt were analysed and compared to the precipitation in the days preceding the failure.

Asacha Gold Mine
Russia

The Asacha gold mine lies close to the divide between a pristine watershed and a partially developed watershed. Hydrologically modelled areas potentially affected by mining operations to aid in developing a safe and detailed water management plan.

PROJECT EXPERIENCE – WASTE MANAGEMENT

Barrie Landfill Reclamation
Barrie, Ontario

Technical advisor for stormwater management modelling and conceptual stormwater infrastructure design. The project included a significant removal and replacement of historic municipal waste. Daily and permanent cover design required new stormwater management strategies and facility design. Interacted with groundwater modellers to develop representative and conservative boundary conditions for modelling.

Nexcycle
Southern Ontario

Technical advisor in support of the ECA (Sewage) application package for a glass recycling facility. The project included conceptual design of Best Management Practices and source controls to improve stormwater quality.

Eagleson Landfill Brookside Creek Channel Design
Northumberland, Ontario

Ongoing support regarding a channel remediation design/assessment for the County of Northumberland on a reach of Brookside Creek located downstream of the closed Eagleson Landfill to reroute unaffected surface water flows away from a zone of leachate influenced groundwater.

Edgewood Landfill Monitoring
Flamborough, Ontario

Designed and implemented a flow and water quality monitoring programme to assess potential historic effects of watercourses surrounding the closed Edgewood Landfill site in Flamborough Ontario. This work was completed as part of an inventory and assessment of historic landfill operations in the City of Hamilton.

Bath CKD Landfill Design and Monitoring
Kingston, Ontario

Monitored existing water quality and flows associated with an existing Cement Kiln Dust landfill. Designed stormwater control measures for design of a new landfill cover for the existing landfill as well as four new cells to increase the capacity of the landfill.

Brow Landfill Storm-water Management Plan
Flamborough, Ontario

Developed a storm-water management plan to address drainage requirements for the site and mitigation measures required to control potential impacts as part of the closure process. Designed drainage channels, a stormwater management pond, hydraulic flow control structures and a drop structure to safely convey stormwater over the edge of the Niagara Escarpment into a purpose designed plunge pool.

Adams Mine Landfill
Kirkland Lake, Ontario

Completed a baseline hydrology assessment including flow and water quality monitoring as part of an investigation into the feasibility of a proposed land-filling operation at Adams Mine. Monitoring included flow measurements from boats in medium to large rivers.

PROFESSIONAL AFFILIATIONS

Professional Engineers Ontario

Engineers Nova Scotia

PUBLICATIONS AND PRESENTATIONS

Other

Rose, G. T and **MacKenzie, K. M**. (2013). Water Quality Forecasting and Infrastructure Optimization System. Meeting #68 of the Atlantic Coastal Zone Information Steering Committee (ACZISC). Bedford Institute of Oceanography, Halifax, Nova Scotia, January 16-17, 2013.

S. I. Ahmed, **K. MacKenzie**, B. Gharabaghi, R.P. Rudra, W.T. Dickinson. (2011). Within-storm rainfall distribution effect on soil erosion rate. ISELE Paper Number 11000. International Symposium on Erosion and Landscape Evolution. Anchorage, Alaska September 18-21, 2011.

Bell, J., **K. MacKenzie** and J. Southwood. (2011). Down Under Up North - Could an Australian water- sensitive urban design project work in the Canadian context? Water Canada July/August 2011.

DeVito, C. and **MacKenzie K**. (2011). Critical Shear Velocity Estimates Improved with In-Situ Flume. 20th Canadian Hydrotechnical Conference, Ottawa Ontario June 14th to 17th 2011.

Davidson C. and **MacKenzie K**. (2011). Golder Daily Climate Record Generator. 20th Canadian Hydrotechnical Conference, Ottawa Ontario June 14th to 17th 2011.

MacKenzie, Kevin. (2009). Industrial Wastewater Approvals. Canadian Environmental Compliance Conference and Trade Show (CANECT). Metro Toronto Convention Centre, April 2009.

MacKenzie, Kevin. (2007). Industrial Wastewater Approvals. Canadian Environmental Compliance Conference and Trade Show (CANECT). Metro Toronto Convention Centre, April 2007.

Mackenzie, K.M., R.P. Rudra and W.T. Dickinson. (1996). Modelling the inter-rill detachment process: Some considerations for improving model results. ASAE Paper No. NABEC96-94, Amer. Soc. Agr. Engr., St. Joseph, MI.

MacKenzie, K.M., R.P. Rudra and W.T. Dickinson. (1995). The effect of temporal distribution of rainfall on inter-rill detachment. ASAE Paper No. 95-2378, Amer Soc. Agr. Engr., St. Joseph, MI.

