6. Channel Morphology

The Wignell Drain subwatershed consists of three subwatersheds: the Port Colborne Drain, the Wignell Drain, and the Michener Drain. The Port Colborne Drain originally outletted into Lake Erie but was diverted to the Wignell Drain (south of Friendship Trail) and renamed as part of Wignell Drain in the 1970s (EWA Engineering Inc., 2022). For the purposes of this study, the historical subwatershed names are used.

The drainage features within the Wignell Drain subwatershed are primarily managed as municipal drains (**Figure □**). Municipal drains were historically constructed to improve drainage of agricultural land by serving as the discharge point for agricultural tile drainage systems. Under the *Drainage Act*, municipalities are legislated to maintain and repair drains (Ministry of Natural Resources and Forestry, 2012). From a morphological perspective, municipal drains are considered watercourses and regulated under the *Conservation Authorities Act* (Ministry of Natural Resources and Forestry, 2012); however these features do not function as natural watercourses. Morphology is primarily dictated by original engineered design and ongoing maintenance to ensure adequate conveyance. The regulation of municipal drains as watercourses by Conservation Authorities necessitates their assessment and protection in association with proposed development.

The *Lake Erie North Shore Watershed Plan* classified the Wignell subwatershed based on fish habitat to facilitate better management of the features. The upper branches of the watershed (north of Snider Road allowance) are considered Class F Drains (intermittent systems that are dry at least 3 months of the year), and the lower branches (south of Snider Road allowance) are considered Class B Drains (permanent systems that restrict in-water work during spring months).

6.1 Drainage Feature Characterization

6.1.1 Port Colborne Drain

The Port Colborne Drain has seven reaches, beginning upstream in the existing quarry and continuing downstream to the confluence with the Wignell Drain, south of the Friendship Trail. Only reaches PC-5 and PC-6 were accessible based on property access. Characterization for the remaining reaches was completed based on road crossings observations and aerial imagery review. Reach photos are found in **Appendix M**.

Reaches PC-1 and PC-2 are located in the existing Port Colborne quarry. Access was not provided to assess the existing conditions of these reaches. Historical imagery indicates that the quarry west of Snider Road was operational as early as 1965 and expanded to the east of Snider Road, where PC-1 and PC-2 are located, between 1972 and 2002. The reaches appeared to be channelized prior to the quarry expansion and were further impacted by the expansion. Both reaches were truncated and realigned to their current alignments. The quarry occupies much of the upstream drainage area and impacts the flows to the reaches through runoff capture, water taking, and eventual discharge (EWA Engineering Inc., 2022).

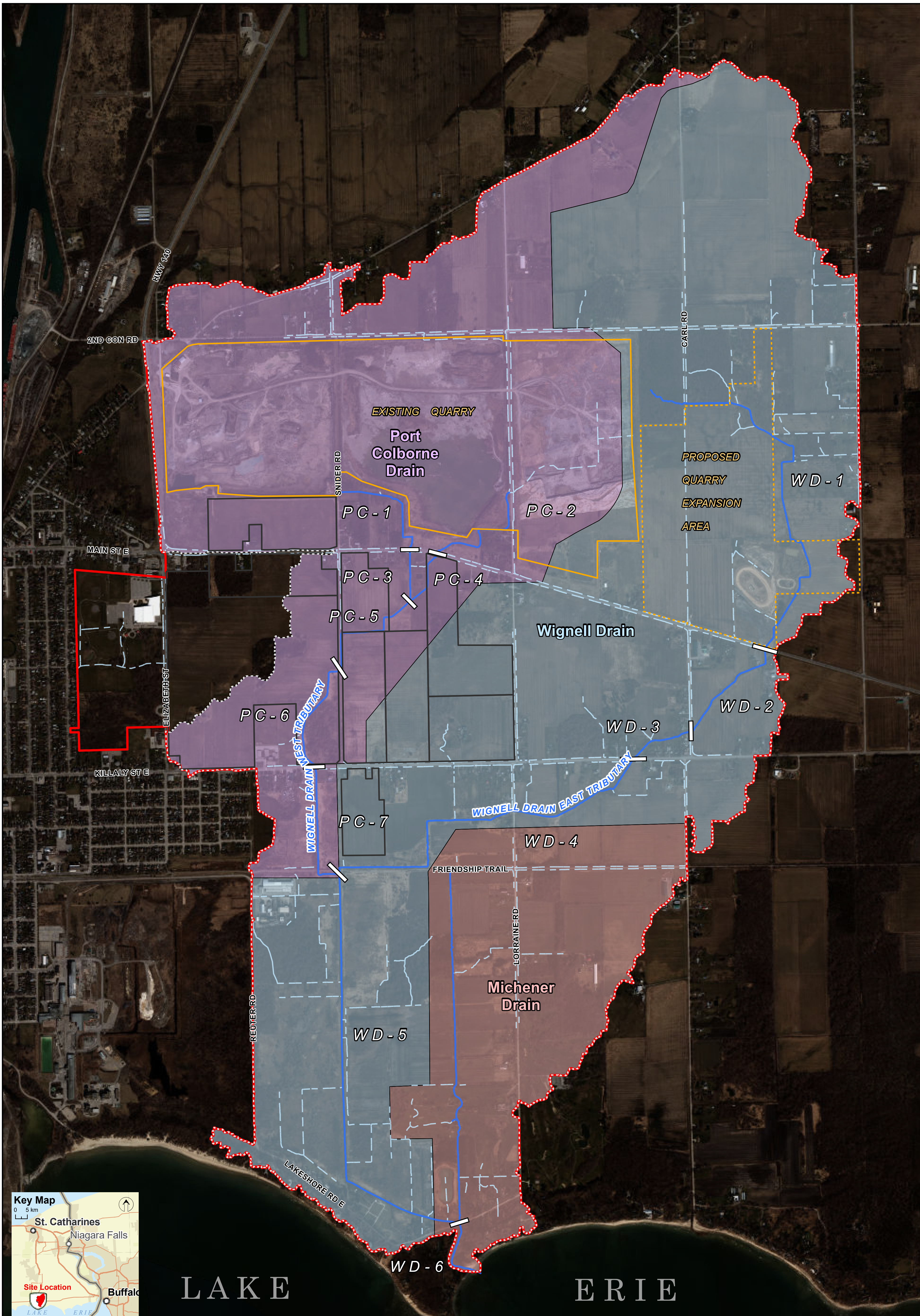
Reach PC-3 is located to the west of PC-4 downstream of the quarry and Main Street East and corresponds to aquatic habitat survey location WD-1. PC-3 was not identified as part of the City of Port Colborne maintenance in 2016 (EWA Engineering Inc., 2022), and it is assumed that it is not maintained. The reach is located on private property and was only assessed at the roadside culvert and through review of aerial imagery. The channel was generally dry, with only standing water observed at the culvert itself. Historical aerial imagery indicates the channel has limited fluvial processes and a minimal riparian corridor. The feature appears to have been straightened prior to 1934, with no subsequent observable channel change to date, although the channel is generally obscured by dense grasses in the imagery.

Reaches PC-4 through PC-7 were cleaned and realigned by the City of Port Colborne in 2016 (EWA Engineering Inc., 2022). This would have included removal of vegetation from top-of-bank to top-of-bank, targeting tree and shrub growth that partly or fully obstructed primary flow paths. Efforts were made to retain trees and understory growth, where possible, to reduce environmental impacts. Removal of sediment accumulation that impedes flow within the channel cross-section may also be completed as part of this maintenance (EWA Engineering Inc., 2022). Reach characterizations are summarized in **Table 12**.

Table 12: Port Colborne Reach Characterization (PC-4 through PC-7)

Reach	**Channel Geometry and Flow Conditions**	**Description**	**Access**
PC-4	Channel width approximately 3.5-4 m (measured from LiDAR). A stagnant pool approximately 0.3-0.4 m deep is located at the road culvert. Aquatic habitat sampling in the right of way (ROW) indicates the reach is generally wet throughout the spring and summer, suggesting permanency of flow.	Limited riparian vegetation or riparian corridor. Aerial imagery indicates some rock placement along a small bend to help direct the channel. Potential minor HDF features are visible on aerial imagery draining towards the reach from the east (agricultural field).	No access to reach (private property). Observations made from ROW.
PC-5	Both bankfull width and bankfull depth were measured in the field. Bankfull width ranged from 2.1-4.8 m. Bankfull depth ranged from 0.5-1.3 m. The channel significantly narrows and shallows as it approaches the Snider Road allowance, flowing through cropped fields. The channel is wider through meadow vegetation in the upstream half of the reach. The reach appears to be permanently flowing, with a wetted depth of 0.70 m during an October field visit.	The channel flows through meadow vegetation in the upstream portion of the reach and through active agricultural fields approaching Snider Road. Limited geomorphic processes. Channel substrates consist of sand and silt with some fine gravel. The reach parallels the Snider Road allowance for approximately 185 m.	Partial – access to downstream half of reach only.
PC-6	Both bankfull width and bankfull depth were measured in the field. Bankfull width ranged from 4.9-5.75 m. Bankfull depth ranged from 1.06-1.12 m. Channel appears to be permanently flowing based on field visits in July and October.	Channel flows through meadow and forested vegetation. Review of the historical aerial imagery indicates some planform development and adjustment of the channel between maintenance years. A small drainage feature from the adjacent elementary school joins the channel near the downstream end, approaching Killaly Street East. Channel	Full access.

Reach	Channel Geometry and Flow Conditions	Description	Access
		substrates consisted of sand and silt with fine gravels. The channel cross-section was well-defined; however, it was frequently populated by cattails.	
PC-7	Both bankfull width and bankfull depth were measured in the field. Bankfull width ranged from 2.5-4.1 m. Bankfull depth ranged from 0.4-0.65 m. Reach was permanently flowing. Channel dimensions were wider at the Friendship Trail culvert.	The channel planform is straight and well-maintained, and there are no visible planform adjustments in the historical aerial imagery. The surrounding vegetation is primarily meadow vegetation. Substrates consisted primarily of silt and sands.	No access to reach (private property). Observations made within 75 m of Friendship Trail.



LEGEND

- Reach Break
- Watercourse [1]

NPCA Flowline

- Natural
- Constructed - open
- Constructed - closed
- Wignell Subwatershed

Description

- Michener Drain
- Port Colborne Drain
- Wignell Drain
- Existing Quarry Footprint
- Proposed Quarry Expansion Lands
- Subject Lands (Owned by Elite Developments)
- Study Area

1 - Contains data sourced from both Niagara Peninsula Conservation Authority (NPCA) and Land Information Ontario (LIO)

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METRE SCALE

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

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CLIENT
Elite M.D. Developments

PROJECT
Wignell Drain Subwatershed Study

TITLE
Wignell Drainage Areas

Palmer PART OF SLR

REF. NO. 2007708-9-1

Figure 9

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Wignell Drain and Michener Drain

Wignell Drain has five reaches beginning upstream in the proposed quarry expansion area and draining into Lake Erie. The confluence of Port Colborne Drain and Wignell Drain is located just south of the Friendship Trail. Access was not granted to any reaches of the Wignell Drain and as such all assessments were completed at ROWs and through desktop approaches (i.e., review of historical aerial imagery and LiDAR). Michener Drain is located to the east of Wignell Drain, south of the Friendship Trail. Similarly, no access was granted to these lands. Michener Drain converges with the Wignell Drain at Lakeshore Road East, at the dam structure that mitigates backwater effects from Lake Erie. Reach characterizations are summarized in Table 13.

Table 13: Wignell Drain and Michener Drain Reach Conditions

Reach	Channel Geometry	Description	Notes
WD-1	Bankfull width 4-5 m based on roadside and LiDAR measurements.	The reach generally flows through agricultural fields with limited to no riparian buffer. There is no visible evidence of planform adjustment based on the historical aerial imagery.	No access to reach (private property). Observations made from ROW.
WD-2	Bankfull width 4-5.5 m based on roadside and LiDAR measurements.	The reach flows behind a residential property and through an active agricultural field. There is a limited riparian buffer, approximately 2 m on either side of the channel. There is no visible evidence of planform adjustment based on the historical aerial imagery.	No access to reach (private property). Observations made from ROW.
WD-3	Bankfull width 4-5 m based on roadside and LiDAR measurements.	The reach flows behind several residential properties with a minimal riparian buffer, approximately 1-2 m on either side of the channel. The channel narrows approaching the downstream end of the reach and culvert at Killaly Street East. There is no visible evidence of planform adjustment based on the historical aerial imagery.	No access to reach (private property). Observations made from ROW.
WD-4	Bankfull width 3-6 m and bankfull depth of 0.50 m based on roadside and LiDAR measurements.	The reach flows primarily through agricultural fields with a minimal riparian buffer, approximately 1-2 m on either side of the channel. Some wetland vegetation was documented in the channel and along the margins. Two small ponds are seen adjacent to the channel. There is no visible evidence of planform adjustment based on the historical aerial imagery.	No access to reach (private property). Observations made from ROW.
WD-5	Bankfull width is 10-15 m and bankfull depth is 0.80-1.25 m based on roadside and LiDAR measurements.	The reach is backwatered, slow flowing, and has significant unconsolidated silt deposition downstream of the culvert at Friendship Trail. Wetland and aquatic vegetation populate the margins of the channel. Dense aquatic	No access to reach (private property). Observations made from Friendship Trail.

Reach	Channel Geometry	Description	Comments
		vegetation is visible in aerial imagery indicating limited flow velocity. The reach exhibits limited fluvial processes.	
Michener Drain	Bankfull width is 2-4 m as measured from LiDAR. No bankfull depth measurement.	Michener drain is straightened through its entire length, except for the reach through Whisky Run Golf Club, where there is some sinuosity. Prior to the golf course development, the reach was straight and ditched. It is assumed the golf course operations altered the planform alignment. The surrounding manicured lawn also provides the opportunity for some natural planform adjustment. A large pond is located on the west side of the channel, downstream of the golf course. There is less evidence of backwatering visible on the aerial imagery compared to in the Wignell Drain reach WD-5.	No access to reach (private property).

[illegible]1[illegible] HDF Characterization

In 2022, HDFs within the Subject Lands were evaluated in accordance with *the Evaluation, Classification and Management of Headwater Drainage Features Guidelines* (Toronto and Region Conservation Authority and Credit Valley Conservation, 2014) (**Table 1[illegible]** and **Figure 1[illegible]**). These guidelines use an integrated approach for the evaluation of key attributes of drainage features including flow and feature form, riparian vegetation, fish and fish habitat, and terrestrial habitat. The evaluation divides HDFs into segments, with breaks between segments occurring where key attributes change.

Table 14: HDF Functional Classification and Management

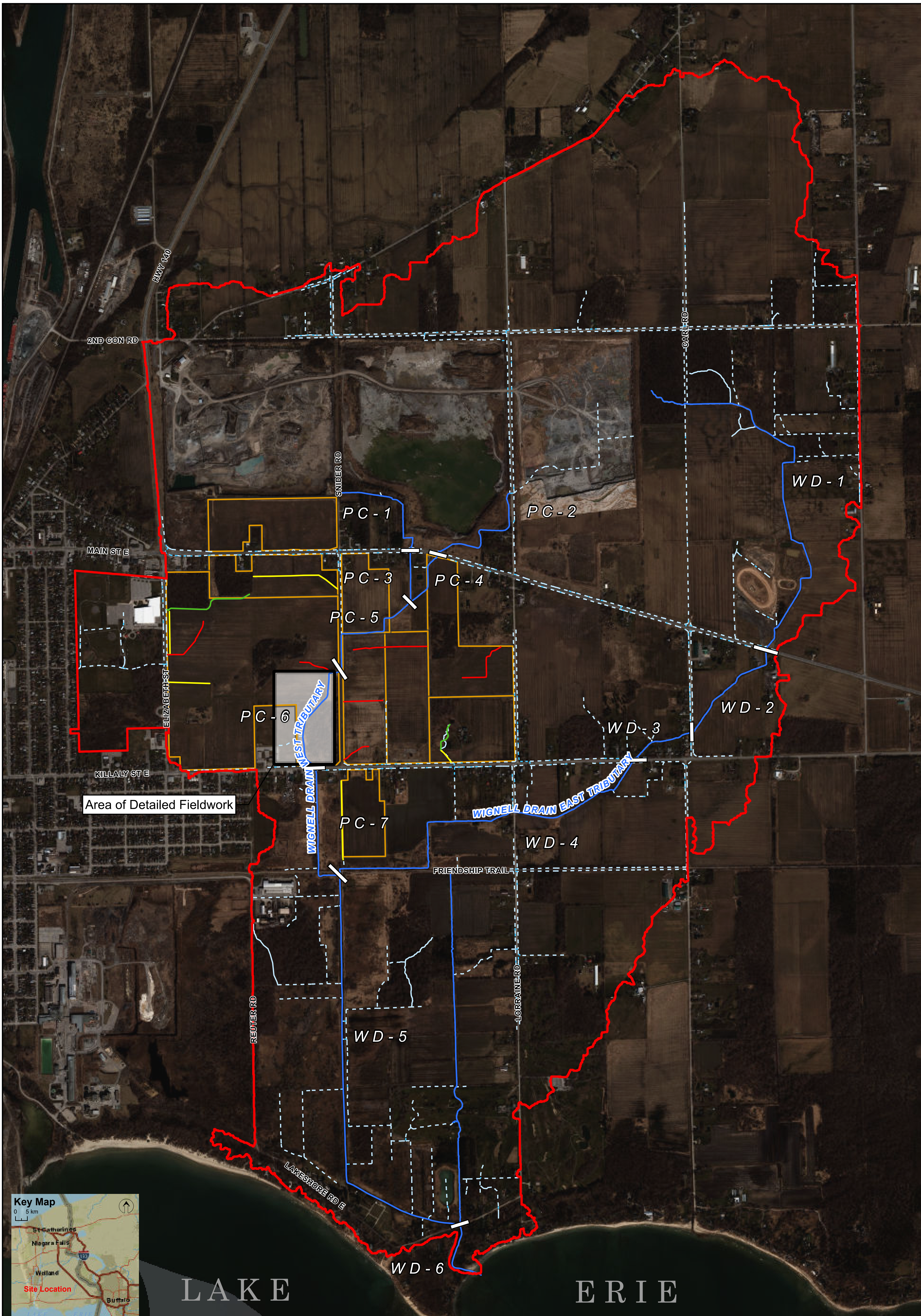
Drainage Feature	Step 1		Step 2	Step 3	Step 4	Management Recommendation
	Hydrology	Modifiers	Riparian	Fish Habitat	Terrestrial Habitat	
HDF-1	Valued	Agriculture	Limited	Contributing Function	Valued	Mitigation
HDF-2	Valued	Agriculture	Important	Contributing Function	Important	Conservation
HDF-3	Valued	Agriculture	Limited	Contributing Function	Limited	Mitigation
HDF-4	Limited	Agriculture	Limited	Contributing Function	Limited	No Management Required
HDF-5	Valued	Agriculture	Limited	Contributing Function	Limited	Mitigation
HDF-6	Limited	Agriculture	Limited	Contributing Function	Limited	No Management Required
HDF-7	Limited	Agriculture	Limited	Contributing Function	Limited	No Management Required
HDF-8	Limited	Agriculture	Limited	Contributing Function	Limited	No Management Required

Drainage Feature	Step 1		Step 2	Step 3	Step 4	Management Recommendation
	Hydrology	Modifiers	Riparian	Fish Habitat	Terrestrial Habitat	
HDF-9	Limited	Agriculture	Limited	Contributing Function	Limited	No Management Required
HDF-10	Valued	Agriculture	Limited	Contributing Function	Limited	Mitigation
HDF-11a	Valued	None	Important	Contributing Function	Important	Conservation
HDF-11b	Valued	Agriculture	Limited	Contributing Function	Limited	Mitigation
HDF-12	Limited	Agriculture	Limited	Contributing Function	Limited	No Management Required

As outlined in **Table 1[illegible]**, the majority of the HDFs identified within the Subject Lands do not provide a significant ecological or hydrologic benefit to the Port Colborne subwatershed; as such, these features are identified by a management recommendation of either *Mitigation*, where some hydrologic function may need to be replicated, or *No Management* where no significant function was identified and these features may be removed from the landscape with no future consideration. A few other features, notably HDF-2 and the HDF-11a segments, were identified as providing more important ecological benefit due to their position within wetland or woodland communities, permanence on the landscape (i.e., standing water in late spring), and their potential ability to aid or support wildlife, in this case, amphibian species, resulting in these features receiving *Conservation* status.

As highlighted above, HDFs identified for *Mitigation* should be considered during future detailed design phases of any development project, with hydrologic function being maintained to benefit downstream systems within the Wignell Drain subwatershed. HDFs identified as *Conservation*, should be maintained on the landscape, preferably in their current location, or in a re-aligned form that maintains the ecological function they provide to the surrounding natural landscape (e.g. HDF-2's proximity to woodlands may support Western Chorus Frog populations that utilize the saturated spring woodland for breeding purposes).

The remainder of the potential HDFs and other small municipal drainage features within the larger Wignell Drain Subwatershed (as shown in **Figure 1[illegible]**), were reviewed using a desktop approach. The NPCA mapping (NPCA, 2023) identifies the features as *natural*, *constructed open*, or *constructed closed*. Most of the drainage features are classified as *constructed open* and flow adjacent to roadways in the upper watershed. Along reach WD-3 and WD-4 there are several *constructed open* features that flow across the landscape and should be evaluated for potential HDF functions at subsequent planning stages should development of those properties occur. Due to constructed nature of these features, they were frequently visible on the LiDAR mapping, further confirming ongoing maintenance of channel geometry. Similarly, there are several *constructed open* features near the downstream end of reach WD-5 and the Michener Drain. Repeated maintenance limits the geomorphic function and aquatic habitat of these features. The value of these features would primarily be based on potential connections and linkages with existing ecological features, such as a number of wetlands identified surrounding reach WD-5 (**Figure [illegible]**). Subsequent studies should focus on identifying these linkages and the functionality of the constructed drains as potential habitat corridors. There are a very limited number of features classified as *natural* throughout the watershed. These features should be prioritized for additional study should development proceed in these areas.



LEGEND

- Reach Break
- Watercourse [1]

NPCA Flowline [2]

- Natural
- Constructed - open
- Constructed - closed

Headwater Drainage Feature

Conservation Type

- Conservation
- Mitigation
- No Management

- Subject Lands (Owned by Elite Developments)
- Study Area

1 - Contains data sourced from Land Information Ontario (LIO)
2 - Contains data sourced from both Niagara Peninsula Conservation Authority (NPCA)

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PROJECT
Wignell Drain Subwatershed Study

TITLE
Fluvial Features

Palmer. PART OF SLR

REF. NO. 2007708-10-1

Figure 10

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6.2 Meander Belt Delineation

To support constraint delineation for the subwatershed Study Area, meander belt width corridors were delineated for the main watercourse branches. Based on limited access to the majority of the Study Area, the meander belt corridors were primarily delineated based on high-level desktop information. Meander belt corridors should be reviewed and refined as appropriate through subsequent studies, particularly for reaches that were not accessible during field assessments.

The meander belt is a designated corridor intended to contain natural meander migration tendencies based on historical planform alignments and potential future planform alignments. The meander belt is determined based on background information, historical data (aerial imagery), topographic mapping (LiDAR), and field observations of existing channel conditions. Empirical methods may be used when the channel planform has been historically altered and is not representative of natural channel geometry or processes.

The drainage features in the Study Area are managed as engineered, municipal drain features (i.e., dimensions and alignments are maintained through anthropogenic intervention to ensure adequate flow conveyance). Historical aerial imagery revealed that the drainage features have been straightened and maintained since at least the earliest available aerial photography (1934).

Empirical meander belt width equations rely on various channel parameters indicative of hydraulic capacity (drainage area, channel area, discharge, cross-section width) to determine an appropriate corridor width. For the Wignell Subwatershed cross-sectional dimensions are imposed and not reflective of channel processes. Heavily altered features typically rely on drainage areas or discharge as inputs for empirical equations and representation of the potential for erosion and channel migration. Due to the scale of the current study, reliable discharge data were not available on a reach-by-reach basis. Thus, meander belt corridors were derived based on drainage area (**Table 15**). The existing meander belt width was derived based on the NRCS (2007) equation. A 20% factor of safety was added (10% on either side) to establish the final meander belt width (**Table 16**).

Table 15: Empirical Meander Belt Width Equation

Source	**Equation**
NRCS (2007)	$120A_w^{0.43}$

Table 16: Meander Belt Width Results

Reach	**Drainage Area (ha)**	**Existing Meander Belt Width (m)**	**Factor of Safety (20%) (m)**	**Final Meander Belt Width (m)**
[illegible]	79	22	4.4	26
[illegible]	221	34	6.8	41
[illegible]	379	43	8.6	52
[illegible]	428	45	9.0	54

Re□□□	Dr□i□□ge □re□ □□□	□□i□i□g Me□□der □e□□ □ id□□ □□ □	F□□□□r □□□□□e□□ □□□□ □ □□ □	Fi□□□Me□□der □e□□ □ id□□ □□ □
□□□	447	46	9.2	55
□ D□□	289	38	7.6	46
□ D□□	310	39	8.0	48
□ D□□	498	48	9.6	58

6.3 Channel Morphology and Hydraulics – Reach PC-6

An erosion threshold analysis was completed for Reach PC-6 based on the detailed field data collected on July 18, 2023, to inform future stormwater management planning in the Wignell Drain Subwatershed. Detailed field data collection included measurements of bankfull cross-sections, longitudinal profiles, and visual inspections of the grain size distribution of alluvial bed material. The field data were analyzed to determine the average bankfull channel geometry (**□□□□e 1□**) and hydraulics (**□□□□e 18**). Bankfull discharge is estimated to be 1.04 m³/s based on channel geometry.

Reach PC-6, located in the Subject Lands west of the Snider Road allowance (**Figure 1□**). The surrounding land use transitions from active agricultural (PC-5) to natural meadow and woodland vegetation (PC-6). Riparian vegetation consisted of dense, tall grasses, which overhung the channel, but did not obscuring flow. Cattail stands were sporadically present in the channel through the reach. Bed material is primarily fine-grained, ranging from silt to coarse sands. Root strength from the riparian vegetation stabilizes bank material and reduces erosion potential. Shear stress during high flows is primarily concentrated on the finer bed material, resulting in a narrow, deep cross-section as indicated by the width-depth ratio (8.15).

Table 17: Reach PC-6 Averaged Bankfull Channel Dimensions

□□r□□ e□er	□□□ue
Width (m)	5.45
Average Depth (m)	0.67
Maximum Depth (m)	1.09
Width:Average Depth	8.15
Cross-sectional Area (m^2)	2.95

Table 18: Reach PC-6 Averaged Bankfull Channel Hydraulics

□□r□□ e□er	□□□ue
Energy Gradient (m/m)	0.0011
Discharge (m^3/s)	1.04
Average Velocity (m/s)	0.30
Froude Number	0.12
Average Shear Stress (N/m^2)	5.24

Erosion thresholds define a theoretical hydraulic condition at which sediment of specific size is entrained and transported by a watercourse. The threshold represents a depth, velocity, or discharge rate at which the material may be entrained based on the cross-sectional geometry. The erosion threshold does not indicate that erosion will occur if this flow is exceeded; it simply indicates the flow conditions at which sediment/bed material is likely to be mobilized.

The bed material within reach PC-6 is fine-grained and does not have a typical gravel-bed distribution, for which most sediment transport relations were developed. As a result, the threshold value is based on empirically-derived data for fine-grained and vegetation-controlled channels (Fischenich, 2001; **Table 19**).

Table 19: Reach PC-6 Permissible Shear and Velocity for Fine Gravels (from Fischenich, 2001)

Boundary Type	**Permissible Shear Stress (N/m²)**	**Permissible Velocity (m/s)**	**Citation**
Fine gravels	1.92	0.53	Chang, H.H. (1988); Data from Fischenich (2001).

Based on the field-measured cross-sections, the critical discharge (erosion threshold) required to produce the critical shear stress is 0.12 m^3/s, approximately 10% of the bankfull discharge (**Table 20**).

Table 20: Reach PC-6 Critical Hydraulic Conditions

Parameter	**Value**
Energy Gradient (m/m)	0.0011
Critical Shear Stress (N/m^2)	1.92
Critical Discharge (m^3/s)	0.12
Bankfull Discharge (m^3/s)	1.04

7. Hydrogeological Characterization

Monitoring well and mini-piezometer locations used to inform the hydrogeological characterization are shown on **Figure 11**, as discussed in Section 3 (Study Approach).

7.1 Physiography

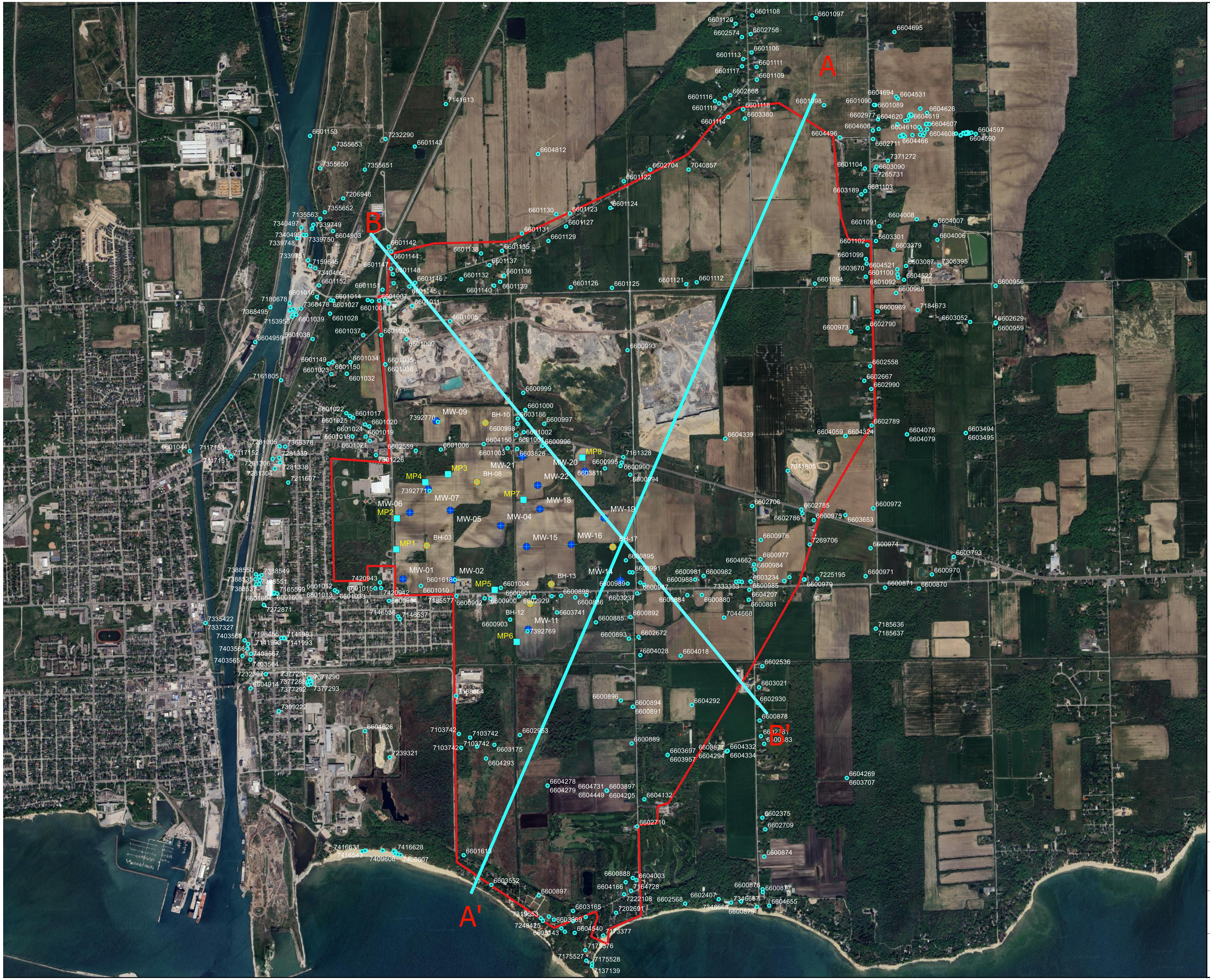
7.1.1 Climate Conditions

The Study Area is in a continental climate region with a warm, humid summer and a cold winter, as well as a wet spring, dry summer, and moderately wet autumn precipitation wise. The region is generally affected by warm, moist air masses from the south and cold, dry air masses from the north, and experiences a wide range of weather conditions throughout the course of an average year. The closest climate station is Port Colborne Station located 1.6 km west of the boundary of the Study Area. **Table 21** lists the average and daily values of major climate parameters collected at this station for the period between 1981 and 2010.

Table 21: Monthly Averaged Climate Data (1981 – 2010)

Average Value	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Daily Air T (°C)	-3.7	-2.9	0.8	7	13.2	18.7	21.9	21.3	17.4	11	5.5	-0.4
Rainfall (mm)	32.5	26.9	46.6	71.9	89.1	78.9	82.2	82.5	98	89.7	95.2	53.2
Snowfall (cm)	40.5	30.1	20.2	4.2	0.6	0	0	0	0	0.8	5.8	35.6
Precipitation (mm)	73.1	57	66.8	76.1	89.7	78.9	82.2	82.5	98	90.4	100.9	88.8
Extreme Daily Value	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Extreme Daily Rainfall (mm)	46.5	29.5	34.8	39	41	108.7	74	102	96	72.6	78.2	38.6
Extreme Daily Snowfall (cm)	35	12	32	17	0	0	0	0	0	20	7	15

It should be noted that the Lake Effect of the Great Lake System of Ontario can moderate air temperatures and snowfalls up to 5 to 10 km inland. The Study Area is on the north shore of Lake Erie, and as such, the weather in the Study Area can be affected by the Lake Effect significantly, which could result in slight moderation of air temperatures and higher than normal snowfalls in the early winter (as shown in **Table 21**).



Legend

- Study Area
- MECP Well Record
- NPCA Wells
- PGMN Well
- Exp Monitoring Well
- Exp Mini-Piezometer
- Exp Borehole

Cross Section

- A-A'
- B-B'

1 2 km

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

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Project
Wignell Drain Subwatershed Study

TITLE
Hydrogeological Investigation Plan

Palmer. PART OF SLR

REF. NO 2007708

Figure 11

[illegible]1[illegible] Geomorphology and Drainage

The Study Area is located in the Haldimand Clay Plain, which was deposited during the era of glacial Lake Warren (12,700 years before present) and lies between the Niagara Escarpment and Lake Erie (**Figure 1[illegible]**). The topography of the Haldimand Clay Plain is basically flat with streams meandering sluggishly across it.

The ground surface of the Study Area has elevations ranging from 194 mASL at the north end to 178 mASL at the south end of, which is a few meters above the average water level of Lake Erie. Natural drainage channels are not well developed and have been modified by channelization to facilitate farmland drainage (**Figure 1[illegible]**). Based on the results of remote sensing interpretation and regional information interpretation by Palmer, the Study Area is further divided into three geomorphological units:

- Bedrock Escarpment;
- Quarry; and
- Lake plain.

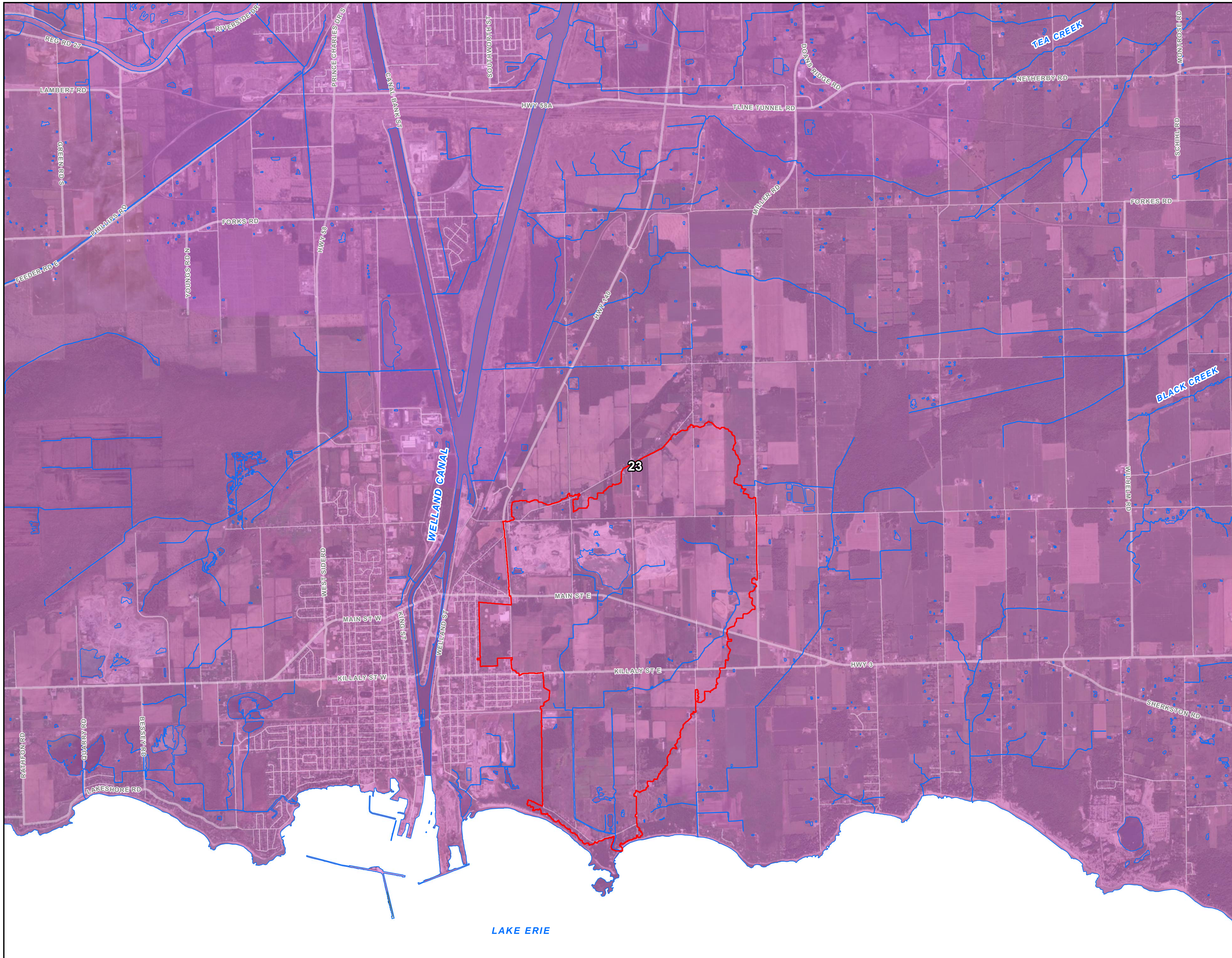
Table 22 list the major properties of the three geomorphological units of the Study Area, as defined by Palmer, while **Figure 1[illegible]** shows the demarcation of these geomorphological features. The Bedrock Escarpment is located on the north end of the Study Area and forms the north divide of the Wignell Drain subwatershed. This unit is characterized by shallow bedrock and apparent relief. Land use is primarily farmland, woodlands and residential. The large quarry within this area is operated by Port Colborne Quarries Inc. and consists of three pits (Pit 1, Pit 2, and Pit 3); however, an application for an extension to Pit 3 is ongoing. Geomorphologically, the quarry pits serve as catch basins for both surface water and groundwater. The Lake Plain unit covers a majority of the Study Area and is characterized by a relatively flat ground surface. Its major land use is farmlands and woodlands.

