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February 1, 2023

Lester Shoalts Limited
c/o Craig Rohe Upper Canada Consultants
214 West Street
Port Colborne, ON L3K 4E3

Re: Feature-Based Wetland Water Balance, Westwood Estates Phase 3, Port Colborne, ON

Dear Mr. Rohe,

1.0 Introduction and Background Information

Terra-Dynamics Consulting Inc. (Terra-Dynamics) respectfully submits this feature-based wetland water balance for residential development of Westwood Estates Phase 3, Port Colborne (Site) (Figure 1). It is our understanding the proposed residential development will be single family and medium density residential (Upper Canada Consultants, 2023, Appendix A). The Site is located east of Cement Plant Road, south of Stanley Street, north of the Eagle Marsh Drain and west of Olga Drive. (Figure 2). The Site is approximately 30.6 hectares with two polygons of the Provincially Significant Wainfleet Eagle Marsh Drain Wetland Complex (MNRF, 2009).

A water balance is required by Niagara Region in the pre-consultation record (City of Port Colborne, 2021):

"*a feature-based water balance will also be required in order to ensure no negative impacts to the natural heritage system*".

Although, the Niagara Peninsula Conservation Authority (NPCA) (City of Port Colborne, 2021) have stated:

"*Typically, water balance studies would be required, however following information provided during the review of the* (EIS) *Terms of Reference the consultant indicated that previous studies combined with ongoing hydrogeological work on the subject property would be used to characterize the hydrology of the wetlands within the study area, hence why they have not been requested again here.*"

The water balance assessment was completed according to Niagara Region and NPCA water balance requirements that have recently included:

1. "*Ensure no negative impacts to the natural heritage system*";

2. Inform stormwater management design at the Site "*in such a manner that pre-development water balance conditions are maintained for all wetlands in the Natural Heritage System Designation. A detailed water balance will be required as part of a stormwater management plan*"; and

3. "*Provincially Significant Wetlands…be conserved, with the successful matching of pre and post development water balances, as best as practical*".

The water balance has addressed these requirements including (i) a description of pre-development conditions, (ii) impact assessment and (iii) recommended mitigation measures for a subdivision on municipal servicing. The feature-based wetland water balance assessment evaluated the hydrologic regime of the Provincially Significant Wetland (PSW) areas on-site associated with the Wainfleet Eagle Marsh Drain Wetland Complex including (a) consideration of wetland buffers, (ii) monthly water balance assessments, and (iii) wetland inflows and outflows.

This water balance exceeds the requirements for "low risk" evaluation as specified by the TRCA (2017) and was also completed to generally conform to the Conservation Authority Guidelines for Development Applications (Conservation Ontario, 2013).

2.0 Methodology

Primary tasks completed as part of the water balance study included:

A. Characterization of the physical setting using published information from the following government agencies: (i) the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), (ii) the Ministry of Natural Resources and Forestry (MNRF), (iii) the Ministry of the Environment, Conservation and Parks (MECP), (iv) the Niagara Peninsula Conservation Authority (NPCA), (v) the Ontario Geological Survey (OGS) and (vi) Environment Canada;

B. Review of the Environmental Impact Study (EIS) for the Site (LCA Environmental Consultants, 2022) and nearby geotechnical/hydrogeological investigation reports (e.g. Jagger Hims Limited, 2008 and Coffey, 2012);

C. Site visits completed in the fall of 2022, which included hand-augering in wetlands and observations of on-site conditions;

D. Modelling of pre-development and post-development monthly water balance conditions through consideration of: surface water catchments, land cover, soils, climate normals and wetland hydroperiods in order to determine if the site design is sufficient; and

E. A Wetland Risk Evaluation (TRCA, 2017).

3.0 Physical Setting

The Site is regionally located on the margin of the Haldimand Clay Plain and the Onondaga Escarpment (Chapman and Putnam, 1984). The Site is currently undeveloped; it was historically farmed prior to 2000 (Brock University, 2022), however only the west side of the property is currently farmed.

The Site is fairly flat, from about 176.5 metres above sea level (m ASL) in the northern portions of the Site to 175 m ASL to the south (Figure 2).

3.1 Surface Water

The 31 hectare Site is located within catchment W100 of the Eagle Marsh Drain, which outlets to Lake Erie (Figure 2) (AquaResource Inc. and NPCA, 2009). The Eagle Marsh Drain watershed has a total area of 1,080 hectares (AquaResource Inc. and NPCA, 2009, Figure 1), making the Site less than 3% of the Eagle Marsh Drain watershed. Between 2017 and 2021, daily Lake Erie surface water levels at Port Colborne were between 174.1 and 175.4 m ASL, averaging 174.7 m ASL (Environment Canada, 2023a, Appendix C). Lake Erie surface water levels annually begin to rise throughout the spring, with the highest elevations in July, and decrease until the start of fall (Appendix C). Maximum daily water levels between 2017 and 2021 were above 175 m ASL commonly between spring and mid-summer (Appendix C). The water levels in Lake Erie are uncontrolled, and are a product of the upper Great Lakes watershed draining into it (NPCA, 2023). These surface water levels are reflect surface water levels at the Eagle Marsh Drain south of the Site (Byron J. Wiebe, 1987, Vander Veen, 2023).

A southerly draining open constructed channel is located at the Site, known to have been hoe-rammed into bedrock in locations, conveying stormwater flows from north of the Site. It is visible in 2000 aerial photography but not in the earlier 1968 aerial photo (Brock University, 2022). It is currently over-grown with phragmites, an invasive species, and NPCA (2017) has listed it as "*intermittent or ephemeral*". The channel drain flows into the Eagle Marsh Drain after leaving the Site but off-site flow is "*limited to peak flow conditions*" because of "*limited connectivity to the Eagle Marsh Drain*" due to impediments to flow (LCA, 2022) although "*pools of standing water*" have been observed in the channel. The channel is not mapped as part of the Eagle Marsh municipal drain which has permanent flow (OMAFRA, 2022).

Floodplain mapping completed by Upper Canada Consultants for the constructed channel and the Eagle Marsh Drain (2022) covers most of the southern wetland polygon, including the area mapped as marsh and a portion of the southern swamp (Figure 2).

3.2 Soils

The Site is underlain by clayey soils which thicken from north to south across the Site. The mapped soils include Farmington, Brooke and Welland (Figure 2). Details on these soil types include (Kingston and Presant, 1989, Figure 5):

i. Farmington Very Shallow Phase – 20 to 50 cm of loam over limestone bedrock (12% of Site, 3.7 ha, northwest portion of Site): rapid drainage, good permeability, summer droughtiness expected (Hydrologic Soil Group B, Table 1).

ii. Brooke Shallow Phase – 50 to 100 cm clay to clay loam over limestone bedrock (72% of Site, 22.1 ha central portion of Site): poor drainage, moderate to slow permeability, usually saturated for long periods, high water-holding capacity, moderate surface runoff (Hydrologic Soil Group C, Table 1).

iii. Welland Loamy Phase – clay loam over reddish-hued lacustrine heavy clay (16% of Site, 4.8 ha southern portion of Site): poor drainage, slowly permeable with some summer increase from surface cracking, groundwater levels are expected to be close to surface most of the year except summer, high water-holding capacities, surface runoff slow to moderate (Hydrologic Soil Group D, Table 1).

Table 1 - Hydrologic Soil Groups (USDA, 1986)

HSG Group	Soil description	Infiltration Rates (mm/hour)
A	sand, loamy sand or sandy loam	>7.6
B	silt loam or loam	7.6-3.8
C	sandy clay loam	3.8-1.3
D	clay loam, silty clay loam, sandy clay, silty clay or clay	<1.3

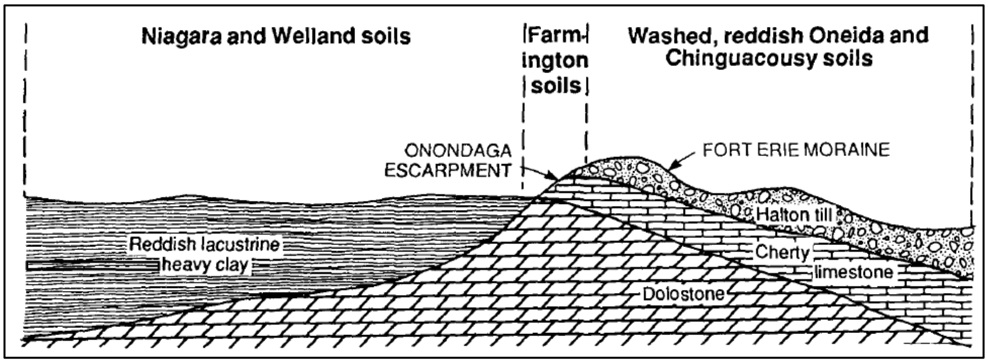


Figure 5 – Schematic landscape cross-section showing the relationship of soils to bedrock in the vicinity of the Onondaga Escarpment

Mapping of Brooke and Welland soils was confirmed at the two wetlands (Section 3.6) via ten hand-auger holes excavated on-site in the fall of 2022, which confirmed silty clay conditions overlain by organic soils (Figure 3). Representative samples of the C Horizon from hand-auger samples at HA-5 and HA-10 were submitted for laboratory grain-size analyses (Appendix B) and classified as poorly sorted clay with fines (Table 2, Appendix B).

Table 2 – Grain-size Analyses Summary

Location	Gravel%	Sand%	Silt%	Clay%	Grain-Size Classification[1]
HA-5 (northern wetland)	0	3	39	58	Poorly sorted clay with fines
HA-10 (southern wetland)	0	3	38	59	Poorly sorted clay with fines

Note: [1] – HydrogeoSieveXL classification (Devlin, 2015)

The hand-augering was completed to between between 0.8 and 1 metre below ground surface (m BGS), and hand-auger location HA-5 may have encountered bedrock at about 1 m BGS. It was noted that at the time of the Site visit, the northern wetland soils held less moisture than the southern wetlands, i.e. northern wetland soils were generally ‘at the plastic limit’ (APL) and ‘wetter than the plastic limit’ (WTPL) in the southern wetlands at hand-auger locations HA-6 through HA-10. Silt and clay (cohesive soils) moisture conditions are assessed based upon their plastic limit (Powell et al, 1980). No precipitation was recorded at the Environment Canada Port Colborne Station 6136606 the day of the hand-augering, November 4, 2022, or for three days prior.

3.3 Surficial Geology

The Site is covered by a layer of low permeability soils (clayey silt to silty clay, Feenstra, 1984), which generally thicken from north to south across the Site. Site conditions are reasonably inferred from three geotechnical/hydrogeological studies completed adjacent the Site:

1. Immediately north of the Site, a geotechnical investigation mapped clayey silt in three boreholes, from 0.5 and 1.1 metres thick above bedrock (Figure 3, Jagger Hims Limited, 2008)

2. Immediately west of the Site, a geotechnical investigation of Cement Road included three boreholes (BH2, BH3 and BH4) mapping silty clay overlying bedrock of between 2.2 and 3.0 m thickness (Landtek Limited, 2014). Groundwater monitoring wells immediately northwest (BH1) and southwest (BH4) recorded groundwater levels within the silt and clay (Figure 3).

3. East of the Site, a hydrogeological assessment of the Scholfield Avenue Groundwater Pumping Station indicated "*Along Scholfield Avenue…the depth below ground surface to bedrock ranged from approximately 0.6 metres at the north end (approximate elevation 177 metres) to more than 4 metres at the south end, and approximately 2.3 metres at the location of the Pumping Station*" (Coffey Geotechnics Inc., 2012). The assessment also identified MECP Water Well Record 6601619, as located at 78 Scholfield Avenue which reported 2.7 m of clay overlying bedrock (Figure 3).

This information was used in creation of a north-south hydrogeologic cross-section through the Site (Figure 4).

3.4 Bedrock

The Site is primarily underlain by Clarence Member '*very cherty limestone*' of the Onondaga Formation (Armstrong, 2017). A small portion of the northwest corner is mapped as Edgecliff Member '*cherty, fossiliferous, locally argillaceous limestone*'. Where present, the Clarence Member overlies the Edgecliff Member. Prior to municipal water supply, the bedrock was the local aquifer for water wells, e.g. MECP Water Well Record 6601619.

3.5 Hydrogeologic Setting

3.5.1 Overburden

As shown on the hydrogeologic cross-section (Figure 4), the Site is overlain by silty-clay which thickens to the south, with a perched water table. The silty clay is an aquitard as the calculated hydraulic conductivities are less than 10^{-8} m/s. An aquitard is "*a low-permeability geologic unit that can store groundwater, but that transmits groundwater slowly*" (Niagara Peninsula Source Protection Authority, 2013). This value was calculated using HydrogeoSieveXL (Devlin, 2015) from grain-size analyses (Appendix B).

Gartner Lee Limited (1987) provides a description of the expected water table conditions within the overburden aquitard materials:

> "*Detailed studies indicate that the water table fluctuates over the weathered/fractured upper two to three metres of the glaciolacustrine silts and clays comprising the overburden aquitard…flow in this shallow zone responds to daily climatic changes such that, during precipitation, the open fractures from weathering will quickly fill with water. The bulk of the discharge will then occur locally in swales that carry intermittent surface water…*"

Given the low permeability of the silt and clay, and the measured groundwater levels near the Site (Figure 4, Landtek, 2014), it is expected that the water table within the silt and clay would generally slope towards: (a) the channel drain and (b) to the south and Eagle Marsh Drain. The reported groundwater levels in August 2014 were 1.1 m BGS near the north part of the Site (at Landtek BH1) and 1.4 m BGS near the southern part of the Site (at Landtek BH4).