Education

BSc Engineering (Co-op), University of Guelph, Guelph, Ontario, 2007

Languages

English – Fluent

Golder Associates Ltd. – Mississauga

Employment History

Golder Associates Ltd. – Mississauga, Ontario
Water Resources Specialist (2007 to Present)

Responsible for conducting water quantity and water quality investigation programs that include hydraulic and hydrologic modelling, analysis of riverine and lacustrine environments, the design, execution and management of meteorological, hydrological and water quality field programs and development of water balance and water quality modelling analyses. Currently working on various surface mine and mine rehabilitation investigations of hydrology and water quality. Completes water resources projects from desktop reviews to design, construction monitoring and erosion and sediment control inspection.

Golder Associates Ltd. – Mississauga, Ontario
Water Resources (Co-Op) (May 2006 to December 2006)

University of Guelph, Environmental Biology – Guelph, Ontario
Co-Op Student (May 2005 to August 2005)

Ontario Clean Water Agency – Toronto, Ontario
Water Resources (Co-Op) (January 2005 to April 2005)

Hydromantis Inc., Consulting Engineers – Toronto, Ontario
Co-Op Student (June 2004 to September 2004)

PROJECT EXPERIENCE – WATER SUPPLY FORECASTING

City of Iqaluit Iqaluit,
Nunavut, Canada

Developed a water balance model (using GoldSim) to quantify water deficit risks under future population growth and climate change scenarios. Analytical output and recommendations were subsequently provided in order to assist the City in water license application process for a supplementary source and provide a risk matrix of long-term probabilistic water supply deficits. (2012 to 2013)

City of Rankin Inlet
Rankin Inlet, Nunavut, Canada

Water supply deficits were evaluated using a water balance model (using GoldSim) under future growth and climate change scenarios. The model evaluated water taking from the supply reservoir and an adjacent river while maintain use for aquatic live and social activities. (2015)

PROJECT EXPERIENCE – CHANNEL / CROSSING DESIGN

County of Northhumberland
Cobourg, Canada

Ongoing support regarding a channel remediation design/assessment for the County of Northhumberland on a reach of Brookside Creek located downstream of the closed Eagleson Landfill to reroute unaffected surface water flows away from a zone of leachate influenced groundwater – conducted field studies, fluvial geomorphic and hydraulic analyses, preparation of conceptual/detailed design plans, liaison with contractor and reporting. (2009 to 2015)

Region of Durham Whitby, Canada	Completed a hydraulic analysis and fluvial geomorphic assessment at East Corbett Creek and tributary of East Corbett Creek. The analyses were conducted in support of a proposed extension of Consumers Drive that includes culvert crossings at the two watercourses – conducted field investigations, fluvial geomorphic analyses, hydraulic modelling, environmental permitting and reporting. (2014 to 2016)
Confidential Client Timmins, Canada	Ongoing support of a natural channel diversion design/assessment for a proposed pit mine. The channel design incorporates fluvial geomorphic processes to accommodate fish passage and habitat. Hydraulic modelling was conducted to limit erosion and maintain stability of the channel banks and crossings. (2015)
Canadian National Railway Southern Ontario, Canada	Many rail crossings were evaluated at locations of aging bridges, collapsed culverts and areas of flooding. Sites were visited and surveyed to confirm conditions and provide detailed data for desktop analysis. Hydraulic analyses were completed for each site to evaluate existing infrastructure. New crossing designs were evaluated based on MTO and CN guidelines and developed to conceptual and final designs. (2016 to 2020)

PROJECT EXPERIENCE – ENVIRONMENTAL COMPLIANCE APPROVALS, WATER DISCHARGES

Canadian National Railway Algonquin Park, Ontario, Canada	Completed an Environmental Compliance Approval for Industrial Sewage Works for a temporary water treatment facility which was designed to treat contaminated water and sediments from a historic train derailment. The facility discharged to a nearby lake within the Park. (2015 to 2017)
Essroc Aggregates Cambridge, Ontario, Canada	Managed and completed an Environmental Compliance Approval for Industrial Sewage Works for an aggregate pit and wash plant in Cambridge, Ontario. The application included supporting documentation of the wash ponds which only discharged to the environment through the groundwater. (2016 to 2017)
Fish and Bird Emporium Innisfil, Ontario, Canada	Lead a team that completed an Environmental Compliance Approval for Industrial Sewage Works for a tropic fish warehouse and distribution centre. The application included multiple water filtration facilities designed to reduce the effluent contaminant concentrations without impacting the health of the fish at the site. (2016)
Lafarge Canada Inc. – Soares Dundas, Ontario, Canada	Carried out field investigations, water budget analysis and coordinated various project tasks related to the proposed Lafarge Soares License Application. (2007 to 2009)
Amherst Quarries Ltd. Windsor, Ontario, Canada	Performed reconnaissance of the local watersheds and hydrologic features of the quarry sumps. Carrying out quarterly volumetric flow monitoring and water quality sampling. Local drainage channels were evaluated using computer models including HEC-RAS. Developed a water balance to model drainage from the site and the adjacent Canard River. (2008)