Table 22: Properties of Geomorphological Units

Unit	Elevation (mASL)	Area (ha)	Relief (m)	Gradient	Land Use
Bedrock Escarpment	183-194	148.18	9	0.8-1.2%	Farmlands, woodlands and residential
Quarry	165-187	206.83	12	-	Quarry operation
Lake Plain	178-184	954.59	6	0.3-0.6%	Farmlands and woodlands

The Study Area is part of the Northeast Lake Erie Shoreline watershed, which is a Tertiary Watershed based on the Ontario Watershed Boundaries (OWB) map. The Welland Canal is the major flow channel adjacent to the Study Area. It flows from Lake Erie to the south to Lake Ontario to the north and is controlled by locks to permit marine vessels to traverse the vertical difference in elevation between the two lakes.

The watercourses identified within the Study Area includes the Port Colborne Drain, the Wignell Drain, and the Michener Drain. Port Colborne Drain and Wignell Drain controls the majority of the subwatershed, while the Michener Drain controls southeast corner of the subwatershed. Both Wignell Drain and Michener Drain have a long history of channelization and alignment and contains NPCA regulated area of different widths along the drains.



KEY MAP

LEGEND

Watercourse[1]

Study Area

Physiographic Region[2]

23: Haldimand Clay Plain

1. LIO/MNRF
2. Chapman, L.J. and Putnam, D.F. 2007. Physiography of southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 228

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km

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

Scale: 1:50,000
Page Size: Tabloid (11 x 17 inches)

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NORTH

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CLIENT
Elite M.D. Developments

PROJECT
Welland S - Wignell SWS

TITLE
Physiography

Palmer™

REF. NO. 2007708-1-1

Figure 1

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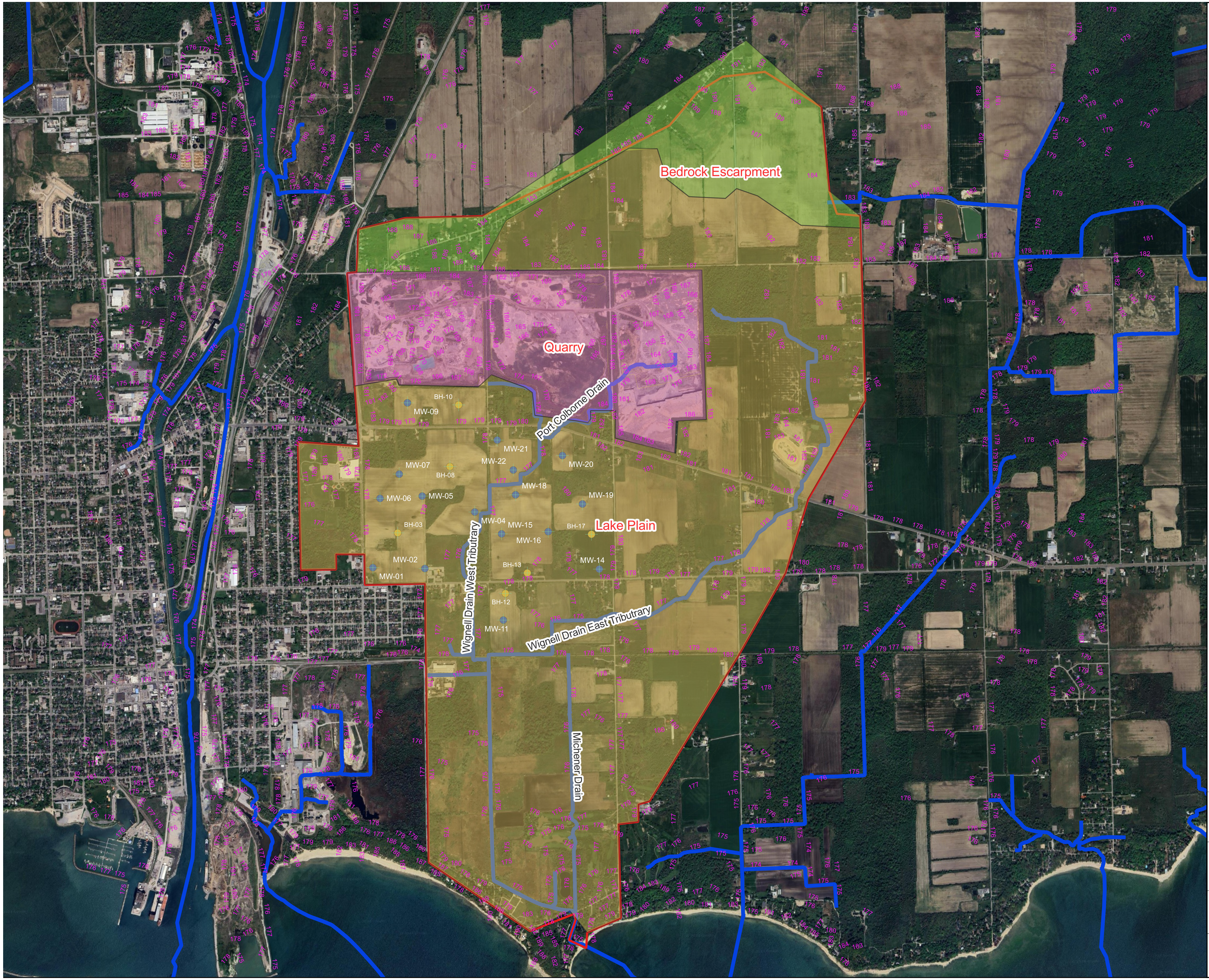


Legend

Study Area

Geomorphological Units

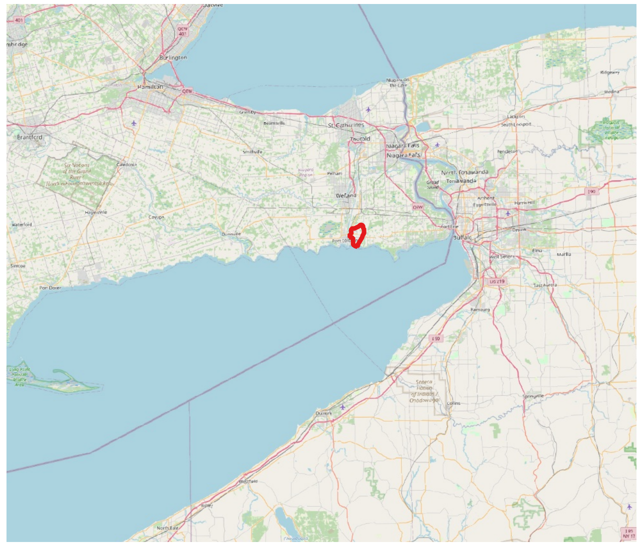
Lake Plain

Bedrock Escarpment

Quarry

Water Course

Topo Contours-1m



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North American Datum 1983
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Client
Odan/Detech and Elite Developments

Project
Wignell Drain Subwatershed Study

TITLE
Geomorphology, Topography and Drainage System

Palmer PART OF SLR

REF. NO 2007708

Figure 13

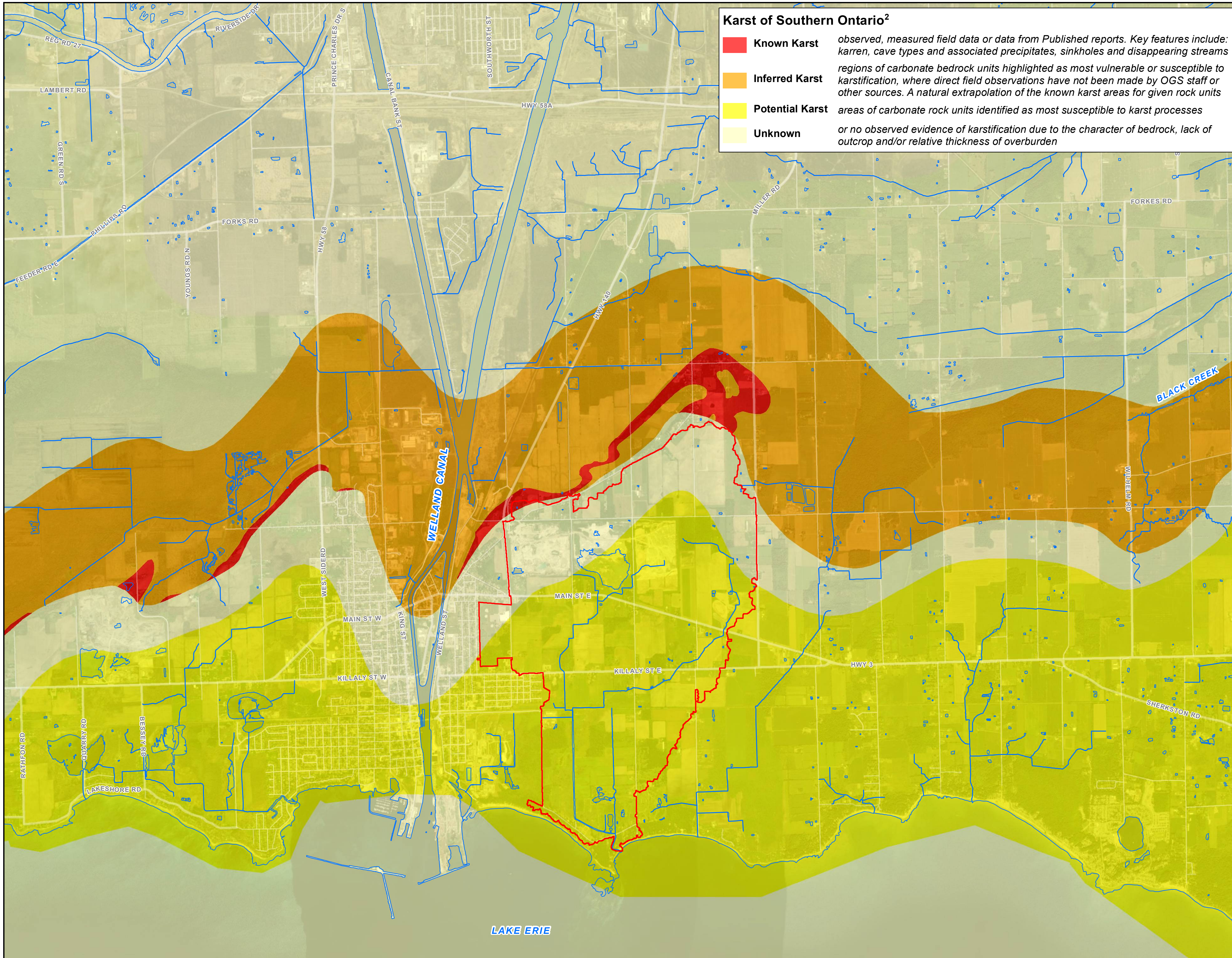
[illegible]1[illegible] Karstification

Karstification refers to the process where carbonate or other soluble rocks, either at surface or under a shallow overburden cover, are exposed to leeching and dissolution by acidic or aggressive atmospheric water to produce a series of landform features, or karst, including sinkholes, caves, natural bridges, sinking streams, dry valleys, karren, stalactites, stalagmites, and/or tufa. The Study Area is located in the Guelph-Smithville Karst Region based on the Karst of Southern Ontario and Manitoulin Island (OGS, 2008). Most of the Study Area was mapped by OGS as Potential Karst Area (**Figure 1[illegible]**). Only a small area in the northwest corner of the Study Area is in Known Karst area. The area between the Potential Karst Area and the Known Karst Area within the Study Area is the Unknown Karst Area. An area of Inferred Karst is located just north of the northern Study Area boundary. **Table 23** provides a summary of the characteristics of the three types of karst areas identified within the Study Area.

Table 23: Karst Classification

[illegible]	Formation	Lithology	Drift Cover	Karst Features	Area (ha)
Known Karst	Bertie	Dolostone; argillaceous, laminated, bituminous or burrowed	None	Unknown	13
Unknown Karst	Bois Blanc	Limestone, dolostone; cherty, argillaceous; local glauconitic sandstone	Yes	Unknown	358
Potential Karst	Onondaga	Limestone; variably cherty, fossiliferous, argillaceous, biohermal	Yes	Unknown	889

Site reconnaissance did not identify any surficial karst features. Karst investigation is beyond the scope of work for this subwatershed study. Site specific karst investigation is recommended for major development projects located in the Known and Potential Karst Areas.



KEY MAP

Watercourse[1]

Study Area

1. LIO/MNRF
2. Brunton, F.R. and Dodge, J.E.P (2008). Karst map of Southern Ontario, including Manitoulin Island; Ontario Geological Survey, Groundwater Resource Study 5

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km

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

Scale: 1:50,000
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CLIENT	Elite M.D. Developments
PROJECT	Welland S - Wignell SWS
TITLE	Karst

Palmer

REF. NO. 2007708-4-1

Figure 1

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7.2 Land Use and Natural Heritage

Based on image interpretation and site reconnaissance, major land use types within the Study Area include farmlands, quarry pits, golf courses, commercial properties, roads, and residential properties.

Based on the provincial dataset, image interpretation, site reconnaissance, and the ecological characterization of the study area as part of the SWS, the primary natural heritage features identified within the Study Area include wetlands, woodlands, and drainage channels. PSWs and other significant features within the Study Area are designated as part of a larger Natural Heritage System in the provincial natural heritage mapping. The types of wetlands as identified by Palmer's ELC for the Study Area include both marsh wetland and swamp wetland.

Table 24 summarises the major attributes of the land use units and natural heritage features.

Table 24: Attributes of Major Land Use Units and Natural Heritage Features

Land Use Unit	Area (m²)	Surface Gradient
Farmland	5,765,118	0.2% - 0.5%
Quarry Pits	1,755,411	0.5%
Golf Courses	289,625	0.6%
Wetland	896,041	0.4%
Woodland	986,341	0.5%
Residential	1,269,453	<0.3%
Grassland	977,369	0.4%
Commercial and Institutional	544,842	<0.3%
Roads	371,453	-

As mentioned above, three drains including the Port Colborne Drain, the Wignell Drain and the Michener Drain exist within the Study Area. Based on channel form, all three drains have been channelized and realigned in some capacity.

7.3 Geology and Stratigraphy

7.3.1 Geotectonic Setting

Geotectonically the Study Area is located in the north edge of the foreland basin of the Appalachian Fold Belt, south of the Algonquin Arch. Ultimately there are three large suites of geological formations underlain the study area including Quaternary overburden deposits, Paleozoic platform sedimentary formations, and Proterozoic basement gneiss formations, as shown in Table 25.

Table 25: Geotectonic Setting

Geological Age	Formation	Geotectonic Environment
Quaternary	Overburden	Glacial to glaciolacustrine
Paleozoic	Clastic to limestone	Foreland basin of Appalachian Orogen
Precambrian	Gneiss	Grenville Orogen

[illegible] Overburden Geology

Surficial geology as mapped by OGS (**Figure 1[illegible]**) includes four units within and surrounding the Study Area:

- Fine-textured glaciolacustrine deposits of massive to laminated silt and clay, minor sand, and gravel;
- Organic deposits of peat, muck, and marl;
- Coarse-textured glaciolacustrine deposits of sand, gravel, minor silt, and clay; and,
- Outcropped Paleozoic bedrock.

The first unit covers most of the Study Area and forms the major farmland soils. Organic deposits occur in the southwest corner of the Study Area and the sand and gravel deposits occur in the northeast corner.

Bedrock outcrops occur at the surface in a substantial part of the Study Area, and almost half of the bedrock outcrop area has been developed into quarry.

[illegible] Bedrock Geology

Bedrock within the Study Area was mapped by OGS (**Figure 1[illegible]**) to consist of the following three units underlying the overburden from south to north:

- Onondaga Formation (D2) – limestone; variably cherty, fossiliferous, argillaceous, biohermal;
- Bois Blanc Formation (D1) – limestone, dolostone; cherty, argillaceous; local glauconitic sandstone (Springvale Member); and,
- Bertie Formation (S3) – dolostone; argillaceous, laminated, bituminous or burrowed.

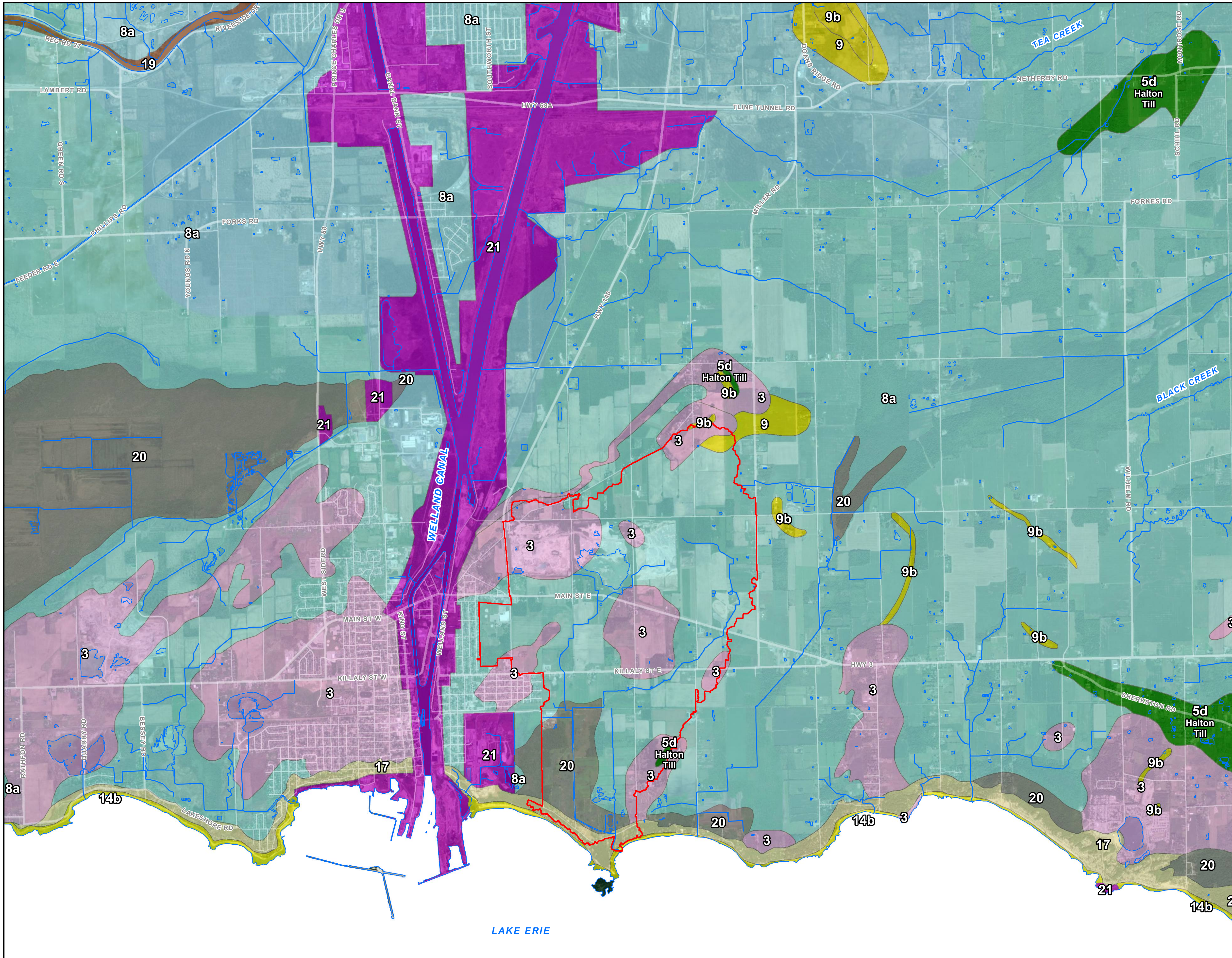
The whole Study Area is underlain by Onondaga Formation and Bois Blanc Formation, with only a small area in the northwest corner of the Study Area being underlain by Bertie Formation. The following details were based on *OGS Special Volume 4, Part 1 and Part 2* (C., Williams, Sutcliffe, & Thurston, 1991), and the occurrence of bedrock units in the Study Area.

Onondaga Formation occupies approximately 70% of the Study Area. This formation was deposited in the Middle Devonian Period (D2) in a reef forming environment. The lithology of the formation includes limestone, cherty to interbeds of chert, fossiliferous, locally argillaceous, biohermal, and has an average thickness of 30 m.

Bois Blanc Formation, underlying the Onondaga Formation, occupies the north part of the Study Area and is composed primarily of glauconitic cherty carbonate, known as Springvale Member, which was deposited in a shallow marine environment during the Early Devonian Period (D1) and has an average thickness of 3 m. The bottom of the Bois Blanc Formation is known to have paleokarst features.

Bertie Formation underlays the Bois Blanc Formation and outcrops along the northwest edge of the subwatershed. This formation was deposited during the Late Silurian Period (S3) in an intertidal to supertidal environment. The lithology consists of dark brown to buff microcrystalline dolostone with oolitic dolostone seams and is lightly fossiliferous. The thickness of the formation reaches 14 m.

Based on the orientation and distribution of the exposed strips of formations as shown in **Figure 1**, the Study Area is located in the core area of a syncline, which plunges gently to the south.



KEY MAP

Watercourse[1]

Study Area

Surficial Geology[2]

Phanerozoic / Cenozoic / Quaternary / Recent

- 21: Man-made deposits *(fill, sewage lagoon, landfill, urban development)*
- 20: Organic deposits *(peat, muck, marl)*
- 19: Modern alluvial deposits *(clay, silt, sand, gravel, may contain organic remains)*
- 17: Eolian deposits *(fine to very fine sand and silt)*
- 14b: Coarse-textured lacustrine *(Littoral deposits)*

Phanerozoic / Cenozoic / Quaternary / Pleistocene

- 9: Coarse-textured glaciolacustrine deposits *(sand, gravel, minor silt and clay)*
- 9b: Coarse-textured glaciolacustrine deposits *(Littoral deposits)*
- 8a: Fine-textured glaciolacustrine deposits *(Massive-well laminated)*
- 5d: Tilll *(Clay to silt-textured till [derived from glaciolacustrine deposits or shale])*

Phanerozoic / Paleozoic

- 3: Paleozoic bedrock

1. LIO/MNRF
2. Ontario Geological Survey 2010 (Mapped at 1:50,000). Surficial geology of southern Ontario; Ontario Geological Survey. Miscellaneous Release- Data 128 - Revised

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North American Datum 1983
Universal Transverse Mercator Projection Zone 17

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CLIENT
Elite M.D. Developments

PROJECT
Welland S - Wignell SWS

TITLE
Surficial Geology

Palmer

REF. NO. 2007708-2-1

Figure 1

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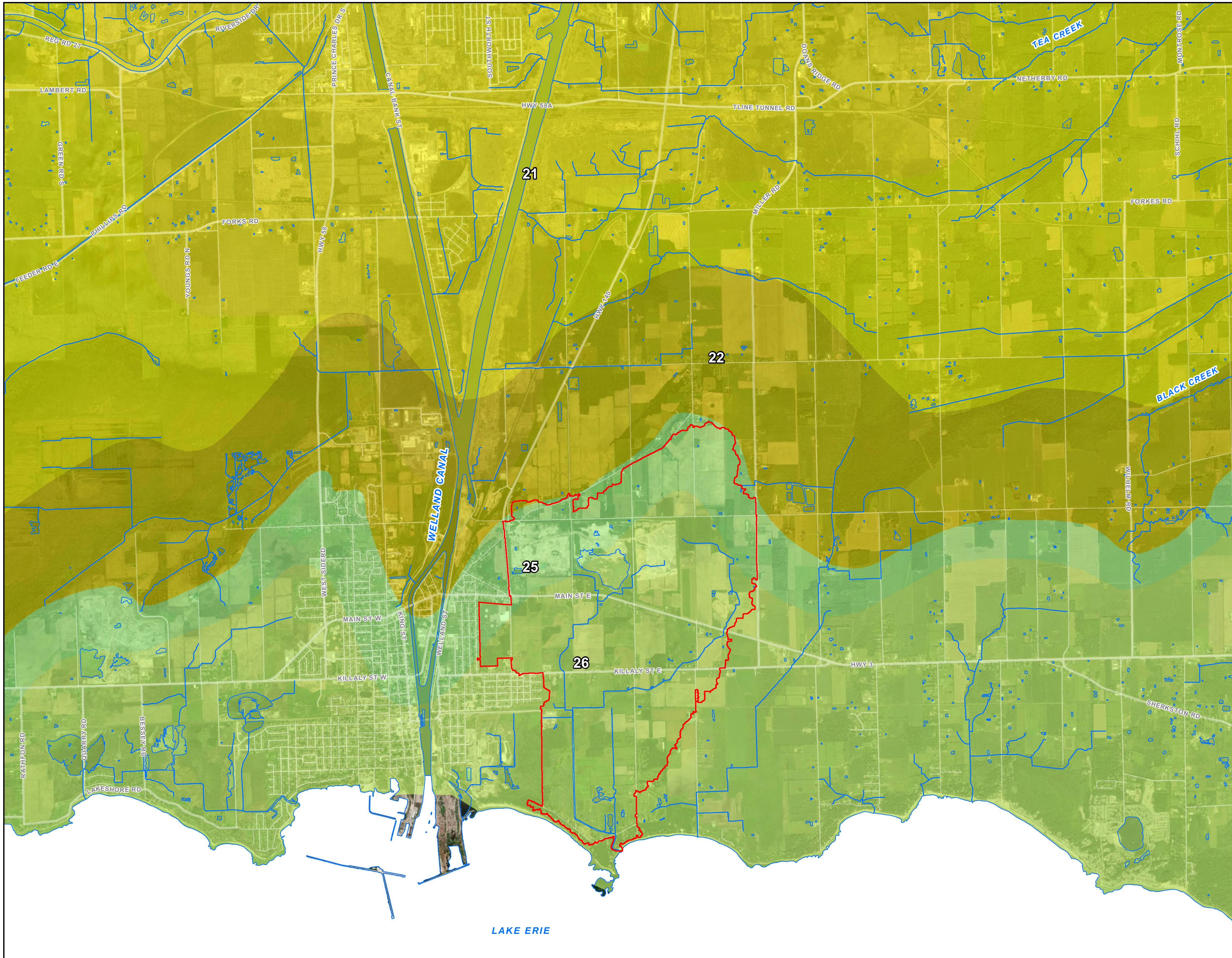

KEY MAP

Watercourse[1]

Study Area

Paleozoic Bedrock Geology[2]

Middle Devonian - Detroit River Group

26: Onondaga *(limestone; variably cherty, fossiliferous, argillaceous, biohermal)*

Lower Devonian

25: Bois Blanc *(limestone, dolostone; cherty, argillaceous; local glauconitic sandstone [Springvale Member])*

Upper Silurian

22: Bertie *(dolostone; argillaceous, laminated, bituminous or burrowed)*

21: Salina *(argillaceous dolostone, shale, gypsum, salt [at depth])*

1. LIO/MNRF
2. Armstrong, D.K. and Dodge, J.E.P. Paleozoic Geology Map of Southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 219

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km

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

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CLIENT
Elite M.D. Developments

PROJECT
Welland S - Wignell SWS

TITLE
Bedrock Geology

Palmer

REF. NO. 2007708-3-1

Figure 1

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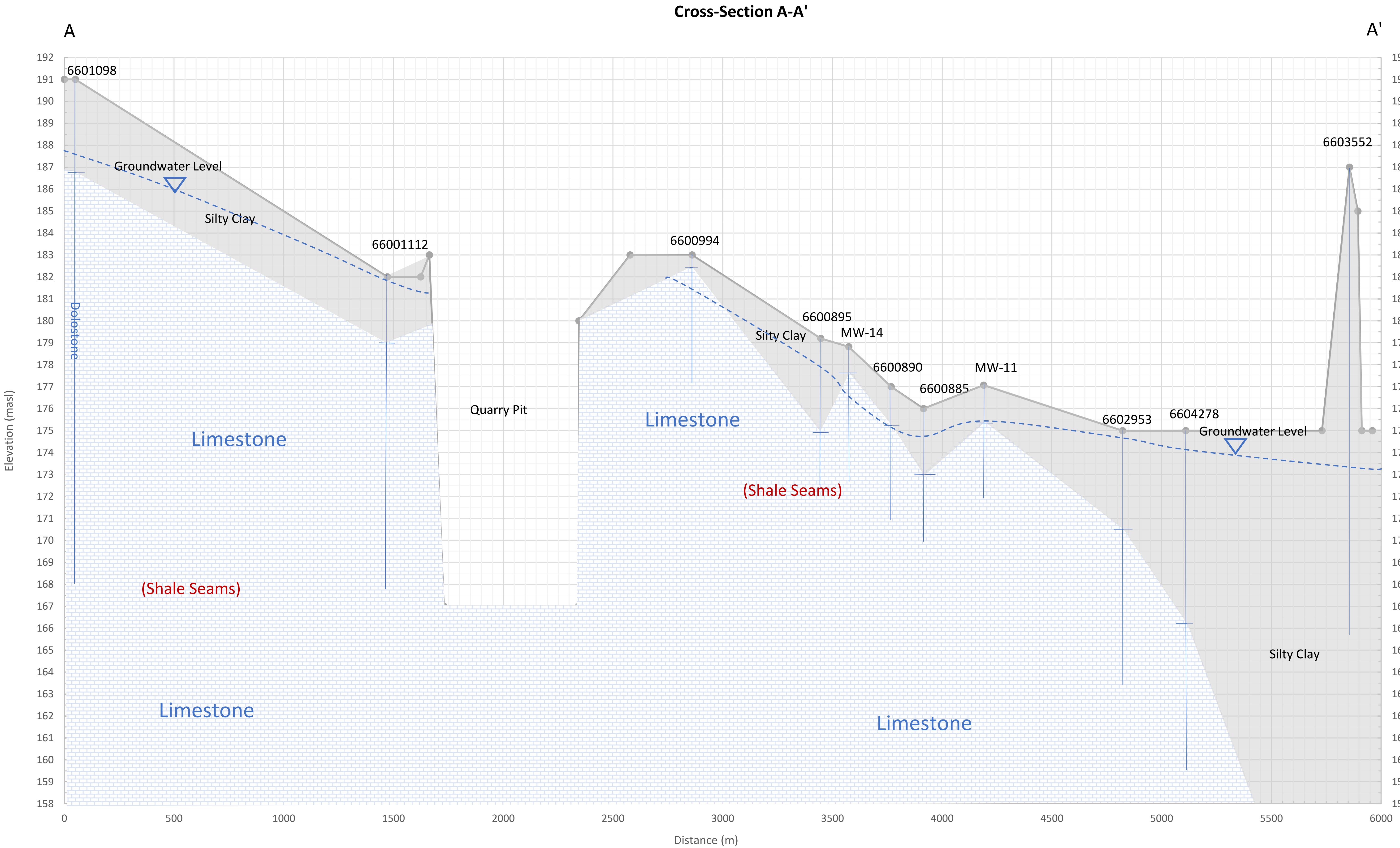
[illegible] Stratigraphy

Stratigraphy for the Study Area was delineated with MECP well records (**Appendix [illegible]**). Due to lack of details and accuracy, detailed classification and correlation of stratigraphic units for both overburden and bedrock is infeasible. To display patterns and trends of stratigraphy under the Study Area, two cross-sections cutting through the Study Area were created and are presented as in **Figure 1[illegible]**, and all information on the cross-sections are adapted from the MECP well records. Well logs of EXP (**Appendix [illegible]**) were also incorporated in the cross-sections. Based on the information from the MECP well records, EXP well logs, and observations during site reconnaissance, the stratigraphy within the Study Area is characterized as below:

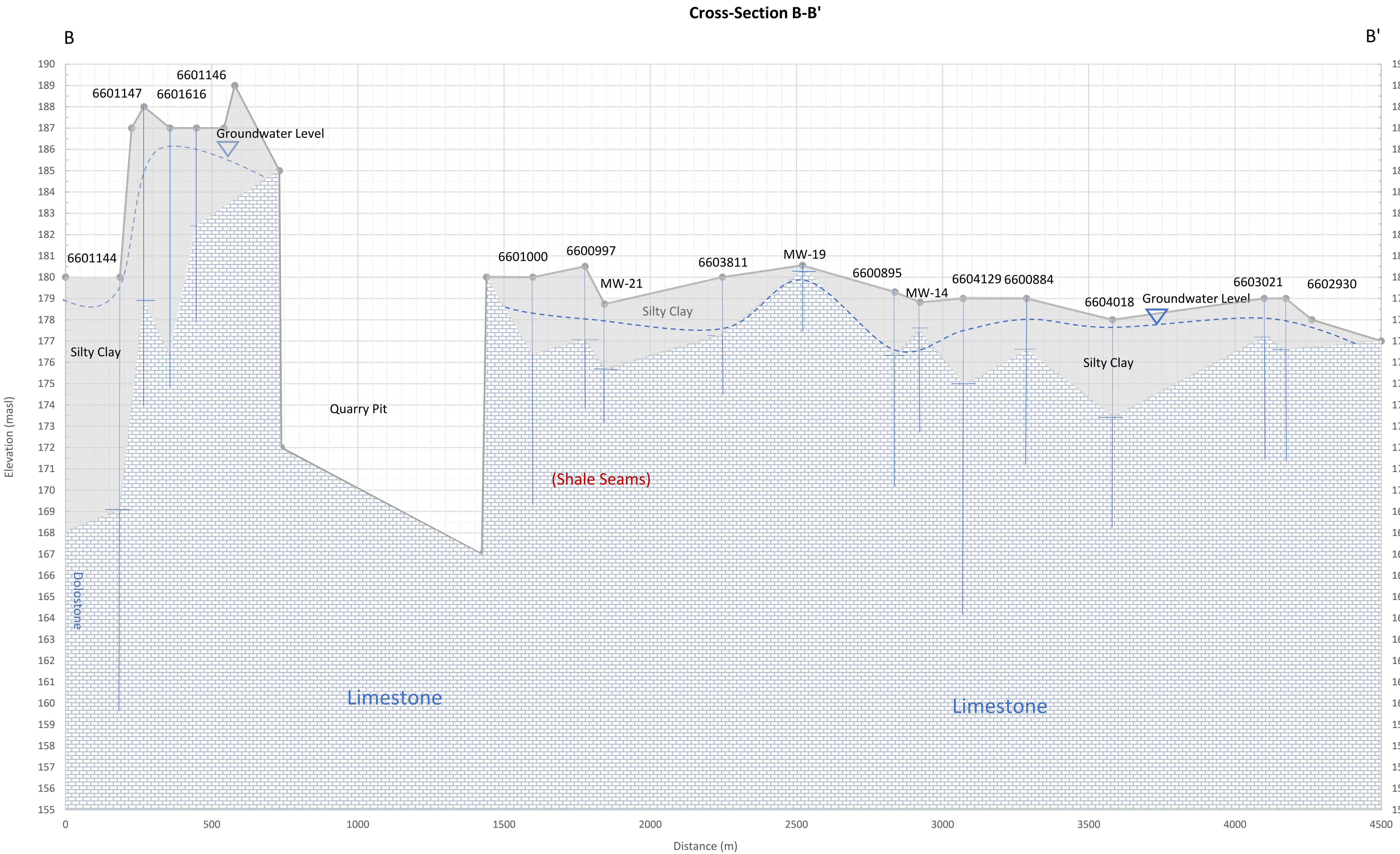
- The lithology of overburden deposits includes brown and blue clay, and black clayey silt with occasional sand lenses. The thickness of overburden deposits ranges from 0.5 to 30 m, and increases from north to south; and,
- The lithology of bedrock consists of microcrystalline limestone with interbedded chert and occasionally gray to black shale seams. Based on observations of lithology, structure, and weathering characteristics of the exposed bedrock, the bedrock in shallow depth has experienced a high degree of physical weathering, which disintegrates rock into pebbles. This may be due to the drastic difference in coefficient of thermal expansion (CTE) of limestone and chert. Rock pebbles are widespread on the bedrock outcrops within the Study Area. The pebbles accumulate on the ground surface and have formed the pebble beaches along the shoreline area of Lake Erie. The physical weathering may also facilitate water infiltration, water storage, and flow.