3.5.2 Bedrock

As shown on the hydrogeologic cross-section (Figure 4), the bedrock is predicted to be partially unsaturated. At the Site the bedrock is actively dewatered by the channel drain, which is at least partially constructed into bedrock, and "…*drains invariably lower the groundwater levels*…" (J. Byron Wiebe Ltd., 1987)

The City of Port Colborne Scholfield Avenue Groundwater Pumping Station may have contributed to a long-term reduction in bedrock water levels beneath the Site for over 40 years. The City of Port Colborne has operated a groundwater pumping station on Scholfield Avenue since 1979 to "*prevent groundwater infiltration into the sanitary sewers*" which also reduces "*residential sump pump use*". This bedrock groundwater pumping station is located approximately 200 metres east of the Site and discharges to Eagle Marsh Drain, with the rate and volume of discharge being a function of precipitation and snowmelt (Coffey, 2012). Additional details include (Coffey, 2012):

a) Pumping station depth of 5.5 m BGS, top of bedrock at 173.6 m ASL, extending approximately 3 metres into bedrock,
b) High- and low-level float elevations triggering operation of the submersible pump are 173 and 171.7 m ASL.
c) Monthly water taking varied seasonally with highest takings in spring and lowest in late summer/early fall, with some continuous pump operation in the spring.
d) "*Without the influence of the Pumping Station it would be anticipated that shallow groundwater flow in the vicinity of the Pumping Station would generally be in a southerly direction, toward the Eagle Marsh Drain and Lake Erie*"
e) "…*it is anticipated that a portion of the water pumped from the Pumping Station would originate from the Eagle Marsh Drain and Lake Erie and flow to the Pumping Station through the upper bedrock and the backfill material placed in the sanitary sewer trench on Scholfield Avenue*."

During field investigations for the Hydrogeologic Assessment (Coffey, 2012), water levels were provided as follows for September 6, 2012 (note - no precipitation was recorded at the Environment Canada Port Colborne Station 6136606 on this day or the day prior):
(i) Lake Erie level 174.02 m ASL,
(ii) Upper reach of the channel drain, 174.6 m ASL, ~0.6 m higher than Lake Erie; and
(iii) 76 Scholfield Avenue private bedrock well 172.8 m ASL.

These water levels and the physical setting suggest bedrock groundwater flow may be both towards (a) the south, as well as (b) to the east at the Site.

3.5.3 Vertical Groundwater Gradient

As shown on the hydrogeologic cross-section (Figure 4), the vertical groundwater gradient is downwards from the silty-clay water table to the inferred bedrock water level either as represented at the drain channel or projected from water well 6601619.

3.6 Wetlands

The Site includes two wetland polygons of the Provincially Significant Wainfleet Eagle Marsh Drain Wetland Complex; a northern wetland (5.38 ha) and a southern wetland (3.81 ha, with 3.27 ha on-site) (MNRF, 2009). The ground surface of the wetlands are fairly flat ranging from 176 and 176 .5 m ASL at the northern wetland and 175 m ASL at the southern wetland. The wetland Ecological Land Classifications (ELCs) were completed by LCA Environmental Consultants (2022, Figure 2, Appendix C) and were as follows:

a) Northern Wetland: Silky Dogwood Deciduous Thicket Swamp (SWTM2-2); and

b) Southern Wetland: Meadowsweet Deciduous Thicket Swamp (SWTM5-7, 0.91 ha, 28%) and Cattail Mineral Shallow Marsh (MASM2-1, 2.36 ha, 72%).

MNRF have classified the northern wetland as palustrine, and the southern wetland as riverine.

<u>Northern Wetland</u>: Palustrine wetlands have intermittent or no inflow, and either permanent or intermittent outflow (MNRF, 2014). The Northern palustrine wetland relies on rainfall with the possibility of some overland inflow/outflow based upon ground surface elevations. However, there is no defined outflow suggesting it is an ‘isolated’ wetland (MNRF, 2014). The NPCA digital elevation model (2020) suggests if overland outflow occurred it may be to the park to the east; no flooding has been reported at the park (City of Port Colborne, 2023). Also, it should be noted that bermed soils along the west side of the wetland prevent interaction with the north-south drain (LCA Environmental Consultants, 2022).

<u>Southern Wetland</u>: Riverine wetlands include wetlands adjacent permanent streams and the normal flood plain (MNRF, 2014). The Eagle Marsh Drain along the southern boundary of the wetland acts as the permanent stream. The surface water elevation is on average 174.7 m ASL (Appendix C) providing water supply for wetland vegetation given an expected to have a rooting depth of 0.5 m (McBean et al, 1995) and an average wetland ground surface elevation of 175 m ASL. In addition, surface water levels have been shown to exceed the average ground surface at the Southern Wetland, typically in spring and early summer (Appendix C). Also, the floodplain of the (i) north-south channel drain and (ii) Eagle Marsh Drain, extends to within the Southern Wetland (Figure 2, UCC, 2022), corresponding with all of the area identified as marsh and a portion of the area identified as swamp (LCA Environmental Consultants, 2022). Although there is also possible overland inflow to the Southern Wetland based upon ground surface elevations, there is no defined inflow or outflow (NPCA, 2017). The NPCA digital elevation

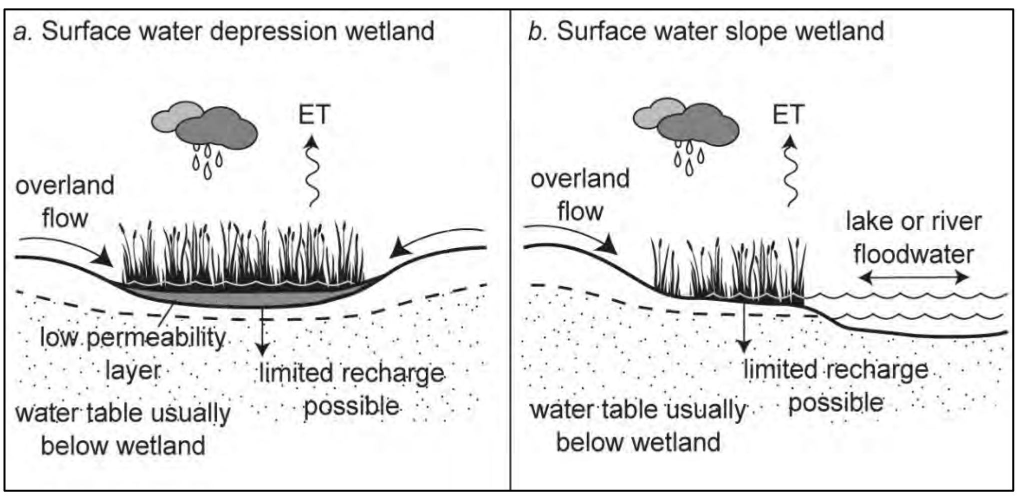
model suggests if overland outflow occurred from this wetland it could be to the Eagle Marsh Drain to the south.

3.6.1 Wetland Characterization

The wetlands are classified as either (a) *surface water depression wetlands (*Palustrine*)* or (b) *surface water slope wetlands* (Riverine) (Figures 6a and 6b) (Mitsch and Gosselink, 2007), which are summarized below.

A surface water depression wetland is summarized as a: "*wetland…dominated by surface runoff and precipitation, with little groundwater outflow due to a layer or low-permeability soils*…". Low permeability soils have been noted beneath the Site (Section 3.5.1) and the palustrine wetlands fit this description.

A surface water slope wetland is summarized as a: "*wetland…generally found in alluvial soil adjacent to a lake or stream and is fed, to some degree, by precipitation and surface runoff but more important, by overbank flooding from the adjacent stream, river or lake. Hydroperiods of these wetlands match the seasonal patterns of the adjacent bodies of water*...." The riverine marsh along the Eagle Marsh Drain fits this description.



Figures 6a and 6b - Surface water depression and slope wetlands (Mitsch and Gosselink, 2007)

3.6.2 Wetland Hydroperiods

A hydroperiod is defined as "*the seasonal pattern of the water level of a wetland…It characterizes each type of wetland, and the constancy of its pattern from year to year ensures a reasonable stability for that wetland. It defines the rise and fall of a wetland's surface and subsurface water by integrating all of the inflows and outflows"* (Mitsch and Gosselink, 2007).

Mitsch and Gosselink (2007) report that the "*hydroperiods of many bottomland hardwood forests and swamps have distinct periods of surface flooding in the winter and early spring due to snow and ice conditions followed by spring floods but otherwise have a water table that can be a meter or more below the surface*" (Figure 7). This characterization is considered reasonable for the northern wetlands at the

Site. However, for the southern wetland, the hydroperiod is expected to be a reflection of the Lake Erie surface water levels (Section 3.1, Appendix C).

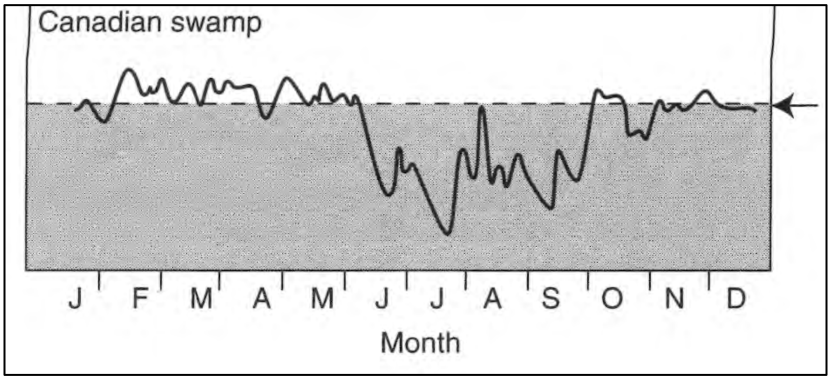


Figure 7 – Canadian Swamp Hydroperiod (Mitsch and Gosselink, 2007)
Note: arrow indicates wetland ground surface

3.6.3 Soil Water Holding Capacity

The soil water holding capacity (SWHC) for the Northern Wetland polygon is assigned 400 mm based upon the soils being hydrologic soil group C (Section 3.2), and 350 mm for the Southern Wetland polygon based upon the soils being hydrologic soil group D (Section 3.2) (Figure 2) as per previous wetland SWHC designations used by NPCA in their water budgeting study (AquaResource Inc. and NPCA, 2009).

3.6.4 Wetland Surface Water Catchments

Pre-development upgradient surface water catchments were calculated for the on-site swamps from a combination of surveyed on-site ground surface contours and NPCA Digital Elevation Model (DEM) points for off-site areas (2020) (Figure 8).

As the Site is very flat, it is conservatively estimated that:

1. The Northern Wetland may receive runoff from areas north (1.28 ha) and south (2.23 ha) of the wetland (Figure 8); and

2. The Southern Wetland (swamp portion) may receive runoff from an area north of the wetland (5.41 ha), and it may also receive runoff from a portion of the marsh (Figure 8).

3.7 Pre-development Subwatershed Water Balance Modelling

NPCA previously completed water balance modelling for 1991-2005, as part of provincial water budgeting for the source water protection program (AquaResource Inc. and NPCA, 2009). This modelling was completed at 1-hour time steps with a filled-in meteorological dataset including solar radiation and a crop coefficient for improved calculation of evapotranspiration.

Modelled annual and monthly water balance results were obtained for the Lake Erie North Shore Hoover Drain Catchment W100 (LENS_HOD_W100) (Tables 3 and 4, respectively) (AquaResource Inc. and NPCA, 2009). Although this catchment is west of the Site (Figure 1), it was chosen as more representative of pre-development Site conditions (e.g. slope, soils, land cover and evapotranspiration) than the lumped catchment parameters of LENS_EMD_W100 (Figure 1). The annual surplus as shown on Table 2 is precipitation minus evapotranspiration, i.e. the water available for runoff and recharge.

Table 3 - Water Balance 15-year (1991-2005) Averages

Catchment	Precipitation	Actual Evapotranspiration	Annual Surplus	Infiltration*	Recharge	Runoff
	(mm/year)					
LENS_HOD_W100	939	531	408	120	60	289

Notes: * - Infiltration is interflow plus recharge

Table 4 - Monthly Runoff and Recharge (Catchment LENS_HOD_W100)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Runoff (mm)	31	37	39	41	27	15	3	2	6	17	38	34
Recharge (mm)	17	21	25	18	8	2	0	0	0	3	9	20

4.0 Water Balance Assessment

A monthly water balance assessment has been completed of the Site's wetlands (Figure 2), as informed by the Conservation Authority Guidelines for Development Applications (Conservation Ontario, 2013) and TRCA's guidance for water balances (2012).

It is noted that the MECP (2003) water balance approach is typically concerned with the evaluation of post-development to prevent (i) increased runoff, and/or (ii) reduction in groundwater recharge. However, given the wetland characterization (Section 3.6.1) any contribution to hydrologic function with respect to the wetlands is via additional surface water flow, not groundwater discharge. Consequently, maintenance of pre-development monthly saturated conditions via runoff to maintain the wetland hydroperiod is the criteria for the water balance assessment.

4.1 Monthly Water Balance Example

An example of water balance modelling from the University of Waterloo is shown below (Figure 9). Annual groundwater recharge begins in the fall following '*soil water utilization*' and '*deficit*' in the summer. Soil water utilization corresponds with evapotranspiration exceeding the precipitation supply. Annual groundwater recharge occurs during the same time period that groundwater levels rise. However, in this example it is noted that the soil water holding capacity (SWHC) modelled was only 100 mm compared to the higher SWHC of the 400 and 350 mm for the Northern and Southern Wetlands, respectively (Section 3.6.3).