O'Shanter Development Company – Arbour Farms Dufferin, Ontario, Canada	Conducting annual dry weather volumetric flow monitoring and groundwater well monitoring related to the Arbour Farms assessment of the proposed quarry. (2007 to 2012)
Brampton Brick – Norval Norval, Ontario, Canada	Performed field investigations and coordinated various project tasks related to the proposed Brampton Brick Norval quarry development. (2007 to 2008)
Lafarge Canada Inc. West Paris, Ontario, Canada	Completed baseline monitoring, including flow and water level monitoring, water quality monitoring. Supported license applications for extension properties and Permit to Take Water applications and continued site plan monitoring. (2016 to 2020)
Lafarge Canada Inc. Wellington, Ontario, Canada	Conducted baseline investigations of site drainage, local watercourses, including the Speed River. Potential impact on the water resources as a result of below water extraction was evaluated to support Permit to Take Water Applications and Environmental Compliance Approvals. (2015-2020)
Lafarge Canada Inc. Woodstock, Ontario, Canada	Completed water quality, water level and flow monitoring at local water features. Developed potential effects assessment of quarry extraction and drain realignments in support of a Major Site Plan Amendment. (2015-2020)
Nelson Aggregate Company Burlington, Ontario, Canada	Carried out volumetric flow monitoring throughout neighbouring watersheds for the proposed Lafarge Nelson License Application. Performed wetland mapping on the proposed quarry site. (2006 to 2007)
CBM Aggregates Various Sites in Southern Ontario	Various aggregate properties have been monitored and evaluated for aggregate license applications. this monitoring included water level monitoring, stream flow monitoring, groundwater piezometer monitoring and meteorological monitoring. Detailed site water balances as well as site and water course characterization have been evaluate and reported as part of the multidisciplinary applications. (2007 to 2020)

PROJECT EXPERIENCE – SITE REHABILITATION

Client Confidential Bancroft, Ontario, Canada	Completed surface water investigations at a decommissioned mine site (uranium) near Bancroft, Ontario, including meteorology, flow and water quality monitoring. Developed a detailed water balance to evaluate the site drainage and adjacent stream networks. Characterized and reported the surface water networks and their impacts. (2010 to 2020)
Client Confidential Near Kenora, Ontario, Canada	Completed surface water investigations at a former mine (nickel) near Kenora, Ontario, including meteorology, flow monitoring, water column profiling and water quality sampling. Flow regimes were characterized and modelled to evaluate impacts of adverse water quality on downstream environments. (2009 to 2018)

Niagara Peninsula Conservation Authority Welland, Ontario, Canada	Completed stream sediment investigations on Lyon's Creek, downstream of the Welland Canal, including a stream survey, sediment sampling, loading, scour and re-suspension analysis. Reported investigation results as part of the Niagara River remedial options. (2009 to 2010)
Lafarge Canada Inc. Bath, Ontario, Canada	Reporting annually on volumetric flow monitoring and water quality data collected monthly on and adjacent to the Lafarge Bath cement kiln dust landfill and rehabilitation. Engineering drainage features on site was also completed. (2006 to 2008)
Canadian Gypsum Company Ltd. Haggersville, Ontario, Canada	Performing volumetric flow monitoring, water quality and continuous water level monitoring on Boston Creek adjacent to the mine site. Annual reporting was also conducted until rehabilitation completion. (2006 to 2013)

PROJECT EXPERIENCE – THREATS ASSESSMENT

Hanson Brick Ltd. – Tremaine Bronte Creek Burlington, Ontario, Canada	Evaluated the risks of a potential drinking water intake on Bronte Creek. Risks in the watershed were evaluated and analysed using plume dispersion algorithms to estimate contaminate impacts on the potential intake. Evaluation was completed using computer models including HEC-RAS. (2008)
Teck Resources Elk Valley, British Columbia, Canada	Conducted water quality modelling to support mine site investigations for a mining project in British Columbia. Water quality parameters were modelled throughout the watersheds from natural sources, mining and metal processing activities as well as their reactions within the watershed. Modelling efforts were used to evaluate treatment options and water handling / management. (2013 to 2015)