Palmer | PART OF SLR

Palmer_2007708_Hydrogeological Characterization

Figure 17a



Cross-Section B-B'
B
B'
6601144
6601147
6601616
6601146
Groundwater Level
Silty Clay
Dolostone
Quarry Pit
Limestone
6601000
6600997
MW-21
6603811
MW-19
6600895
MW-14
6604129
6600884
6604018
Groundwater Level
6603021
6602930
Silty Clay
(Shale Seams)
Silty Clay
Limestone
Elevation (masl)
Distance (m)

7.4 Groundwater Conditions

□□□1 □□ur□e □r□e□□i□□□□ □er □u□□□□e□er□ge □□□e□ □□□d Gr□u□d□ □er Re□□ur□e□

The Study Area is located within the Niagara Peninsula Source Protection Area (NPSPA) under the Source Protection Plan approved on October 1, 2014 (NPCA, 2014). The Source Protection Plan has designated the following 10 types of vulnerable areas:

- Wellhead Protection Area (WHPA)-Quality;
- Wellhead Protection Area E-(GUDI);
- Intake Protection Zone-Quality;
- Intake Protection Zone-Quantity;
- Issue Contributing Area;
- Significant Groundwater Recharge Area (SGRA);
- Highly Vulnerable Aquifer (HVA);
- Event Based Area;
- Wellhead Protection Area (WHPA) Q1-Quantity;
- Wellhead Protection Area Q2-Quantity.

Based on the provincial source protection mapping, the City of Port Colborne Official Plan, and the abovementioned Source Protection Plan, the following source protection designations were identified within the Study Area (Error! Reference source not found.):

- A Significant Groundwater Recharge Area (SGRA) with a score of 6 for the north, east, and south portions of the Study Area;
- A SGRA with a score of 4 for the east corner of the Study Area; and
- A Highly Vulnerable Aquifer (HVA) with a default score of 6 for entirety of the Study Area.

Based on information from the City of Port Colborne, municipal services do not currently extend to the undeveloped areas of the Study Area. Municipal drinking water supply for Port Colborne is provided by the Regional Municipality of Niagara through the Port Colborne Water Treatment plant. Wastewater is collected by the City's wastewater collection system and treated by the Region through its Seaway Wastewater Treatment Plant.

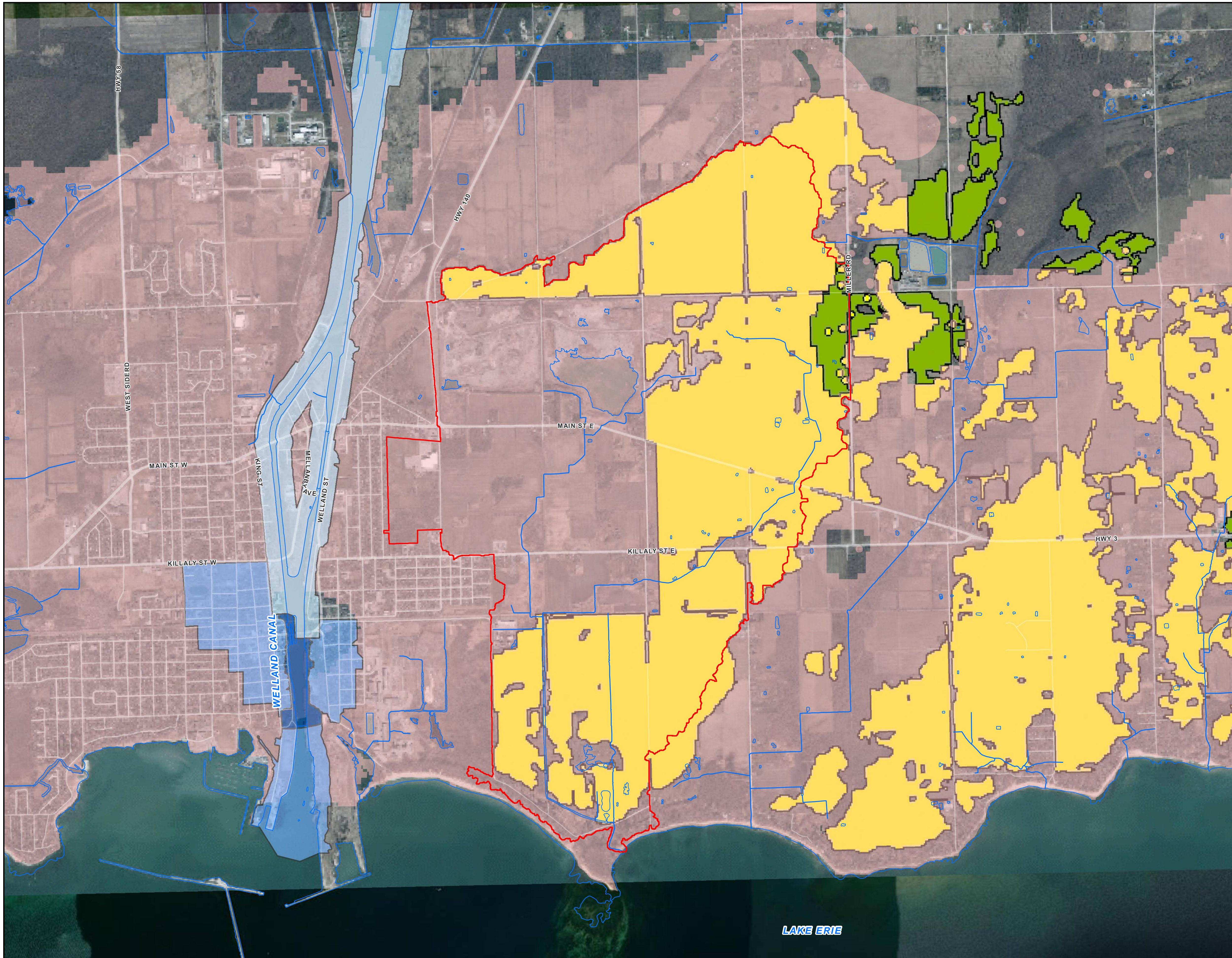
Stormwater management is a shared responsibility between the City of Port Colborne, the Regional Municipality of Niagara, and residents, businesses, and developers. Homeowners are responsible for stormwater on their properties. The City and Region operate and maintain the municipal stormwater drainage systems to collect, control, and transport stormwater from properties.

The results of the MECP well records inventory query are summarized in **□□□□e □□** and displayed in **Figure 11**. In total, 499 water well records were found within 1000 m of the Study Area. The water well records have been broken down to provide well use, water quality, and aquifer information. Most of the wells are domestic / livestock, have freshwater quality, and are completed in bedrock. A majority of the supply wells were built from 1967 to 2000, reflecting a long history of private water supply prior to the year 2000.

Table 26: Summary of MECP Well Records

□□□□□i□□i□□		Re□□rd □u□□er
□□er □□e	Domestic/Livestock	279
	Commercial	8
	Industrial	4
	Municipal/Public	7

Classification		Record Number
	Monitoring and Test Hole	57
	Irrigation	3
	Decommissioned	-
	Unknown/Not used/Other	138
Water Quality	Fresh	302
	Gas	1
	Mineral	4
	Sulfur	56
	Unknown/Untested	135
Aquifer	Overburden	125
	Bedrock	374
	Unknown	-



KEY MAP

Watercourse[1]

Study Area

Source Water Protection[2]

Intake Protection Zone 1

Intake Protection Zone 2

Intake Protection Zone 3

Highly Vulnerable Aquifer

Significant Groundwater Recharge Area

Score 6

Score 4

1. LIO/MNRF
2. NPCA & *Source Protection Information Atlas* MECP © King's Printer for Ontario 2023

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km

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

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CLIENT	Elite M.D. Developments
PROJECT	Welland S - Wignell SWS
TITLE	**Source Water Protection**
Palmer	REF. NO. 2007708-5-1
	Figure 18

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[illegible] Groundwater Levels, Flow Direction and Gradients

Based on MECP well record data and the EXP well logs ([illegible]), groundwater levels range from 0.3 to 24 m below ground surface (mbgs) and show a moderate degree of correlation in well depths. The moderate correlation degree shows that vertical groundwater gradients should be downward for most wells and upward for some wells.

As shown in **Figure 1[illegible]**, groundwater flow direction is affected by local topography, aquifer structure, and well structures; however, the dominant flow direction is from north to south.

[illegible] Groundwater Quality

MECP well records show that groundwater quality from most of the supply wells is fresh, but wells with gas, minerals, and sulfur were identified, indicating that groundwater quality becomes deteriorated locally due to natural reasons.

The groundwater quality monitoring for Buchner and Townline wells ([illegible]), as found in the Summary Reports of NPCA Water Quality Monitoring Program (NPCA, 2009) (NPCA, 2022a) identified only one exceedance (sodium) over Ontario Drinking Water Standards (ODWS). The groundwater quality monitoring for well W0000289 has not identified any exceedances over ODWS.

Groundwater sampling completed by EXP identified two exceedances over PWQO, including sulphide and cobalt, which are listed in [illegible]. The exceedance for sulphide is in line with the regional pattern, as reflected in MECP well records. The exceedance for cobalt may be caused by localized mineralization of groundwater in carbonate rock or due to sample contamination.

Table 27: Exceedances Over PWQO (EXP)

Parameter	Unit	[illegible]	M[illegible]	M[illegible]1
Sulphide	mg/L	0.002	0.037	0.33
[illegible]	ug/L	0.9	2.3	1.6
Dissolved [illegible]	ug/L	0.9	2.3	<0.5

[illegible] Groundwater Recharge

Groundwater recharge is a hydrologic process in which water (i.e., rain, melt snow, or other surface water) moves downward from ground surface to groundwater. The three steps in this process include:

- Infiltration – Rain or melted snow migrate through shallow zones (fertile soil zone, root zone, evaporation zone, burrow zone, etc.) into unsaturated zones. This is accompanied with a series of physical, chemical, and biological processes in shallow zones such as dissolution, precipitation, redox reactions, and evapotranspiration;
- Percolation – Infiltrating water migrates through the unsaturated zone, accompanied with relatively simple physical and chemical processes; and,
- Percolating water reaches saturated zone joining the groundwater system.

Groundwater recharge is divided into the following six types based on the recharge mechanisms and tempo-spatial characteristics in Southern Ontario:

1. Direct or diffuse recharge (areal) – water added to groundwater after satisfying soil moisture deficit and evapotranspiration by direct infiltration of precipitation through the unsaturated zone. Direct recharge is impulsive following the subdued pattern of precipitation and accounts for a majority of groundwater reserves;
2. Indirect recharge (localized) – recharge from surface water features such as stream, wetlands, and lakes. Indirect recharge is continuous. This may result in the drying up of reaches in a stream, wetlands, and lakes when groundwater levels are lower than the water stages;
3. Depression focused recharge (localized or areal) – hummocky area recharge in glaciated regions and mountain front recharge (MFR) in arid region. This type of recharge is controlled by landforms. It can be intermittent or continuous depending on the supply of water sources;
4. Pathway recharge/preferential recharge (localized) – recharge through preferential flow paths (faults, joints, solution voids, cracks, root hole, burrow holes, geostrata boundaries, and even man-made structures);
5. Incidental recharge (localized or areal) – recharge that results from artificial structures and activities that have prolonged water flow and storage, such as leakage from reservoirs, canals, sewers, stormwater ponds, as well as quarries and pits and irrigation facilities. This type of recharge can be intermittent or continuous, and can be localized or areal; and,
6. Recharge from neighbouring aquifer – recharge across aquitard from neighbouring aquifers above or under the subject aquifer.

Based on the conditions of the Study Area, the overburden thickness ranges from 0 to 30 m, with most of the Study Area having overburden thickness of greater than 1.5 m. Therefore, the groundwater recharge within the Study Area will go through all the steps as presented above.

The natural drainage system within the Study Area is not well developed, and most of the watercourses had been channelized to facilitate agricultural drainage. Thus, direct or diffuse recharge occurs in a majority of the Study Area. Indirect recharge occurs mostly within wetland areas.

The rate of groundwater recharge will be estimated through a water balance assessment, which is provided in Section 7.5 below.

Groundwater Discharge

Groundwater discharge is a hydrological process in which groundwater from aquifers flow out of the feature to become surface water. Groundwater discharge can occur diffusely across a landscape, such as when deep rooted vegetation relies on groundwater, and can also occur in concentrated areas where the ground surface cuts through aquifer. In general groundwater discharge is referred to as the discharge along concentrated areas, and is classified into natural and induced groundwater:

- Natural groundwater discharge:
  - Stream discharge;
  - Springs and wet area;
  - Depression discharge;
  - Lake discharge.

- Induced groundwater discharge:
  - Basement flooding;

- Infiltration into sewer system;
- Passive dewatering;
- Supply wells;
- Flowing wells.

Site reconnaissance and background review of the Study Area did not identify natural groundwater discharge features such as springs, wet areas along streams, and low lying areas. Stream flow was observed within the Study Area; however, further studies would be needed in these areas to determine if the flow was baseflow derived from groundwater discharge. Based on terrain analysis, the potential places of groundwater discharge within the Study Area include:

- Streams or drainage channels – especially in southerly reaches of the Study Area as groundwater levels become shallower downstream, as shown in the cross-sections (**Figure 1[illegible]**);
- Wetland – the wetland may be supported partly by groundwater discharge, especially for the wetland located in southerly reaches of the Study Area;
- Lake Erie – as the final sink for both surface water and groundwater in the Lake Erie North Shore watershed, most of the groundwater discharge should occur along the shoreline area of the lake. The water edge of Lake Erie is at about 174.5 mASL. This elevation corresponds to the elevation of the predominant aquifer, as shown by the MECP well records of the supply wells (**Figure 1[illegible]**). Consequently, a groundwater discharge zone is anticipated along the shoreline of Lake Erie.

Post-development, induced groundwater recharge such as infiltration into sewer systems and passive dewatering is anticipated.

7.5 Water Balance Analysis

Water balance analysis for the pre-development condition, as part of the hydrogeological characterization, was conducted to fulfill several purposes including providing a baseline condition of water balance to assess the impact of the future development, quantifying groundwater recharge rates, addressing concerns from agencies regarding stormwater management, and providing inputs to stormwater management design. The water balance assessment was conducted in general accordance with the *Hydrogeological Assessment Submissions, Conservation Authority Guidelines to Support Development Applications* (Conservation Authorities Geoscience, 2013) and the *Stormwater Management Planning and Design Manual* (Ministry of the Environment, Conservation and Parks, 2003) and consists of the following steps:

- Water balance unit delineation and infiltration factor determination for pre-development scenario;
- Water surplus determination; and,
- Pre-development water balance analysis.

7.5.1 Water Balance Unit Delineation and Infiltration Factor Determination

A Water Balance Unit (WBU) is defined as a land unit with uniform land cover, soil type, and ground surface slope gradient (surface gradient), and has distinctive hydrological properties in comparison to the surrounding land units. A WBU was delineated for the Study Area through three steps of GIS classification and GIS area measurement. The three steps of classification include land use and natural coverage classification, surficial/overburden soil classification, and surface gradient classification. **[illegible]** summarizes the major attributes of the land use units and natural heritage feature, while **Table 28** summarizes the details of each type of WBU. **Figure 1**[illegible] shows the distribution of WBUs.

Table 28: Details of Water Balance Units

WBU	Land Cover	Surficial Geology	Surface Gradient	Area (m²)	Infiltration Factor	Impervious Factor
Farmland-clay	Farmland	Clay	0.4%	5760179	0.5	0
Farmland-sand	Farmland	Sand	0.4%	4939	0.7	0
Wetland-clay	Wetland	Clay	0.4%	641300	0.5	0
Wetland-org	Wetland	Organic soil	0.4%	254741	0.6	0
Woodland-clay	Woodland	Clay	0.5%	830191	0.6	0
Woodland-org	Woodland	Organic soil	0.5%	116172	0.7	0
Woodland-sand	Woodland	Sand	0.5%	39978	0.8	0
Grassland-clay	Grassland	Clay	0.4%	392321	0.5	0
Grassland-org	Grassland	Organic soil	0.4%	585048	0.6	0
Golf Courses-clay	Golf Courses	Clay	0.6%	289625	0.6	0
Residential-clay	Residential	Clay	<0.3%	1148306	0.6	0.2
Residential-sand	Residential	Sand	<0.3%	121147	0.7	0.2
Commercial-clay	Commercial	Clay	<0.3%	508907	0.5	0.4
Commercial-sand	Commercial	sand	<0.3%	35917	0.7	0.4
Industrial-clay	Industrial	Clay	<0.3%	31423	0.6	0.9
Industrial-org	Industrial	Organic soil	<0.3%	23363	0.7	0.9
Quarry Pits	Quarry Pits	Bedrock	0.5%	1755411	0.3	0.95
Roads-paved	Roads	-	<0.5%	266516	0.3*	0.5
Roads-gravel	Road	-	<0.5%	104937	0.3*	0

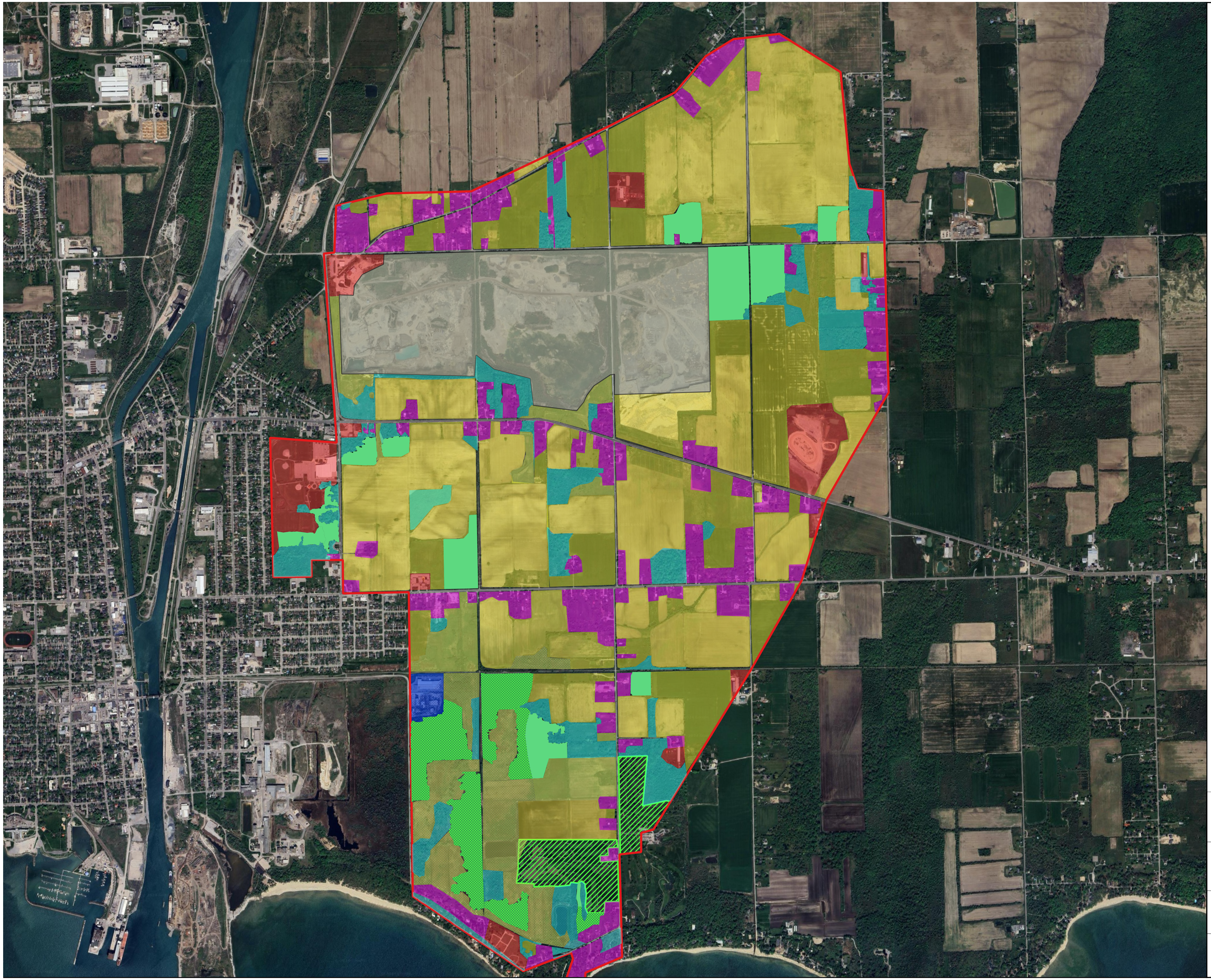
***Applied to Roads**

It should be noted that many of the areas that were mapped as bedrock have been developed into farmland, indicating the overburden soil has a thickness of over 1 m, as 1 m of overburden soil is considered to be the minimum amount required for agricultural purposes. For the purposes of the water balance analysis, where the OGS has mapped bedrock at surface but was confirmed to have overburden soils for agricultural purposes, it is reasonable to treat these mapped bedrock areas as areas covered with the type of soil that surrounds the mapped bedrock areas.

The roads within the Study Area include paved roads and gravel roads. Drainage corridors were not modeled separately and were combined with adjacent WBUs as most of these corridors are narrow and merged well with neighbouring land uses.

Infiltration factors for each land use unit was determined based on the scoring table presented in the Stormwater Management Planning and Design Manual (Ministry of the Environment, Conservation and

Parks, 2003) and in the MECP Hydrogeological Technical Information Requirements for Land Development Applications (Ministry of Environment and Energy, 1995). Impervious factors were based on empirical values that are accepted in Ontario.



Legend

- Study Area

Farmland

- Farmland-clay
- Farmland-sand

Commercial/Institutional

- Commercial-clay
- Commercial-sand
- Golf Course-clay

Grass Area

- Grassland-clay
- Grassland-org
- Quarry Pits

Residential

- Residential-clay
- Residential-sand

Wetland

- Wetland-clay
- Wetland-org

WoodLand

- Woodland-clay
- Woodland-org
- Woodland-sand

Industrial

- Industrial-clay
- Industrial-org

0.9 1.8 km

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

Scale: 1:22000
Page Size: Tabloid (11 x 17 inches)

Drawn: FL
Checked: NS

Date: April 2024

Source Notes:
Basemap: Google satellite imagery (2020)
Contains information licensed under the Open Government Licence - Ontario

Client
Odan/Detech and Elite Developments

Project
Wignell Drain Subwatershed Study

TITLE
Water Balance Units

Palmer PART OF SLR

REF. NO 2007708

Figure 19

[illegible] Water Surplus Determination

Water surplus for pervious vegetated areas is estimated with the Thornthwaite and Mather water balance method (Thornthwaite, 1957). This method is an accounting procedure that is based on the reasonable principle to quantify components of the hydrologic cycle, as expressed in the following equation:

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

P= Precipitation (mm/year)
ET= Evapotranspiration (mm/year)
R= Runoff (mm/year)
I= Infiltration (mm/year)
ΔS= Change in groundwater storage (mm/year)

And where:
R+I=Water surplus (mm/year)

Palmer developed an in-house spreadsheet program to execute the Thornthwaite and Mather water balance analysis. The input data includes:

- Long term (30 years) monthly average precipitation and temperatures, collected from the closest climate station (Port Colborne Station) between 1981 and 2010 (Table 11);
- Degrees of altitude = 42.87 to 42.92º; and,
- Soil moisture storage capacity for major WBUs within the Study Area:
  - Farmland-clay = 100 mm;
  - Farmland-sand = 50 mm;
  - Wetland-clay = 250 mm;
  - Wetland-org = 250 mm;
  - Woodland-clay = 250 mm;
  - Woodland-org = 300 mm;
  - Woodland-sand = 150 mm;
  - Grassland-clay = 100 mm;
  - Grassland-org = 200 mm;
  - Golf Courses-clay = 125 mm;
  - Residential-clay = 100 mm;
  - Residential-sand = 50 mm;
  - Commercial-clay = 100 mm;
  - Commercial-sand = 50 mm;
  - Industrial-clay = 100 mm;
  - Industrial-org = 150 mm
  - Roads = 125 mm.

Table [illegible] summarizes the average water surplus for each WBU every month of the year.

Table 29: Water Surplus (mm/year) for Each Water Balance Unit

□ □□	□□□	Fe□	M□r	□□r	M□□	□u□	□u□	□ug	□e□	□□□	□□□	De□	□u□
Farmland-clay	73.1	57.0	64.5	43.8	13.3	-16.0	-7.0	4.0	11.1	44.1	83.4	88.8	460.0
Farmland-sand	73.1	57.0	64.5	43.8	13.3	-6.0	-1.0	1.0	11.1	44.1	83.4	88.8	473.0
Wetland-clay	73.1	57.0	64.5	43.8	13.3	-17.0	-16.0	9.0	11.1	44.1	83.4	88.8	455.0
Wetland-org	73.1	57.0	64.5	43.8	13.3	-17.0	-16.0	9.0	11.1	44.1	83.4	88.8	455.0
Woodland-clay	73.1	57.0	64.5	43.8	13.3	-27.0	-16.0	9.0	11.1	44.1	83.4	88.8	445.0
Woodland-org	73.1	57.0	64.5	43.8	13.3	-29.0	-17.0	10.0	11.1	44.1	83.4	88.8	443.0
Woodland-sand	73.1	57.0	64.5	43.8	13.3	-21.0	-11.0	6.0	11.1	44.1	83.4	88.8	453.0
Grassland-clay	73.1	57.0	64.5	43.8	13.3	-16.0	-7.0	4.0	11.1	44.1	83.4	88.8	460.0
Grassland-org	73.1	57.0	64.5	43.8	13.3	-25.0	-14.0	8.0	11.1	44.1	83.4	88.8	448.0
Golf Courses-clay	73.1	57.0	64.5	43.8	13.3	-18.0	-10.0	5.0	11.1	44.1	83.4	88.8	456.0
Residential-clay	73.1	57.0	64.5	43.8	13.3	-16.0	-7.0	4.0	11.1	44.1	83.4	88.8	460.0
Residential-sand	73.1	57.0	64.5	43.8	13.3	-6.0	-1.0	1.0	11.1	44.1	83.4	88.8	473.0
Commercial-clay	73.1	57.0	64.5	43.8	13.3	-16.0	-7.0	4.0	11.1	44.1	83.4	88.8	460.0
Commercial-sand	73.1	57.0	64.5	43.8	13.3	-6.0	-1.0	1.0	11.1	44.1	83.4	88.8	473.0
Industrial-clay	73.1	57.0	64.5	43.8	13.3	-16.0	-7.0	4.0	11.1	44.1	83.4	88.8	460.0
Industrial-org	73.1	57.0	64.5	43.8	13.3	-21.0	-11.0	6.0	11.1	44.1	83.4	88.8	453.0
Roads	73.1	57.0	64.5	43.8	13.3	-18.0	-10.0	5.0	11.1	44.1	83.4	88.8	456.0

Water surplus for impervious areas (paved roads, industrial areas, and quarry pits) was calculated based on the assumption that 10% of total precipitation will evaporate off impervious surfaces (acceptable range is 10% to 20%). The total precipitation, based on **□□□□e □11□** is 984.4 mm/year. Consequently, the water surplus for impervious areas is 886 mm/year.

Quarry pits have certain levels of infiltration owing to fractures and cracks. The water surplus for the pervious parts of the quarry pits is assumed to be 500 mm/year, which is greater than the water surplus in vegetated area as no transpiration takes place on the quarry floor.

Wetlands are assumed to receive surface water infiltration or groundwater recharge for the purpose of water balance analysis. The surface water and groundwater interaction in the wetland is currently unknown and should be delineated through monitoring and future studies, as recommended in Section 10.3 below.

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The pre-development water balance, or water balance for the current conditions, was calculated based the results of the WBU delineation and water surplus analysis. **□□□□e □□** presents the water balance results for the Study Area, which shows that the Study Area currently receives an infiltration quantity of 2,551,185 m^3/year and generate a runoff quantity of 4,353,571 m^3/year, corresponding to 198 mm/year in infiltration and 337 mm/year in runoff.

Table 30: Pre-Development Water Balance Analysis Results

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Farmland-clay	576.02	1,324,841	1,324,841	230	230
Farmland-sand	0.49	701	1,635	142	331
Wetland-clay	64.13	145,896	145,896	228	228
Wetland-org	25.47	46,363	69,544	182	273
Woodland-clay	83.02	147,774	221,661	178	267
Woodland-org	11.62	15,439	36,025	133	310
Woodland-sand	4.00	3,622	14,488	91	362
Grassland-clay	39.23	90,234	90,234	230	230
Grassland-org	58.50	104,841	157,261	179	269
Golf Courses-clay	28.96	52,828	79,241	182	274
Residential-clay	114.83	372,510	253,546	324	221
Residential-sand	12.11	35,220	32,089	291	265
Commercial-clay	50.89	250,586	70,229	492	138
Commercial-sand	3.59	15,787	7,135	440	199
Industrial-clay	3.14	25,635	867	816	28
Industrial-org	2.34	18,947	741	811	32
Quarry Pits	175.54	1,508,249	13,166	859	8
Roads-paved	26.65	160,603	18,230	603	68
Roads-gravel	10.49	33,496	14,355	319	137
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]				[illegible]	[illegible]

8. Floodplain Analysis

8.1 Modelling Results

Flood Scenario (Peak Flows)

Table 31 provides a summary of the storage volumes required in Stormwater Management Ponds (SWPs) to control the 100-year storm volumes to pre-development levels within the Subject Lands.

Table 31: Required Storage Volumes: Subject Lands - Developed

Pond ID	[illegible] Contributing Area (ha)	100-Year Storage Required (m³)	100-Year HGL in Pond (m)	100-Year Storage Provided [illegible] depth (m³)	[illegible] Elevation (m)	Pond Freeboard (m)
Pond A	51.83	24,908	179.37	32,453	179.78	0.41
Pond B	23.33	13,777	178.83	25,792	179.70	0.87
Pond C	31.35	17,978	179.29	22,161	179.60	0.31
Pond D	33.85	20,467	178.52	25,508	178.85	0.33
Pond E	11.83	7,785	178.63	13,383	179.30	0.67
Pond F	8.00	5,596	179.24	8,726	179.80	0.56

Table 32 provides a comparison of peak outflows for the ponds (existing target flows vs. developed target flows). Note, existing target flows have been inferred from the XPSWMM existing model, while the developed target flows have been inferred from the XPSWMM post model results for the ponds.

Table 32: Comparison of Pre-Development and Developed Site Pond Flows

Storm Event	Storm Type	Peak Flow Rate (m³/s)											
		Pond A		Pond B		Pond C		Pond D		Pond E		Pond F	
		Existing [illegible]	Developed	Existing [illegible]	Developed	Existing [illegible]	Developed	Existing [illegible]	Developed	Existing [illegible]	Developed	Existing [illegible]	Developed
2 Year	24Hr SCS	0.113	0.070	0.112	0.070	0.151	0.122	0.163	0.112	0.057	0.031	0.039	0.000
5 Year	24Hr SCS	0.240	0.197	0.214	0.099	0.288	0.298	0.311	0.151	0.109	0.090	0.074	0.003
10 Year	24Hr SCS	0.361	0.372	0.300	0.129	0.404	0.412	0.436	0.188	0.152	0.117	0.103	0.029
25 Year	24Hr SCS	0.555	0.605	0.430	0.198	0.579	0.541	0.625	0.334	0.218	0.148	0.148	0.063
50 Year	24Hr SCS	0.727	0.739	0.542	0.252	0.728	0.623	0.786	0.460	0.275	0.167	0.186	0.088
100 Year	24Hr SCS	0.921	0.851	0.584	0.290	0.784	0.686	0.847	0.562	0.296	0.185	0.200	0.110
100 Year	12Hr AES	0.862	0.879	0.487	0.304	0.654	0.658	0.706	0.578	0.247	0.184	0.167	0.117

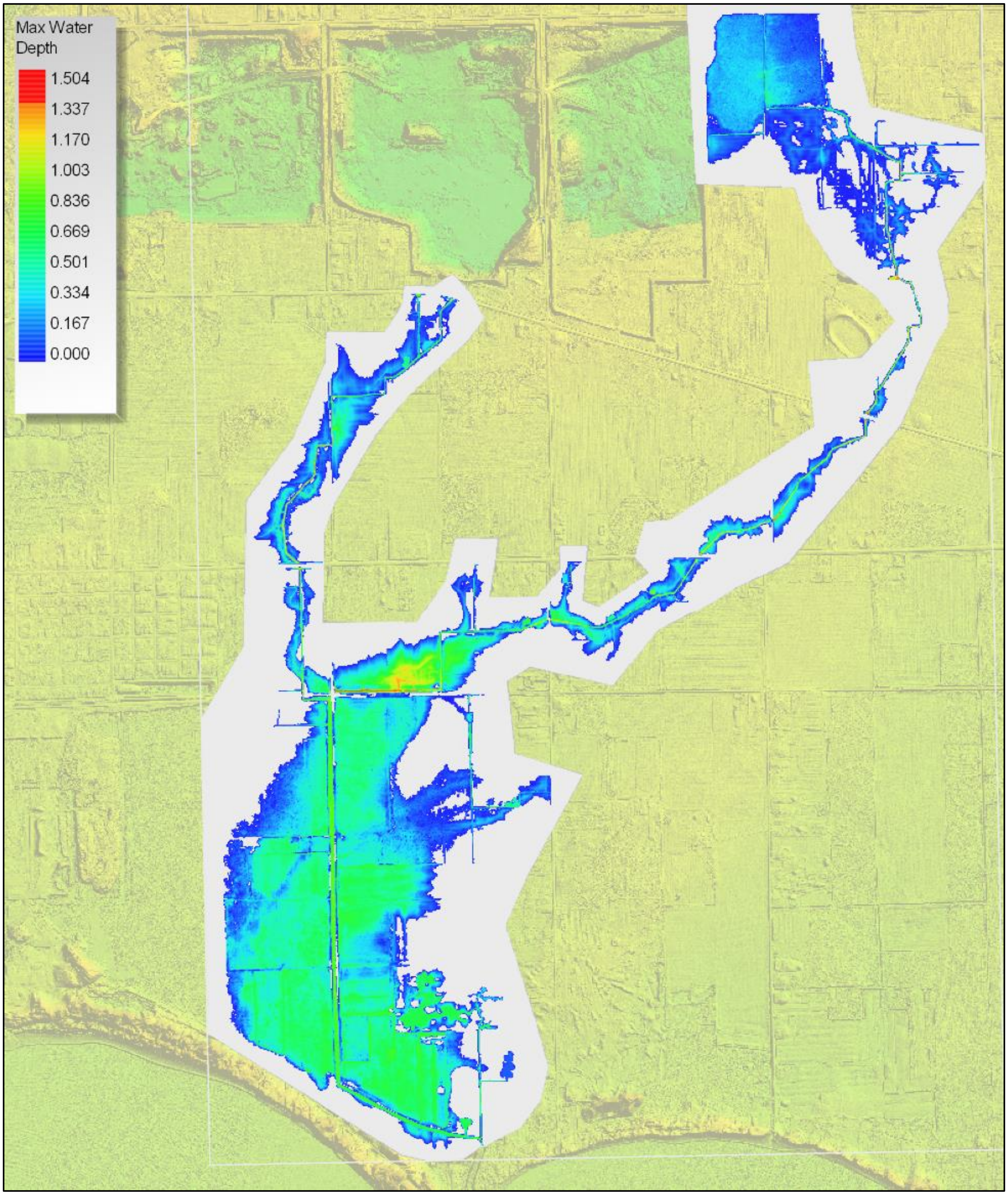
8□1□1 □□e□□ri□ 1 □ □

Gr□□□i□□ □ □1□ are from the *Functional Servicing & Stormwater Management Report* (The Odan/Detech Group Inc., 2023), which depict the modeling and mapping for Scenario 1 – Existing Undeveloped (base). **Gr□□□i□□ 1□□□□** are from the *Functional Servicing & Stormwater Management Report* (The Odan/Detech Group Inc., 2023), which depict the modeling and mapping for Scenario 2 – Subject Lands Developed.