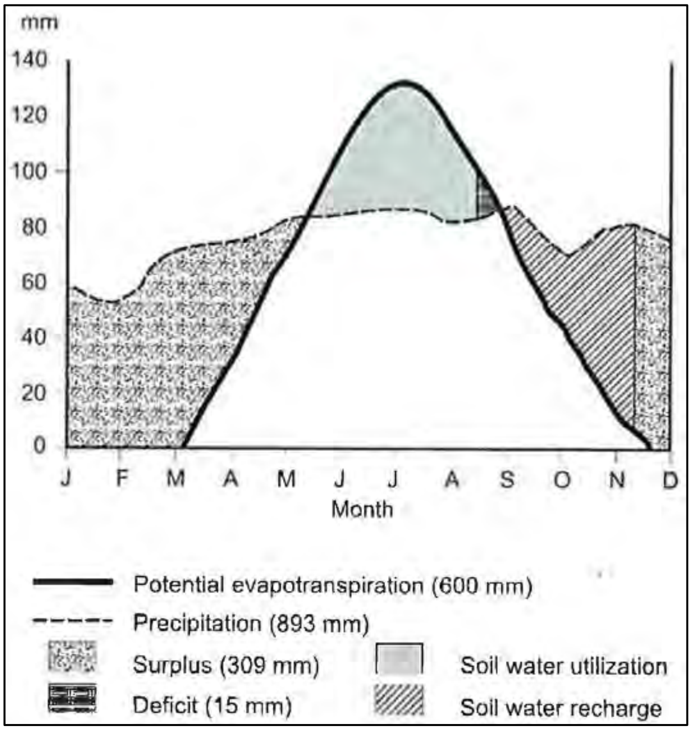


Figure 9 – Brantford Average Water Balance (Sanderson, 2004)

4.2 Wetland Monthly Water Balance

A monthly water balance for the two wetlands was completed using the U.S. Geological Survey (USGS) Monthly Water Balance Model (McCabe and Markstrom, 2007), which considers direct precipitation to the wetland. For temperature and precipitation, climate normal inputs (1981-2010) from Port Colborne Station ID 6136606 were used (Environment Canada, 2023b). The monthly water balance modelling results (Tables 5a and 5b) are summarized below and in Tables 6a and 6b (without decimal places):

1. Potential evapotranspiration exceeded precipitation for June, July and August, i.e. soil water utilization occurred;
2. Soil water holding capacities were less than saturated, i.e. less than either 400 mm (Northern Wetland) or 350 mm (Southern Wetland), for the months of June to October; and
3. Soil water recharge occurred in September and October.

Table 6a – Monthly Northern Wetland Water Balance (mm)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation (mm)	73	57	67	76	90	79	82	83	98	90	101	89
Potential (mm) Evapotranspiration	10	12	21	39	71	105	127	105	63	34	18	11
Soil Moisture (mm)	400	400	400	400	400	370	324	303	333	385	400	400
Soil Water [1] Depletion (mm)						30	76	97	67	15		

Notes: [1] Difference between the SWHC (400 mm) and the modelled soil moisture

Table 6b – Monthly Southern Wetland Water Balance (mm)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation (mm)	73	57	67	76	90	79	82	83	98	90	101	89
Potential (mm) Evapotranspiration	10	12	21	39	71	105	127	105	63	34	18	11
Soil Moisture (mm)	350	350	350	350	350	320	275	254	284	336	350	350
Soil Water [1] Depletion (mm)						30	75	96	66	14		

Notes: [1] Difference between the SWHC (350 mm) and the modelled soil moisture

4.3 Wetland Water Balance Assessment

4.3.1 Pre-Development

As introduced in Section 4.0, "*maintenance of pre-development monthly saturated conditions via runoff, to maintain the wetland hydroperiod, is the criteria for the water balance assessmen*t". Assessment of this condition is a concern only for the months of June through October, when the monthly wetland water balance indicated less than saturated conditions may be expected because direct precipitation alone was relied upon to maintain average saturated conditions. The pre-development wetland water balance assessment is a calculation of the summer monthly runoff area required for the wetland to have saturated conditions (Tables 7a and 7b). Under pre-development conditions, drainage areas are modelled to potentially provide upgradient runoff to the Northern Wetland and the Southern Wetland swamp portion (Section 3.6.4, Figure 8).

Northern Wetland

It is modelled that upgradient runoff does not sustain saturated conditions during June to October at the Northern Wetland because there is insufficient upgradient runoff area (3.51 ha) to do so (Table 7a).

Table 7a – Modelled Summer Runoff to Northern Wetland

Month	Jun	Jul	Aug	Sep	Oct
Soil Water [1] Depletion (mm) [see Table 6a]	30	76	97	67	15
Wetland Soil Water Depletion Volume[2] (m^3)	1,614	4,089	5,219	3,605	807
Modelled Runoff (Section 3.8) (mm) [see Table 4]	15	3	2	6	17
Upgradient area [3] required to produce saturated wetland – Drainage Area (ha)	10.8	136.3	261.0	60.1	4.8

Notes: [1] Difference between the SWHC (400 mm) and the modelled soil moisture
[2] Depletion depth multiplied by the area of Northern Wetland (5.38 ha).
[3] Volume of soil water depletion (m^3) divided by monthly modelled runoff (mm) (from Table 4) converted to hectares

Southern Wetland

Upgradient runoff may assist sustaining saturated conditions in June and October at the Southern Wetland. This is because the upgradient runoff area is 5.41 ha, potentially providing sufficient runoff to meet the soil water deficits of those months (Table 7b). However, given the slope of the ground surface is only 0.3%, these calculations are conservative assuming there is sufficient water to cause flow to the wetland.

Table 7b – Modelled Summer Runoff to Southern Wetland

Month	Jun	Jul	Aug	Sep	Oct
Soil Water [1] Depletion (mm) [see Table 6b]	30	75	96	66	14
Wetland Soil Water Depletion Volume[2] (m^3)	273	683	874	601	127
Modelled Runoff (Section 3.8) (mm) [see Table 4]	15	3	2	6	17
Upgradient area [3] required to produce saturated wetland – Drainage Area (ha)	**1.82**	22.75	43.68	10.01	**0.75**

Notes: [1] Difference between the SWHC (350 mm) and the modelled soil moisture
[2] Depletion depth multiplied by the area of Southern Wetland swamp (0.91 ha)
[3] Volume of soil water depletion (m^3) divided by monthly modelled runoff (mm) (from Table 4) converted to hectares – bolded values indicate upgradient drainage area (5.41 ha) sufficient for saturated conditions

However, this potential intermittent source of surface runoff to the wetland is much less important than the constant supply from Eagle Marsh Drain which provides lateral groundwater recharge for wetland vegetation as well as an intermittent source of surface water flooding to the Southern Wetland. As described in Section 3.1, surface water levels in the Eagle Marsh Drain are also higher during the summer period further supporting this water balance assessment interpretation.

4.3.2 Post-Development

The areas provided for continued runoff to the wetlands by the proposed 15 m buffers are: (a) Northern Wetland 1.58 ha and (b) Southern Wetland 0.8 ha (0.5 ha for the 15 m buffer and 0.3 ha from lots and stormwater pond area abutting the wetland).

The Northern Wetland 15 m buffer is sufficient to maintain pre-development conditions. Additional roof runoff towards the wetland may also further supply vegetative needs but is not required.

The Southern Wetland 15 m buffer is modelled as sufficient to maintain pre-development runoff conditions except in June, as a pre-development runoff drainage area of 1.82 ha was modelled to be required for this month (Table 7b). The implied remaining wetland water deficit in June is 153 m^3 (subtracting 0.8 ha from 1.82 ha multiplied by the modelled June runoff of 15 mm). Additional roof runoff from the eight residential lots (i.e. Blocks 137 through 144) on Street 'C' (Appendix A), with an average roof area of 90 m^2, and an average June precipitation of 79 mm provide an additional 57 m^3 of surface water runoff. This accounts for 65% of the modelled June runoff to produce average monthly saturated conditions at the swamp portion of the Southern Wetland. This is considered a reasonable effort given: (a) it is a riverine wetland, (b) subsurface saturated conditions will continue from Eagle Marsh Drain for wetland vegetation, (c) the slope of the upgradient catchment area is only 0.3% making the pre-development runoff rates conservatively high from a model that was 1.4% slope (Section 3.7) and (d) any pre-development runoff patterns to the swamp from the marsh will continue.

4.4 Wetland Risk Evaluation

4.4.1 Magnitude of Hydrological Change

TRCA's wetland risk evaluation (2017) decision tree (Figure 10) includes four key hydrological change criteria:

1) Impervious cover in catchment;
2) Change in catchment size;
3) Dewatering; and
4) Impact to recharge areas.

(1) The amount of impervious cover is 46% within the areas proposed for development (Upper Canada Consultants, 2022). Taking into account the areas within the Site not proposed for development, the future impervious area is 38% impervious area.

(2) The surface water catchments will be changed through development. The Northern Wetland drainage area will be reduced by about 40%. The Southern Wetland drainage area will be reduced by 78%.

(3) Construction dewatering is not expected to affect wetlands as the wetlands are perched systems (Section 3.5.1) or fed by Eagle Marsh Drain (Section 3.6). The aquitard underlying the Site is of sufficiently low permeability that overburden dewatering may not be feasible and/or necessary (Preene, 2020).

(4) No impacts to wetland recharge areas are predicted as TRCA (2017) defines this as "*replacement of existing soils with significantly less permeable materials*" and the on-site soils are already of low permeability. In addition, there are no locally significant recharge areas to be impacted as these are defined by TRCA (2017) as "*highly porous sedimentary deposits or otherwise having high hydraulic conductivity*".

"*The highest magnitude category with one or more criteria satisfied determines the potential magnitude of change*" with the magnitude thresholds of less than 10% change as low, 10-25% medium and greater than 25% high (TRCA, 2017). Therefore, a high hydrologic risk is assigned based upon the magnitude of impervious cover and the change in upgradient catchment areas. However, as discussed in Section 4.3.2, negative hydrologic impacts to the downgradient wetlands are not predicted.

4.4.2 Sensitivity of the Wetlands

The risk assignment (Figure 10) is to consider the type of wetlands (Figure 8), and their hydrological sensitivity (TRCA, 2017). The Silky Dogwood Deciduous Thicket Swamp (SWTM2-2), Meadowsweet Deciduous Thicket Swamp (SWTM5-7) and the Cattail Mineral Shallow Marsh (MASM2-1) have medium hydrological sensitivities (TRCA, 2017, LCA Environmental Consultants, 2022).

4.4.3 Risk Assignment

As per Figure 10, a medium risk is assigned based upon a (i) high magnitude of hydrological change and (ii) a medium wetland sensitivity. The TRCA recommended study, modelling and mitigation requirements are:

(i) Pre-development monitoring as outlined in the Wetland Water Balance Monitoring Protocol (TRCA, 2016).
- Pre-development monitoring is not required as the background information and modelling has reasonably predicted water conditions at the Site.

(ii) Continuous hydrological modelling at daily aggregated to weekly resolution.
- Existing modelling (completed at 1-hour time steps) completed by NPCA was utilized for this report (AquaResource Inc. and NPCA, 2009) as part of a monthly analysis. This existing work could be re-visited to extract weekly results, however this would appear to have no benefit.

(iii) Design of a mitigation plan to maintain the wetland water balance, in some cases an interim mitigation plan may also be required.
- Mitigation is not required as wetland buffer, rear yard and roof runoff of lots adjacent wetlands, will provide additional water for wetlands and Eagle Marsh Drain will continue to supply the Southern riverine wetland.

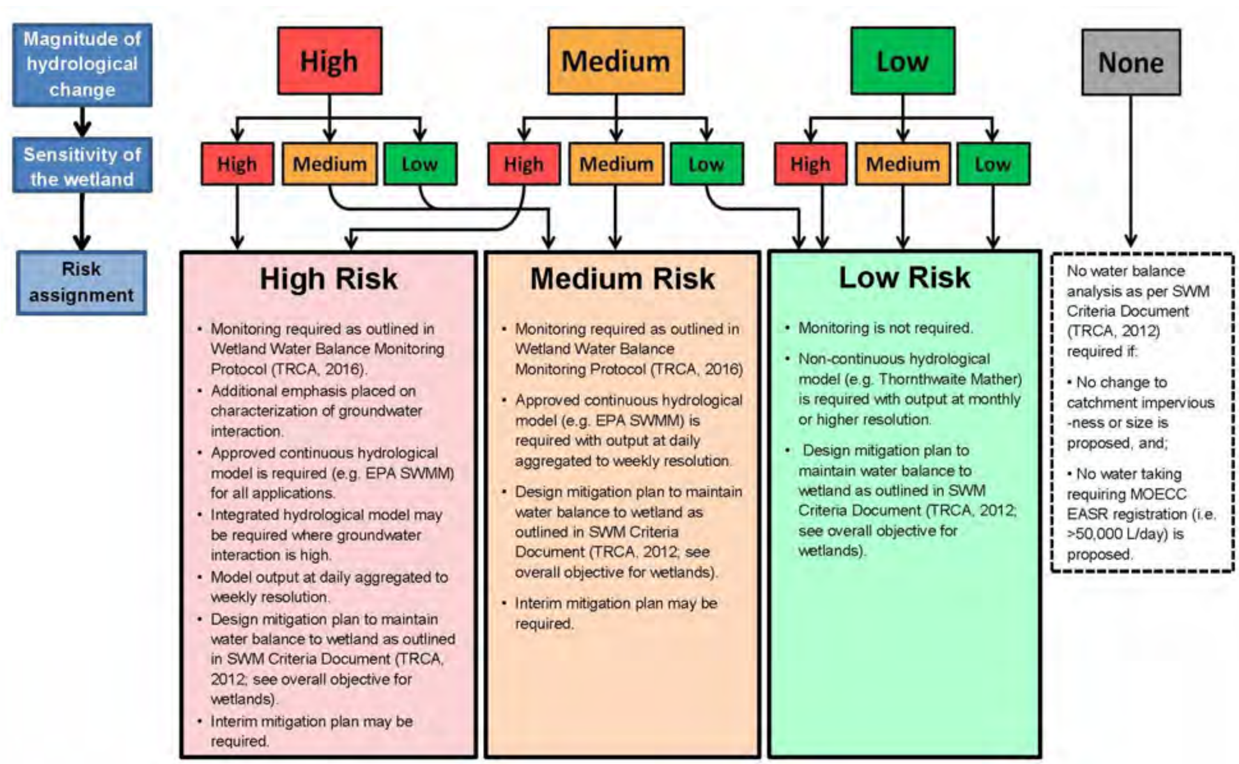


Figure 10 - Wetland Risk Evaluation Decision Tree (TRCA, 2017)

5.0 Conclusions and Recommendations

The following conclusions are provided:

1. The Site is 30.55 hectares, with 8.56 hectares of wetlands on-site, consisting of (a) a Northern palustrine wetland and (b) a Southern riverine wetland via the Eagle Marsh Drain connected to Lake Erie.