PROJECT EXPERIENCE – URBAN WATER MANAGEMENT

Metrolinx Toronto, Ontario, Canada	Project manager for the program which included stormwater sampling of a Metrolinx rail yard. The sample results were compared to the municipal stormwater sewer quality limits and reported at the season. (2017 to 2018)
Toronto Transit Commission Vaughan, Ontario, Canada	Task Manager of the stormwater monitoring and reporting as part of the ECA requirements at the 407 subways station. The monitoring involved storm event water quality monitoring to evaluate Stormwater Management Pond performance, erosion and sediment control inspections, annual reporting and recommendations for performance improvements. (2018 to 2019)
Town of Oakville Oakville, Ontario, Canada	Project manager for the program which included dry weather outfall sampling and wet weather storm sewer sampling. Results were analysed to develop water quality trends in order to estimate contaminate sources and evaluate the effectiveness of Best Management Practices and Stormwater Management Plans (Town of Oakville). (2008 to 2012)
City of Barrie Barrie, Ontario, Canada	Performing volumetric flow monitoring under flash flooding or melting conditions in areas of low permeability in the City of Barrie. (2008)

Black and McDonald Ltd. – Castrol Toronto, Ontario, Canada	Conducted reconnaissance and water quality sampling regarding the Castrol Oil storm water discharge to the city storm sewer. Testing performance of the on-site water treatment equipment and evaluating replacements. (2007)

PROJECT EXPERIENCE – MINING OPERATIONS AND EXPLORATION

Adrianna Resources Lac Otelnuk, Quebec, Canada	Conducted transducer installations and collected cross sectional geometry information at surface water points of interest influencing site drainage and watersheds adjacent to Lac Otelnuk. (2010)
Xstrata, Copper Las Bambas, Peru	Conducted transducer installations at surface water points of interests influencing the site drainage and watersheds located on and adjacent to site Las Bambas. (2008)
Xstrata, Copper Antapaccay, Peru	Conducted transducer installations at surface water points of interests influencing the site drainage and watersheds located on and adjacent to site Antapaccay. (2008)
Xstrata, Nickel Loma Miranda, Dominican Republic	Managed and carried out quarterly field campaigns for Loma Miranda and Energy Conversion Project, which involved installation and monitoring of river hydrology, water quality sampling and rain data collection. Quarterly reporting was conducted, summarizing campaigns. (2007 to 2010)

PROJECT EXPERIENCE – PIPELINE WORK

Trans Canada Pipelines Channel Rehabilitation Ontario, Canada	Designed a stream channel rehabilitation to remediate TransCanada Line 100-1 exposure caused by erosion and beaver activity near Dryden, Ontario. The project progressed from conceptual design through to construction monitoring. The final design was focused on improving channel stability over the pipelines to reduce meander and erosion. (2017)
Trans Canada Pipelines New Gas Line Ontario, Canada	Managed and supported continuous instream turbidity monitoring of many watercourse crossings as part of the Vaughan Mainline pipeline construction and Gravenhurst pipe replacement. This program included site reconnaissance, equipment installation, intensive 24-hour monitoring and troubleshooting, daily and final reporting. (2017 to 2018)
Trans Canada Pipelines Channel Rehabilitation Ontario, Canada	Developed the design and supported construction of channel rehabilitation works at a tributary of Bear Creek that is crossed by TransCanada pipelines Line 100-1 and Line 100-2 near Barrie, Ontario. The goal of the rehabilitation is to improve long term channel stability at the watercourse crossing. The work includes the completion of field studies and hydraulic modelling, development of conceptual designs, and the preparation of environmental permitting. (2016 to 2017)
Trans Canada Pipelines New Gas Line Ontario, Canada	Completed watercourse baseline investigations for Eastern Mainline Expansion in Ontario (260 km long new gas pipeline spanning central and eastern Ontario). Responsible for field data collection of baseline conditions at major watercourse crossings and evaluating the hydrotechnical characteristics of each potential crossing. (2015 to 2016)

Trans Canada Pipelines Gas Line Construction Ontario, Canada	Designed drainage improvements at a gas pipeline valve station to control flooding in the area to allow maintenance staff to work safely. The work involved conservation authority permitting and negotiation with landowners and other stakeholders. (2018-2020)

PROJECT EXPERIENCE – ENVIRONMENTAL ASSESSTMENT AND PERMITTING

Walker Environmental Group Inc. Ingersol, Ontario, Canada	Completed baseline evaluation and impact assessment for the proposed landfill in the Town of Ingersol. This included the flow and water quality monitoring of the Thames River and local tributaries. Desktop analysis of the potential impacts utilized hydrologic models, climate change predictions, water quality models and stormwater design. (2018-2019)
Marten Falls First Nation Marten Falls, Ontario, Canada	Drafted existing surface water conditions report and impact assessment to support the proposed all season road from Marten Falls to Nakina Ontario. This work involved watercourse crossing surveys utilizing helicopter transportation. The field studies visited a subset of the crossings to evaluate the impacts of the road alignment. (2019-2020)
NextBridge Northern Ontario, Canada	Completed water quality and hydrotechnical analysis to support the NextBridge Infrastructure East-West Tie Transmission Line Project in Northern Ontario (430 km long new transmission line). Conducted baseline studies, effects evaluations, permitting support through hydrotechnical analysis and preliminary design criteria. (2018)

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