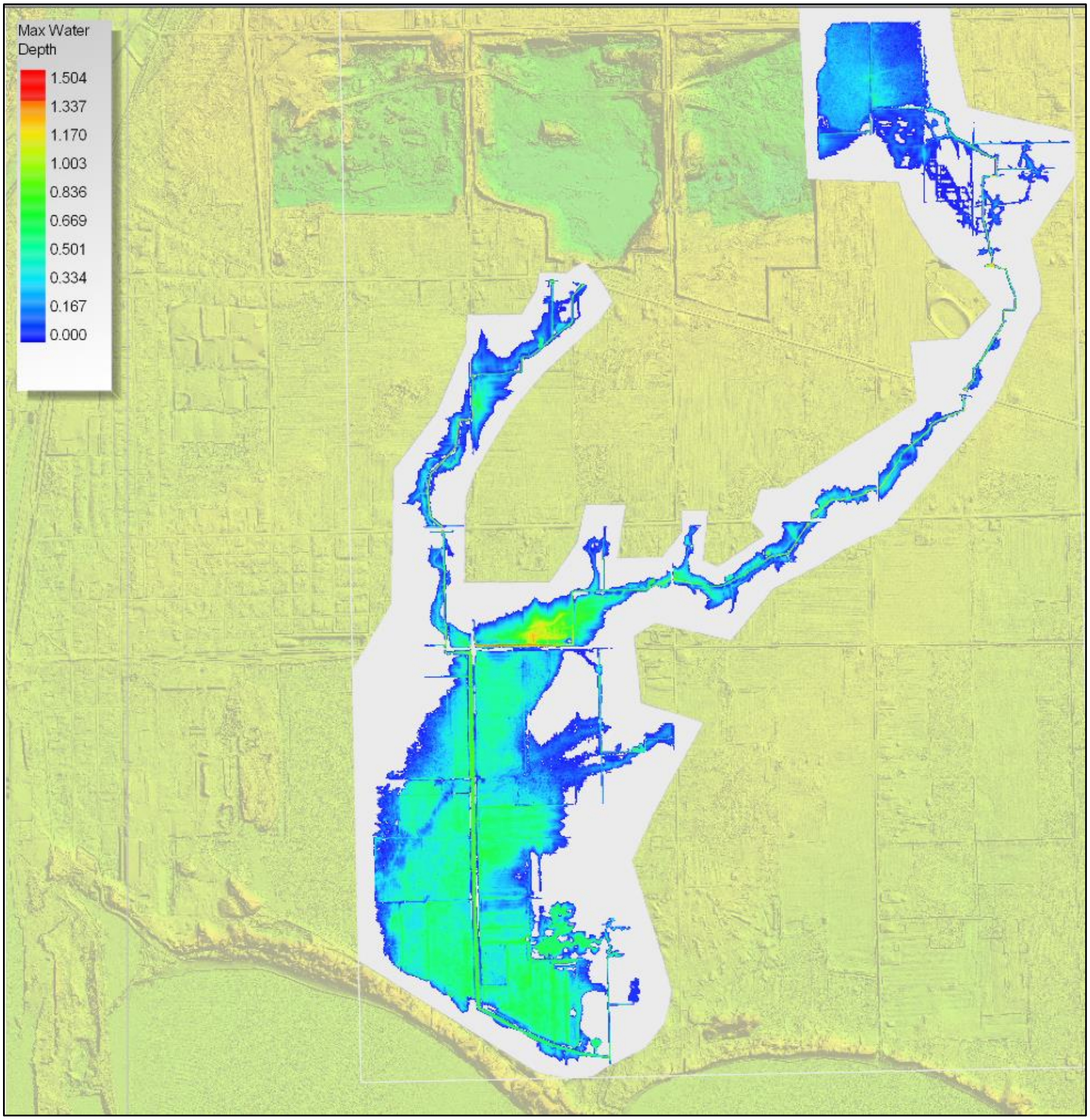
The hazard maps shown on **Gr□□□i□1□** and **Gr□□□i□ □1** are a visualization of hazards, which are a quotient of velocity and depth for each grid cell used to assess risk. Please note that all hazard areas are outside the proposed urban boundary and are contained within the floodplain areas.

The bed shear maps shown on **Gr□□□i□1□□Gr□□□i□1□□Gr□□□i□ □□**, and **Gr□□□i□ □□** illustrate the erosion potential for frequently occurring storms. Note that **Gr□□□i□1□** and **Gr□□□i□ □□** show a 100-year shear bed map, which is less than the allowable for the vegetation in situ. See Section 8.2 for further information on bed shear and erosion.

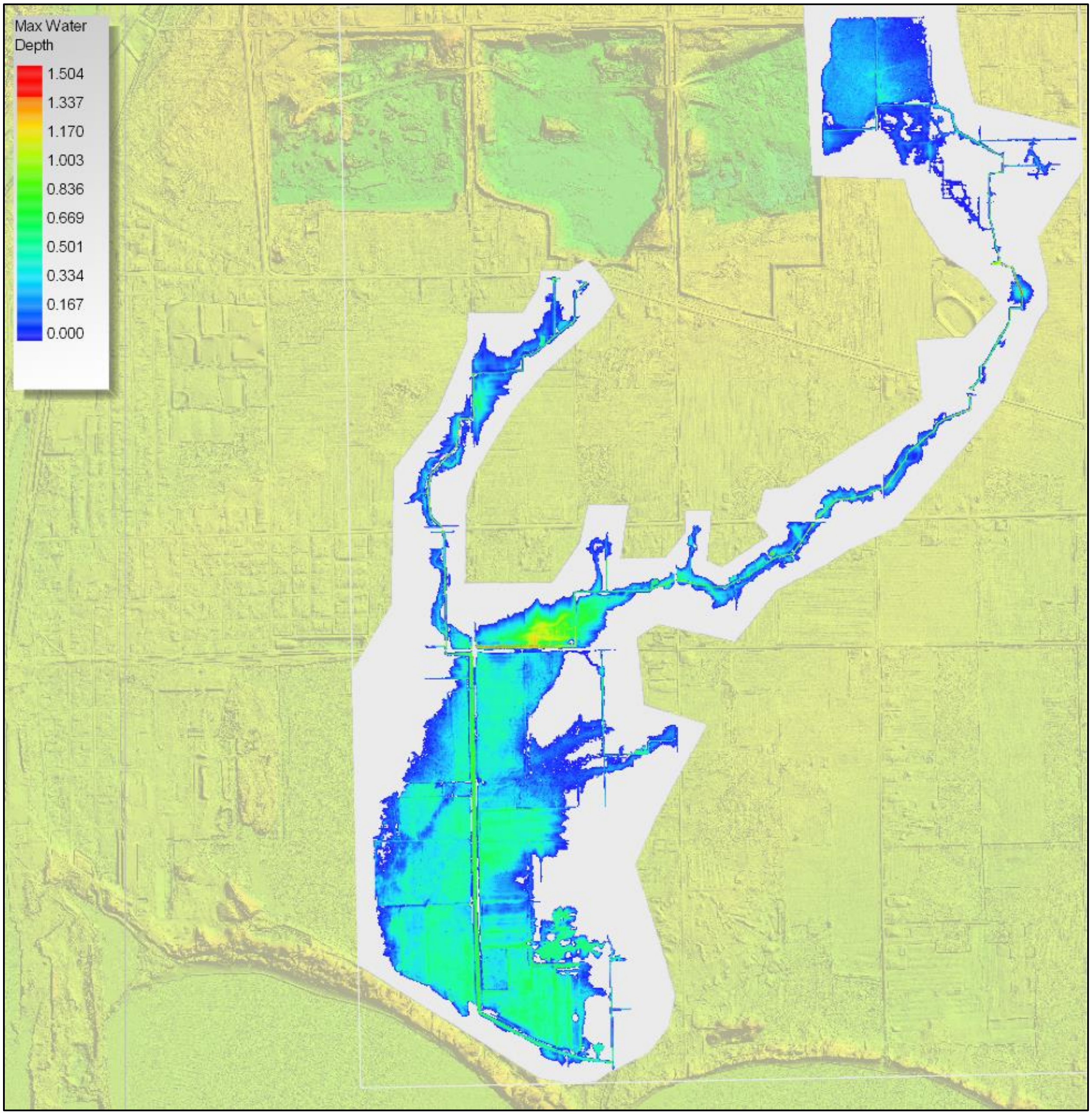
Graphic 6: XPSWMM Depth MAP (100 year) – Site Undeveloped Existing Flows



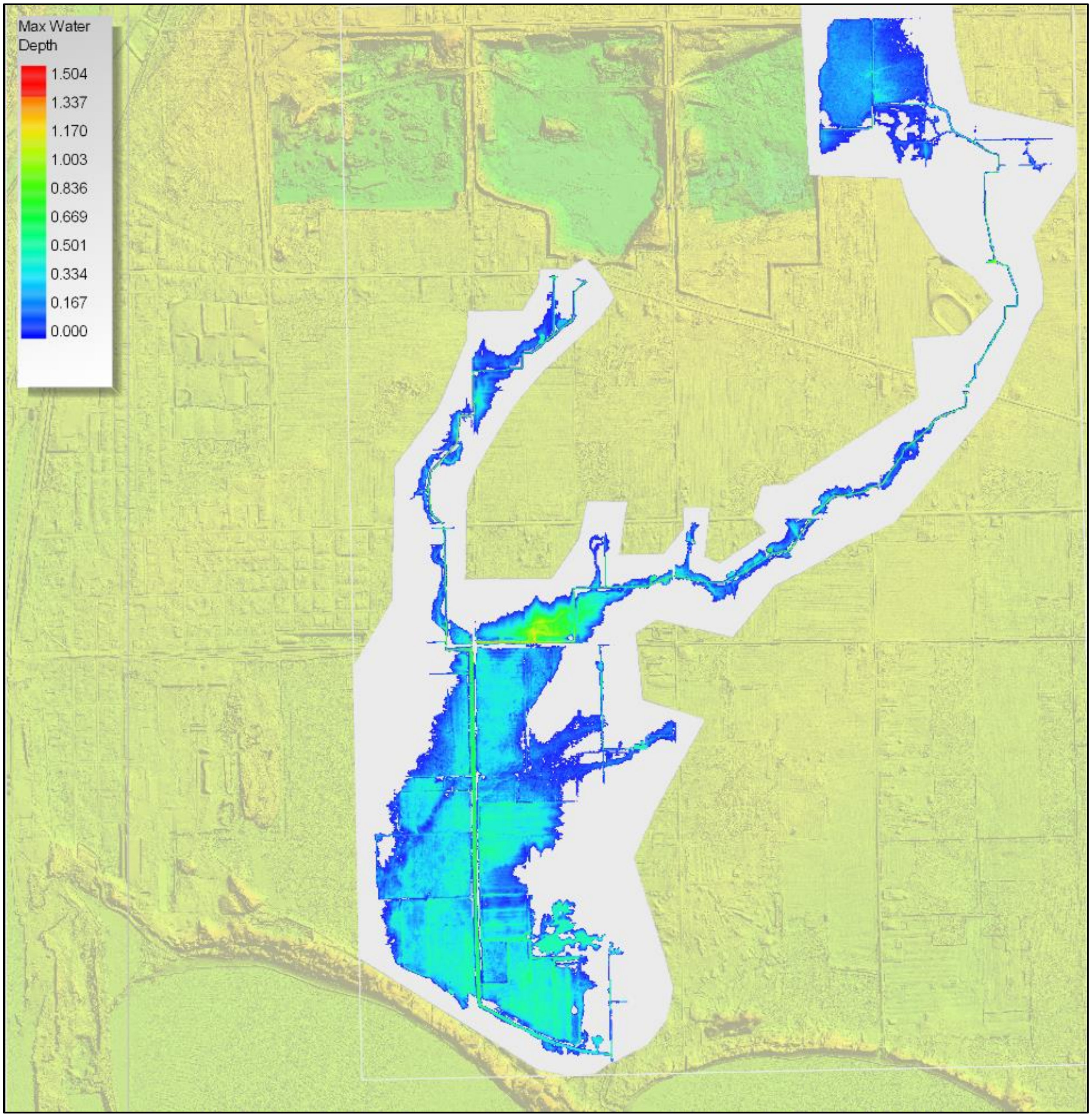
Graphic 7: XPSWMM Depth MAP (50 year) - Site Undeveloped Existing Flows



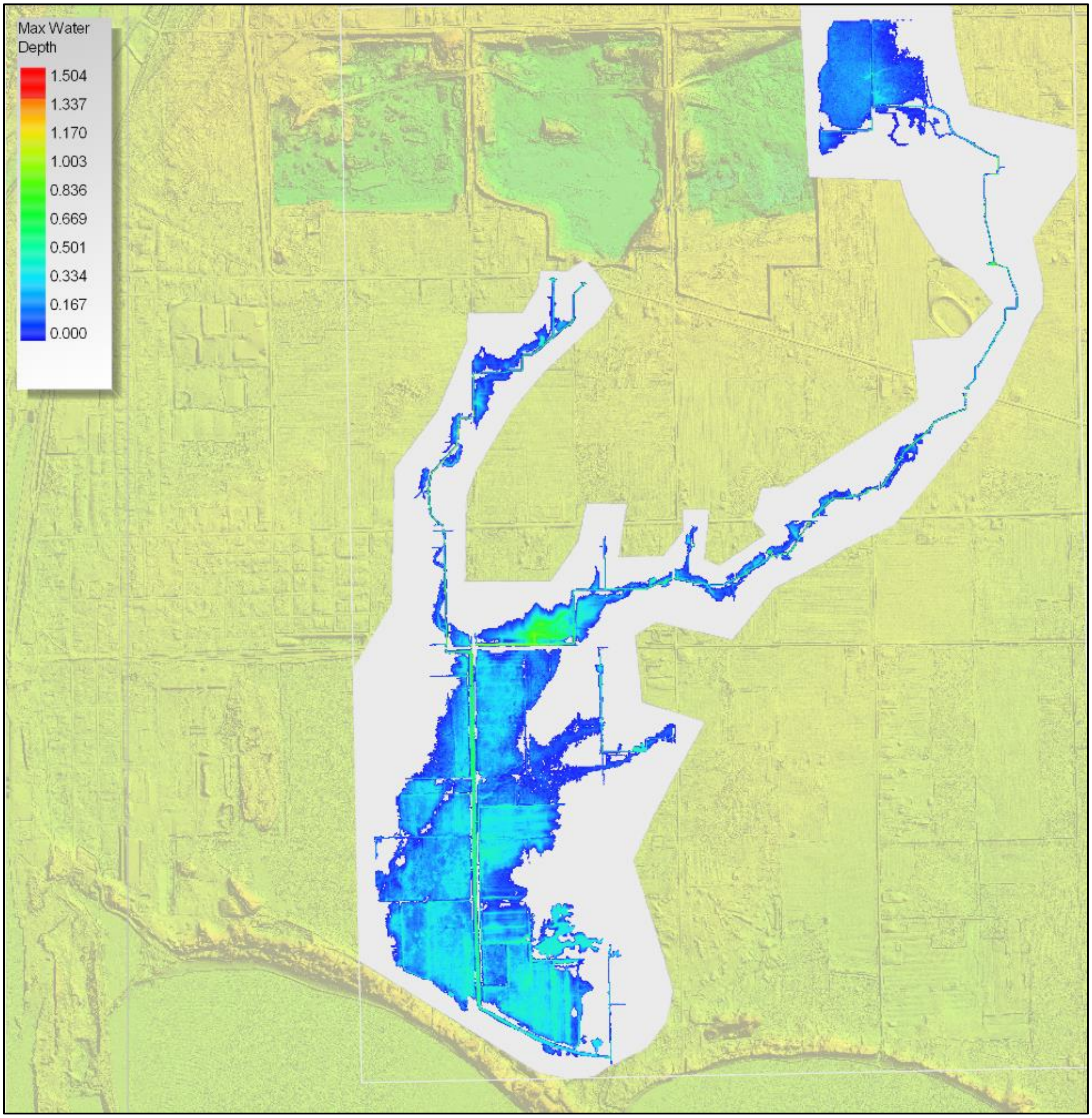
Graphic 8: XPSWMM Depth MAP (25 year) – Site Undeveloped Existing Flows



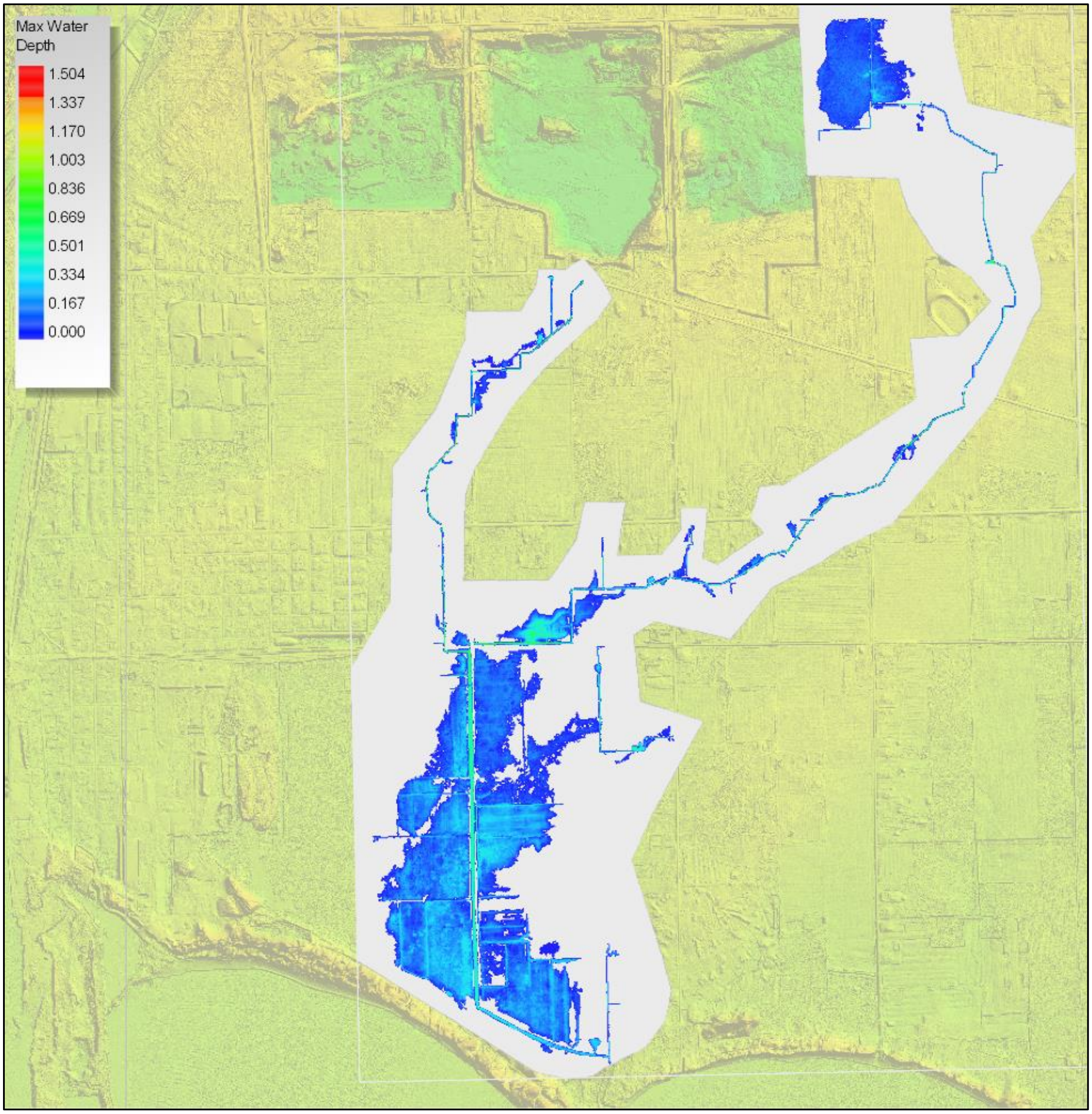
Graphic 9: XPSWMM Depth MAP (10 year) – Site Undeveloped Existing Flows



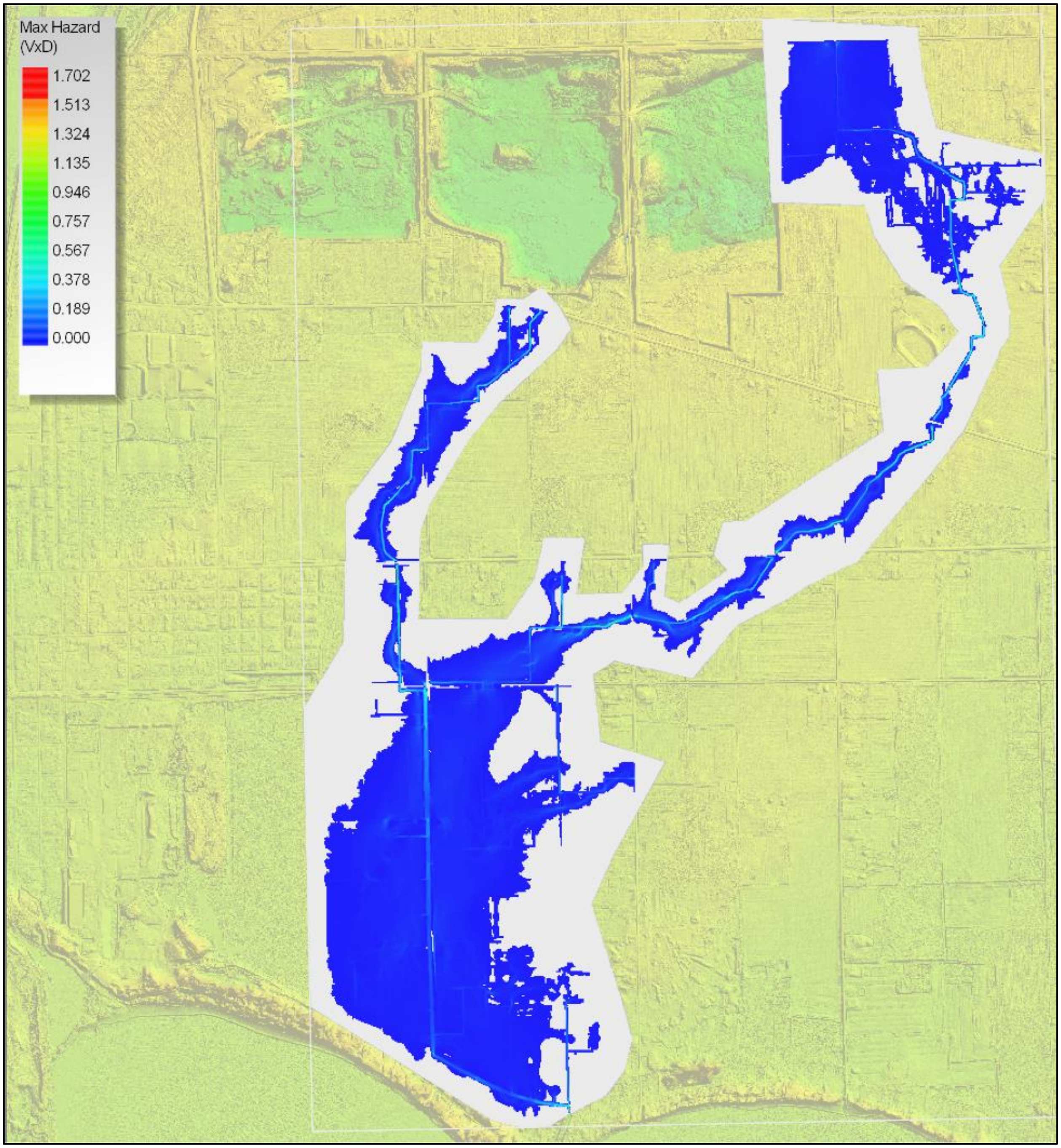
Graphic 10: XPSWMM Depth MAP (5 year) – Site Undeveloped Existing Flows



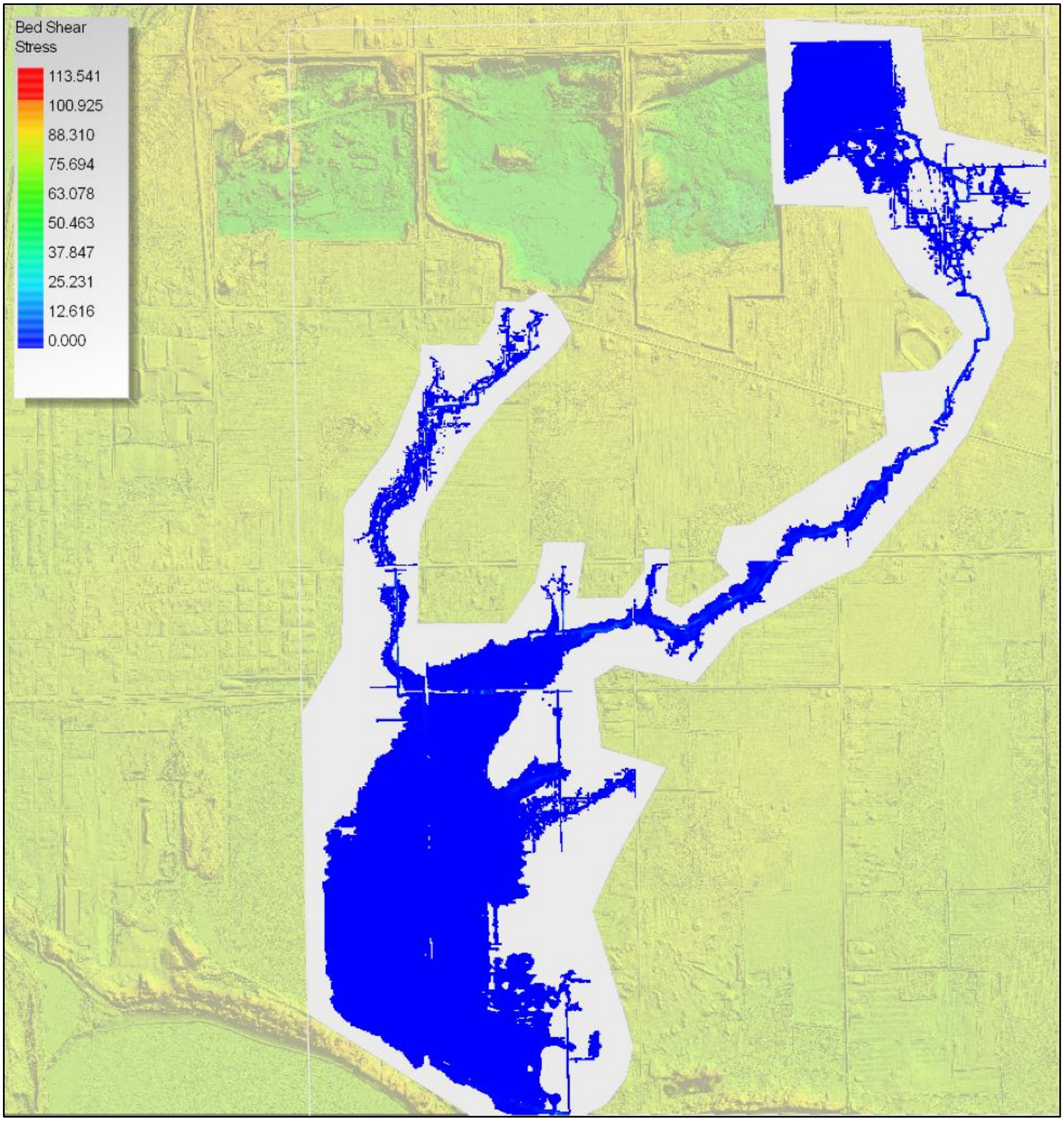
Graphic 11: XPSWMM Depth MAP (2 year) - Site Undeveloped Existing Flows



Graphic 12: XPSWMM Hazard MAP (100 year) – Site Undeveloped Existing Flows

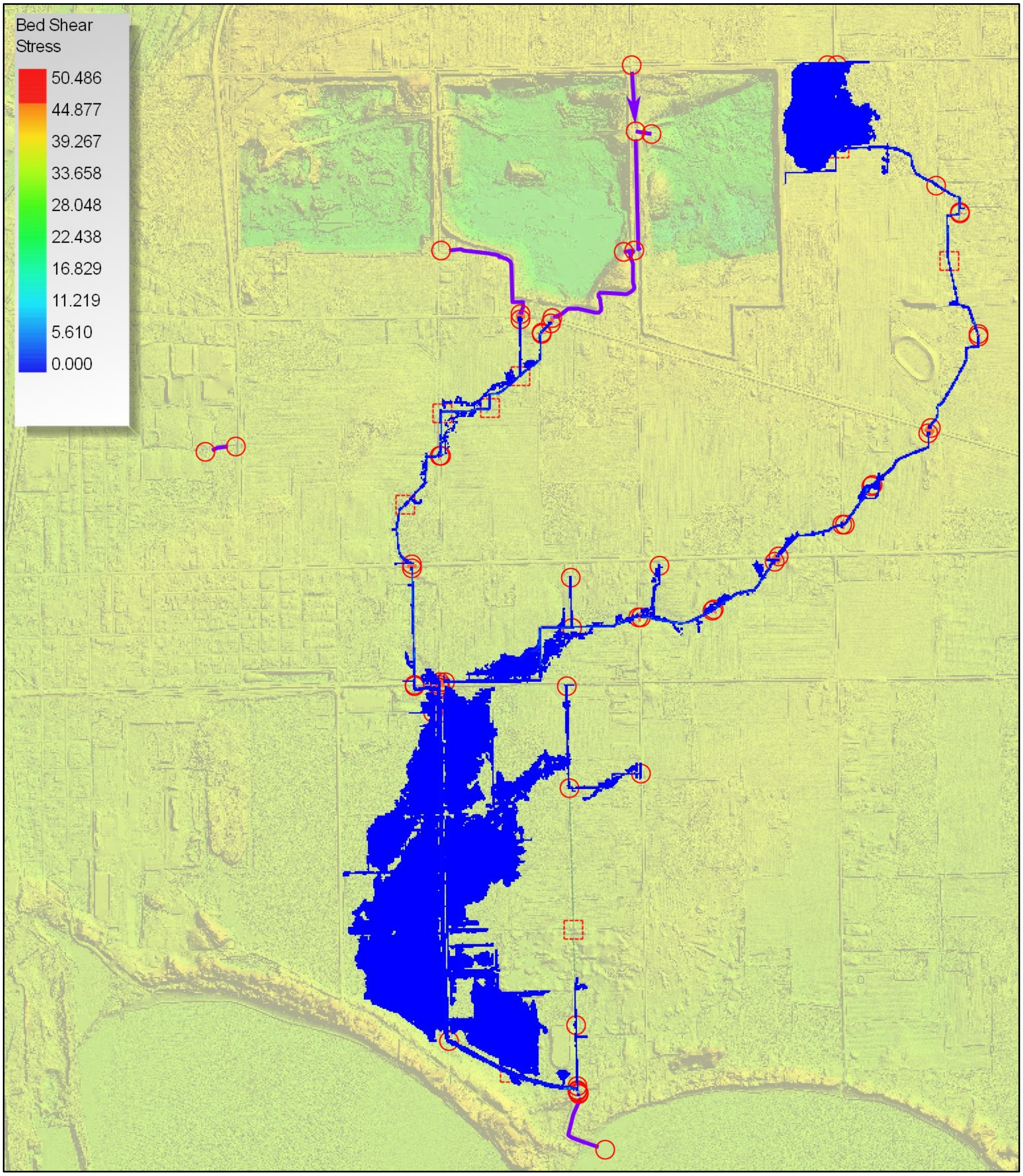


Graphic 13: XPSWMM Bed Shear MAP (100 year) - Site Undeveloped Existing Flows



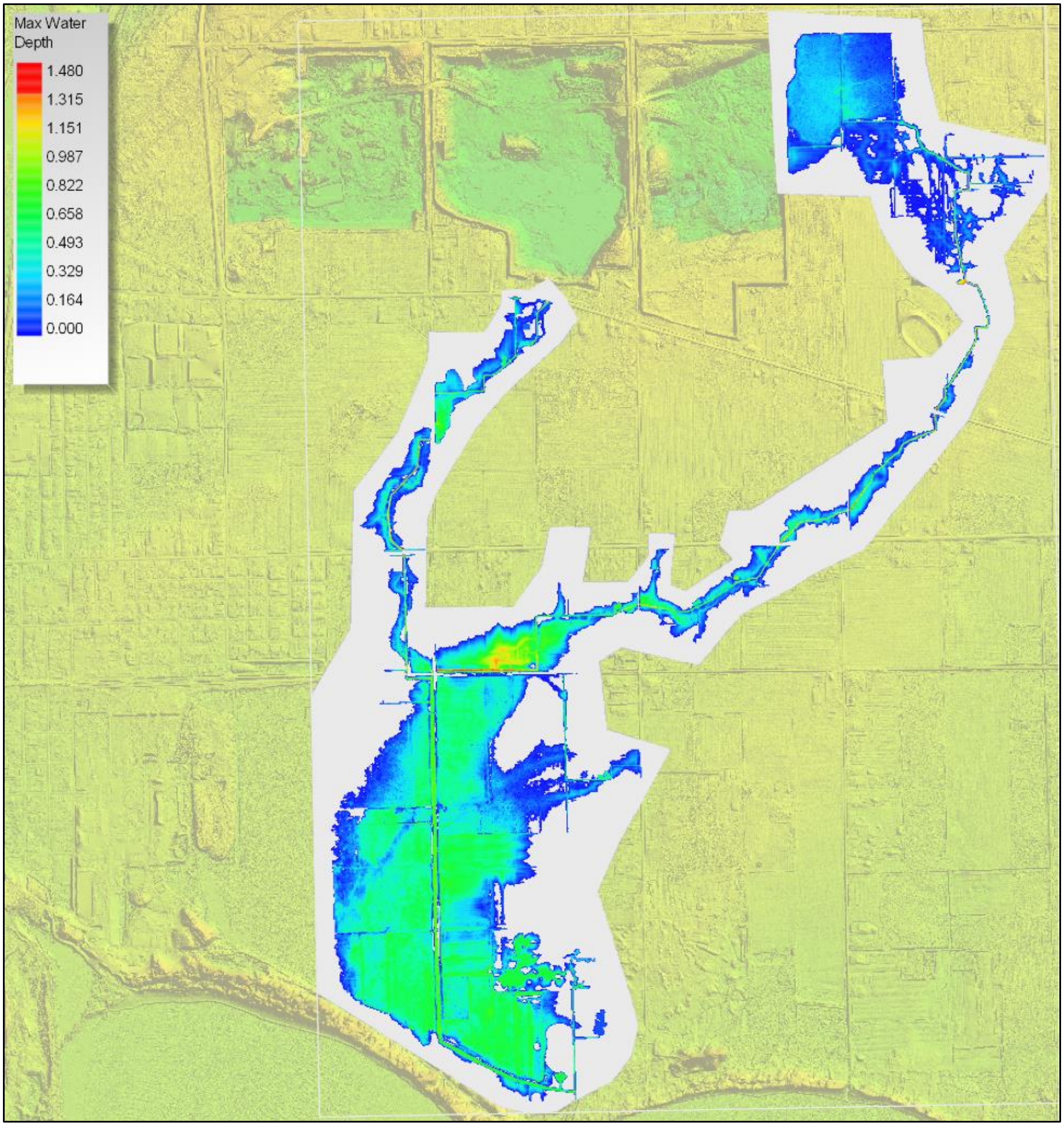
The above map is the 100-year bed shear. The maximum is 114 Pa anywhere in the system.

Graphic 14: XPSWMM Bed Shear MAP (2 year) - Site Undeveloped Existing Flows

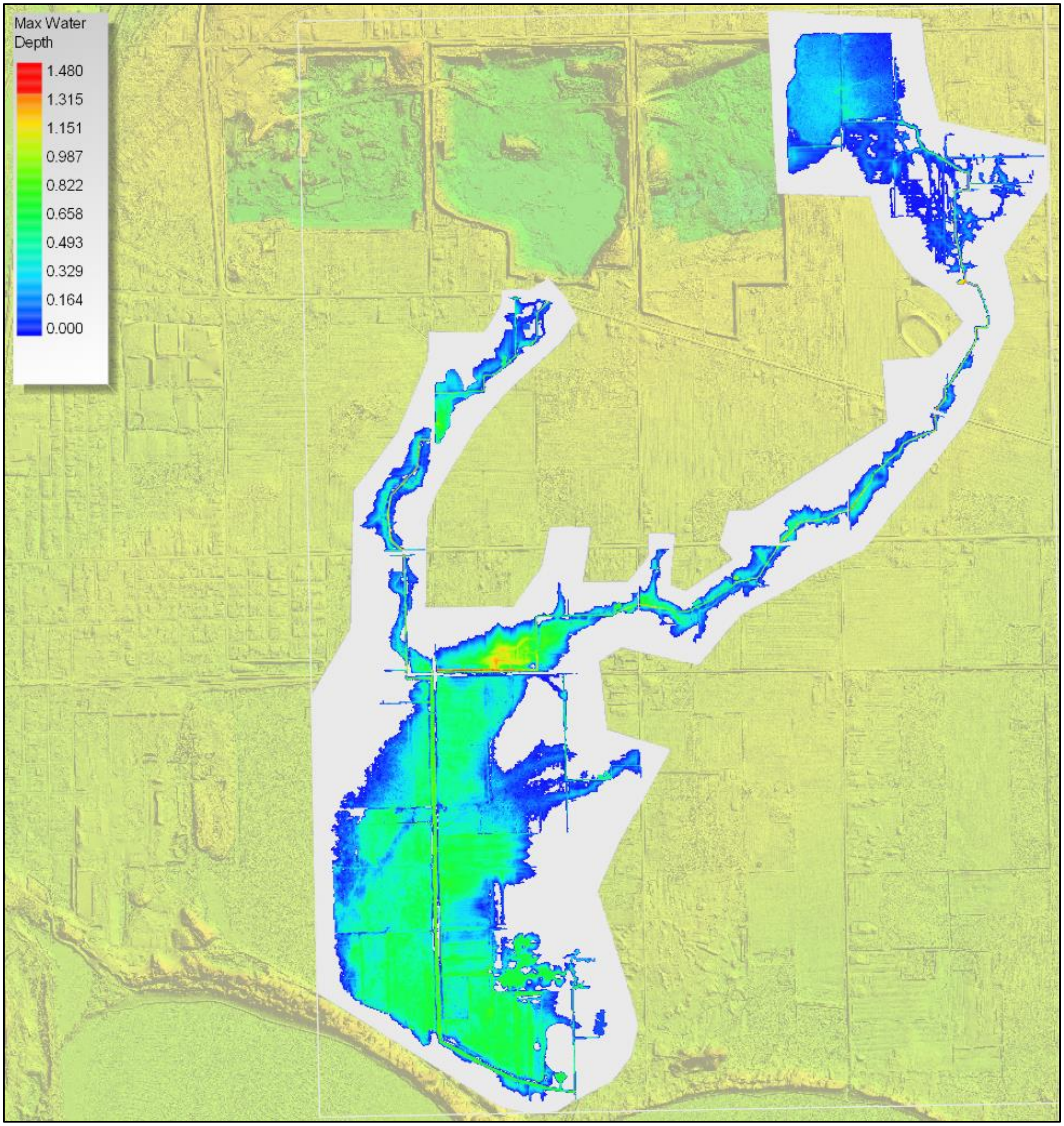


The above map is the 2-year bed shear. The maximum is 50 Pa anywhere in the system.