2. The Site is located on the Haldimand Clay Plain with a regional aquitard of silty clay soils.

3. The wetlands are perched on low permeability silty clay, consisting of either surface water depression, or surface water slope, wetlands.

4. A monthly water balance for the wetlands (not considering potential runoff, flooding or subsurface water supply to the wetlands) identified potential evapotranspiration as exceeding precipitation for June, July and August, with soil water holding capacities less than saturated also in September and October.

5. The Eagle Marsh Drain surface water levels (as measured at Lake Erie) average 174.7 m ASL providing lateral saturated conditions beneath the Southern riverine wetland, and are highest during the summer period and frequently exceed the average ground surface at the adjacent wetland during the early summer.

6. Monthly runoff modelling completed by NPCA reported runoff amounts for June, July, August, September and October of 15, 3, 2, 6 and 17 mm/month, respectively.

7. Pre-development monthly water balance modelling for the (a) Northern Wetland indicates upgradient lands do not saturate the dry summer soils downgradient and that (b) Southern Wetland upgradient lands may saturate the summer soils downgradient in June and October.

8. The TRCA wetland risk screening tool assigned a medium risk, based upon the potential for a high magnitude of hydrological change and medium wetland sensitivity.

9. Residential development of the Site should not negatively impact the hydrology of the wetlands. This is because precipitation is the primary source of surface water supply during the summer period to the palustrine Northern Wetland, and the Eagle Marsh Drain provides water supply to the riverine Southern Wetland during the summer period.

The following recommendations are provided:

1. Implement rear yard and roof lot drainage towards the wetlands for lots adjacent wetlands; and

2. Implement the 15 m wetland buffers as recommended by LCA Environmental Consultants.

We trust this information is sufficient for your present needs. Please do not hesitate to contact us if you have any questions.

Yours truly,

TERRA-DYNAMICS CONSULTING INC.

Jayme D. Campbell, P. Eng.
Senior Water Resources Engineer

Annie Michaud, M.Eng., P. Eng.
Senior Water Resources Engineer

LICENSED PROFESSIONAL ENGINEER
Feb 1, 2023
J. D. CAMPBELL
PROVINCE OF ONTARIO

cc. Craig Rohe, M.Pl., MCIP, RPP
Anne McDonald, LCA Environmental Consultants

Attachments
Figure 1 – Location of Subject Lands
Figure 2 – Soils and Wetlands
Figure 3 – Overburden and Bedrock
Figure 4 – Hydrogeologic Cross-Section A-A'
Figure 8 – Wetland Surface Water Catchments
Tables 5a/5b – USGS Monthly Wetland Water Balance
Appendix A – Draft Plan of Subdivision
Appendix B – Soils Information
Appendix C – Wetland Information

6.0 References

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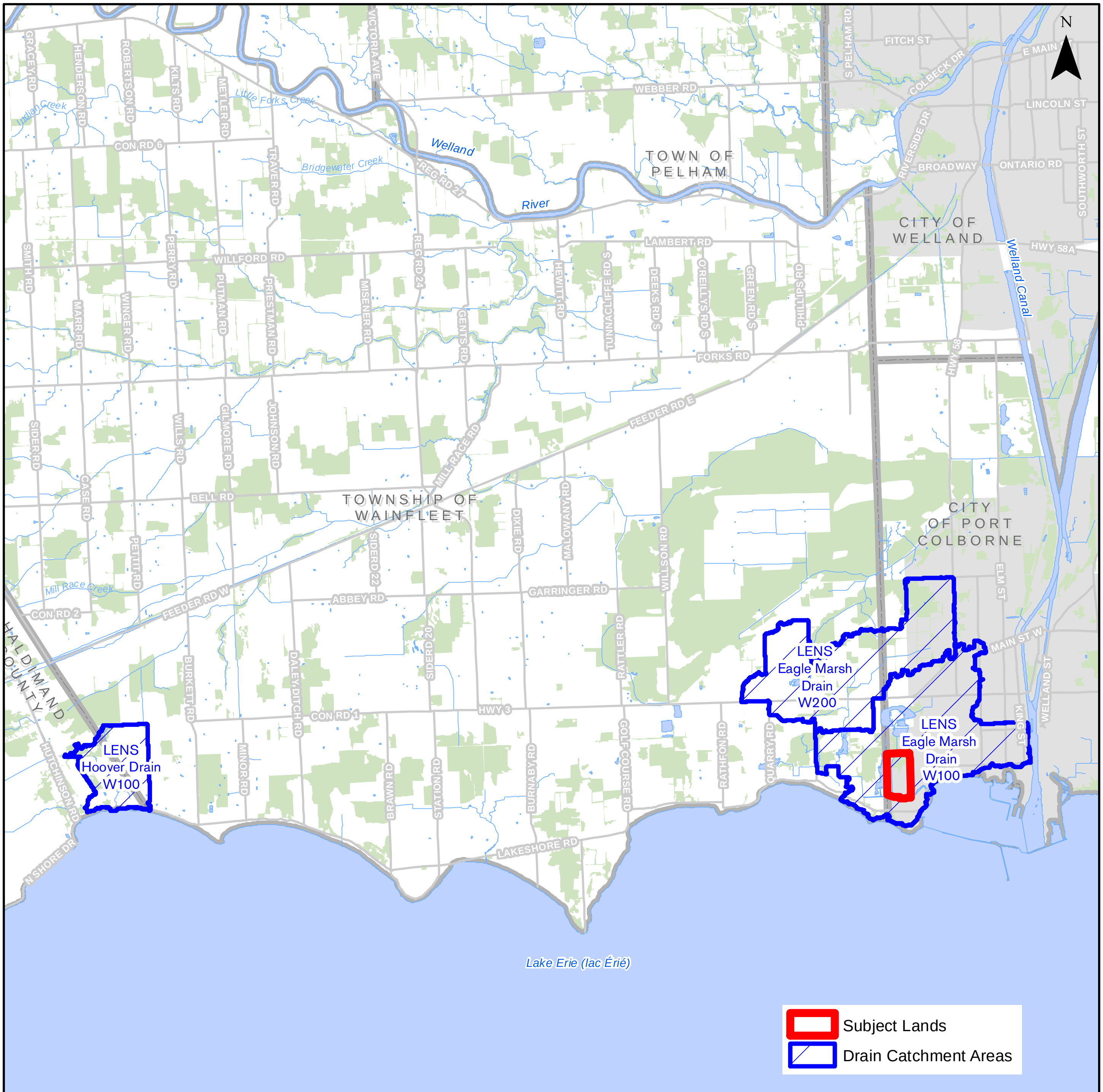
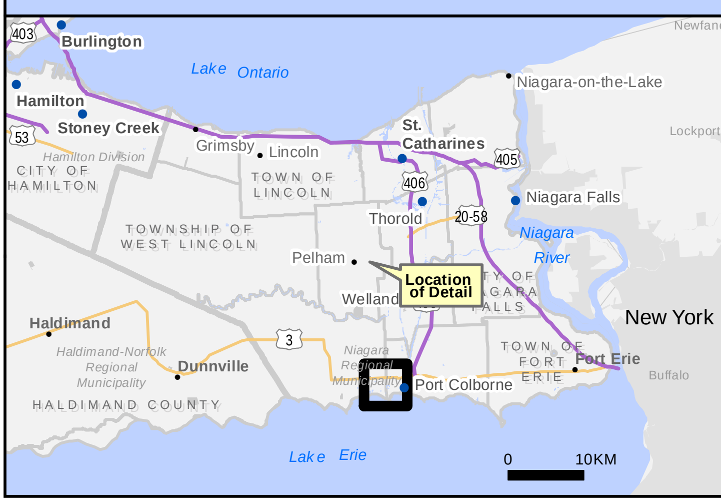




Location of Subject Lands

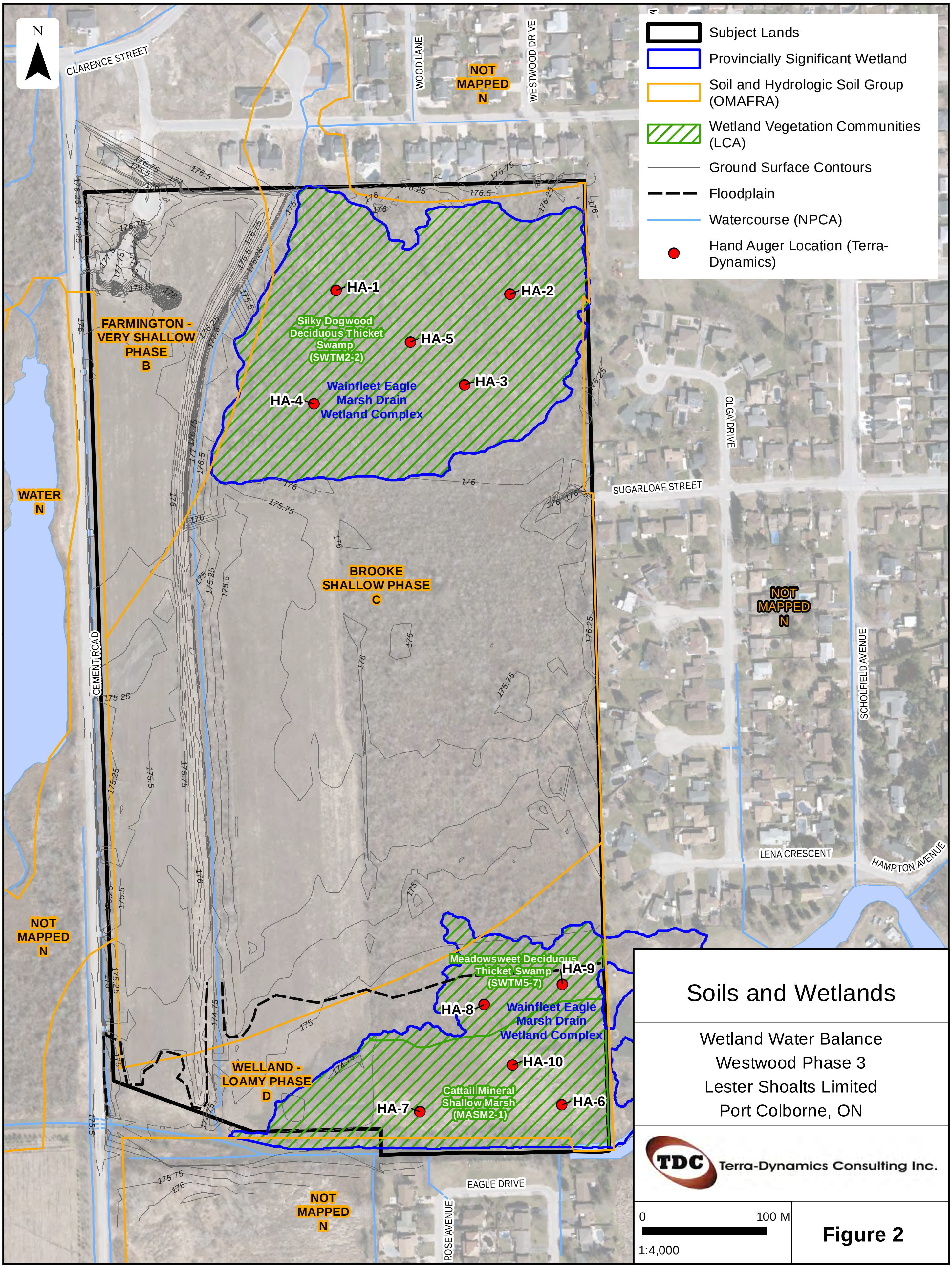
Wetland Water Balance, Westwood Phase 3
Lester Shoalts Limited, Port Colborne, ON

Terra-Dynamics Consulting Inc.