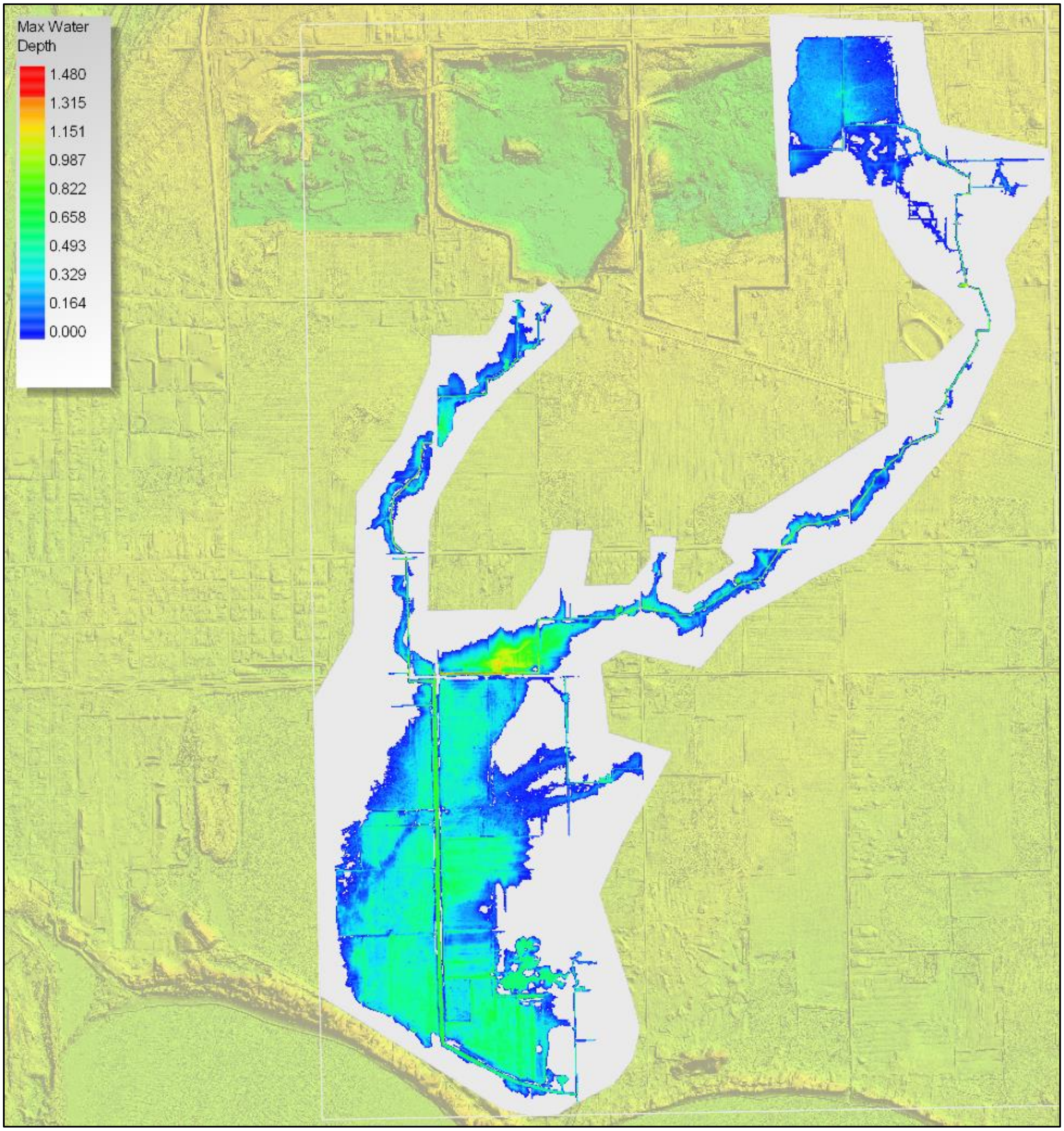
Graphic 15: XPSWMM Depth MAP (100 year) – Subject Lands Developed



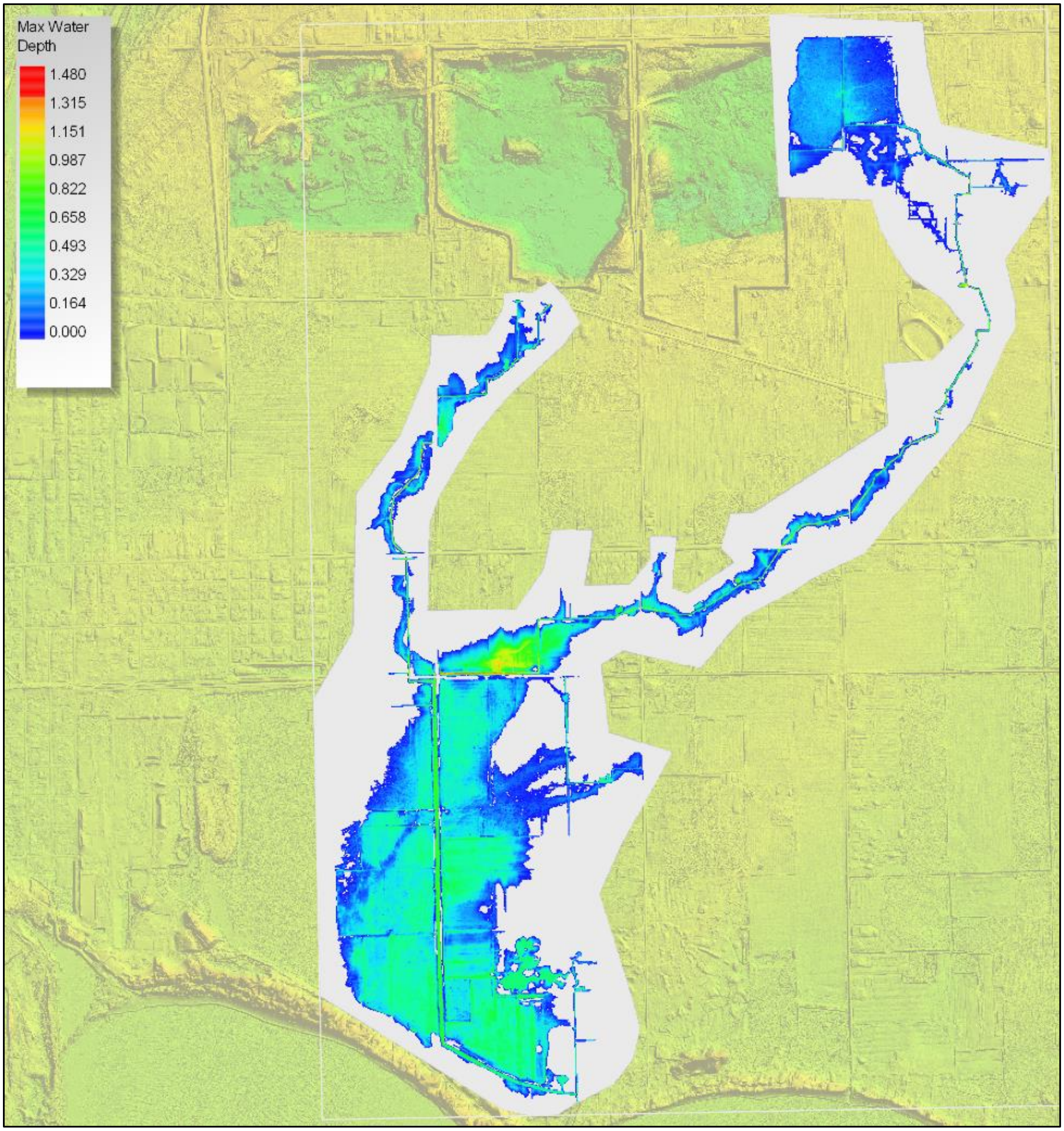
Graphic 16: XPSWMM Depth MAP (50 year) - Subject Lands Developed



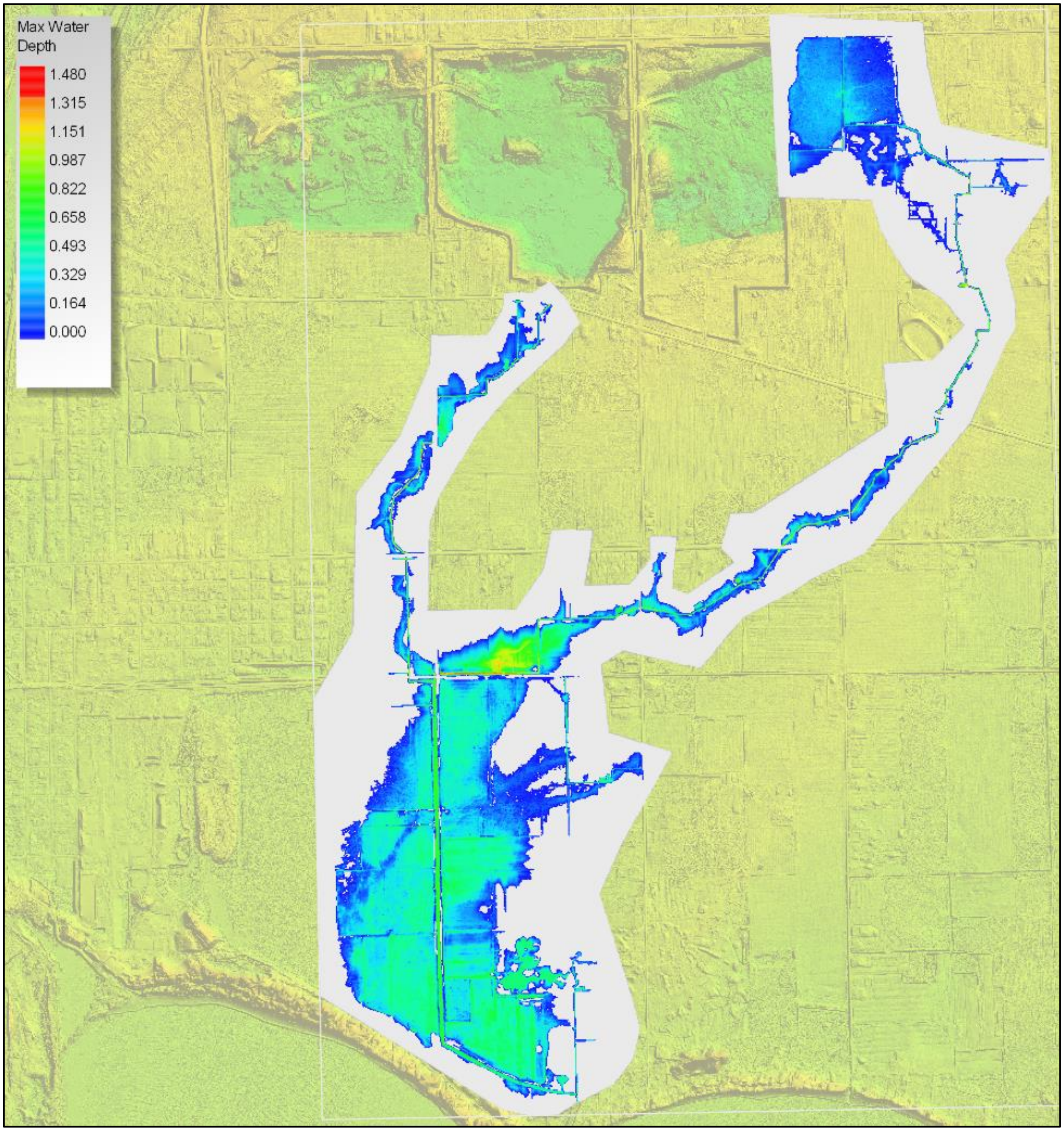
Graphic 17: XPSWMM Depth MAP (25 year) - Subject Lands Developed



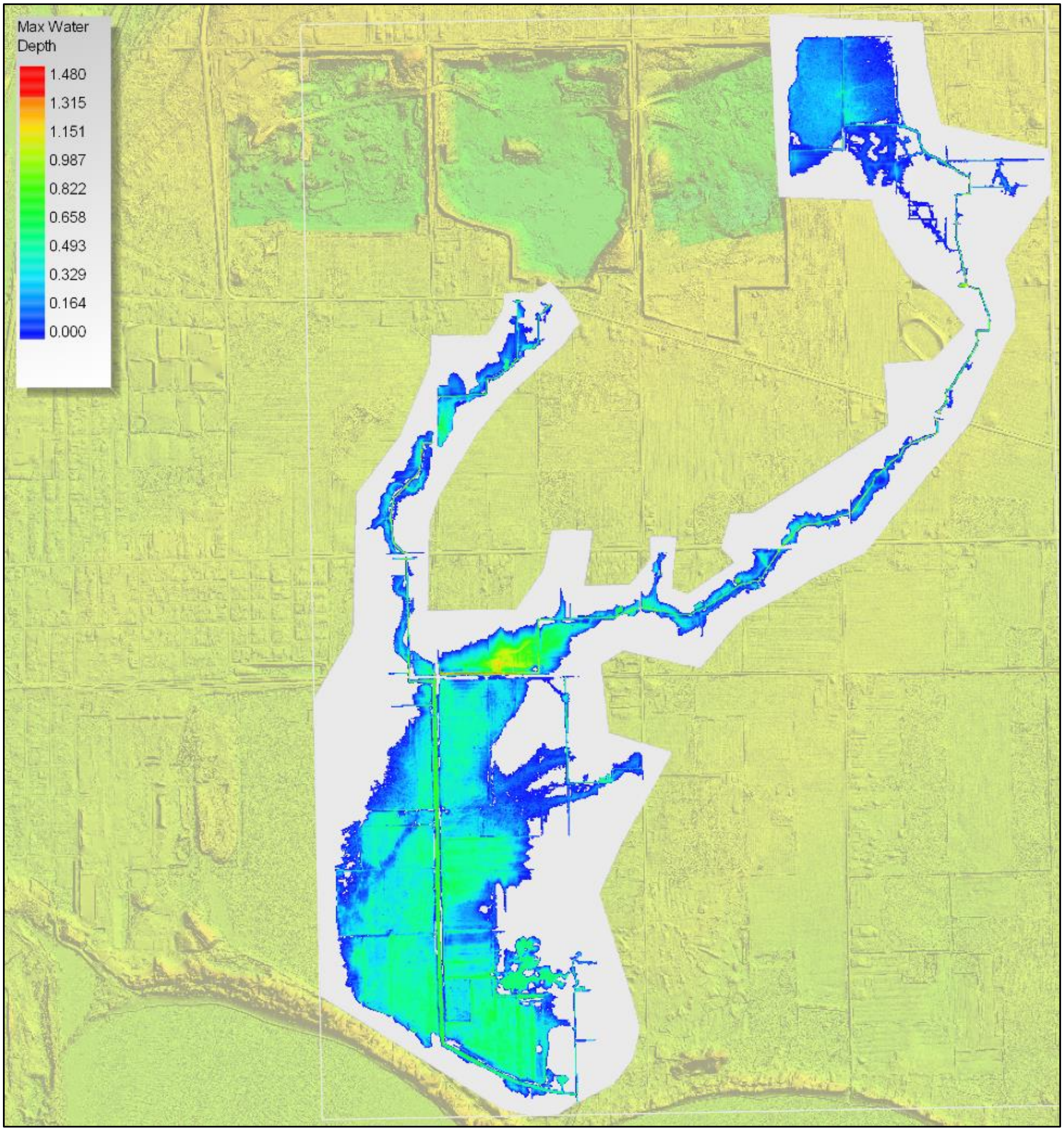
Graphic 18: XPSWMM Depth MAP (10 year) - Subject Lands Developed



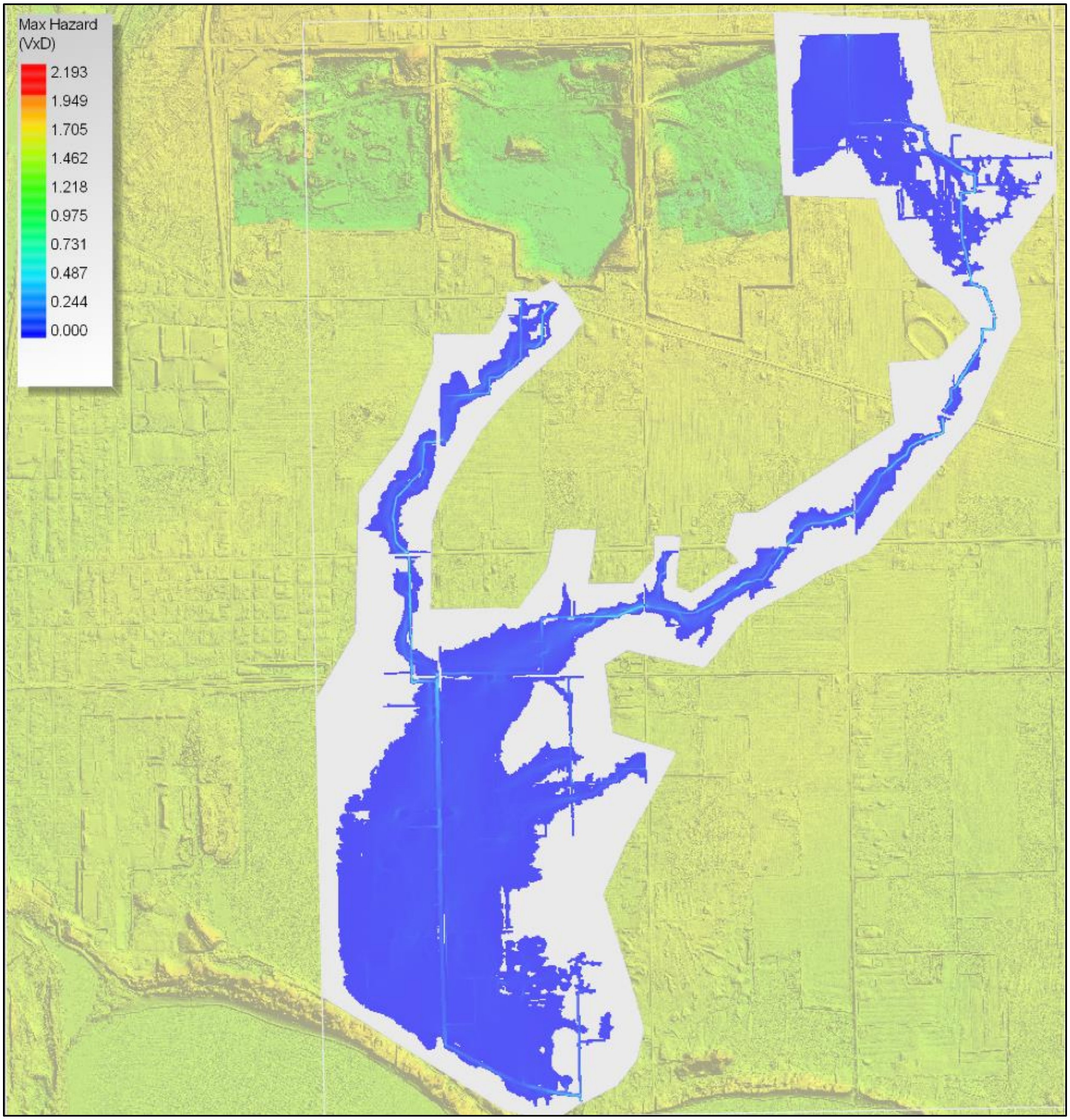
Graphic 19: XPSWMM Depth MAP (5 year) - Subject Lands Developed



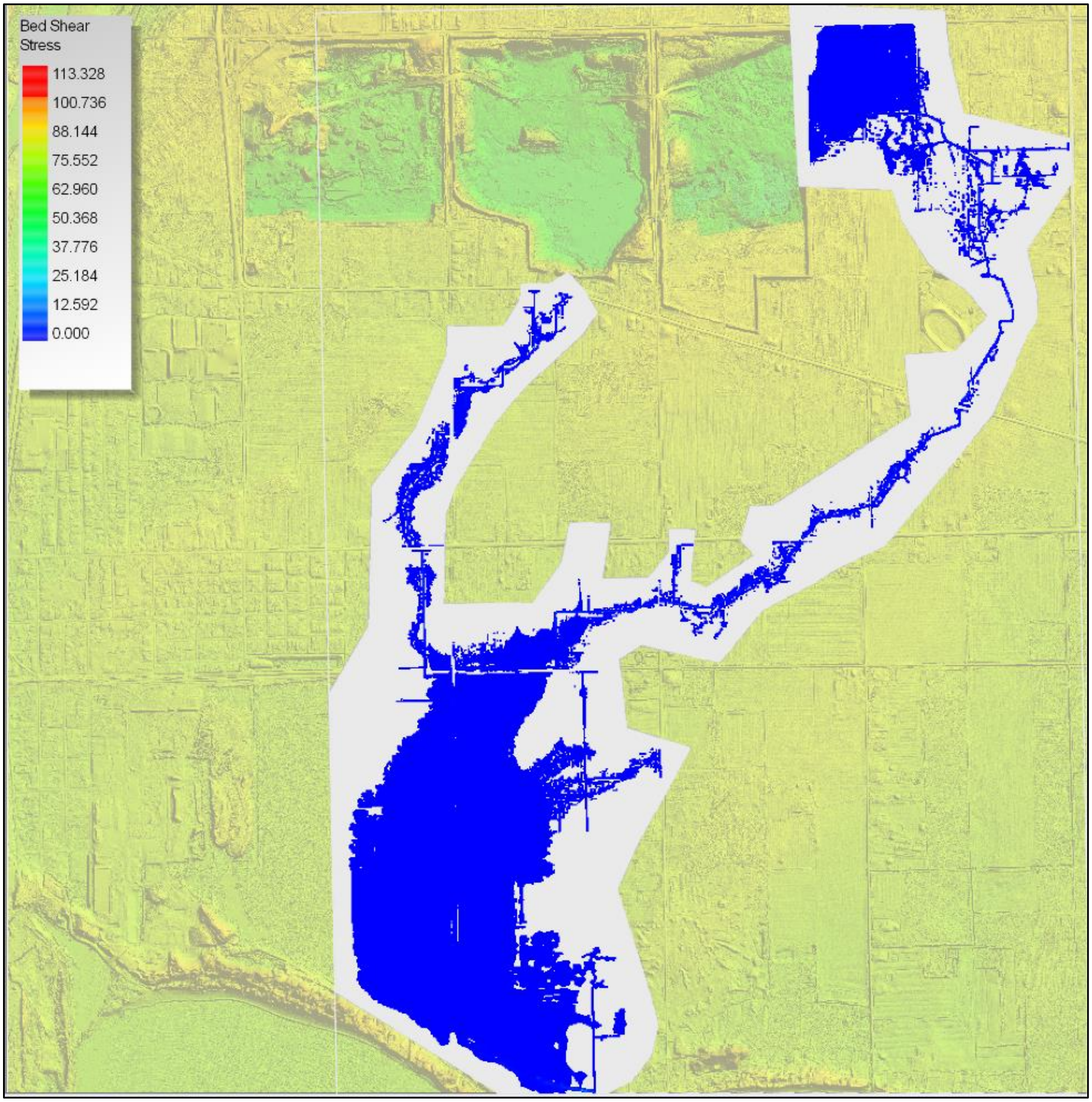
Graphic 20: XPSWMM Depth MAP (2 year) - Subject Lands Developed



Graphic 21: XPSWMM Hazard MAP (100 year) - Subject Lands Developed

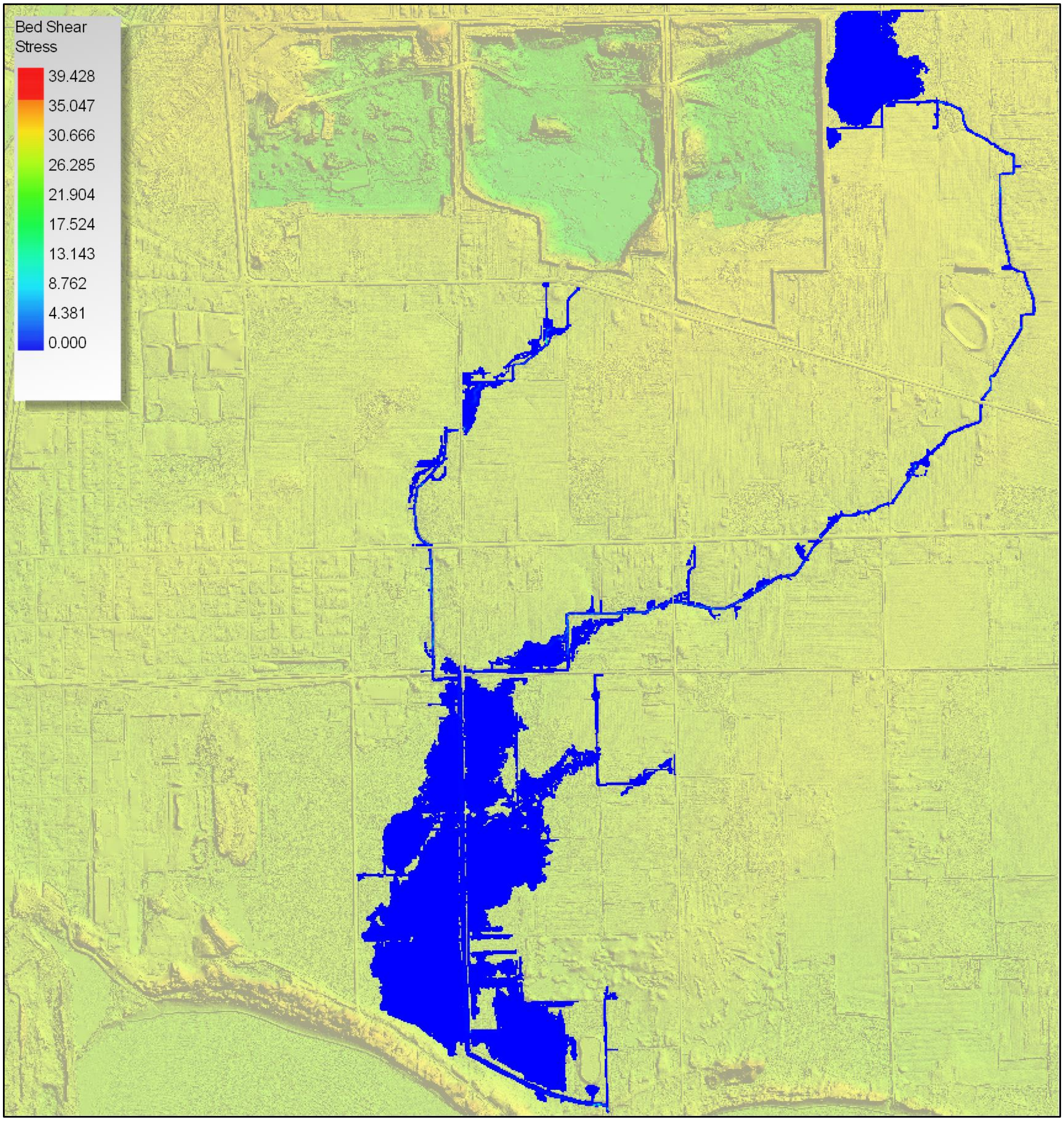


Graphic 22: XPSWMM Bed Shear MAP (100 year) - Subject Lands Developed



Note, the 100-year maximum in the Subject Lands is less than the existing conditions.

Graphic 23: XPSWMM Bed Shear MAP (2 year) - Subject Lands Developed



Note, the 2-year maximum in the Subject Lands is less than the existing conditions.

Point Head Plot

In addition to the modeling and mapping, **Gr□□□i□ □□** below provides the points from which the HGLs were retrieved, as well as the locations of profile plots (sections plots) for the existing and proposed models. **□□□e □□** provides a summary of these points HGLs, with the section plots graphed below. It should be noted that the geospatial locations of these points and sections are identical for the existing conditions scenario and the Subject Lands scenario.

Graphic 24: Point Head Plot

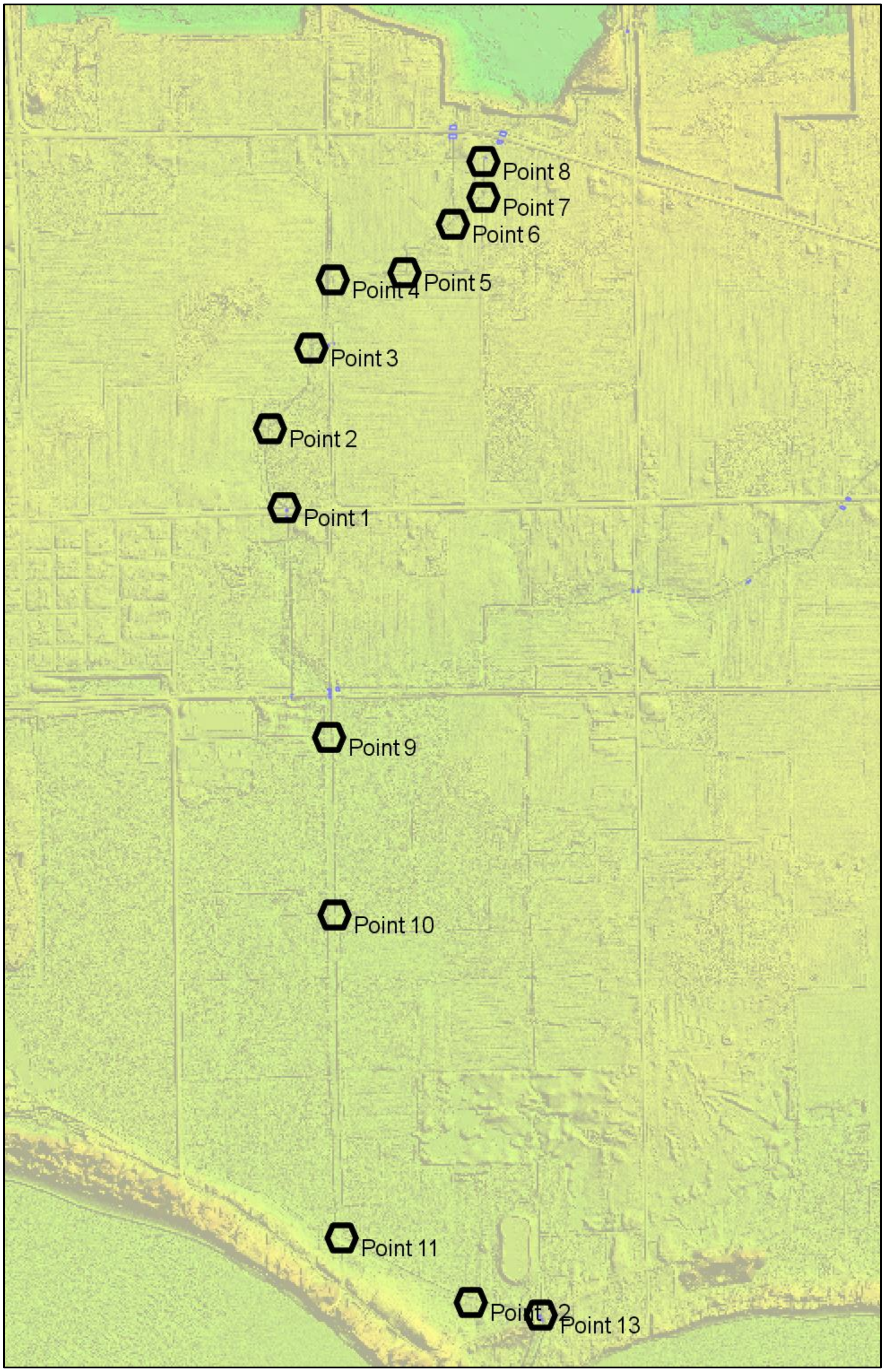


Table 33: Summary of Hydraulic Effects - Existing and Subject Lands Developed

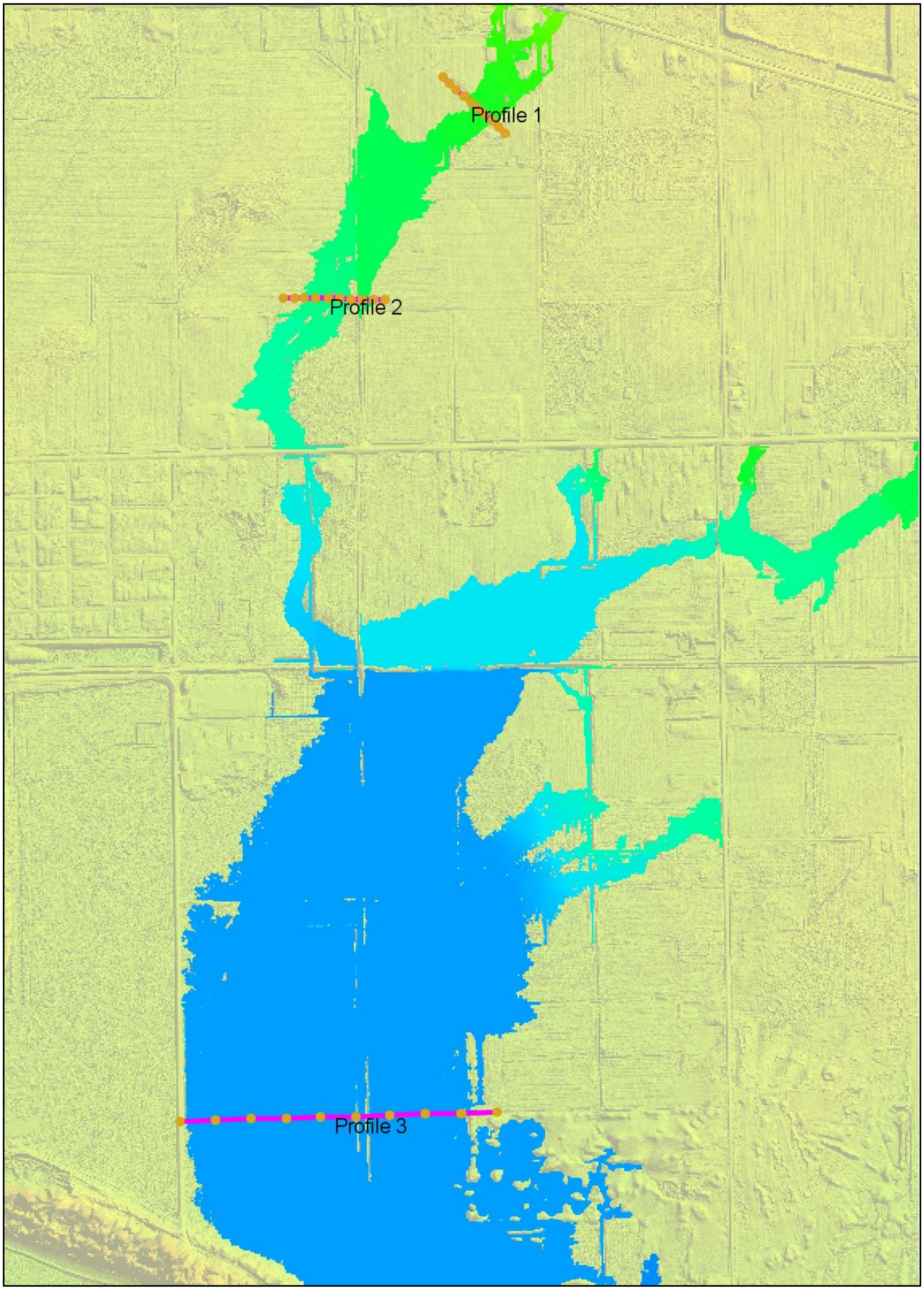
□□□□□i□□	1□□□e□r □□ □r □□□		□□□□e□r □□ □r □□□		□□□□e□r □□ □r □□□		1□□e□r □□ □r □□□		□□□e□r □□ □r □□□		□□□e□r □□ □r □□□	
	□G□ □□ □											
	□i□□i□g	De□e□□□ed	□i□□i□g	De□e□□□ed	□i□□i□g	De□e□□□ed	□i□□i□g	De□e□□□ed	□i□□i□g	De□e□□□ed	□i□□i□g	De□e□□□ed
Point 1	177.08	177.06	176.94	176.95	176.80	176.83	176.60	176.61	176.50	176.52	176.35	176.36
Point 2	177.20	177.18	177.10	177.14	177.03	177.08	176.96	177.00	176.88	176.92	176.74	176.76
Point 3	177.44	177.45	177.40	177.43	177.36	177.40	177.30	177.34	177.24	177.27	177.08	177.10
Point 4	177.77	177.90	177.74	177.82	177.68	177.74	177.58	177.66	177.50	177.62	177.40	177.59
Point 5	177.96	178.02	177.94	177.93	177.92	177.96	177.90	177.91	177.85	177.86	177.78	177.78
Point 6	177.44	177.39	178.41	178.37	178.40	178.36	178.38	178.32	178.32	178.30	178.22	178.22
Point 7	178.69	178.70	178.66	178.69	178.62	178.66	178.57	178.62	178.54	178.59	178.44	178.54
Point 8	179.05	179.04	178.98	178.99	178.90	178.90	178.78	178.79	178.68	178.70	178.54	178.60
Point 9	175.74	175.74	175.69	175.69	175.67	175.67	175.64	175.64	175.60	175.59	175.49	175.49
Point 10	175.73	175.74	175.68	175.68	175.63	175.64	175.55	175.55	175.47	175.48	175.40	175.40
Point 11	175.73	175.73	175.68	175.68	175.63	175.63	175.54	175.54	175.45	175.46	175.36	175.35
Point 12	175.69	175.68	175.62	175.61	175.54	175.54	175.43	175.43	175.35	175.35	175.27	175.27
Point 13	175.53	175.48	175.45	175.44	175.38	175.37	175.25	175.25	175.16	175.16	175.00	175.00

Note, essentially the existing and Subject Lands HGL are the same.