0 2 KM
1:100,000

Figure 1

Path: H:\TERRA_DYNAMICS\9608 - TD Westwood Phase 3\gis\mxd\Figure 1 Location of Subject Lands.mxd Revised: January 24, 2023



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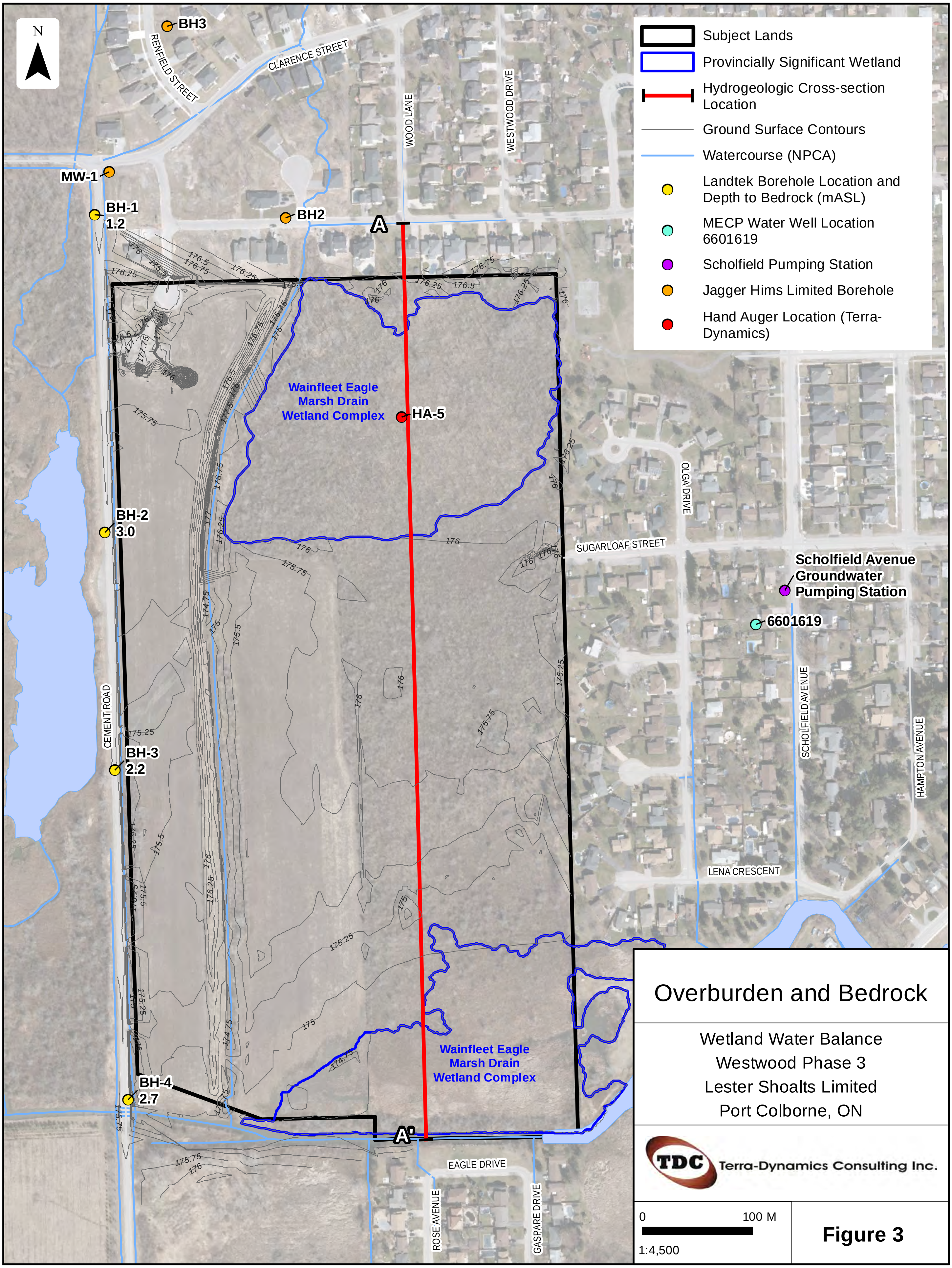


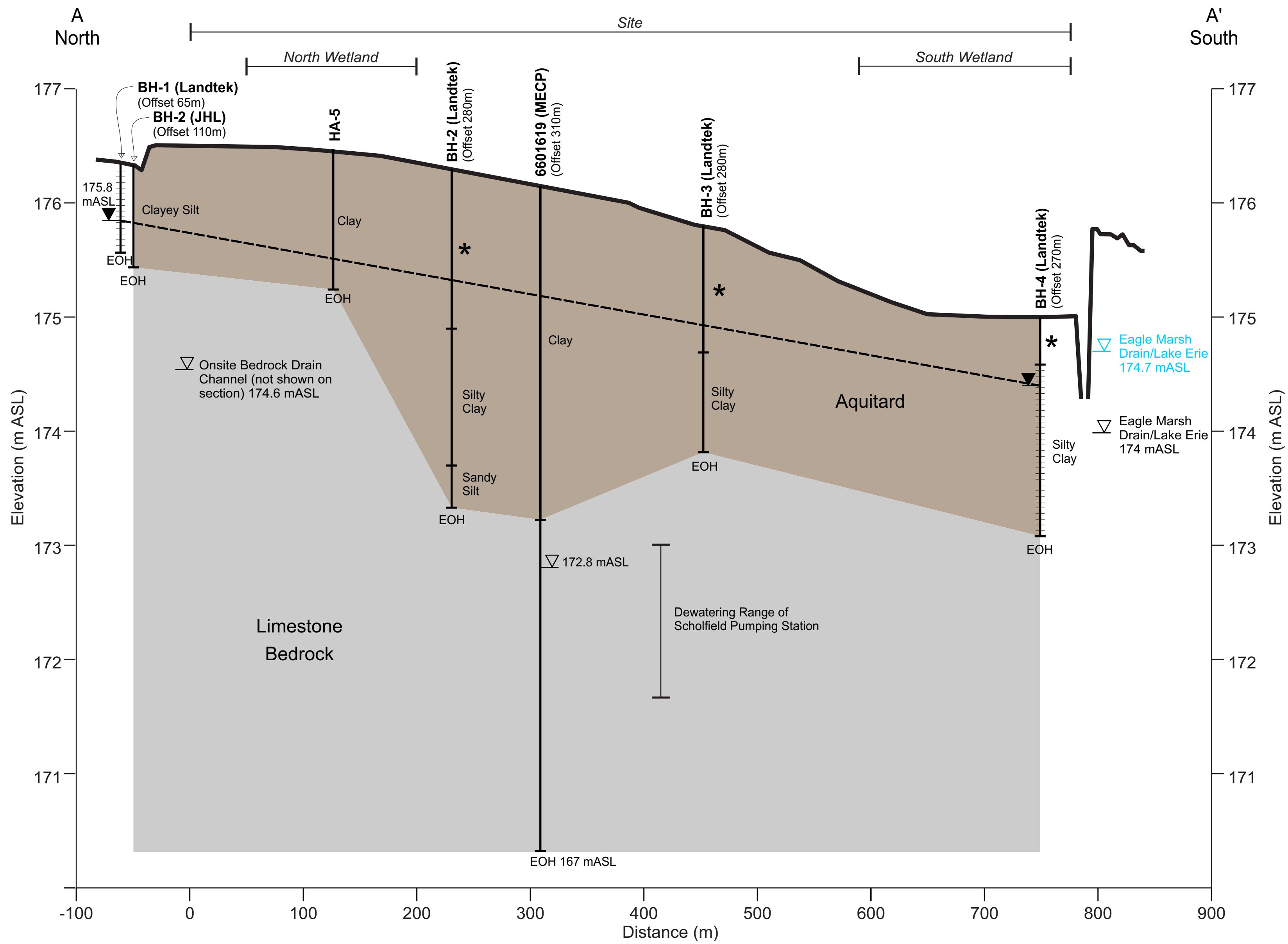
Overburden and Bedrock

Wetland Water Balance
Westwood Phase 3
Lester Shoalts Limited
Port Colborne, ON

TDC Terra-Dynamics Consulting Inc.

Figure 3

Path: H:\TERRA_DYNAMICS\9608 - TD Westwood Phase 3\gis\mxd\Figure 3 Overburden and Bedrock.mxd Revised: January 24, 2023



Borehole/Monitoring Well
EOH End of Hole
Groundwater Level (mASL) August 6, 2014
Water Level (mASL) September 6, 2012
Average Water Level (mASL) 2017 - 2021
Monitoring Well Screen
Water Table
* Off-site Possible Road Bed Fill
Clay
Bedrock

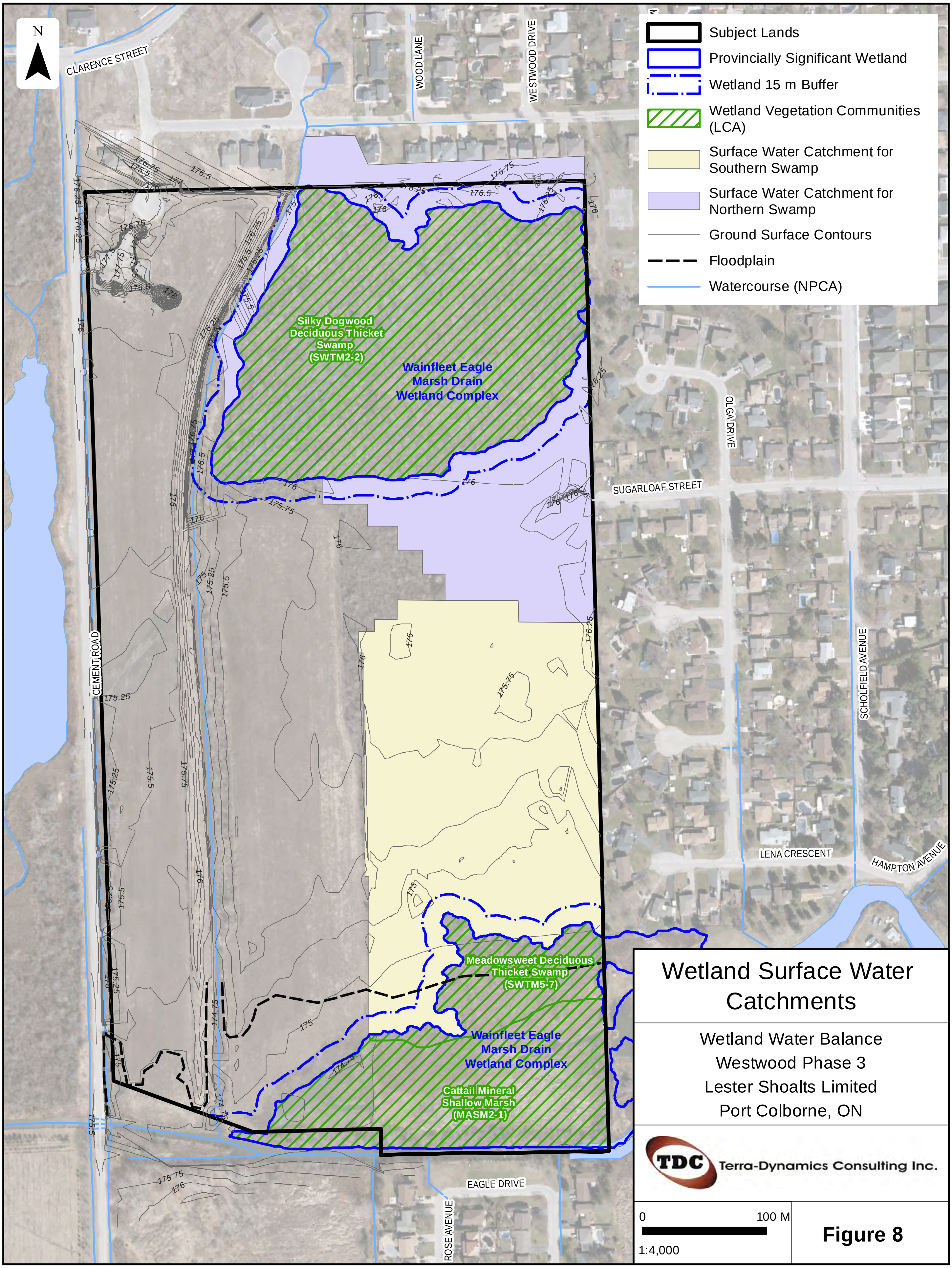
Hydrogeologic Cross-section A-A'

Wetland Water Balance Westwood Estates Phase 3, Port Colborne, ON

TDC Terra-Dynamics Consulting Inc.

Figure 4

H:\TERRA_DYNAMICS\9608 - TD Westwood Phase 3\corel\Figure 4 Hydrogeologic Cross-section A-A'.cdr Revised: January 31, 2023



Wetland Surface Water Catchments

Wetland Water Balance
Westwood Phase 3
Lester Shoalts Limited
Port Colborne, ON

TDC Terra-Dynamics Consulting Inc.

Figure 8

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TABLE 5a
USGS Wetland Monthly Water Balance

Date	P	PET	P-PET	Soil Moisture	AET	PET-AET	Snow Storage	Surplus	ROtotal	Comments
========	========	========	========	========	========	========	========	========	========	
January	73.1	10.1	44.3	400	10.1	0	23.9	44.3	48.6	Surplus
February	57	12	43.9	400	12	0	23.5	43.9	46.9	Surplus
March	66.8	21.4	59.4	400	21.4	0	6.8	59.4	55.1	Surplus
April	76.1	38.9	40.2	400	38.9	0	0	40.2	50.1	Surplus
May	89.7	70.7	14.5	400	70.7	0	0	14.5	34.9	Surplus
June	78.9	105.2	-30.2	369.8	105.2	0	0	0	19.1	Soil Water Utilization
July	82.2	127.1	-49	324.4	123.4	3.7	0	0	11.7	Soil Water Utilization
August	82.5	104.7	-26.3	303.1	99.7	5	0	0	7.9	Soil Water Utilization
September	98	63.3	29.8	332.9	63.3	0	0	0	6.8	Soil Water Recharge
October	90.4	34.1	51.8	384.7	34.1	0	0	0	5.5	Soil Water Recharge
November	100.9	18.2	77.7	400	18.2	0	0	62.4	36.7	Surplus
December	88.8	11.4	67.3	400	11.4	0	6.9	67.3	52.7	Surplus
Sum	984.4				608.4				376	

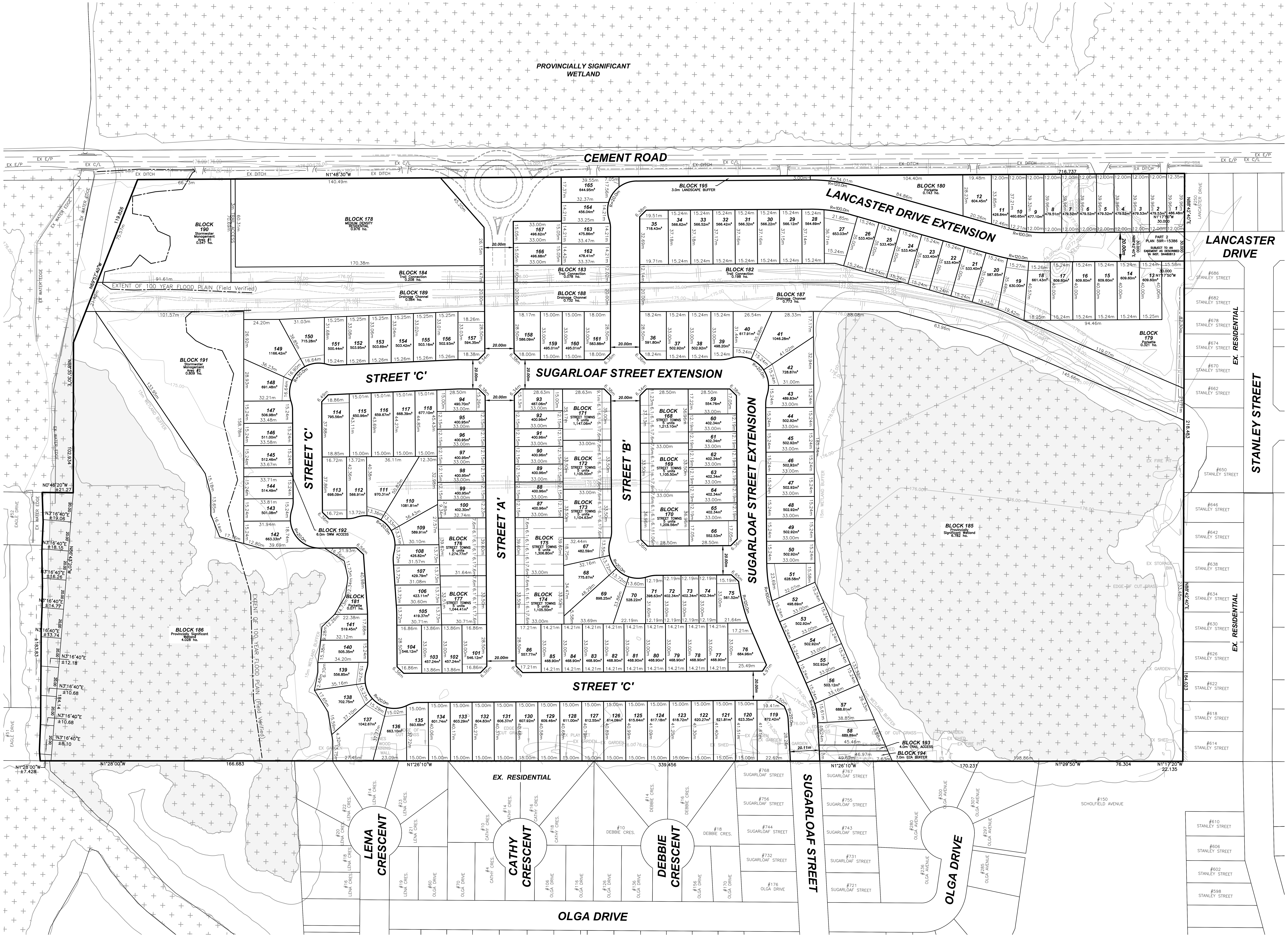
TABLE 5b
USGS Wetland Monthly Water Balance

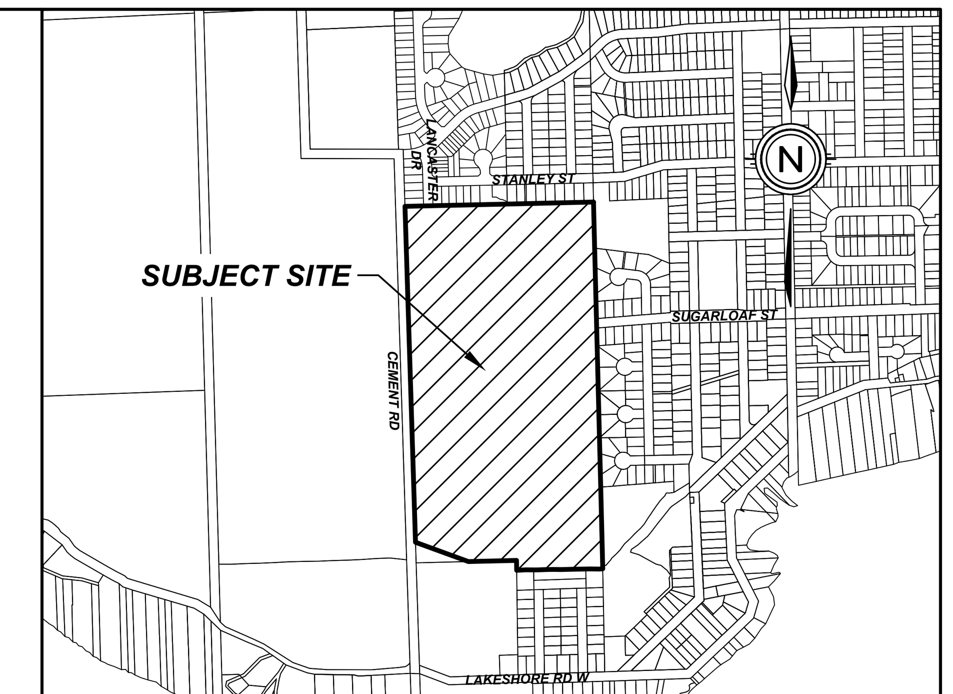
Date	P	PET	P-PET	Soil Moisture	AET	PET-AET	Snow Storage	Surplus	ROtotal	Comments
========	========	========	========	========	========	========	========	========	========	
January	73.1	10.1	44.3	350	10.1	0	23.9	44.3	48.8	Surplus
February	57	12	43.9	350	12	0	23.5	43.9	47	Surplus
March	66.8	21.4	59.4	350	21.4	0	6.8	59.4	55.1	Surplus
April	76.1	38.9	40.2	350	38.9	0	0	40.2	50.1	Surplus
May	89.7	70.7	14.5	350	70.7	0	0	14.5	34.9	Surplus
June	78.9	105.2	-30.2	319.8	105.2	0	0	0	19.1	Soil Water Utilization
July	82.2	127.1	-49	275	122.9	4.2	0	0	11.7	Soil Water Utilization
August	82.5	104.7	-26.3	254.3	99	5.6	0	0	7.9	Soil Water Utilization
September	98	63.3	29.8	284.1	63.3	0	0	0	6.8	Soil Water Recharge
October	90.4	34.1	51.8	335.9	34.1	0	0	0	5.5	Soil Water Recharge
November	100.9	18.2	77.7	350	18.2	0	0	63.6	37.3	Surplus
December	88.8	11.4	67.3	350	11.4	0	6.9	67.3	53	Surplus
Sum	984.4				607.2				377.2	

Appendix A

Draft Plan of Subdivision

WESTWOOD ESTATES - PHASE 3
CITY OF PORT COLBORNE





KEY PLAN
N.T.S.

DRAFT PLAN OF SUBDIVISION

LEGAL DESCRIPTION

PART OF LOT 33
CONCESSION 1
GEOGRAPHIC TOWNSHIP OF HUMBERSTONE, NOW IN THE
CITY OF PORT COLBORNE
REGIONAL MUNICIPALITY OF NIAGARA

OWNER'S CERTIFICATE

BEING THE REGISTERED OWNER, I HEREBY AUTHORIZE UPPER CANADA CONSULTANTS TO PREPARE AND SUBMIT THIS DRAFT PLAN OF SUBDIVISION TO THE CITY OF PORT COLBORNE FOR APPROVAL.

DECEMBER 14, 2022
TODD SHOALTS, LESTER SHOALTS LIMITED — DATE

SURVEYOR'S CERTIFICATE

I HEREBY CERTIFY THAT THE BOUNDARIES OF THE LANDS TO BE SUBDIVIDED ARE CORRECTLY SHOWN.

JANUARY 11, 2023
MATT GILMORE, O.L.S. — DATE
LANTHIER & GILMORE SURVEYING LTD.

REQUIREMENTS OF SECTION 51(17) OF THE PLANNING ACT

a) SEE PLAN
b) SEE PLAN
c) SEE PLAN
d) SEE PLAN
e) SEE PLAN
f) SEE PLAN
g) SEE PLAN
h) MUNICIPAL WATER
i) VARIOUS TEXTURES OVER BEDROCK
j) SEE PLAN
k) FULL SERVICE
l) SEE PLAN

LAND USE SCHEDULE

LAND USE	LOT/BLOCK	# OF UNITS	AREA(ha)	AREA(%)
SINGLE FAMILY RESIDENTIAL	LOT 1–167	167	9.222	30.18
STREET TOWN RESIDENTIAL	BLOCK 168–177	52	1.162	3.80
MEDIUM DENSITY RESIDENTIAL	BLOCK 178	96	0.976	3.19
PARKS	BLOCK 179–181		0.535	1.75
TRAIL CONNECTIONS	BLOCK 182–184		0.484	1.58
PROVINCIALLY SIGNIFICANT WETLAND	BLOCK 185–186		10.810	35.38
DRAINAGE CHANNEL	BLOCK 187–189		1.489	4.87
STORMWATER MGMT FACILITY	BLOCK 190–191		1.356	4.44
SWM ACCESS	BLOCK 192		0.020	0.07
TRAIL ACCESS	BLOCK 193		0.018	0.06
BUFFER AREAS	BLOCK 194–195		0.075	0.25
ROADWAY			4.407	14.42
TOTAL		315	30.554	100.00

DEVELOPABLE AREA = 18.25ha
DEVELOPABLE DENSITY = 17.26 units/ha

#	REVISION	DATE	INIT
.	.	.	.
.	.	.	.
0	ISSUED FOR APPROVAL	2023–01–11	M.K

UPPER CANADA CONSULTANTS
ENGINEERS / PLANNERS

DRAWING TITLE	
DRAFT PLAN OF SUBDIVISION	DRAFTING MK
	DATE APRIL 8, 2022
	PRINTED JANUARY 11, 2023
	SCALE 1:1250
	DWG No. 2160-DP — REV 0

Appendix B

Soils Information

E3 Laboratories Inc.
SS#4, 360 York Rd., Unit 10, Niagara-on-the-Lake, Ontario L0S 1J0
Email: info@e3labs.ca
Tel: (905) 641-9000, Fax: (905) 641-9001

CERTIFICATE OF ANALYSIS

Terra-Dynamics Consulting
Jayme Campbell
432 Niagara St
St.Catharines
L2M 4W3
Tel: Fax:

Email: jcampbell@terra-dynamics.com

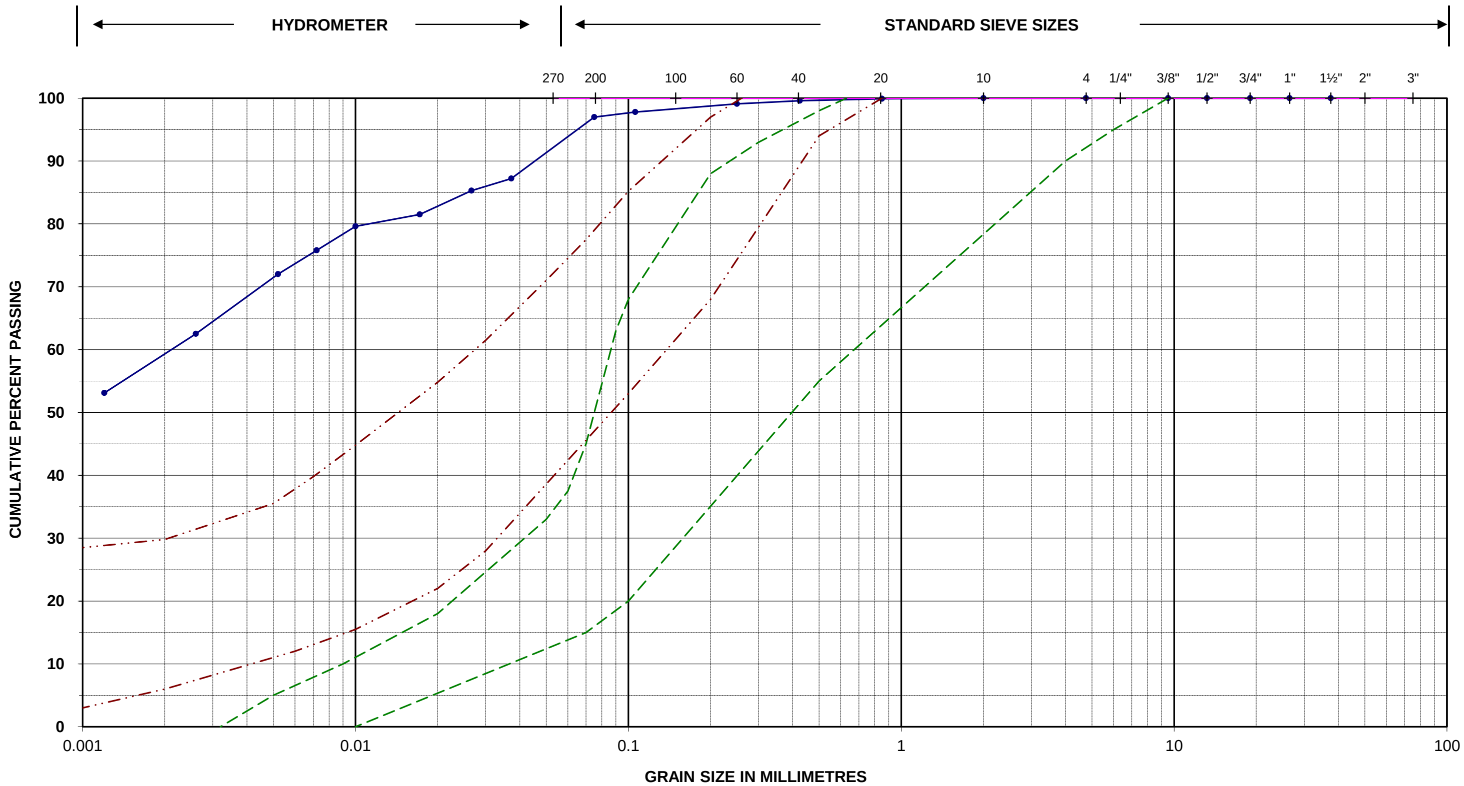
Work Order No.:2641839
Received : 2022-11-09
PO Number:
Reported: 2022-11-30
Project Name: Westwood Phase 3
Chain of Custody No.: 2641839