Section Plots

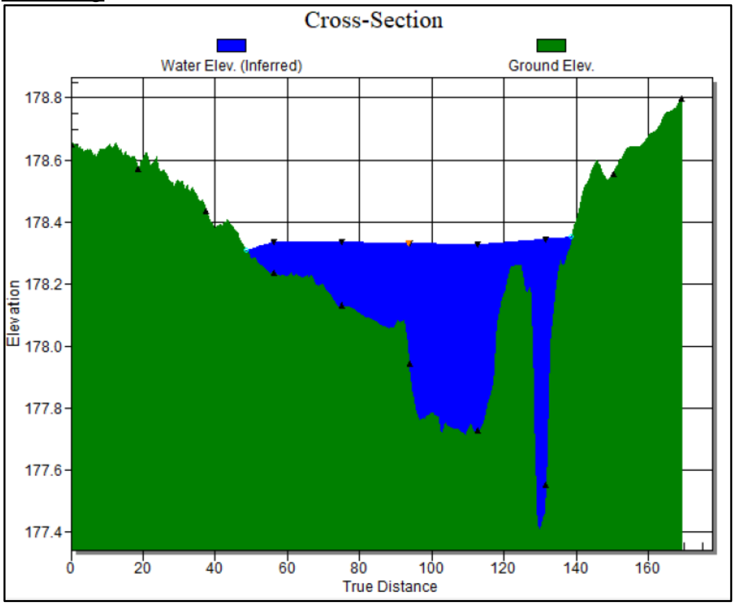
Gr□□□i□ □□ shows the locations of profile plots for existing and proposed models.

Graphic 25: Section Plots

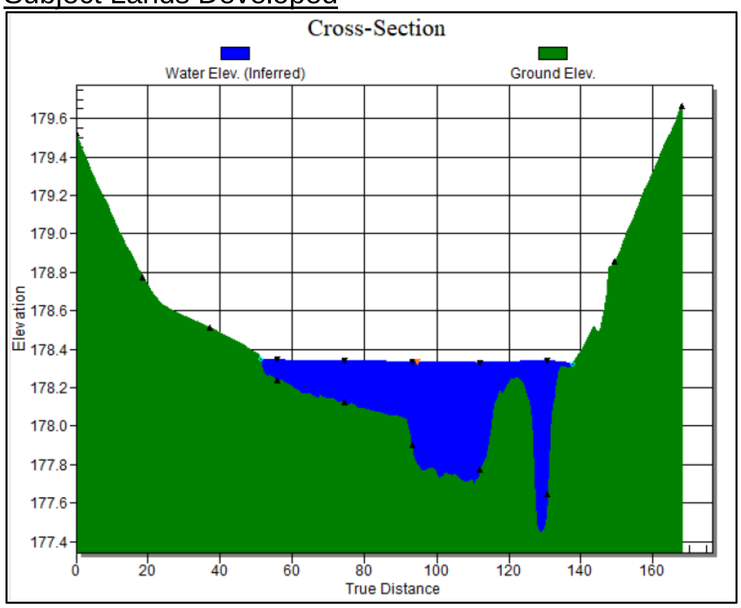


□r□i□e 1□1 □□□e□r □□ □r □□□

Existing

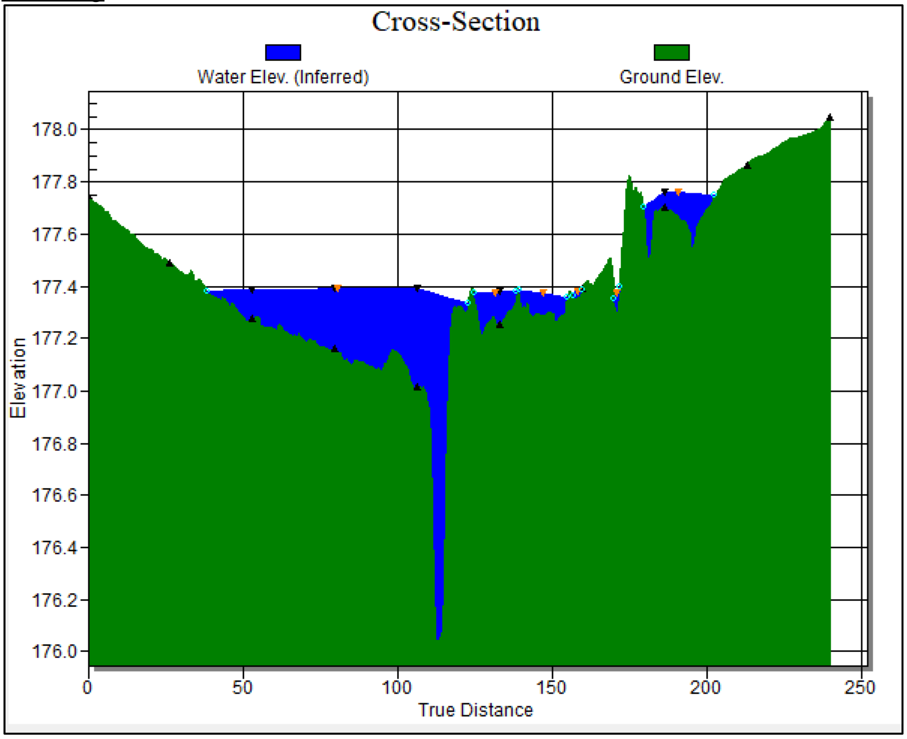


Subject Lands Developed

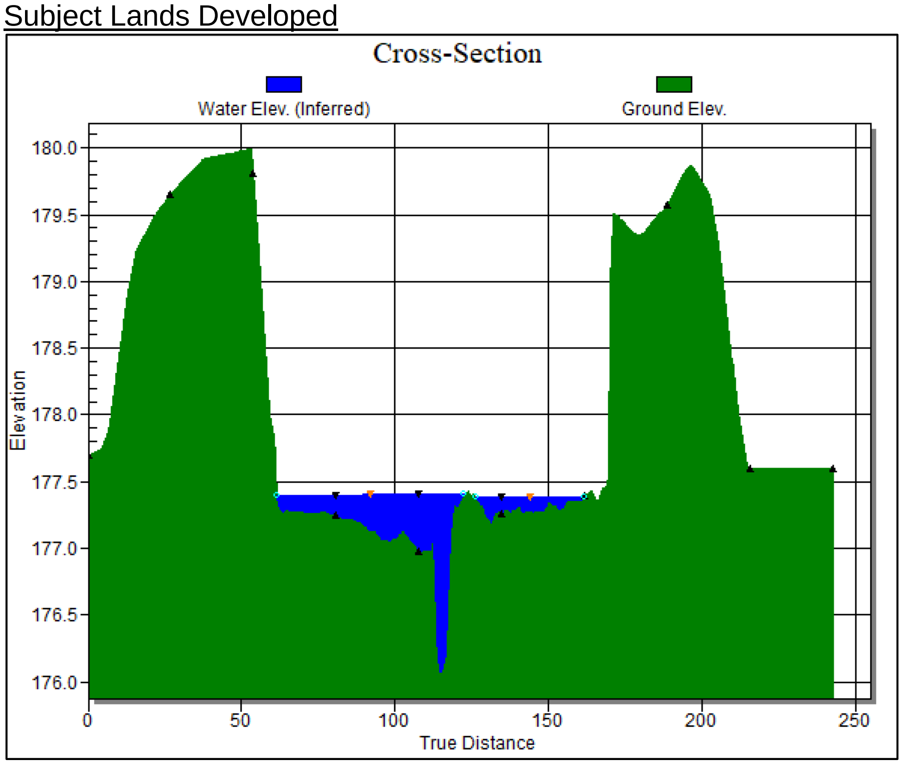


□r□i□e □□1 □□□e□r □□ □r □□□

Existing

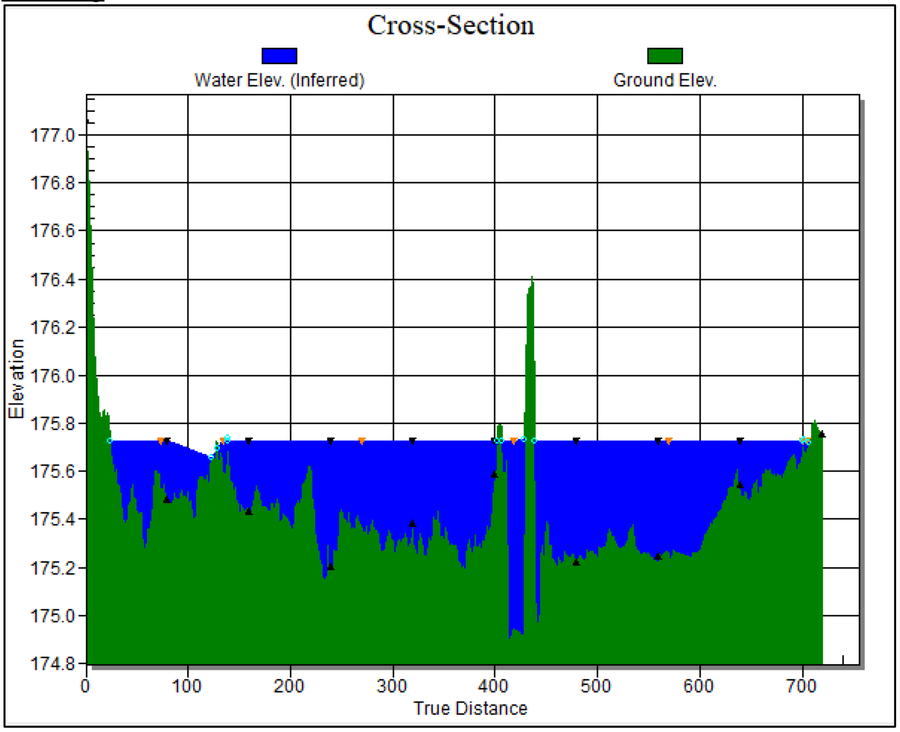


Subject Lands Developed

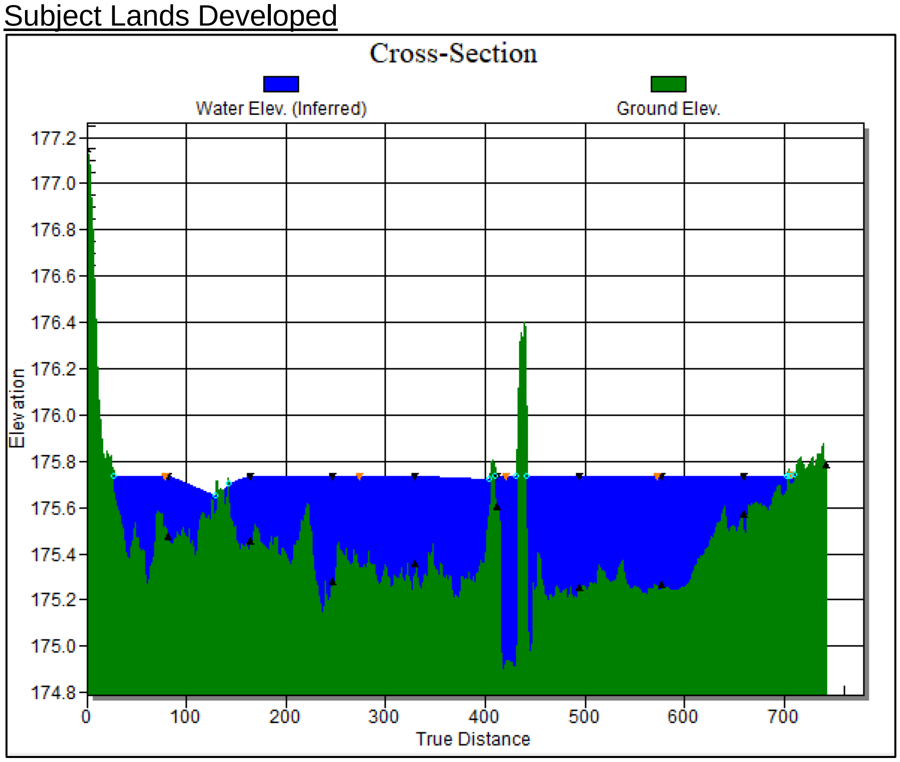


□r□□i□e □□1□□□□e□r □□ □r □□□□

Existing



Subject Lands Developed



8.2 Erosion Review

The bed shear stress is calculated as follows in XP2D:

$$\tau_{bed\,(metric)} = \frac{\rho g v^2 n^2}{y^{1/3}}$$

where:

ρ = Density

g = Gravity

v = Velocity

n = Manning's n

y = Depth

Units are in N/m^2

Reproduced from the HEC-15, FHWA-NHI-01-021 Urban Drainage Design Manual (2001), the following are the recommended shear stresses as per vegetative cover.

Lining Category	Type	Permissible [illegible] Stress [illegible]
Vegetative	Class A	177.2
	Class B	100.6
	Class C	47.9
	Class D	28.7
	Class E	16.8

Using the formula and graphs provided above, a majority of the cells in the landscaped areas and the drain areas have a bed shear stress of less than 114 N/m^2. Note this is calculated using the 100-year storm scenario. The 2-year storm bed shear graphs and formula calculations indicate a bed shear of 50 N/m^2 in the existing condition scenario and 39 N/m^2 in the developed condition (maximum) scenario. This is well within the permissible range for well vegetated areas.

The objective of the floodplain analysis is to not increase the erosion forces in the receiving natural streams. The Ministry of Environment (MOE) outlined an interim approach in 1994 and updated it in the Stormwater Management Planning and Design Manual (Ministry of the Environment, Conservation and Parks, 2003). This updated approach consists of either a detailed design approach or a simplified design approach that is currently being improved to address inadequacies. Accordingly, it is recommended that the general approach be followed as outlined in the Stormwater Management Planning and Design Manual (Ministry of the Environment, Conservation and Parks, 2003). This consists of designing SWM ponds to include active storage for the runoff from a 25 mm storm, followed by a check on erosion velocities in the downstream receiver. Quantity control to detain and release the 25 mm, 4-hour Chicago design storm over a 24-hour period shall be provided for all receiving systems that are demonstrated to be stable watercourses or for proposed development that comprise less than 10% of the total area that drains to the receiving system.

Note, the shear bed method in 2D modelling is quickly becoming the method of choice due to testing that shows shear stress is a better indicator of erosion than velocity.

□□□□**e** □□ provides a comparison of existing to developed flows (target flows).

Table 34: WMM Comparison of Outflow – Existing (target) and Redeveloped

Storm Event Storm Type	Target Peak Flow Rate ([illegible])																				
	[illegible]1			[illegible]			[illegible]			[illegible]			[illegible]			[illegible]			[illegible]		
	Existing	Redeveloped	PCSWMM	Existing	Redeveloped	PCSWMM	Existing	Redeveloped	PCSWMM	Existing	Redeveloped	PCSWMM	Existing	Redeveloped	PCSWMM	Existing	Redeveloped	PCSWMM	Existing	Redeveloped	PCSWMM
2 Year 24Hr SCS	0.439	0.440	0.406	0.730	0.730	0.764	1.070	1.044	1.169	0.685	0.690	1.184	1.025	0.975	1.803	1.026	1.007	2.923	0.479	0.462	2.908
5 Year 24Hr SCS	0.794	0.799	0.750	1.215	1.209	1.256	1.787	1.804	2.156	1.554	1.546	2.806	1.946	1.834	4.266	1.954	1.896	6.375	1.046	1.041	6.580
10 Year 24Hr SCS	1.054	1.064	1.009	1.591	1.595	1.671	2.357	2.501	2.975	2.326	2.320	4.276	2.521	2.358	5.189	2.531	2.442	7.933	1.484	1.435	8.521
25 Year 24Hr SCS	1.401	1.405	1.370	2.160	2.168	2.328	3.157	3.397	4.220	3.422	3.419	5.018	2.663	2.626	5.719	3.335	3.264	7.933	1.781	1.746	9.380
50 Year 24Hr SCS	1.646	1.654	1.655	2.651	2.653	2.906	3.873	4.013	5.273	4.239	4.243	5.294	2.694	2.654	6.081	3.848	3.869	7.933	1.966	1.920	9.791
100 Year 24Hr SCS	1.903	1.904	1.951	3.157	3.157	3.557	4.626	4.533	5.719	4.994	5.002	5.629	2.698	2.652	6.481	4.335	4.339	7.933	2.179	2.146	10.00
100 Year 12Hr AES	0.606	0.606	-	1.976	1.976	-	4.043	4.026	-	4.628	4.637	-	2.701	2.699	-	4.020	4.101	-	1.774	1.746	-

Note, PCSWMM had approximately 0.53 m^3/sec from the quarry area which should not be included.

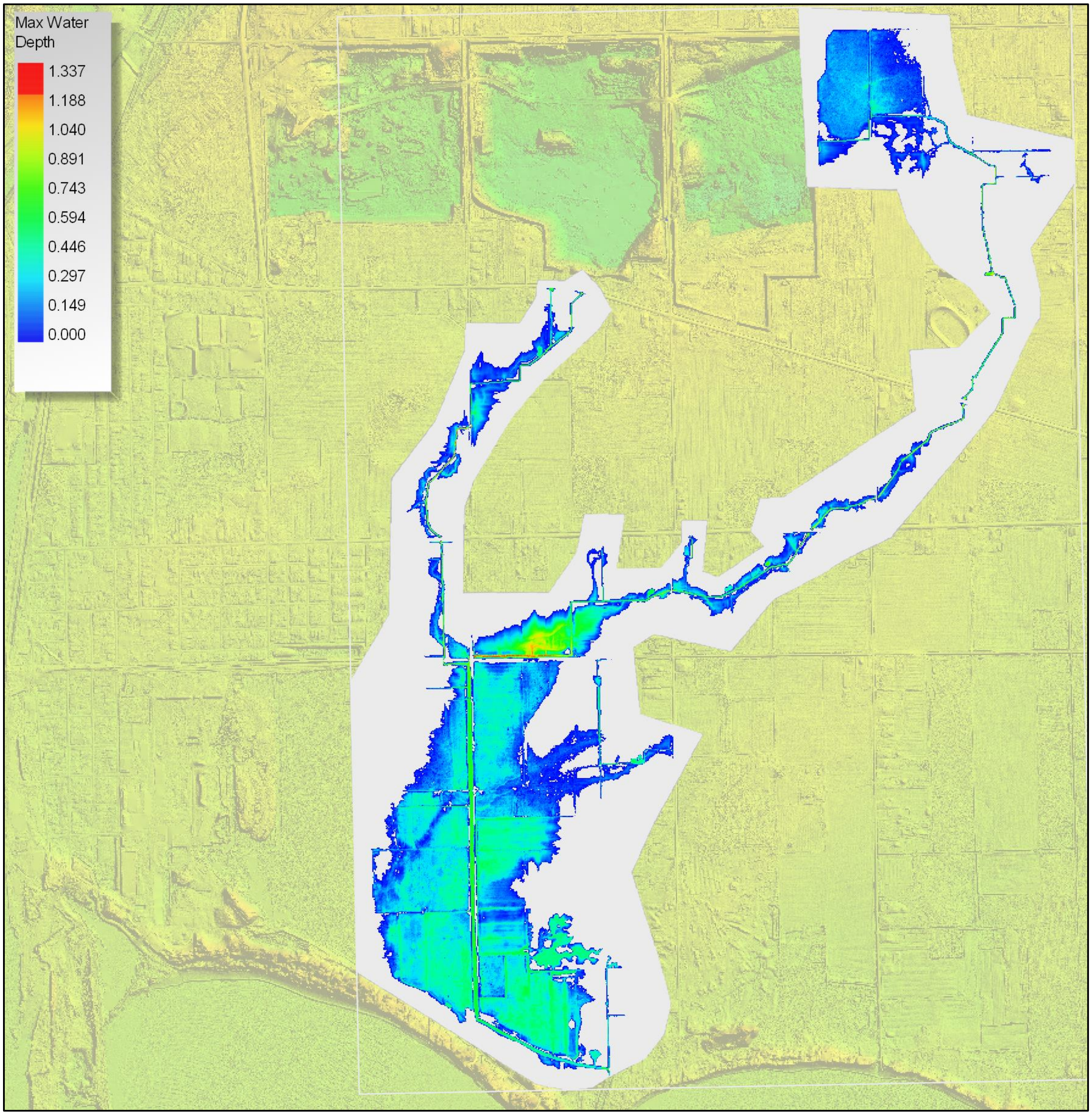
8.[illegible].1 Scenario Existing Conditions Lake Boundary Modified

In this scenario the existing condition were used, and the Lake Erie boundary condition was 100-year lake level + 10-year surface runoff event (**Gr[illegible]**). The outfall was raised to 75.10 m to represent the 100-year lake level + wave setup. At the control structure a flap gate was added since the control structure has sluice gates. Only the 10-year storm scenario was run.

In order to keep probabilities of lake levels and surface runoff real, the scenarios were as follows:

- 10-year surface and 100-year Lake Level and vice versa. Many Conservation Authorities and the MNR use this criterion.

Graphic 26: XPSWMM Depth MAP- Existing – 100 Year Lake – 10 Year Storm



8[illegible] Scenario [illegible] Developed – Lake Boundary Modified

In this scenario the developed Subject Lands conditions were used, and the Lake Erie boundary condition was 100-year lake level + 10-year surface runoff event (**Graphic [illegible]**). The outfall was raised to 75.10 m to represent the 100-year level + wave setup. At the control structure a flap gate was added since the control structure has sluice gates. Only the 10-year storm was run. **Table [illegible]** below summarizes the effect of Lake Erie water levels on the drain system for the 10-year storm under free flow conditions, as well the effect of Lake Erie water levels on the drain system for the 100-year storm.

Graphic 27: XPSWMM Depth MAP- Subject Lands – 100 Year Lake – 10 Year Storm

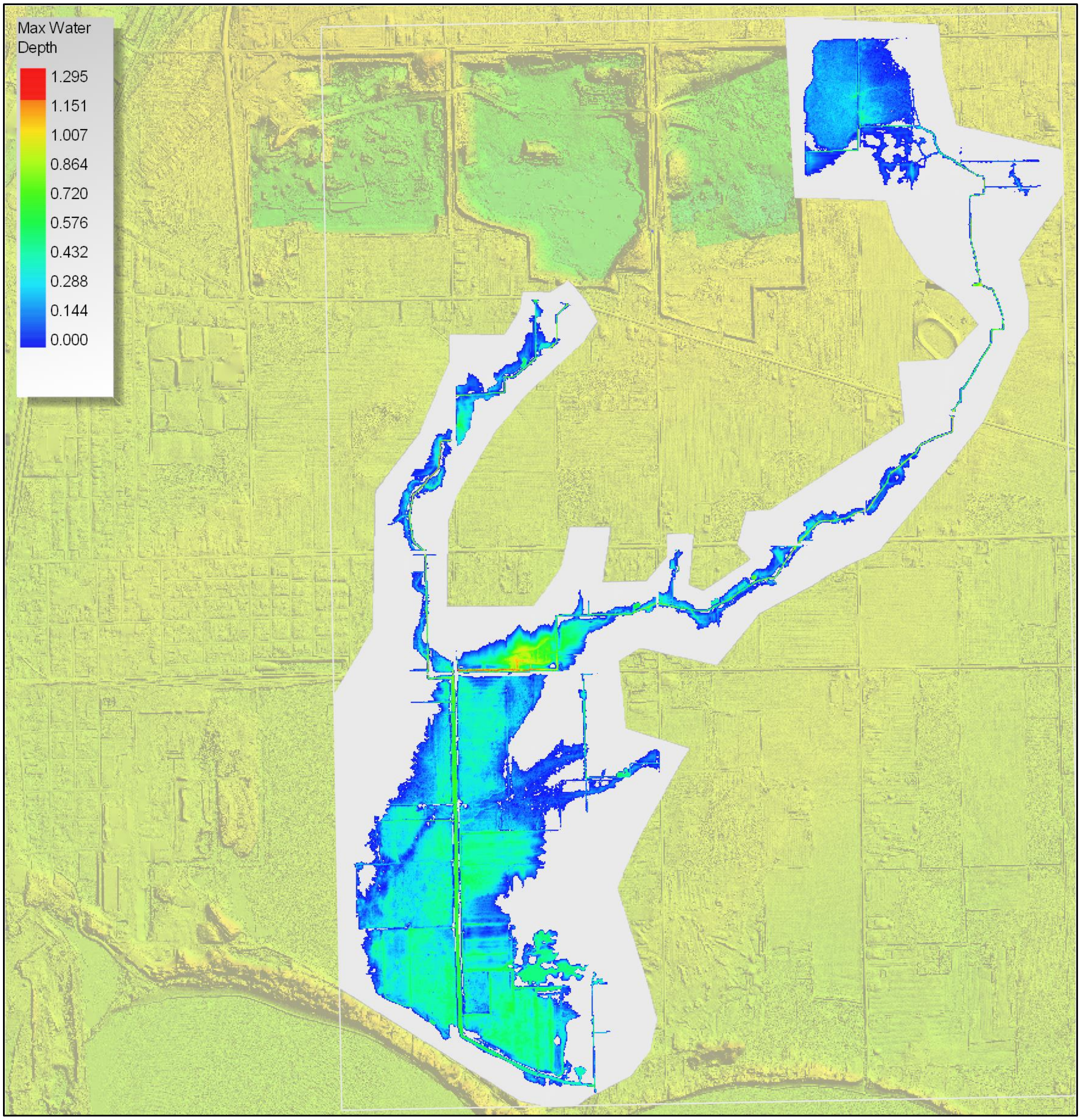


Table 35: Summary of Lake Effects - Hydraulic Effects Existing and Subject Lands Developed

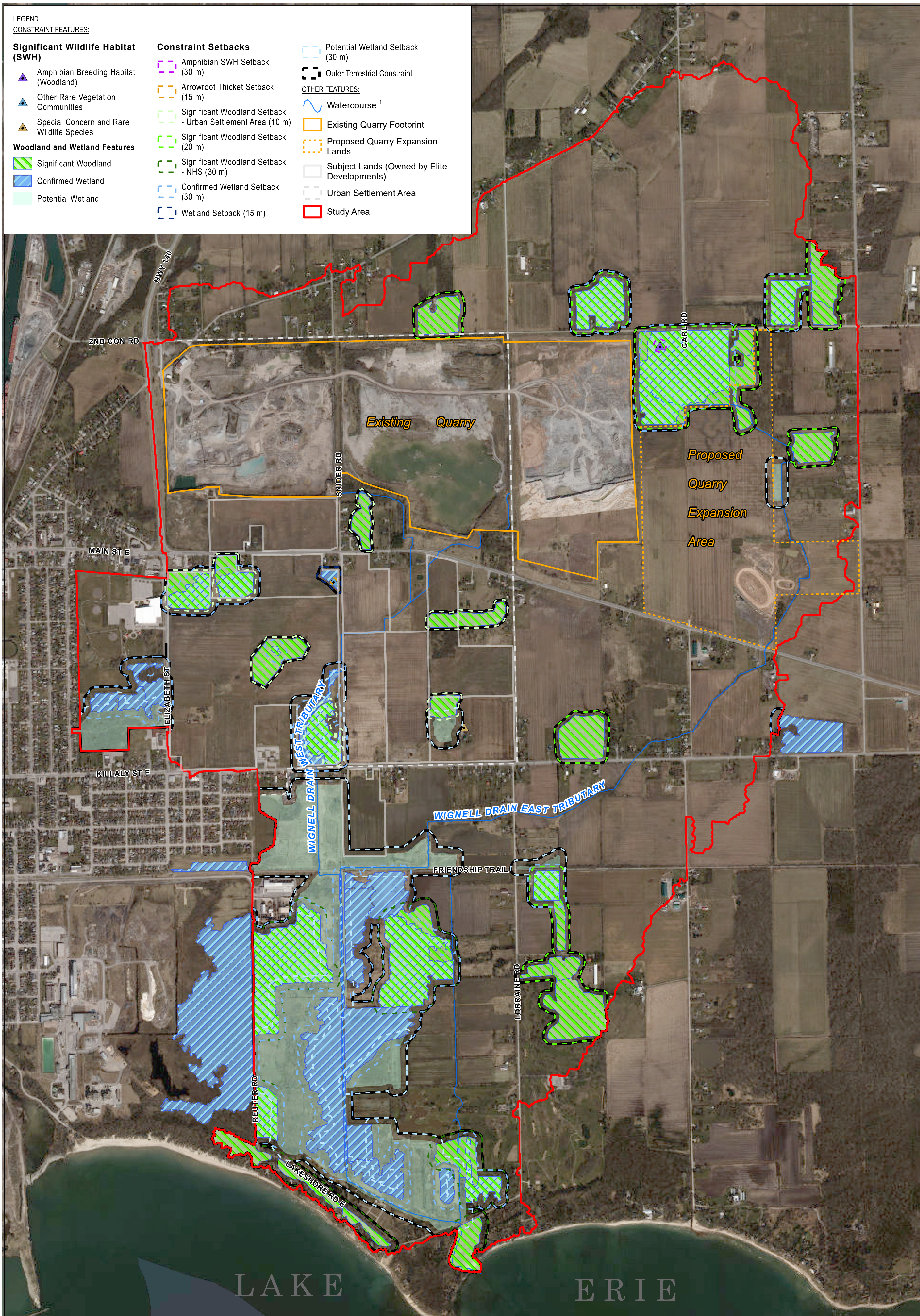
Location	1[illegible] 1[illegible]		1[illegible] Free [illegible]	
	[illegible]			
	Existing	Developed	Existing	Developed
Point 1	176.60	176.61	176.60	176.61
Point 2	176.96	177.00	176.96	177.00
Point 3	177.30	177.34	177.30	177.34
Point 4	177.58	177.66	177.58	177.66
Point 5	177.90	177.91	177.90	177.91
Point 6	178.38	178.32	178.38	178.32
Point 7	178.57	178.62	178.57	178.62
Point 8	178.78	178.79	178.78	178.79
Point 9	175.64	175.64	175.64	175.64
Point 10	175.55	175.55	175.55	175.55
Point 11	175.54	175.54	175.54	175.54
Point 12	175.44	175.43	175.43	175.43
Point 13	175.30	175.30	175.25	175.25

Notes:
1. Based on [illegible] the only area affected by the high lake water is Point 13, near Lake Erie.
2. The Subject Lands not appreciably affect the area when the Lake is high.
3. The probability of lake levels and surface runoff rare events concurring are unlikely, thus the scenario of 10-year surface and 100-year lake level is more realistic.

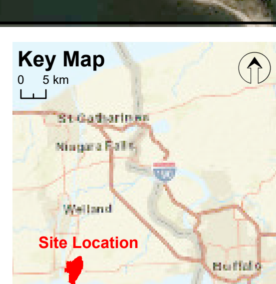
9. Development Constraints and Opportunities

9.1 Ecological Constraints

Ecological constraints for the Wignell Subwatershed Study Area are detailed in □□□□**e** □□ and illustrated on **Figure** □□ (Terrestrial Constraints) and **Figure** □**1** (Aquatic Constraints). The recommended development limit (i.e., outermost constraints) for the Study Area is highlighted on **Figure** □□. The development may be subject to refinement for areas where site-level field work could not be completed. Other areas may still require feature staking with the appropriate agencies.



Key Map



1 - Contains data sourced from Land Information Ontario (LIO)

0 100 200 300 400 500
METRE SCALE

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

Scale: 1:17,000
Page Size: Tabloid (11 x 17 inches)

Drawn: SM
Checked: RC
Date: Apr 25, 2024

NORTH

Source Notes:
Imagery (2019) provided by ESRI basemapping. Contains information licensed under the Open Government Licence – Ontario.