Client Sample ID	Sample Date	Lab ID	Parameter	Result	Unit	RDL	Date Analyzed	Method
Hand Auger 5	2022-10-04	**740141**	T Time	See	Attached	N/A	2022-11-22	Subcontracted
Hand Auger 10	2022-10-04	**740142**	T Time	See	Attached	N/A	2022-11-22	Subcontracted

Reported by: Niloufar Ghazi

Nilou Ghazi, Ph.D.,P.Eng.
Laboratory Manager

PARTICLE SIZE DISTRIBUTION LS702/ASTM D422



GRAVEL	0	%
SAND	3	%
SILT	39	%
CLAY	58	%

Unified Classification System

SILT AND CLAY	SAND	GRAVEL

------------------------ sm envelope T = 8 - 20 min/cm

—·—·—·—·— ml envelope T = 20 - 50 min/cm

Estimated T = >50 min/cm

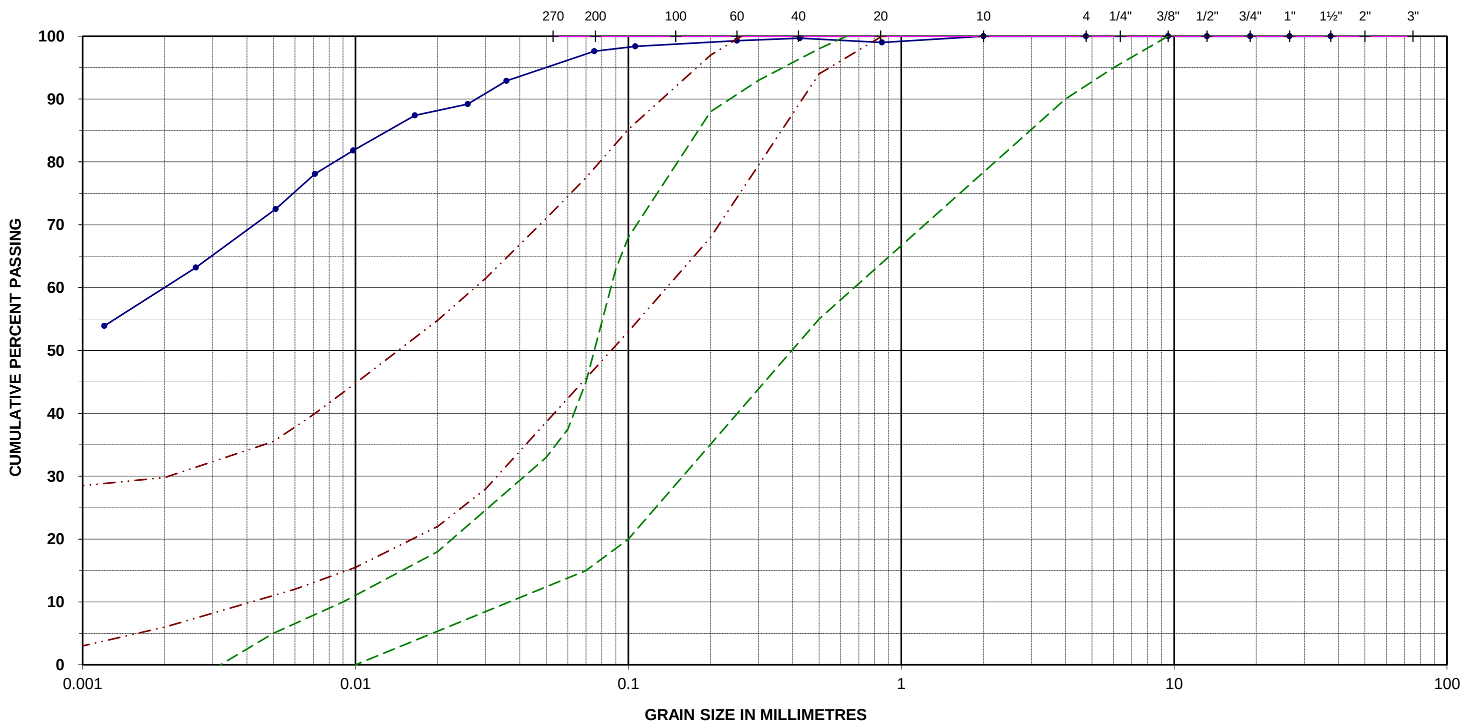
Project Name: E3 Laboratories **Project No.:** 111-53143-00 (20140924)

Location ID.: - **Sample No./Depth:** 740141

Sieve Size	% Passing Coarse	Sieve Size	% Passing Fine	Hydrometer (mm)	% Passing
37.5 mm	100.0	**2.00 mm**	100.00	**0.037**	87.2
26.5 mm	100.0	**0.850 mm**	99.9	**0.017**	81.5
19.0 mm	100.0	**0.425 mm**	99.6	**0.007**	75.8
13.2 mm	100.0	**0.250 mm**	99.1	**0.003**	62.5
9.50 mm	100.0	**0.106 mm**	97.8	**0.001**	53.1
4.75 mm	100.0	**0.075 mm**	97.0		

Note: More information is available upon request. Tested by: SG Reviewed by: Date: 22-Nov-22

PARTICLE SIZE DISTRIBUTION LS702/ASTM D422



GRAVEL	0	%
SAND	3	%
SILT	38	%
CLAY	59	%

Unified Classification System

SILT AND CLAY	SAND	GRAVEL

sm envelope T = 8 - 20 min/cm

ml envelope T = 20 - 50 min/cm

Estimated T = >50 min/cm

Project Name:	E3 Laboratories	**Project No.:**	111-53143-00 (20140924)
Location ID.:	-	**Sample No./Depth:**	740142

Sieve Size	% Passing Coarse	Sieve Size	% Passing Fine	Hydrometer (mm)	% Passing
37.5 mm	100.0	**2.00 mm**	100.00	**0.036**	92.9
26.5 mm	100.0	**0.850 mm**	99.0	**0.017**	87.4
19.0 mm	100.0	**0.425 mm**	99.7	**0.007**	78.1
13.2 mm	100.0	**0.250 mm**	99.3	**0.003**	63.2
9.50 mm	100.0	**0.106 mm**	98.4	**0.001**	53.9
4.75 mm	100.0	**0.075 mm**	97.6		

Note: More information is available upon request. Tested by: SG Reviewed by: Date: 22-Nov-22

K from Grain Size Analysis Report

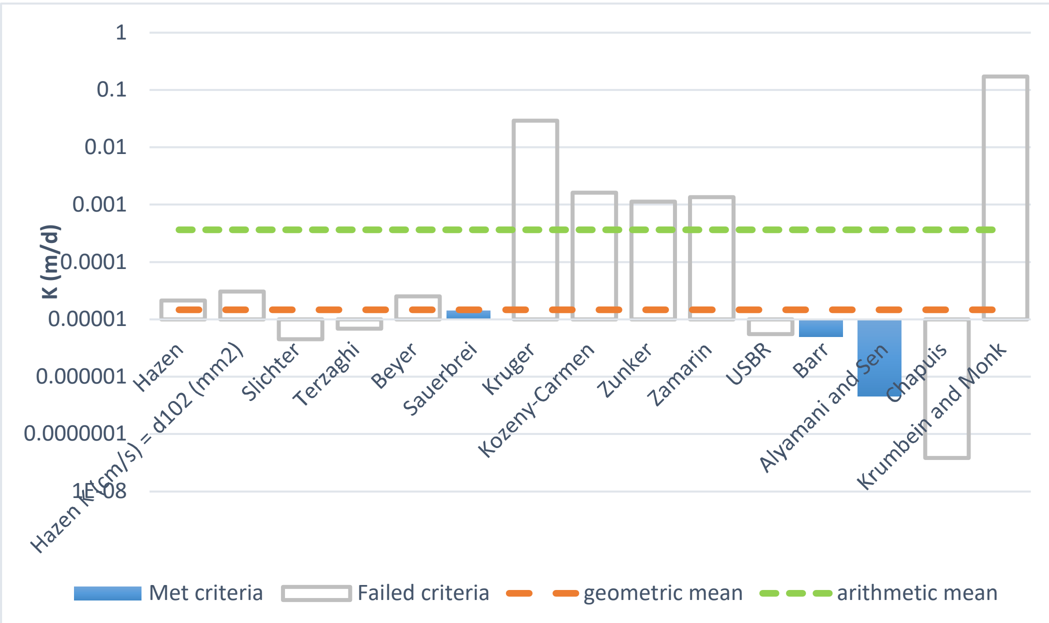
Date: 30-Nov-22

Sample Name: HA-5, Site: Westwood Phase 3, Port Colborne

Mass Sample (g): 100

T (oC) 20

Poorly sorted clay with fines



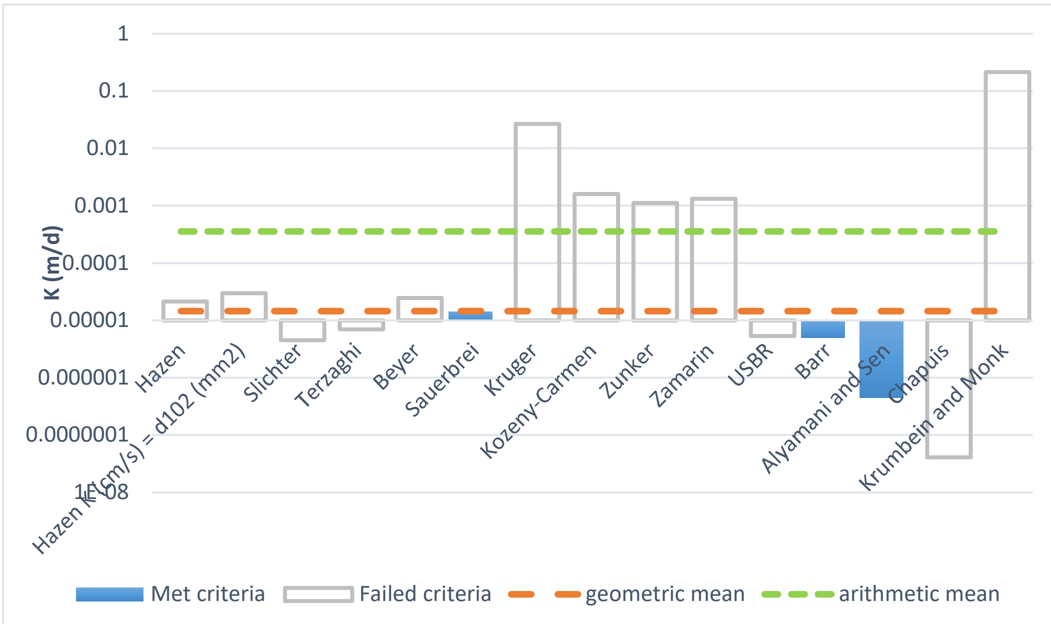
Estimation of Hydraulic Conductivity	cm/s	m/s	m/d	de
Hazen	2.E-08	2.E-10	0.00	
Hazen K (cm/s) = d_{10} (mm)	4.E-08	4.E-10	0.00	
Slichter	5.E-09	5.E-11	0.00	
Terzaghi	8.E-09	8.E-11	0.00	
Beyer	3.E-08	3.E-10	0.00	
Sauerbrei	2.E-08	2.E-10	0.00	
Kruger	3.E-05	3.E-07	0.03	
Kozeny-Carmen	2.E-06	2.E-08	0.00	
Zunker	1.E-06	1.E-08	0.00	
Zamarin	2.E-06	2.E-08	0.00	
USBR	6.E-09	6.E-11	0.00	
Barr	6.E-09	6.E-11	0.00	
Alyamani and Sen	5.E-10	5.E-12	0.00	
Chapuis	4.E-11	4.E-13	0.00	
Krumbein and Monk	2.E-04	2.E-06	0.17	
Shepherd	2.E-06	2.E-08	0.00	
geometric mean	2.E-08	2.E-10	0.00	
arithmetic mean	4.E-07	4.E-09	0.00	

K from Grain Size Analysis Report　　Date: 30-Nov-22

Sample Name: HA-10, Site: Westwood Phase 3, Port Colborne

Mass Sample (g): 100　　T (oC) 20

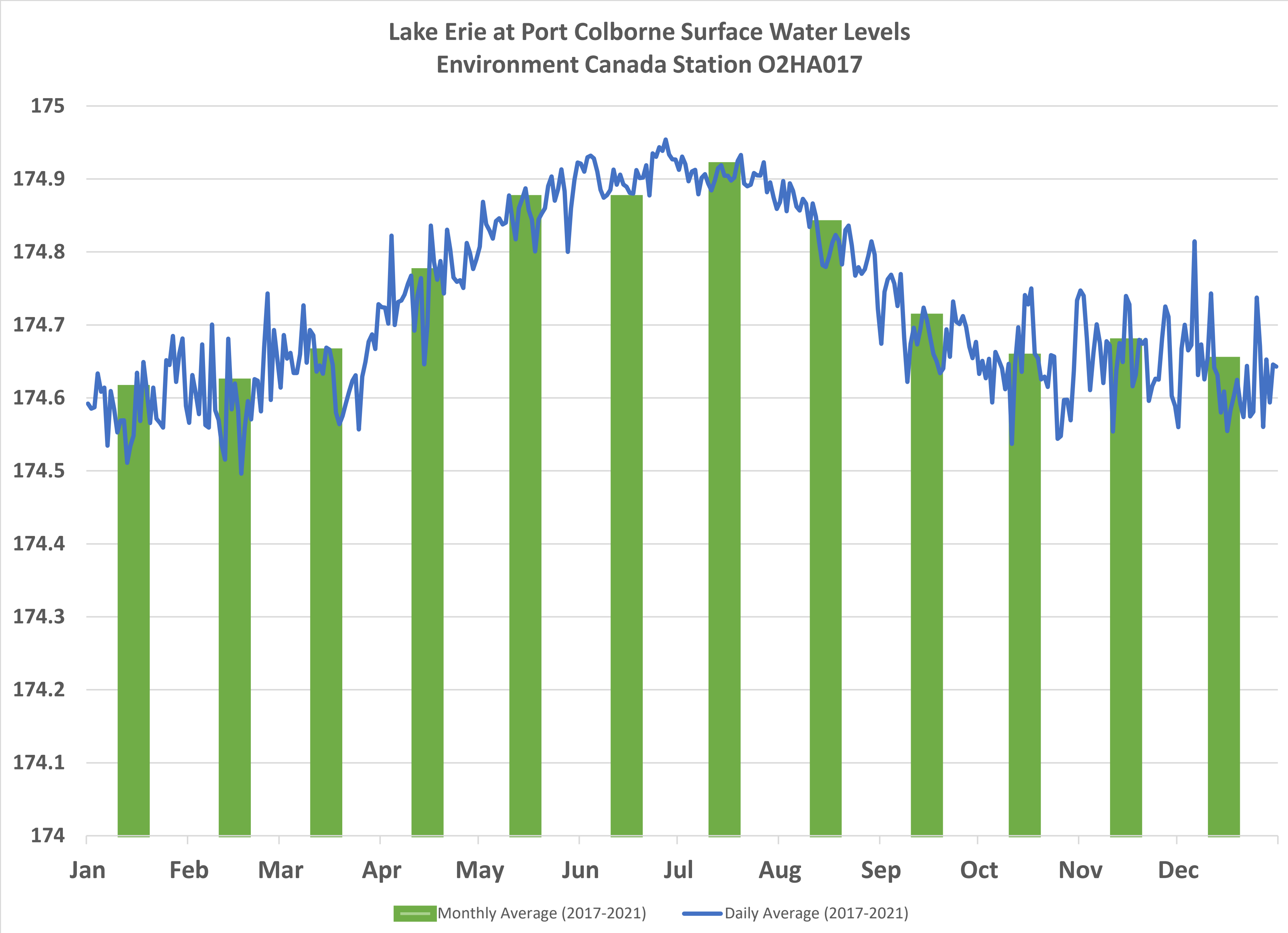
Poorly sorted clay with fines



Estimation of Hydraulic Conductivity	cm/s	m/s	m/d	de
Hazen	2.E-08	2.E-10	0.00	
Hazen K (cm/s) = d_{10} (mm)	3.E-08	3.E-10	0.00	
Slichter	5.E-09	5.E-11	0.00	
Terzaghi	8.E-09	8.E-11	0.00	
Beyer	3.E-08	3.E-10	0.00	
Sauerbrei	2.E-08	2.E-10	0.00	
Kruger	3.E-05	3.E-07	0.03	
Kozeny-Carmen	2.E-06	2.E-08	0.00	
Zunker	1.E-06	1.E-08	0.00	
Zamarin	2.E-06	2.E-08	0.00	
USBR	6.E-09	6.E-11	0.00	
Barr	6.E-09	6.E-11	0.00	
Alyamani and Sen	5.E-10	5.E-12	0.00	
Chapuis	5.E-11	5.E-13	0.00	
Krumbein and Monk	2.E-04	2.E-06	0.21	
Shepherd	2.E-06	2.E-08	0.00	
geometric mean	2.E-08	2.E-10	0.00	
arithmetic mean	4.E-07	4.E-09	0.00	

Appendix C

Wetland Information


Lake Erie at Port Colborne Surface Water Levels
Environment Canada Station O2HA017
175
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Monthly Average (2017-2021)
Daily Average (2017-2021)

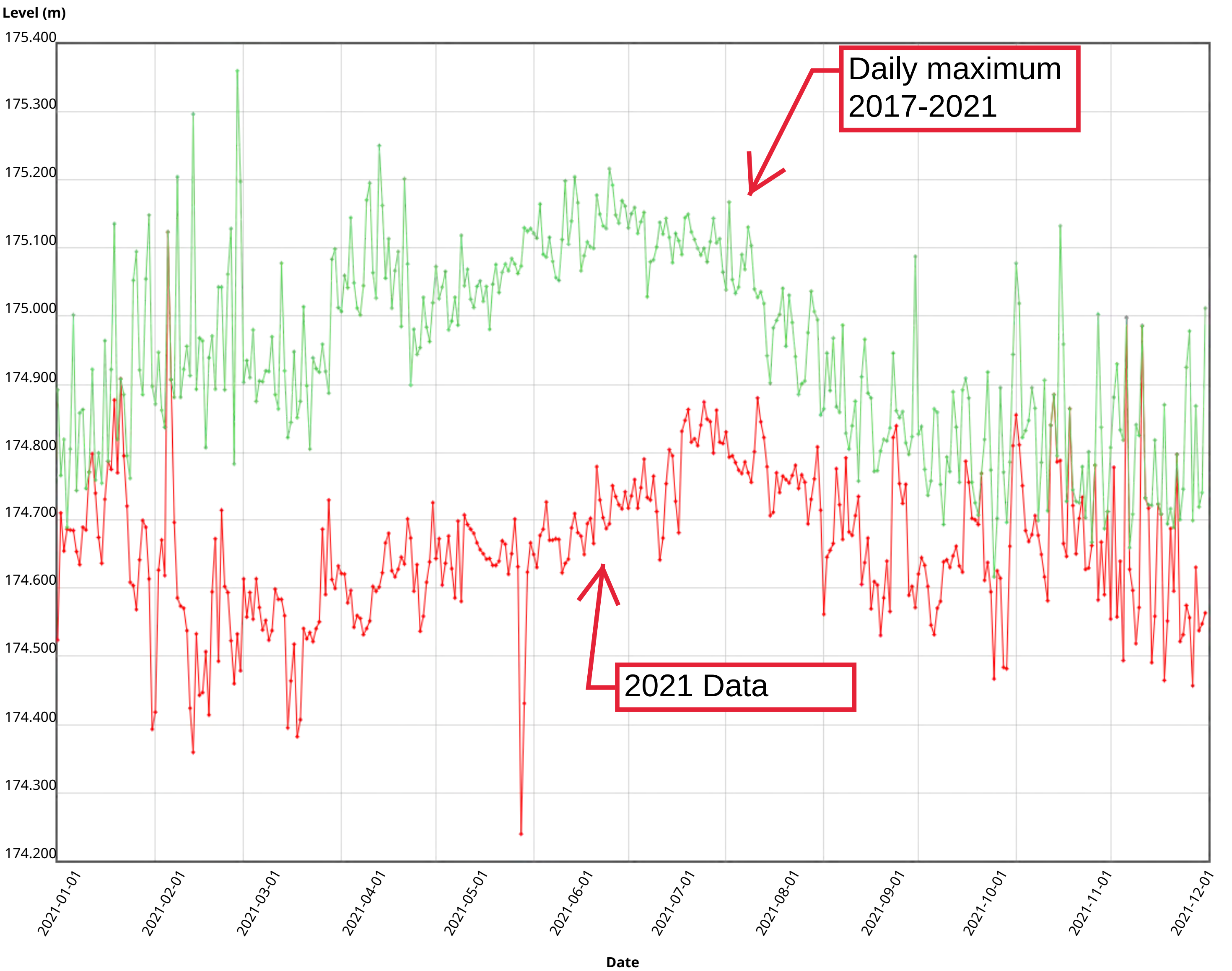
Government of Canada Gouvernement du Canada

Daily Water Level Graph for LAKE ERIE AT PORT COLBORNE (02HA017) [ON]

All times are specified in Local Standard Time (LST). Add 1 hour to adjust for Daylight Saving Time where and when it is observed.

▾ **Legend**

2021 Data Maximum 2017-2021



*Note: If n<10, percentiles are not calculated.

Station Information

Active or discontinued:	Active
Province / Territory:	Ontario
Latitude:	42° 52' 28" N
Longitude:	79° 15' 10" W
Gross drainage area:	N/A
Effective drainage area:	N/A
Record length:	113 Years
Period of record:	1911-2023
Regulation type:	Natural
Regulation length:	N/A
Real-time data available:	No
Sediment data available:	No
Type of water body:	Lake

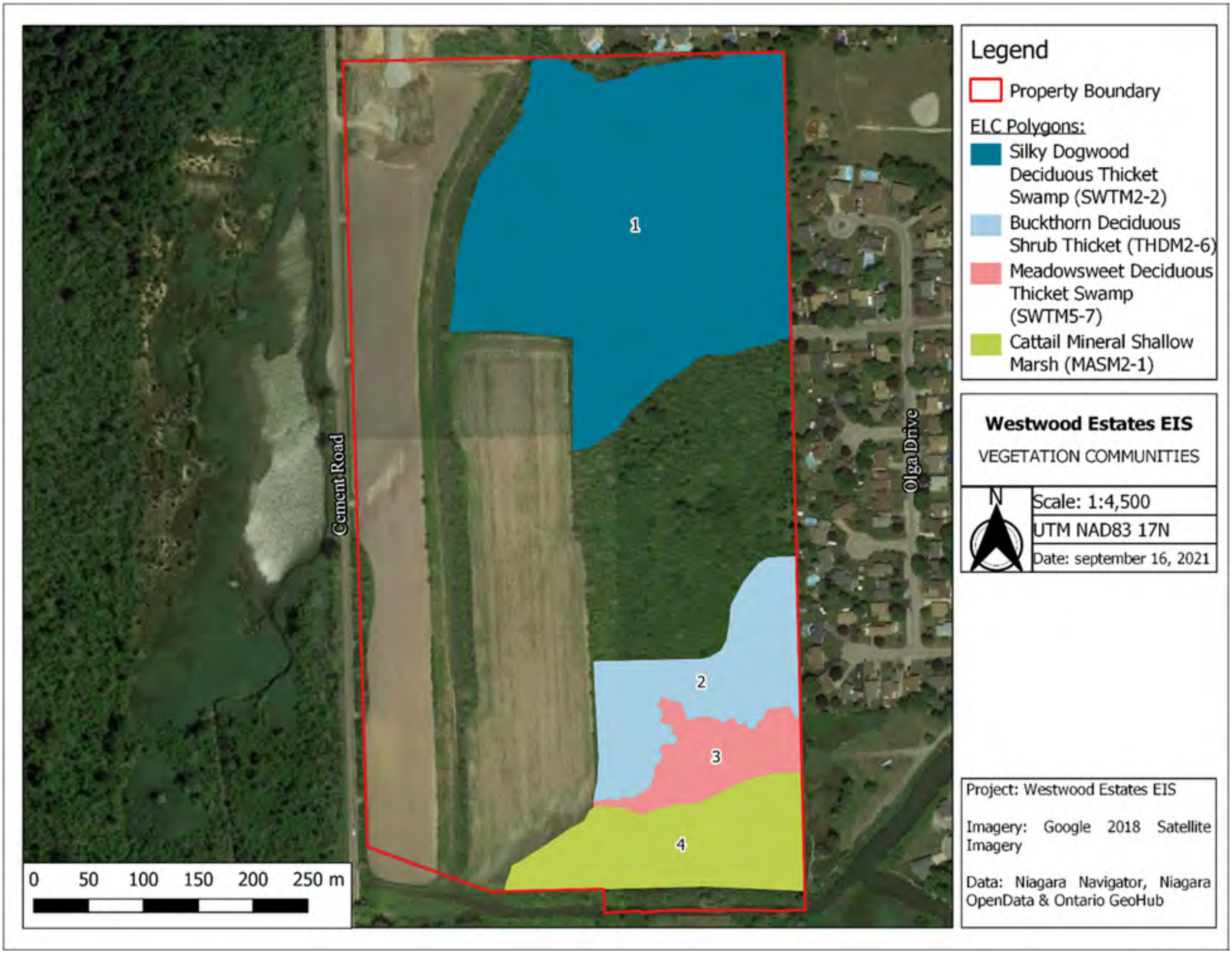


Figure 4: A map of the distribution of community types located in the study area.