CLIENT
Elite M.D. Developments

PROJECT
Welland S - Wignell SWS

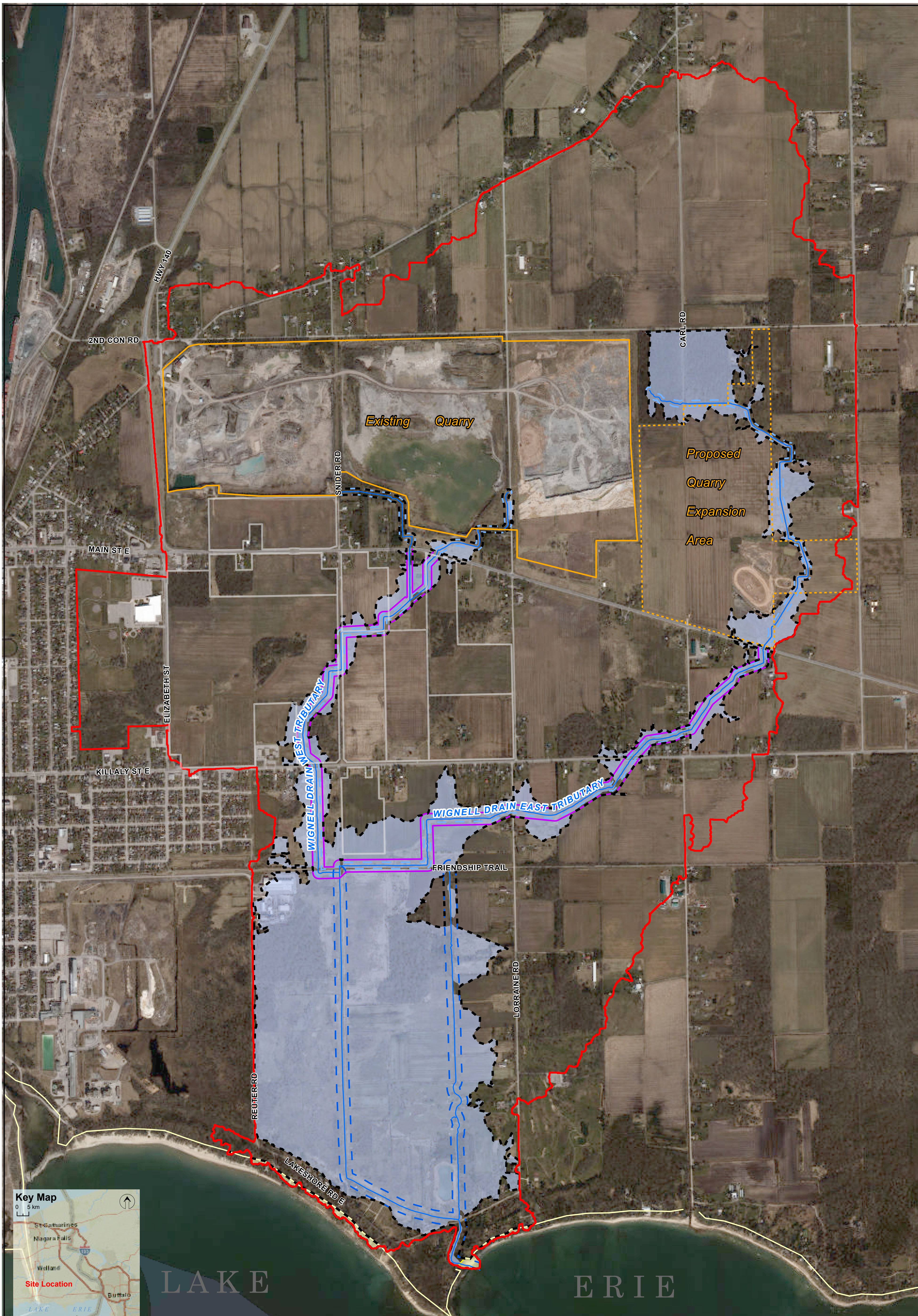
TITLE
Terrestrial Constraints

Palmer. PART OF SLR

REF. NO. 2007708-20-2

Figure 20

Document Path: G:\Shared drives\Projects 2020 (20044 to 20087)\20077 - Elite M.D. Developments\2007708 - Welland S - Wignell SWS\GIS\1_Workspace\Task 3 - Ecology Figures\(2023-03) Subwatershed Study\ArcPro Space\ArcPro Space.aprx



LEGEND

- Final Meander Belt
- Watercourse [1]
- Permanent Watercourse Setback (30 m)
- Intermittent/Ephemeral Watercourse (15 m)
- Watercourse Setback (15 m)
- Floodplain [2]
- Shoreline Hazard Limit [3]
- Outermost Aquatic Constraint
- Existing Quarry Footprint
- Proposed Quarry Expansion Lands
- Subject Lands (Owned by Elite Developments)
- Study Area

1 - Contains data sourced from Land Information Ontario (LIO)
2 - Niagara Peninsula Conservation Authority (NPCA) adjsuted by Odan/Detech Group Inc.
3 - Niagara Peninsula Conservation Authority (NPCA)

0 100 200 300 400 500
METRE SCALE

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

Scale: 1:17,000
Page Size: Tabloid (11 x 17 inches)

Drawn: SM
Checked: RC
Date: Apr 25, 2024

NORTH

Source Notes:
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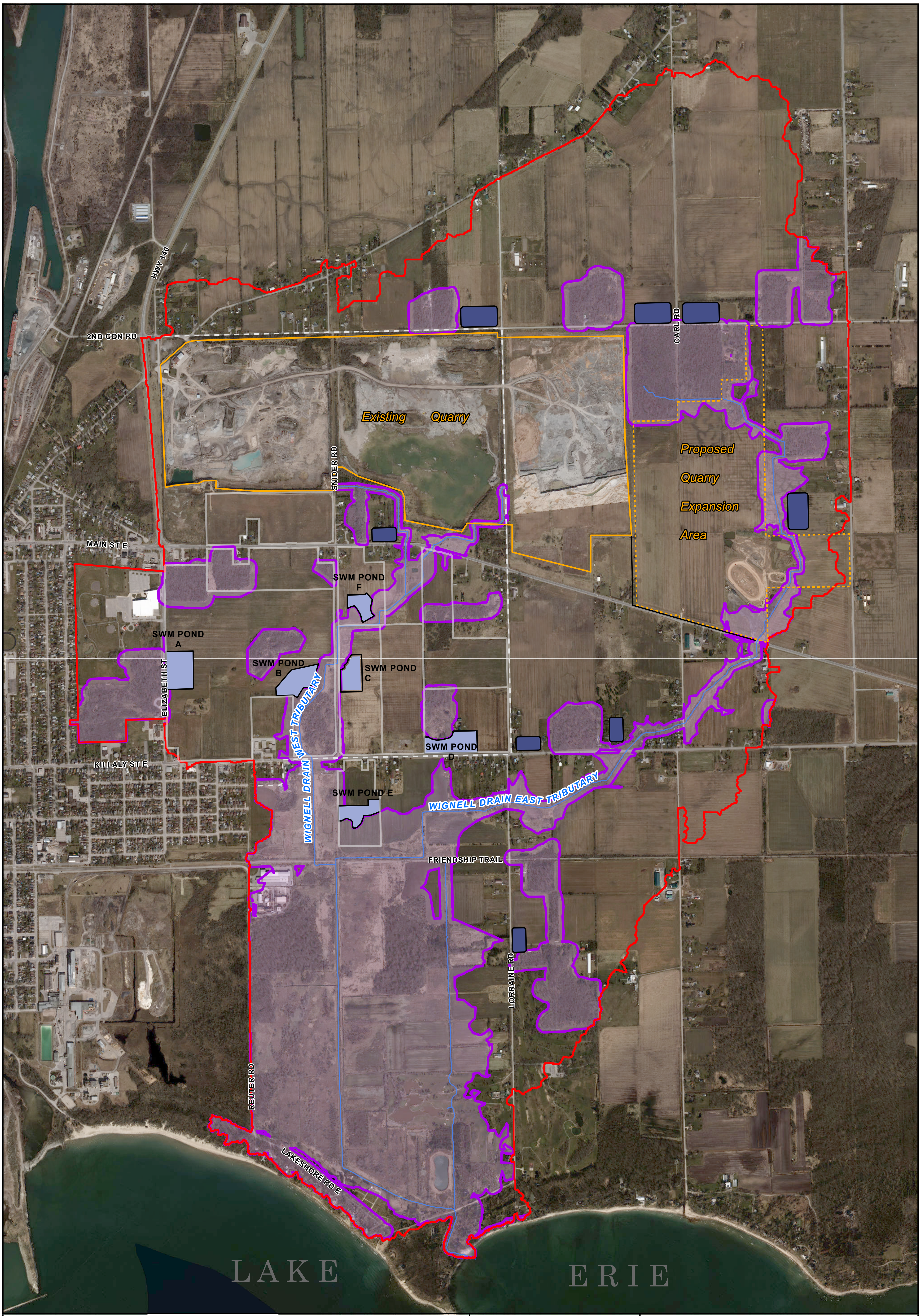
CLIENT	Elite M.D. Developments
PROJECT	Welland S - Wignell SWS
TITLE	**Aquatic Constraints**
REF. NO.	2007708-21-1
	Figure 21

Palmer. PART OF SLR

Document Path: G:\Shared drives\Projects 2020 (20044 to 20087)\20077 - Elite M.D. Developments\2007708 - Welland S - Wignell SWS\GIS\1_Workspace\Task 3 - Ecology Figures\(2023-03) Subwatershed Study\ArcPro Space\ArcPro Space.aprx

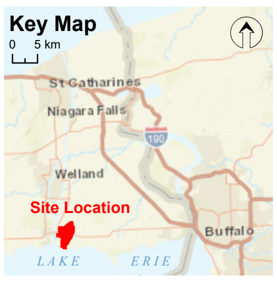


LEGEND

- Watercourse [1]
- Existing Quarry Footprint
- Proposed Quarry Expansion Lands
- Subject Lands (Owned by Elite Developments)
- Urban Settlement Area
- Confirmed SWM Pond
- Proposed SWM Pond
- Study Area
- Outermost Constraint

1 - Contains data sourced from Land Information Ontario (LIO)

Key Map



0 100 200 300 400 500
METRE SCALE

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

Scale: 1:17,000
Page Size: Tabloid (11 x 17 inches)

Drawn: SM
Checked: RC
Date: Apr 25, 2024

NORTH

Source Notes:
Imagery (2019) provided by ESRI basemapping. Contains information licensed under the Open Government Licence – Ontario.

CLIENT
Elite M.D. Developments

PROJECT
Welland S - Wignell SWS

TITLE
Proposed Development Limit

Palmer. PART OF SLR

REF. NO. 2007708-18-3

Figure 22

Document Path: G:\Shared drives\Projects 2020 (20044 to 20087)\20077 - Elite M.D. Developments\2007708 - Welland S - Wignell SWS\GIS\1_Workspace\Task 3 - Ecology Figures\(2023-03) Subwatershed Study\ArcPro Space\ArcPro Space.aprx

Table 36: Required and Recommended Buffers for Natural Heritage Features and Key Hydrological Features

Natural Feature Type	**Niagara Region OP**	**City of Port Colborne OP**	**NPCA Policy Document**	**Required or Recommended Buffers**
Wetland (Evaluated - Other, Other Wetland, Potential Wetland)	**Outside Settlement Areas** Not defined for non-PSW **Within Settlement Areas:** The width of an ecological appropriate buffer would be determined though an EIS (or SWS) and/or hydrologic evaluation at the time of an application for development or site alteration is made (Section 3.1.9.10.1 of the OP).	50 m, unless reduced buffers are determined by an EIS or SWS (Section 4.1.1 j) of the OP).	Not defined for non-PSW.	**Proposed**: • [illegible] for all except • **1**[illegible] for A2 (reduced through site-specific EIS)
Wetland (Provincially Significant Wetland)	**Outside Settlement Areas and the Provincial Natural Heritage System**: 30 m (Table 3-2 of the OP) **Within the Provincial Natural Heritage System**: 30 m (Section 3.1.5.3 of the OP) **Within Settlement Areas:** The width of an ecological appropriate buffer would be determined though an EIS (or SWS) and/or hydrologic evaluation at the time of an application for development or site alteration is made (Section 3.1.9.10.1 of the OP).	120 m, unless reduced buffers are determined by an EIS or SWS (Section 4.1.1 j) of the OP).	30 m	**Proposed**: • [illegible] for all
Municipal Drain (Stream)/Fish Habitat	The width of an ecological appropriate buffer would be determined though an EIS (or SWS) and/or hydrologic	15 m from stable top of bank of Municipal drain	15 m if the watercourse is warmwater, intermittent or	**Proposed**: • **1**[illegible] from drain edge north of Friendship Trail

Natural Feature Type	Niagara Region OP	City of Port Colborne OP	NPCA Policy Document	Required or Recommended Buffers
	evaluation at the time of an application for development or site alteration is made.	(Section 4.3.7.1 h) of the OP).	permanent and Fish Habitat is Important or Marginal - reductions of these buffer requirements will only be considered in special circumstances based on a site-specific evaluation by NPCA staff (Section 9.2.5.1 b) of the policy document). A 30 m setback is required from stream areas with permanent flow (NPCA Section 9.2.5.1).	(as no valley or permanent flow is present) • [illegible] from drain edge south of Friendship Trail (as permanent flow is present)
Floodplain	NA	NA	None given.	0 m
Lake Erie Shoreline	NA	NA (however, the City's OP Schedule B1 was used to estimate the 100-year flood line)	15 m setback from the 100-year flood line (NPCA Section 4.1.2.7, page 82).	15 m (from 100-year flood line)
Significant Woodland	**Outside Settlement Areas and the Provincial Natural Heritage System:** 20 m (Table 3-2 of the OP) **Within the Provincial Natural Heritage System:** 30 m (Section 3.1.5.3 of the OP) **Within Settlement Areas:** The width of an ecological appropriate buffer would be	50 m, unless reduced buffers are determined by an EIS or SWS (Section 4.1.1 j) of the OP).	NA	**Proposed:** • [illegible] (outside of settlement areas) • [illegible] (within the Provincial Natural Heritage System) • 1[illegible] (within settlement areas)

Natural Feature Type	**Niagara Region OP**	**City of Port Colborne OP**	**Other Policy Documents**	**Required or Recommended Buffers**
	determined though an EIS (or SWS) and/or hydrologic evaluation at the time of an application for development or site alteration is made (Section 3.1.9.10.1 of the OP).			
Significant Wildlife Habitat	The width of an ecological appropriate buffer would be determined though an EIS (or SWS) and/or hydrologic evaluation at the time of an application for development or site alteration is made (Section 3.1.9.9.2 of the OP).	50 metres unless reduced buffers are determined by an EIS or SWS (Section 4.1.1 j) of the OP).	NA	**Proposed:** • **1[illegible]** for A2 (Sufficient to protect uncommon/rare shrub and small numbers of breeding amphibians). See **Figure [illegible]**. **Proposed:** • [illegible] for Amphibian SWH (Sufficient given that the SWH is within a larger woodland / wetland complex). See **Figure [illegible]**. **Proposed:** No buffer is proposed for Special Concern and Rare Wildlife Species SWH.

It is important to note that, as mentioned in Section 7, a majority of the Study Area is considered 'potential karst' (Brunton & Dodge, 2008) and may cause additional environmental constraints if a surface karst feature is found.

9.2 Climate Change Discussion

As part of this SWS, Palmer reviewed a report entitled *Climate Projections for Niagara Region* (Toronto and Region Conservation Authority, 2022). Within this report it noted that by the 2080s, in the Great Lakes Basin, air temperatures are anticipated to rise between 1.5 to 7°C along with an estimated 20% increase in annual precipitation. An increase in the frequency and severity of storms, drastic fluctuations in water levels, and a significant reduction in total lake ice cover within the Great Lakes region are anticipated to have profound consequences on both terrestrial and aquatic systems and the interactions between the two.

Assuming a 'high emissions' scenario (a Representative Concentration Pathway of 8.5) where Greenhouse Gas emissions continue to increase beyond the end of the century, the Niagara Region is projected to experience similar climate-related impacts to that of the overarching Great Lakes Basin (Toronto and Region Conservation Authority, 2022) in that it will experience a wetter and warmer climate in the future. The *Climate Projections for Niagara Region* report, discusses these projected changes over the short- (2021-2050) and long-term (2051-2080).

In the short-term air temperatures are expected to rise on average by 2℃. As a consequence, this will lead winter precipitation to increasingly occur as rain instead of snow. With the less pervious (i.e., frozen) soils during the winter months, additional runoff and flooding within the Region's aquatic systems may occur. Contrastingly, an increase in rain during the winter months may reduce snow accumulation and therefore, spring freshet. Increased temperatures will lead to warming waters and heat stress on the aquatic systems. Moreover, due to the increased winter precipitation and the maintenance of total summer precipitation, the total annual precipitation is expected to increase. Lastly, the growing season is expected to increase in length; however, as a result of the projected temperature fluctuations pests are expected to thrive resulting in the crops that need to be hardier to both temperatures and pests.

In the long-term (2015-2080), assuming a Representative Concentration Pathway of 8.5, air temperatures are predicted to rise on average by 3.6℃ relative to baseline numbers (1971-2000). The aforementioned climate trends predicted over the short-term are only anticipated to continue and intensify. The *Climate Projections for Niagara Region* report (pg. 4) writes,

> *However, projections further into the future (i.e., the long-term period) should be interpreted as having greater uncertainty. This is because policies, conditions and decisions made locally and globally may influence the climate condition trajectories.*

The anticipated warmer and wetter climate within the Niagara Region, and thus the Study Area, will likely have serious implications on agricultural success (i.e., pests), wildlife migration patterns, and land development (i.e., flooding, erosion), among others. Despite the greater need to inform climate adaption strategies, it is important to note that any climate modeling scenario assumes a certain level of uncertainty. Additional inter-disciplinary initiatives, such as those listed below in Section 10, will help better understand how climate change will affect the systems of both the Subwatershed Study Area and the Niagara Region as a whole.

9.3 Hydrogeological Constraints and Impacts

9.3.1 Hydrogeological Constraints and Impacts

The hydrogeological constraints to the development in the Study Area were assessed based on the above hydrogeological characterization (Section [illegible]). The hydrogeological conditions of the Study Area can be summarized as shallow to moderately shallow groundwater levels, low permeability overburden soils with shallow bedrock, good groundwater quality, potential karst conditions, and a low infiltration rate. The interaction between groundwater and surface water features is not well known; however, the limited data available suggests that groundwater recharging conditions exist. This; however, is limited by low infiltration through the overburden soils. Depending on the types of developments, hydrogeological constraints and issues may include:

- Locally shallow groundwater levels and bedrock top;
- Karst risk;
- Challenge in stormwater management through infiltration;
- Impact of development to natural heritage features supported partly or wholly by groundwater discharge.

Shallow groundwater levels occur in the areas around MW-19 and 6604018 (**Figure 1[illegible]**) and other areas. Shallow bedrock is usually associated with shallow groundwater levels and karst risk. A majority of the Study Area is underlain with varved silty clay with low hydraulic conductivity ($7.5x10^{-7}$ to $1.7x10^{-6}$ m/s). Based on the shallow overburden soil, stormwater management through infiltration may be difficult to implement due to the large space that would be required to infiltrate sufficient volumes of water.

Major hydrogeological impact as a result of development is the decreased infiltration due to increased impervious area, which will result in reduced groundwater recharge and lowered groundwater level, as well as reduced groundwater discharge. Lowered groundwater levels will reduce the yield of supply wells and increase the energy consumption of water taking. The reduced groundwater discharge may have a negative effect on the groundwater-supported natural features.

9.3.2 [illegible] Pumping for Quarry Dewatering and Site Drainage

Site reconnaissance conducted by Palmer hydrogeologist on February 19, 2023, did not see water pumps and pumping operation in quarry pits, and did not identify sign of groundwater seepage from quarry walls. Based on exp. report, the bedrock aquifer has a geometric mean k-value of 7.9×10^{-7} m/s. Assuming the possible maximal dewatering height of 17.0 m, which is the averaged depths of the quarry pits, the influence zone of the dewatering is approximately 45.0 m based on Sichardt and Kryieleis formula ($R0 = C(H\text{-}hw)K^{1/2}$, C=3000). The influence zone is measured from the excavation boundary of the quarry pits. The cease of pumping will cause groundwater recovery within 45.0 m buffer from the quarry boundary only.

The closest monitoring wells adjacent to the quarry installed by exp. include MW-9, MW-20, and MW-21, and they recorded groundwater depth of 3.5, 1.7 and 0.5 mbgs respectively. As these three wells are all located away from the influence zone, the groundwater levels recorded from these monitoring wells can be viewed as background groundwater levels. It is reasonable to assume that the groundwater levels under the west pit will recover to the groundwater levels in MW-9, groundwater levels under the middle pit will recover to the groundwater levels in MW-21 and groundwater levels under the east pit will recover to the groundwater levels in MW-20. Consequently, the cease of pumping will not have significant effect to the groundwater system and futural development.

It is noted that climate change, especially global warming, will lead to reduced river flows and warm surface waters, more drought conditions and more frequent severe weather, and finally results in reduced groundwater recharge. Reduced groundwater recharge will lead to lowered groundwater levels, which should not have significant effect to the development as global warming is a long-term process.

9.4 Stormwater Management Recommendations

9.4.1 Target Flows

The City PCSWMM model was used to establish pre-development hydrology target values to compare to the post development conditions within the Subject Lands added (Table 37).

Table 37: Target Flow Locations for the Wignell Drain

[illegible]	Location description or crossing	Notes
S-1	Hwy # 3 culvert crossing west branch	Should be similar to PCSWMM
S-2	Hwy # 3 culvert crossing east branch	Should be similar to PCSWMM
S-3	Killaly culvert crossing west of Snider Road	Should be similar to PCSWMM
S-4	Killaly culvert crossing east of Lorraine Road	
S-5	Snider road culvert crossing just north of Friendship Trail (former CNR)	
S-6	Friendship trail culvert crossing adjacent to Snider Road west side	
S-7	Outlet to Lake	

Table 38 summarizes the allowable (target flows) for the existing outlets per storm event.

The comparison will be made with XPSWMM (2D) existing conditions and XPSWMM (2D) with the Subject Lands development added. It is the only honest way to compare because the PCSWMM model is not 2D and does not include the culverts in real time. The NPCA HEC-RAS model maintains continuity of flow and thus has no attenuation at culverts. We will include the flows of PCSWMM at the above locations for comparison only.

Table 38: Pre-Development Existing Flow Targets

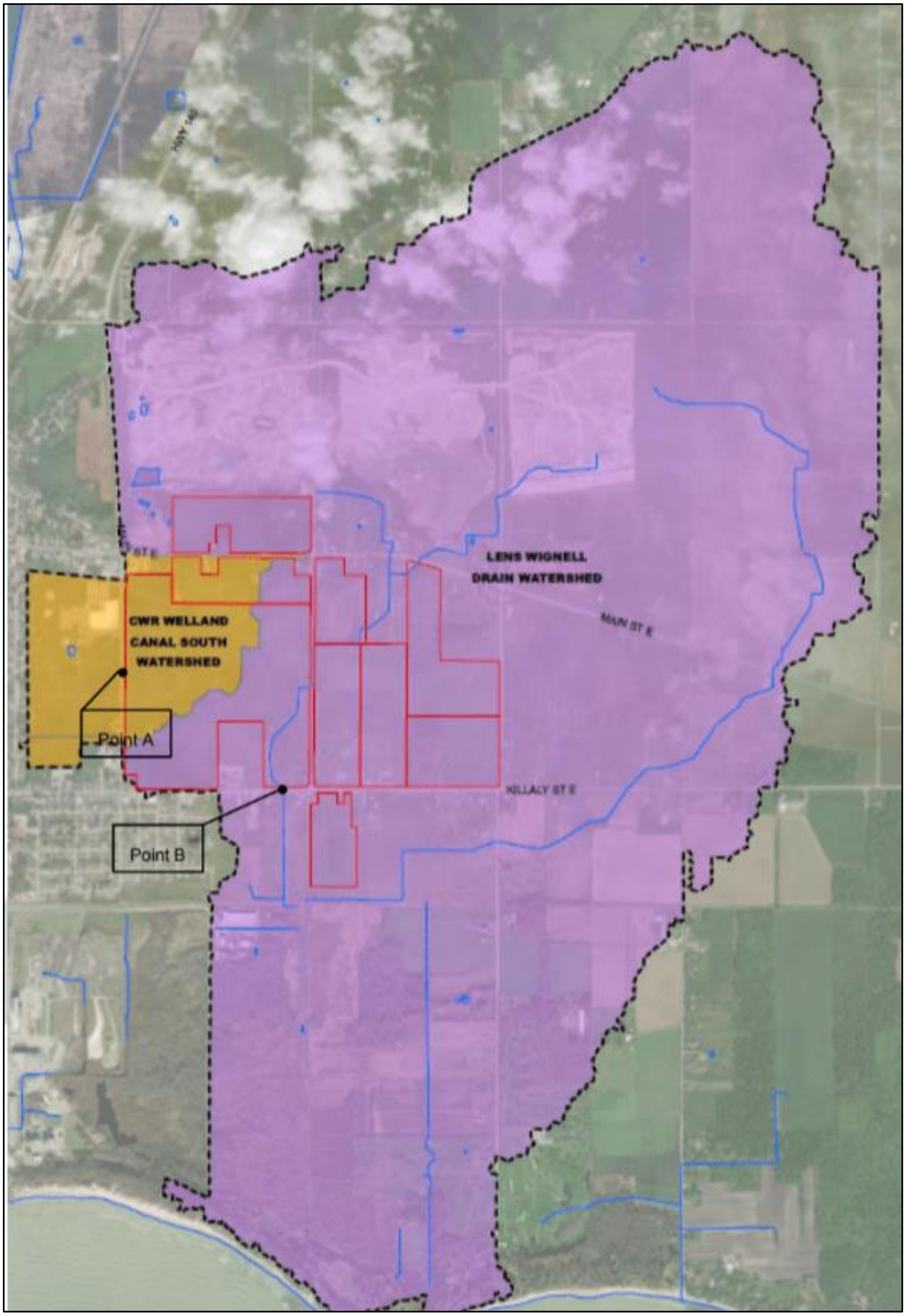
[illegible]	[illegible]	[illegible]						
		[illegible]1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2 Year	24Hr SCS	0.439	0.730	1.070	0.685	1.025	1.026	0.479
5 Year	24Hr SCS	0.794	1.215	1.787	1.554	1.946	1.954	1.046
10 Year	24Hr SCS	1.054	1.591	2.357	2.326	2.521	2.531	1.484
25 Year	24Hr SCS	1.401	2.160	3.157	3.422	2.663	3.335	1.781
50 Year	24Hr SCS	1.646	2.651	3.873	4.239	2.694	3.848	1.966
100 Year	24Hr SCS	1.903	3.157	4.626	4.994	2.698	4.335	2.179
100 Year	12Hr AES	0.606	1.976	4.043	4.628	2.701	4.020	1.774

A development, such as the one proposed on the Subject Lands, requires a team approach with many disciplines including but not limited to Planners, Environmental Consultants, Hydrogeologist/Soil Consultants, and Civil Engineering Consultants.

In the case of the Subject Lands, the development fabric was determined based on a Survey/Topographical Plan, Provincial Lidar derived DEM, and the natural heritage features. Weston was the Planner, Palmer was the Environmental Consultant, EXP was the Hydrogeologist/Soil Consultant for the Subject Lands, Palmer was the Hydrogeologist Consultant for the Wignell Drain Subwatershed Study Area, and Odan/Detech Group Inc. was the Civil Consultant. The Draft Plan of Sub-Division was assembled by Weston through input by the Developer, Palmer, EXP, and Odan/Detech Group Inc. and can be found in the document entitled *Environmental Impact Study Elite Properties East of Port Colborne* (Palmer, 2023). It is recommended to utilize six SWM ponds for the development of the Subject Lands. Refer to **Figure [illegible]** for locations. The ponds within the Subject Lands outlet to the Wignell Drain at various locations. The preferred method to determine an allowable (target flow) is to use the predevelopment unit runoff rates. The following is the procedure:

1. Pick a point in the drainage system where there is a known flow from PCSWMM model. The Subject Lands as mentioned above has two drainage areas as follows:
    - Welland Canal South Watershed - Point A - ditch at Elizabeth Street (see **Gr[illegible]8**)
    - Wignelll Drain Watershed - Point B - culvert crossing Killaly Street, west of Snider Road (see **Gr[illegible]8**).
2. For the Welland Canal South Watershed (Point A) - the calculated flows are based on hydrology information shown above (**[illegible]8**).
3. For the Wignell Drain Watershed (Point B) – **Gr[illegible]** summarizes the procedure used to derive the target flow at Point B using tributary areas in the original PCSWMM and unit flow rates per hectare for the 2-year storm to the 100-year storm. The target flows were determined for each pond (Pond A – Pond F) as shown in **Gr[illegible]**.
   Notes: The quarry areas were removed because they do not contribute runoff flow.

Graphic 28: Wignell Drain Subwatershed Drainage Areas



Graphic 29: Procedure to Derive Target Flows & Summary of Target Flows Using Procedure

From PCSWMM model									unit rate
					Point B		Point B		m3/s/ha
Name	Area (ha)				area (ha)		flow (m3/sec)		
W10	8.32				274.24		6.86		0.025
W6	28.7457								
W2	26.526	Flow area to point B							
PC3-QW1	41.95								
PC4-QE1	18.79					Pond Trib		100 year	
W1	16.7049	19.3425				area (ha)		allowable flow	
PC7	19.3425	63.43							
W4	1.98	7.7			Outlet A	52.28		0.921	
M3	3.65	18.3597							
W7	36.5969	42.97							
W3	66.06	82.3056							
PC8	63.43	23.23			Outlet B	274.24		6.86	
PC2	7.7	6.88							
W14	20.8394	10.0218							
M1	54.0114				Pond A			0.921	
W13	39.1345	**274.24**	ha						
M2	8.8715				Pond B	23.33		0.584	
W11	5.4412								
W9	58.2949				Pond C	31.354		0.784	
W5	100.6								
PC6	26.23				Pond D	33.849		0.847	
PC1	18.3597								
M4	28.7148				Pond E	11.827		0.296	
W12	34.15								
M5	77.959				Pond F	8.004		0.200	
WB2	41.21								
PC9_3	42.97								
B1	22.3			example : 100 year allowable flow pond B = 23.33 x 0.025					
PC5	82.3056						=	0.584	
WB1	41.66								
W8	6.61			for Outlet A - the flows are based on existing hydrology					
PC9_4	23.23								
PC11	6.88								
PC10	10.0218								
	1089.59								

Summary of Pond Target Flows:

Pond	Pond Trib area (ha)	24 hr SCS 100 year Target flow m3/sec	24 hr SCS 50 year Target flow m3/sec	24 hr SCS 25 year Target flow m3/sec	24 hr SCS 10 year Target flow m3/sec	24 hr SCS 5 year Target flow m3/sec	24 hr SCS 2 year Target flow m3/sec	12 hr AES 100 year Target flow m3/sec
Pond A	51.83	0.921	0.727	0.555	0.361	0.24	0.113	0.862
Pond B	23.33	0.584	0.542	0.430	0.300	0.214	0.112	0.487
Pond C	31.35	0.784	0.728	0.579	0.404	0.288	0.151	0.654
Pond D	33.85	0.847	0.786	0.625	0.436	0.311	0.163	0.706
Pond E	11.83	0.296	0.275	0.218	0.152	0.109	0.057	0.247
Pond F	8.00	0.200	0.186	0.148	0.103	0.074	0.039	0.167

□□□□ □ □er □u□i□

The SWS and the Stormwater Management Plan (SWMP) Implementation Document establishes the required guidelines for implementing stormwater quality for the future development. The requirements for water quality are as follows.

“Control pollutant loadings in accordance with current MOE guidelines. Enhanced Level 1 protection as defined in the 2003 Stormwater Management Planning & Design Manual – reduce average long term annual load of suspended sediment by 80% or better. Accomplish through the use of LID source and conveyance controls.”

Stormwater Source Control Policy for Industrial, Commercial, and Institutional (ICI) Land Uses by NPCA is also to be used as a guide.

In order to achieve water quality for any proposed development, each site will be required to implement the above measures to achieve an Enhanced Level 1 Protection of 80% removal of total suspended solids prior to discharge into downstream outlets. □□□□e □□ provides values established and generally accepted throughout the province for use of various total suspended solids removal techniques.

Table 39: Total Suspended Solid Removal Method & Removal Efficiency

Re□ □□□□Me□□□d	Re□ □□□□□□i□ie□□□
Rooftop	*80%*
Grassed Swale (with Perforated Pipe)	*80%*
Grass Swale (no perforated Pipe)	*50%*
Soakaway & Infiltration Systems	*70-90%*

Removal Method	Removal Efficiencies
Chambers (with Infiltration)	*70-90%*
Bio retention	*80%*
Dry Swale	*80%*
Permeable Pavers (with Storage Bed)	*80%*
OGS (Oil/Grit Separator)	*50%-80%*
CB Shield	** 50%*
Wet Pond	*** up to 90% total suspended solid removal if extended detention is used*

** - Based on Table provided by Manufacturer.*
*** - New Jersey Department of Environmental Protection*

The above methods can be considered at the detailed design stage. Removal methods will largely be dependent on constraints, such as limited landscape space available throughout the Study Area for implementing Low Impact Developments (LIDs), underlying soils conditions and conductivity to LIDs, groundwater conditions, and other factors that can limit the use of LIDs. All reasonable attempts should be made during the detailed design stage to provide for the use of LIDs to enhance water quality measures. The efficiencies of LID strategies are variable and dependent on the maintenance and loading from the Study Area usage. [illegible] values are based on the generally accepted removal.

In order to ensure the removal of oils, each outlet will require an oil grit separator or method of removing oil spills prior to discharging to the downstream outlet and receiving watercourse.

Volume Control and Water Balance

As per City, Region, and NPCA criteria, Enhanced (Level 1) classification must be achieved, improving the quality of drainage discharging to each outlet from that of existing conditions. Reduction of the Total Suspended Solids (TSS) released to an Enhanced (Level 1) system must result in 80% TSS removal, based on the MOECC 2003 criterion. This will be attained using a train treatment approach, in which a series of LIDs will be implemented.

LIDs

The following LID methods are possible:

- Imbrium Filterra Bioretention System
- Silva Cells
- Soak Away Pits
- Bio Swales
- Others

It is believed the following can be adapted for the SWM quality/water balance component:

1. Wet ponds as detailed in this report
2. Silva Cells or Imbrium Filterra Bioretention System on the roads if City will accept.
3. Soak away pits in the park area.

4. Bioswales if landscaped areas can accept.
5. Irrigation reuse.
6. Roof flow capture via barrels for reuse.

Imbrium Filterra Bio-retention System

This is an appropriate method for water quality treatment in a train treatment environment. Stormwater runoff enters the Filterra system through a curb-inlet opening and flows through a specially designed filter media mixture contained in a landscaped modular container. The following photos (□□□□□ □ and **8**) show the installed Filterra unit and a section through the unit.

Photo 7. Filterra System: External View.

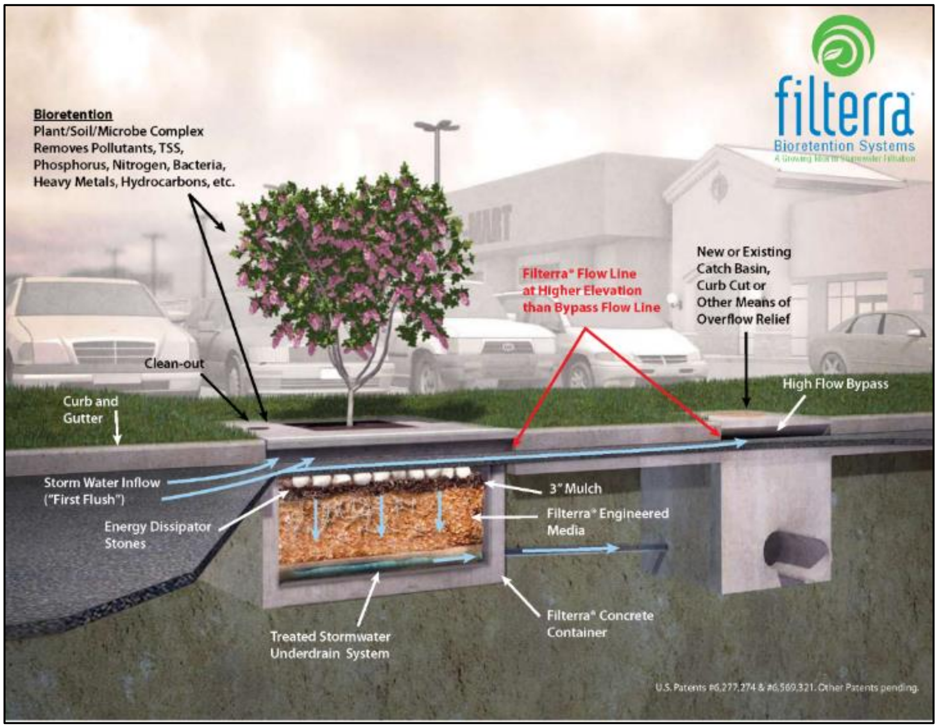


Photo 8. Filterra System: Internal View.

Silva Cells

The Silva Cell is a modular, suspended pavement system that uses soil volumes to support large tree growth and provide powerful on-site storm water management through absorption, evapotranspiration, and interception. The system is typically installed under pavement applications and can be configured in several different ways:

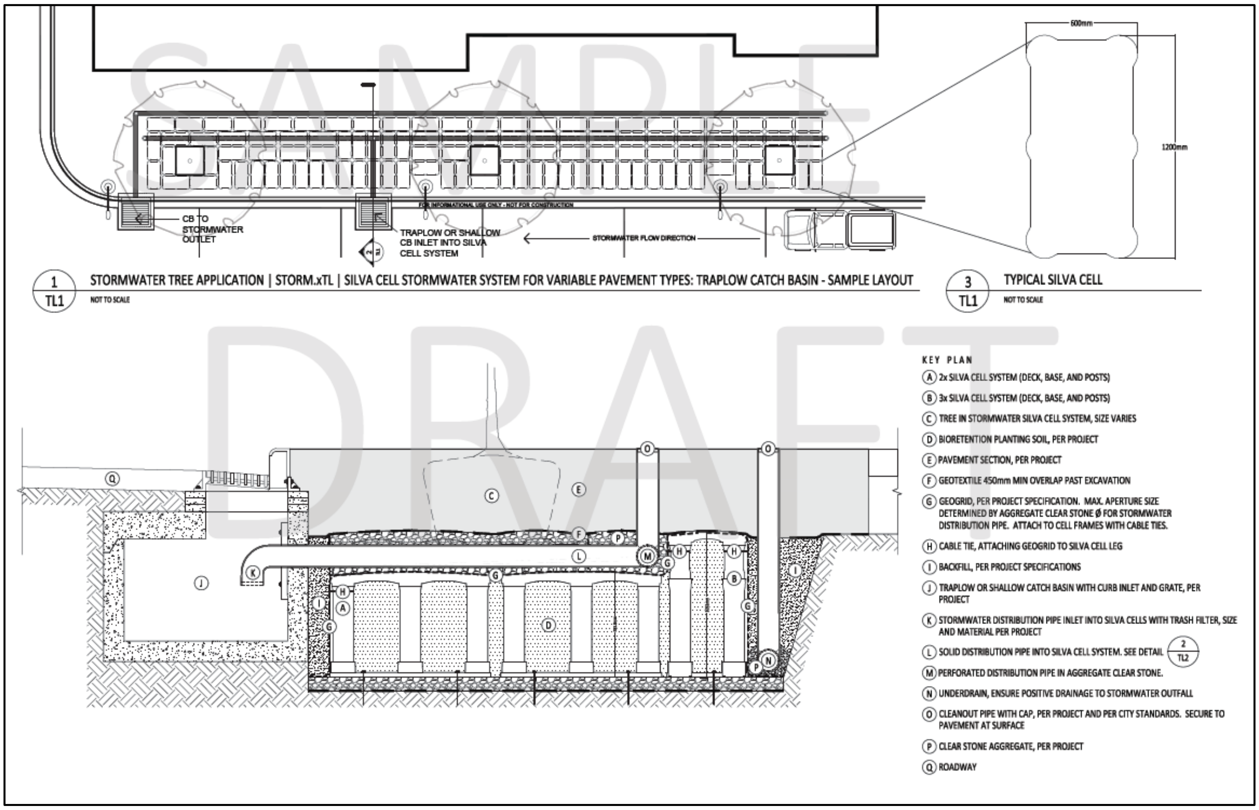
Streetscapes
Adjacent to or under sidewalks, between buildings and streets.

Parking Areas
Under parking stalls adjacent to medians or islands.

Public Spaces
Under plazas, promenades, courtyards, or other public spaces at office buildings, museums, schools, and transit centers.

The Region of York is using Silva Cells on the widening and reconstruction of Yonge Street.

The following detail is a typical Silva Cell application.



Water Balance Groundwater

Refer to report by EXP Hydrogeologist "*Preliminary Hydrogeological and Water Balance Investigation, Killaly Street East, Port Colborne, Ontario*."

The following is the summary from that report. Note, there is 33,161 m^3 deficient in the infiltration rate from pre to post conditions. The Subject Lands will require to infiltrate 33,161 m^3 of rainfall on an annual basis.

Killaly Street East, Port Colborne, ON
BRM-21000726-A0

Appendix E-4
Summary of Pre and Post-Development Water Balance (Unmitigated)

6. Comparison of Pre-Development and Post-Development Un-Mitigated

	Precipitation (cu.m.)	Actual Evapotranspiration (cu.m.)	Run-off (cu.m.)	Corrected Infiltration Rate for Areas with Shallow Groundwater Table (cu.m.)
Pre-Development	1,490,625	868,758	423,299	198,568
Post Development	1,490,625	579,163	746,057	165,406
			Pre-development Infiltration Rate	**133.3**
			Post-development Infiltration Rate Un-Mitigated	**111.1**
			Deficit Post Development Un-Mitigated	**33,161**

Criteria

Criteria for stormwater balance, retention, and low-impact-development (LID) is provided for the City of Port Colborne and by NPCA. The NCPA provides criteria in their manual *Niagara Peninsula Conservation Authority Stormwater Management Guidelines* (March 17, 2010).

Stormwater Volume Control Requirements in the NPCA manual provides criteria. The criteria applying to this development is generally described as follows:

- Any major development or disturbance that reconstructs 0.5 ha of impervious surfaces are subject to storm water volume control criteria.
- Stormwater volume reduction (stormwater retention) may include such techniques as infiltration, reuse, rainwater harvesting, canopy interception, evapotranspiration and/or additional techniques.
- Redevelopment volume control – nonlinear redevelopment projects meeting the foregoing criteria shall capture and retain/treat on-site the runoff from a pre to post water balance analysis event from the new and/or fully reconstructed impervious surfaces.
- The retained runoff is to be dispersed on-site by the acceptable measures (above) in 48 hours.

The proposed development which comprises approximately 148.93 ha of which 53.94 ha of impervious surface, is subject to the storm water balance/retention requirements. It is demonstrated as follows that the criteria can be addressed in the proposed development principally by infiltration, with additional retention provided by irrigation (evapotranspiration) and rainwater harvesting.

Based on the EXP report the deficit is 22.3 mm/a rainfall event, falling on the proposed new and reconstructed impervious surfaces, will generate the following storm water retention volume requirement.

Area of impervious surfaces = 53.94 x 10000 = 539,400 m^2

Required Stormwater Retention Volume = 539,400 m^2 x 22.3 mm = 12,029 m^3

Retention Strategy

It is proposed to principally retain the foregoing 12,029 m^3 by infiltration galleries whereby the foregoing volume of water will percolate into the underlying soil.

The locations and footprint available for infiltration galleries have been functionally considered in potential locations for infiltration galleries with a total footprint of 4.20 ha. The infiltration footprint identified is located within lands planned to be allocated for parks such that all infiltration galleries will be controlled. The footprints will need to be sized such that there is a minimum 5 m setback (OBC latest edition) from the potential location of any buildings (above- or below-ground) on the adjacent development blocks.

The design criteria for infiltration galleries comprises the following factors. The province of Ontario's Stormwater Management Planning & Design Manual (2003) provides design criteria for infiltration galleries. The criteria are identified and addressed as follows:

- Underlying groundwater table elevation
- Criteria: the MECP states that the groundwater table or bedrock elevation should be 1.0 m below the bottom of infiltration galleries.
- Design: A Hydrogeological Investigation was prepared by EXP, Dated September 15, 2021. Table 3.1: Summary of measured groundwater elevations in Monitoring Wells from 14 wells. The observed groundwater is typically 0.4 to 3 m below existing grade. This is sufficient depth below-grade in which to install an infiltration gallery with 1m clear above the groundwater/bedrock. If necessary, the

landscaped space in which the infiltration galleries will be installed can be graded such that there is sufficient cover above the stable groundwater table in which to install an infiltration gallery.

- Percolation rate of underlying soils. The MECP states that infiltration galleries should only be proposed where the percolation rate of receiving soils is greater than 15 mm. Infiltration gallery footprints are to be designed considering percolation rates.
- EXP has not provided infiltration rate. We are assuming the MOE 2003 minimum of 15mm/hr in the following analysis – this has been applied in the following infiltration gallery design calculations.
- Drain down time of infiltration galleries.
- Criteria: The MECP and NCPA manuals state that infiltration galleries should drain-down in 48 hours following the design storm event.
- Design: A drain-down time of 48 hours has been applied in the following infiltration gallery calculations.

Shown below is a sample infiltration gallery sizing calculation (**Gr□□□i□ □□**) showing that the infiltration gallery footprint required to drain-down a retention volume of 12,029 m^3 (above) within 48 hours is 41,766 m^2, which aligns with the potential infiltration gallery areas within the site mentioned above (42,000 m^2). This is less than the required footprint, therefore this is preliminarily a feasible means of addressing the storm water retention requirement in-full.

It is possible that in the future design refinement of the infiltration galleries' placements may yield small available footprints than has been preliminarily identified above. In such a case, the water balance volume can be made up by other forms such as irrigation and other forms of greywater reuse such as roof capture barrels.

Graphic 30: Sample Infiltration Gallery Sizing Calculation

INFIILTRATION GALLERY CALCULATION						
PROJECT: Elite - Killaly Street East - Port Colborne						
PROJECT No. :	21247					
Location of infiltration gallery: TBD						
						DESCRIPTION
						A = 1,000V / (PnΔt)
					UNIT	
	d = PΔt/1000		P=	15	mm/hr	Where:
			Δt =	48	hr	
d =	0.72	m				A = Filter bed surface area (m2)
			n=	0.40	-	V = Water volume (m3)
						Δt = time to drain (hr)
						n = void space ratio for aggregate used
V=	12029	m3	Atrib	539400	m2	(note: void space ratio of 0.4 to be used)
			runoff	22.3	mm	P = soil percolation rate mm/hr
						d = PΔt/1000
						Atrib = pervious area contributing runoff
						Where:
						d = maximum soak-away depth (m)
A =	1,000V / (PnΔt)					P= infiltration rate for native soils (mm/hr)
						Δt = time to drain (hr)
Af=	41766	m2				Af = Filter bed surface area provided (m2)
Af provided =	42000	m2				Vpit req'd = V/n
						Vpit provided = L x W x d
Vpit req'd =	30072	m3				
			Af =	42000	m	L = length of pit (m)
Vpit provided =	**42000**	m3				W = width of pit (m)
			d =	1	m	d = depth of pit (m)
NOTE: 10 SOAK-AWAY PITS WILL BE PROVIDED THAT TOTAL THE ABOVE VOLUME						

□□□□ □□e□i□□□er□i□i□g Re□uire□e□□□ Due □□ R□□□ □□d Gr□u□d□□□er

Groundwater levels in the monitoring wells on site ranged from 0.4 to 3.0 m below grade (elevation 175.2 to 180.3 m).

In the event the base of the pond is to be constructed below the recorded, static groundwater table, dewatering will be required to allow the excavation of the pond and the construction of the clay liner. Due to this site being in a well head protected zone a liner would be required.

□□□□ Di□□u□□i□□□□□□ □e□□r□ □□d □□er□□i□□□

The following are in no particular order:

1) The 1D/2D model approach is more realistic. The EWA model does not capture the culverts interacting with the channels in real time. The NPCA HEC-RAS has no respect to the attenuation effect behind the culverts.

2) The proposed infill development will not have a negative effect on the properties adjacent to the Site when developed.
3) Erosion is not a concern for the Subject Lands. Refer to section on erosion review. Erosion control can be implemented as per MOE 2003 in the proposed wet ponds. Quantity control to detain and release the 25mm, 4-hour Chicago design storm over a 24-hour period.
4) Snider Road will be raised in the post developed Subject Lands. It must be taken out of the flood plain.
5) Raising Snider Road creates a stacking effect on the flood waters on the east side. This can be seen in the HGL point 4. In the pre scenario the flood waters flow over Snider Road in the post they do not. Compare figure 23 to 31. This can be rectified in the final design by provided a ditch at point 4 to the new outlet culvert crossing on Snider Road.
6) There is a difference in the topography of the drain area through the developed area. This will create small differences in the sections (pre to post). Refer to 3D view of post-developed graded Site.
7) The aquatic, wetland and terrestrial resources as identified by Palmer and shown on the draft plan by Weston are to be protected.
8) All wet ponds will have bottom draw outlets to control temperature.
9) All pond outfall structures will be above the 100-year flood plain.
10) All ponds are outside the 100-year flood plain.

Refer to **Gr□□□i□ □1** for the summary of SWM for the Wignell Drain Subwatershed Study Area, which depicts the following:

1) The global locations for the entire Subwatershed SWM facilities.
2) The potential future quarry and the existing quarries.
3) The NPCA 100-year flood extents.
4) The pond location for the Elite developed area depicted as solid blue hatch areas.
5) Approximate pond location for other areas within the watershed depicted as rectangular blue hatches.
6) Major roads in the Wignell Drain Subwatershed Study Area.

Development within the Subject Lands has been advanced such that the SWM facilities have known locations. The remaining portion of the Wignell Drain Subwatershed Study Area has not had potential future development advanced, thus the SWM facility locations depicted in the **Gr□□□i□ □1** and **Figure □□** are approximate and will require refinement as development applications are advanced.

All SWM facilities will be designed as per the MOECP 2003 design manual. Quality control will be Level 1. Quantity control will be post-development to pre-development flows for each storm event as outlined above.

Refer to Sections 10 and 11 below for future SWS requirements.

10. Subwatershed Mitigation, Management Strategy and Monitoring Recommendations

10.1 Impact Assessment

As part of the impact analysis process, the project team has considered the scenario of the development of lands within the Study Area from mostly agricultural uses (as well as vegetated areas) to urbanized residential and associated land uses. Based on this proposed land use scenario, an assessment of the Wignell Drain Subwatershed's (and its catchment areas) sensitivity to ecological and hydrological changes has been considered. This scenario was assessed from a hydrologic perspective in consideration of surface water conditions, water balance, and the potential impacts on stream and drainage conditions. Consideration of terrestrial, wetland, and aquatic conditions (and associated management requirements) was also included in order to manage the preservation and enhancement of environmental conditions.

Based on this assessment, management strategy has been developed that includes elements of protection, mitigation, and enhancement of the hydrological and environmental conditions of the Study Area.

Due to the range of processes that influence subwatershed conditions, the following components were considered as part of the management strategy:

- SWM measures for the maintenance and protection of flow regime conditions, which include baseflow, flood flows, and water quality.
- The protection of terrestrial features with an approach that identifies preservation, restoration, and enhancement of the Study Area's existing conditions.
- The preservation and enhancement of linkages to ensure that a sustainable natural heritage system is maintained.
- The characterization, functional understanding, and protection of watercourse corridors for aquatic habitat, hydrologic processes, and water quality.
- The identification, preservation, and restoration of key landscape elements that are important to the watercourse corridor functions including the hydrologic, geomorphologic, hydrogeologic, aquatic, and terrestrial attributes.
- The identification of rehabilitation opportunities to maintain and improve the stream system.

10.2 Management Strategy and Recommendations

The development of a management strategy provides guidance for the future management of the Wignell Subwatershed in order to meet the goals and objectives within the context of future land uses within the watershed.

The characterization of the existing conditions within the Wignell Drain Subwatershed has been completed to provide the context of current conditions. This includes ecological and significant features (Sections 4 and 5), watercourse and HDF channel morphology (Section 6), hydrogeological conditions (Section 7), and and understanding of the floodplain (Section 8). The identification of current conditions allows for the SWS-related goals and objectives to be established.

The management strategy for a SWS must be broad enough to include all of the technical and administrative tools that are involved in land use and resource management measures. Thus, the scope of the management strategy should currently or in the future include:

- Land Use Management Measures – That guide land use in a manner that recognizes the natural environment which includes terrestrial resources, wildlife, wildlife habitat, ecological linkages and associated environmental corridors, stream and riparian corridors, and the subwatershed processes that influence these resources;
- SWM Measures – To preserve or enhance hydrologic functions/flow conditions related to surface water and groundwater flows and water quality;
- Terrestrial and Wetland Resource Management – To protect and enhance terrestrial and wetland resources;
- Riparian Corridor Management Plans – To protect and enhance riparian systems;
- Rehabilitation and Remediation Plans – For environmental (terrestrial and aquatic) features to increase the resiliency of the catchments and stream system;
- Monitoring Plan – Must be practical and focused to measure the environmental health of the catchments and to track the effectiveness of the watershed management strategy; and
- Implementation Plan – That describes how the strategy is to be put into place, based on the mandates of the various agencies and stakeholders, as well as identify the specific roles and responsibilities for each group.

1[illegible]1 Management Strategy

To adhere to the overall approach that protects and enhances the natural environment in a sustainable fashion, the management strategy should address all of the key components and processes of the watershed. These components should at a minimum include:

- Natural Heritage System:
  - Terrestrial and Wetland – The development of a management approach for terrestrial and wetland features that will protect and enhance overall biodiversity, including the flora and fauna associated with terrestrial and wetland features, in an environmentally sustainable fashion. This includes the provision of a corridor system to provide necessary linkages for wildlife and plant movement.
  - Streams – The provision of a corridor system for streams that have been identified as having environmental characteristics or watershed functions that require protection and/or enhancement to meet the watershed goals and objectives. A riparian corridor approach is to be applied which will consider all the stream functions including:
    - hydrologic;
    - hydrogeologic;
    - geomorphologic; and
    - environmental.
- SWM – The development of an approach that will protect and enhance environmental characteristics through managing related stormwater response and conveyance processes.

1[illegible] Natural Heritage System – Terrestrial and Wetland

The current landscape pattern of terrestrial and wetland habitats throughout the Study Area is the result of a number of human and natural influences. The resulting landscape pattern largely centers around the main watercourses and drainage channels, with areas of connected woodlands and wetlands. Isolated wetlands and woodlands are noted within the landscape of the Study Area as well.

The functional contributions and connections between natural areas are an integral part of the management strategy for individual components of and the overall NHS. The overall goal relates to the sustainability of the natural heritage features and resources of the NHS, which is based on the maintenance and the restoration of biodiversity at a series of levels (species and habitats). For the terrestrial environment (i.e., vegetation communities within aquatic, wetland and terrestrial systems), the goals and objectives of the SWS is to focus on the protection of important naturally vegetated features in both terms of structure and function. The objectives of a sustainable NHS are to follow a systems-based approach that protects and maintains the identified ecological features (e.g., woodlands, wetlands, significant wildlife habitat), the ecological functions (breeding amphibian habitat, riparian/wetland water attenuation and control), and a range of ecological interactions (wildlife movement through linkages).

Woodlands

The overall goal of protecting woodlands within the Study Area is identified through the natural environmental policies at the provincial, regional, and local levels. This has been completed through a detailed characterization of woodlands and the applicable policies and criteria that defines significant woodlands. These are mapped for the Study Area with the management strategy objective of maintaining the woodlands despite urbanization.

<u>Targets:</u>

Based on the character of the woodlands in the Study Area, the following targets were identified:

- Woodlands are not to be fragmented;
- Maintain and enhance, wherever possible, the function of all woodlands that supports the overall NHS;
- Maintain and enhance, wherever possible, the function of woodlands associated with wetlands and watercourses;
- Provide enhancement of the woodland quality (e.g., managing invasive species) and shape (i.e. to reduce edge habitat) wherever possible; and,
- Maintain and enhance woodland size where there are opportunities to do so.

Wetlands

The overall goal of protecting wetlands within the Study Area is identified through the natural environmental policies at the provincial, regional, and local levels. This goal is reflected in the objective of maintaining the roles of the wetlands despite urbanization.

The approach used here focuses on the identification of the types of wetlands, their functions and the hydrologic benefits and requirements. While there is limited representation of wetlands in the Study Area, these features provide supporting functions to the NHS (both terrestrial and aquatic). The wetlands in the Study Area are also known to provide habitats for a number of plant and wildlife species and play an important role in the hydrology of the Wignell Drain Subwatershed.
Wetlands in the Study Area consist of the follow types:

1. Wetlands with no permanent inflow or outflow of water (isolated wetlands, as defined in the Ontario Wetland Evaluation System) – These are represented by small pockets of wetlands that are a result of accumulation of runoff in low-lying areas with less permeable soils. Some of these are found as vernal components of woodland blocks, and in other areas.

2. Wetlands with a direct outflow (palustrine wetlands, as defined in the Ontario Wetland Evaluation System) – These wetlands are associated with a watercourse or other wetland feature and may play an important hydrological role in addition to their ecological role (i.e., water attenuation and conveyance to downstream features).

3. Wetlands associated with the channels and riparian areas of watercourses (riverine wetlands, as defined in the Ontario Wetland Evaluation System) – These wetlands are generally online features that have established as a result of flow patterns in the channels (*e.g.,* low gradient systems and areas with impeded flows).

<u>Targets:</u>

Based on the character of the wetlands in the Study Area, the following targets were identified:

- Avoid the fragmentation and hydrological interference of wetlands;
- Maintain the function of all wetlands associated with watercourses; and
- Maintain the function and structure of wetlands within woodlands.

Terrestrial Feature Buffers

The identification of buffers around wetlands and woodlands are driven by the natural environmental policies at the regional, local, and watershed (i.e., conservation authorities) levels. There are a number of similarities in the approaches typically used to determine buffers for situations where specific buffers can be determined through a SWS or an EIS. From review of numerous past studies on buffers, general components/approaches have been used to identify the extent of buffers:

1. Cases where the immediate protection of the edge of the natural habitat is considered (i.e., for the protection of wetland vegetation and control of runoff to wetlands), these dimensions are typically larger (a dimension of 30 m is in common usage for provincially significant wetlands)

2. In some cases, the protection of woodlands considers arboricultural approaches in which the focus is on the physical protection of the outer trees based on root zone protection. This type of approach results in a modest buffer normally in the range of 10 to 15 m from the dripline.

3. Buffers around natural habitats may be based on specific species' habitat requirements.

The targets associated with buffers are based on the overall objectives of maintaining the biodiversity of the habitats in the area. The identification and use of appropriate buffers and consideration of edge effects and the ecological needs of species within the natural areas is recommended.

<u>Targets:</u>

- Establish appropriate feature-specific buffers for protection of natural habitats that contributes to the function of these areas.

Plants and Wildlife

For the most part, the goals for plants and wildlife species overlap with those noted above for wetlands, woodlands, and other habitat types. The key objective for plants and wildlife is the preservation of biodiversity. Given the character of the habitats and species known from the Study Area and the relationship of these habitats to others outside the Study Area, the management of plants and wildlife species must be considered at the metapopulation level. The defined NHS is key to maintaining biodiversity. Many wildlife species use a range of habitat types for different aspects of their life history, and therefore this range of habitats must be considered.

Amphibians provide a prime example on why metapopulations must be managed. Depending on their life cycle stage and season, amphibians require different habitats. Spring peepers, for example, use wetland habitats (i.e., vernal pools, flooded swamps) for breeding, but then migrate to upland areas once breeding is complete or once tadpoles have transformed. In winter, this species hibernates under logs, bark, or fallen leaves. The overwintering habitat needs to be protected and location in proximity to the breeding habitat.

The targets for the maintenance of plant and wildlife biodiversity are for the most part reflected in those cited for wetlands and woodlands discussed above. Linkages are an important consideration for the maintenance of sustainable populations and are therefore discussed separately below.

<u>Targets:</u>

- See targets listed for wetlands, woodlands, and other vegetation community types.
- Provide for linkages and buffers.

Linkages

A range of linkages and opportunities currently exist within the Study Area. Linkages are an integral part of the objectives of maintaining sustainable woodlands, wetlands, watercourse corridors, and wildlife populations within subwatersheds.

Linear habitats, either associated with riparian habitats or other upland features, may provide an intrinsic habitat function (Riley and Mohr, 1994). Ecological linkages must be designed with an understanding of the species that will use the connection.

Within the Study Area there are existing linkages between and along wetland/woodland patches. There is also a good linkage function along the primary watercourses due to the length and extent of natural cover and adjacent tablelands.

To improve connectivity of features within the Study Area, some linkage opportunities exist along watercourses between isolated woodland and wetland areas.

<u>Targets:</u>

- Minimize the discontinuities in linkages (especially those >30 m).
- Local linkages to be generally a minimum 60 m wide.

- Crossing structures such as culverts must take into account terrestrial and aquatic wildlife passage.
- Allow for linkages to habitats or other linkages located outside the Study Area.

1 Aquatic Environment and Surface Water Quality and Quantity

Upstream of the Friendship Trail, two main tributaries anchor the Wignell Subwatershed surface water network and aquatic environment (**Figure □**). The tributaries serve as conduits for surface water drainage, provide aquatic habitat for fish and other aquatic wildlife and invertebrates, and provide ecosystem services such as providing 'stepping stone', hydration, and refuge habitat for various wildlife including amphibians, reptiles, and urban-tolerant mammals. Downstream of the Friendship Trail, the Wignell Drain Subwatershed's drainage network provides similar services and is primarily contained in one channel area; however, the expansive adjacent wetlands and the un-surveyed drainage channel located immediately west of Lorraine Road, also anchor the natural heritage system.

Protection of the stream corridors and the associated aquatic ecological functions can be achieved by:

- Prohibiting development and site alteration within or adjacent to the municipal drains or associated drainage features, including HDFs identified as requiring protection or conservation, as part of future studies;
- Maintaining existing water balances of the surface water features by implementing various recommendations outlined in future SWM Management Plans and LID Management Plans;
- Consistent with NPCA policies, applying a 15 m buffer to the top of slope limits of intermittent, warmwater surface water features, as identified upstream of the Friendship Trail (**Figure □1**). And, applying a 30 m buffer to the top of slope limits of permanent, warmwater surface water features, as identified downstream of the Friendship Trail. To accurately delimit the top of slope boundaries, completion of a top of bank assessment, or where necessary a stable top of slope analysis, should be completed in consultation with the NPCA and other regulatory agencies.
- Placing the surface water features and their associated buffers within an EPA or NHS designation.

Maintenance and enhancement of the ecological integrity of the surface water features and their associated ecological functions, including surface water quality and quantity, can be achieved by:

- Removing foreign waste and debris;
- Controlling populations of invasive species present within surface water features or their buffers;
- Restoring native species diversity to riparian habitats by planting appropriate native vegetation;
- Enhancing wildlife habitat opportunities through strategic plantings and artificial habitat creation, while respecting localized drainage requirements;
- Enhancing fish habitat and stream stabilization by providing more diverse riparian cover and removing barriers to fish passage, while respecting localized drainage requirements;
- Naturalizing surface water feature corridors with dense shrub planting to create a living fence barrier between future development and surface water areas;
- Incorporating LIDs within buffers to improve inflowing water quality by promoting infiltration and reducing overland runoff;
- Installing comprehensive ESC measures (ex. Silt fencing) at the limits of all future development;
- Posting educational signage in feature buffers to discourage encroachment into surface water corridors;

- Monitoring the health and condition of surface water features and the performance of environmental protection and management plans developed as part of future development applications; and,
- Monitoring and identifying areas of groundwater recharge and discharge and ensuring areas of significant groundwater recharge are protected and maintained.

Climate Change

To gain a better understanding of climate change's impacts on the Wignell Drain Subwatershed, climate change vulnerability assessments and risk assessments can be conducted. These assessments (i.e., ecosystem impact analyses, neighborhood-scale vulnerability assessments, etc.) will provide a better understanding of the climatic, biophysical, and human factors that contribute to the effects of climate change on various systems (e.g., natural systems, infrastructure, etc.) and will support better adaptive management and planning for the Study Area. In addition, these assessments will allow the Region and the City to identify and map highly vulnerable locations within the Study Area.

Hydrogeology

Hydrogeological constraints and impacts can be overcome through appropriate engineering designs and environmental planning and further hydrogeological study and monitoring.

Considering the complexity of forms and function of the natural elements of the Study Area, each development project within the Study Area should be accompanied with a detailed, site-specific hydrogeological study completed following the guide of Hydrogeological Assessment Submissions, Conservation Authority Guidelines to Support Development Applications (2013), and with reference to the NPCA Policy Document (Policies for the Administration of Ontario Regulation 155/06 and the Planning Act, Niagara Peninsular Conservation Authority, 2020). The hydrogeological studies should focused on site water balance and feature-based water balance assessment. To maintain infiltration and post- to pre-development, water balance should be the major target of stormwater management design.

Karst screenings should also be conducted as part of each hydrogeological study. Karst (Unstable Bedrock) Investigation Guidelines of Quinte Conservation (2023) can be referred to when screening for karst.

10.3 Mitigation, Enhancement, and Monitoring Recommendations

Monitoring and adaptive management plans are generally developed as part of Subwatershed Impact Studies. The information collected as part of these plans is intended to verify the performance of the environmental and stormwater management systems advanced in the Subwatershed Impact Study, as well as to provide guidance for potential modifications to the management plan to satisfy the objectives of the Subwatershed Study. Additional details regarding various components of the monitoring and adaptive management plans are provided below.

10.3.1 Mitigation

A primary goal of the management strategy is to ensure that there are no negative impacts to natural heritage features and the aquatic environments and their associated hydrological functions. Key objectives for mitigation measures to be implemented in order avoid potential negative impacts are listed below.

- Develop and implement appropriate mitigation measures that are necessary to avoid negative impacts to natural features that may result from new development, including infrastructure.
- Watercourse crossings, including bridges and culverts, are designed appropriately to address and mitigate for potential channel migration.
- Utilize the analysis and recommendations of the multi-disciplinary classification forms of watercourses and drainage features to manage for the protection and conservation of fish habitat.
- To mitigate for the potential reduction in baseflow consider that LID measures be employed to minimize the potential reduction in groundwater recharge/discharge where applicable and appropriate. Opportunities for infiltration may require further analysis on a site-specific level for the identification of suitable infiltration opportunities.
- High constraint areas are to be excluded from development with the establishment of appropriate buffers that mitigate potential impacts from development to natural features and maintain the ecological functions.

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Given the current developed and disturbed nature of the Wignell Drain Subwatershed, several actions should be considered by the City and Region to better understand the subwatershed or to improve the health of the subwatershed:

- Increasing the forest cover of the Study Area; this might be undertaken through:
  - Buffer plantings during development;
  - Selective municipal or conservation authority purchase and restoration of private properties when they are for sale;
  - Planting of riparian corridors that are apparently unused/abandoned or have become part of the Natural Heritage System assuming they are safe to access and with landowner permission; and
  - Ensuring that, when Port Colborne Quarry lands are exhausted, restoration plans are in place that include re-forestation.

10.3.2.1 Landscape Connectivity Enhancement Opportunities

The ecological connectivity of almost every southern Ontario landscape can be improved through a combination of creating larger natural areas or widening connections in a variety of directions between existing natural areas. Within the low connectivity landscape context of the Wignell Drain Subwatershed, some of the recommended areas to enhance connectivity are depicted in **Figure □**. The areas where it is more important to improve connectivity (where feasible) are shown as wider arrows. Narrower arrows are less important areas of potential enhancement. All watercourses are also areas of potential future natural connection if naturalized and restored. The Niagara Region Official Plan (2022) also indicates areas of potential linkage on Schedule C2.

Additionally, any time a) a new road is built, b) a road is widened or c) watercourse crossings are replaced, consideration should be given to wildlife passage. Attention should be given to the following: which wildlife species might use a passage and if they are aquatic or terrestrial; whether a dryland passage should be added; whether a culvert should be increased in size; whether a dryland passage should be added to a passage that is primarily aquatic; and whether wildlife funnel fencing along either side of the road should be added (this will depend on the presumed extent of wildlife usage, type of wildlife, etc.).

1□□□□ Surface Water Quantity

To better understand localized water quantity conditions across multiple seasons, it is recommended that continuous flow monitoring be completed as part of future development applications, particularly in catchments that were not accessible as part of this SWS (**Figure □**). More detailed stream flow monitoring will better inform baseline hydrologic conditions, identify natural and anthropogenic inputs, and will inform if future stormwater management facilities are functioning as intended. Flow monitoring should be paired with future water quality monitoring efforts.

As part of future development proposals, mitigations for surface water quantity may be achieved through approaches such as reducing impacts associated with runoff from agricultural and rural areas, reducing impacts of runoff from new development, and maintaining the baseline hydrologic regime. Incorporation of development features such as LIDs may alleviate water quantity impacts and promote improved water quality conditions through increased infiltration and surface runoff attenuation. Other improvements to water quantity may also be achieved through enhancement or retrofits to existing stormwater infrastructure, and completion of functional servicing and stormwater management designs for new development that reduce runoff and implement effective water quantity controls.

1□□□□ Surface Water Quality and Temperature

As a general requirement for future development and associated monitoring, surface water quality within the Wignell Drain Subwatershed should maintain or surpass general baseline conditions outlined in this report and should not exceed parameter targets outlined in the PWQO, where feasible. For instance, where baseline water quality does not meet the PWQOs as identified in this report, the water quality should not be degraded further, and all practical measures should be taken to upgrade the water quality to PWQO targets.

Areas with relatively higher water quality (i.e., downstream reaches of the subwatershed including monitoring stations WD-5 and WD-6) should be protected and enhanced, where feasible. This includes protecting and enhancing upstream surface water corridors, which supply flow to downstream surface water environments. Proponents of future development within the Wignell Drain Subwatershed should be required to prepare appropriate hydrologic, hydrogeological, and/or environmental studies to ensure that adjacent and downstream surface water environments are protected and enhanced, from a surface water quality perspective.

As part of future development proposals, additional surface water quality enhancement may be achieved through items such as streambank stabilization and rehabilitation, reducing impacts associated with runoff from agricultural and rural areas, reducing impacts of runoff from new development, and maintaining the baseline hydrologic regime.

To capture the degree of potential impacts and rehabilitation the following monitoring approaches may be incorporated into monitoring programs including, but not limited to, surface water chemistry and nutrient sampling, benthic invertebrate sampling, fish community sampling, and aquatic habitat monitoring. Future surface water quality monitoring should span from spring to fall and include dry and wet weather conditions to provide a more fulsome understanding of subwatershed under varying conditions. Comprehensive baseline water quality conditions should be completed for catchments that were not accessible as part of this SWS.

For future development proposals, surface water temperature monitoring should be completed on a continuous basis for pre-, during-, and post-development basis to monitor changes in baseline conditions and incorporate background atmospheric parameters including precipitation levels and daily air temperature. During-, and post-construction monitoring should capture upstream and downstream conditions for major development outlet points.

Groundwater

Groundwater flows and resides underground and has complicated interactions with other natural resources and environmental elements. In view of the complex nature of the groundwater system, an adaptive environmental monitoring program (AEMP) is recommended as part of the ongoing development planning for the Study Area. The AEMP is to achieve three objectives including:

- Provide further knowledge and understanding of the groundwater conditions and its interactions with other environmental elements;
- Establish baseline hydrogeological conditions such as groundwater levels, quality, recharge and discharge, and their patterns and trends;
- Monitor the impact of the development to groundwater conditions and related environmental elements; and
- Monitor the effectiveness of various best practices and mitigation measures adopted by the proponents.

AEMP is a key component of adaptive environmental management. AEMP is usually adopted to monitor convoluted impact-receiver systems such as mining sites, quarries, and large developments. Because these systems, in general, cannot be recognized thoroughly at the beginning of a program, AEMP takes a form of cycling steps: study-monitoring-adjustment-study-monitoring. Through multiple cycles, the system becomes better understood and the monitoring becomes more precise. AEMP is realized through setting up a clear matrix of actions, locations, duration, triggers, thresholds, and mitigation measures, and all these elements in the matrix are executed in a systematic (feedback and action) way. AEMP has proved to be the most cost-effective way of monitoring complicated environmental systems. The AEMP recommended should include the following monitoring points or stations:

- Monitoring wells in strategic locations to monitor patterns, trends, and stability of groundwater levels and groundwater quality;
- Mini-piezometer and surface water stage stations for major wetlands and certain spots of drainage channels to delineate hydroperiods of wetlands and the interaction of groundwater and surface water;
- Baseflow measurement or observation stations along drainage channels to characterize baseflow conditions and groundwater discharge.

Stream Morphology

The collection of field data from similar sites over an extended period of time can provide great insight on channel processes and function. Monitoring is critical to determining a channel's response to surrounding land use changes. Typically land use changes without mitigation will result in alteration to hydrologic regimes (increased flow volumes) and sediment regimes (initially more sediment being supplied to the channel followed by an overall decrease). These alterations can result in changes in the channel planform, bank erosion, cross-sectional area, and substrate composition, which, in turn, may locally impact aquatic habitat and water quality.

From a geomorphic perspective, monitoring and pre-construction baseline surveys should be established 1-2 years prior to land alteration. Preferably monitoring should be installed in relevant or sensitive reaches prior to stormwater being released into the system. Monitoring would subsequently take place annually during- and post- construction to fulfill performance evaluation requirements. The post-construction monitoring period should extend for 3-years following completed build out.

11. Implementation of Subwatershed Plan

The implementation of the Subwatershed Plan should follow a process of addressing the components outlined in the management strategy. This includes a process that involves technical components of the SWS analysis and specific planning steps guided by the Provincial Policy Statement and Regional and Local Official Plans.

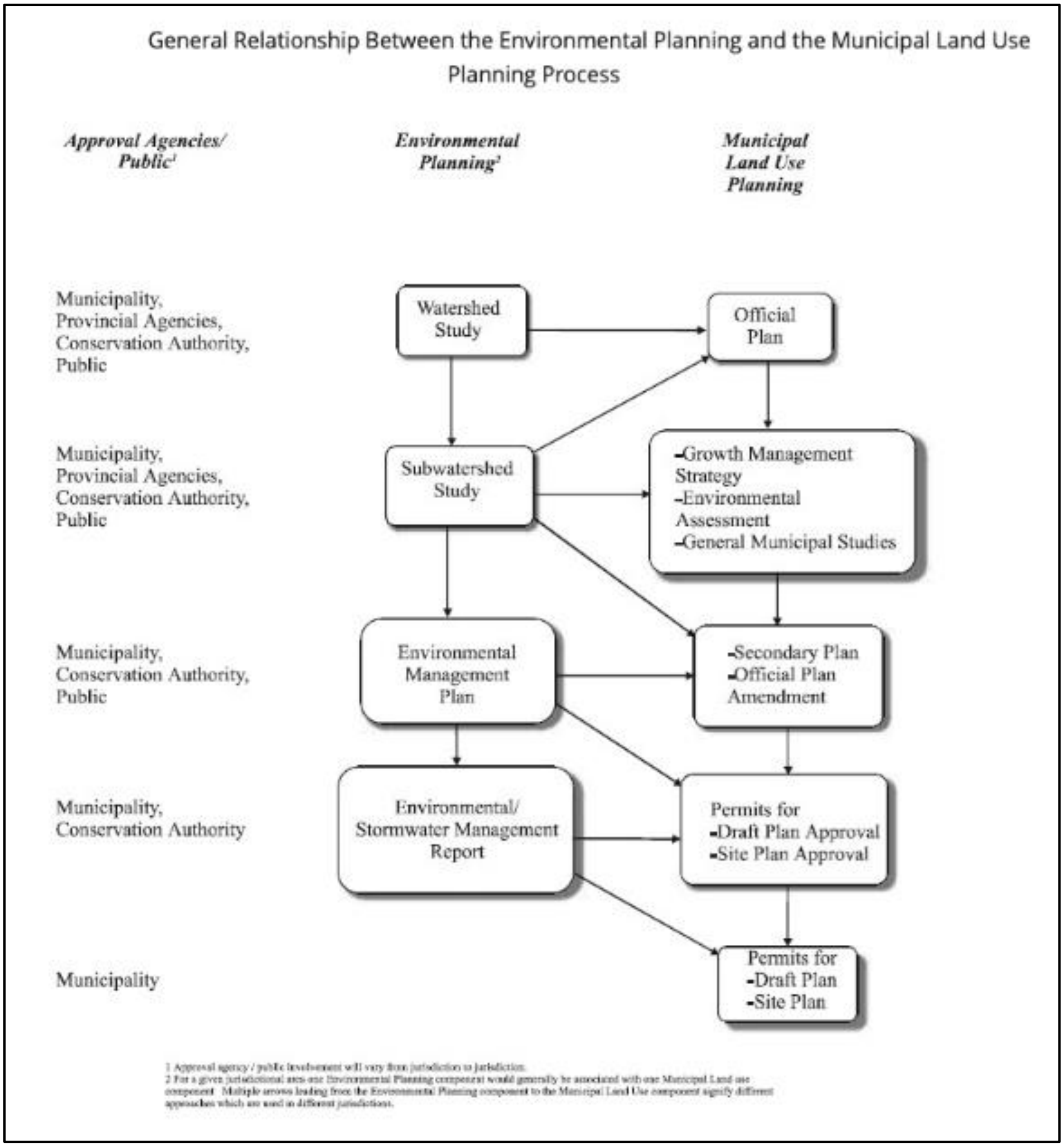
The implementation process for a SWS fits within an environmental planning and municipal land use planning process with agency stakeholders and associated review and approval process. **Gr□□□i□ □1** provides an illustration of this process with a summary of the major planning process steps provided below:

- Official Plan (OP);
- Secondary Plan;
- Draft Plan;
- Subdivision Design Plan; and
- Registered Plan.

The supporting studies that are necessary may include a(n):

- Subwatershed Study;
- Environmental Implementation Report (EIR);
- Functional Servicing Study (FSS);
- Preferred Servicing Plan;
- Draft Plan or Site Plan;
- Environmental Impact Study;
- Restoration and Enhancement Plan;
- Tree Preservation and Protection Plan;
- Grading Plan;
- Erosion and Sediment Control Plan;
- Servicing Plan;
- Stormwater Management Design Plan; and/or,
- Approvals and permits as required by agencies and the municipalities.

Graphic 31: Example Overview of Planning Process for Implementation of a SWS



Additional Requirements and Future [illegible]

Regulated areas (i.e. hazard limits and wetlands) and stormwater management pond design will need to be further revised at the site specific and watershed level as part of the ongoing implementation of the SWS and the site-specific EIS'. The following requirements are provided:

1. Future studies must follow the TOR approved by all agencies.

2. Refinement of flooding (including spill) and erosion hazards.

3. There are no known valleylands in the Wignell Drain Subwatershed; however, if determined to be present a site visit with NPCA staff to determine whether there is a top of bank associated with the Wignell Tributary. If confirmed, top of bank staking will be required.

4. Further site visits with NPCA staff to determine the presence of any wetlands. If confirmed, wetland staking will be required during the appropriate staking season (June – September).

5. A refined SWM review/design which maintains the NPCA setbacks and requirements.

12. Certification

This report was prepared, reviewed, and approved by the undersigned:

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