Subwatershed Study Phase 1: Characterization and Integration

Smithville Subwatershed Study and Stormwater Management Plan
Township of West Lincoln
TPB198161

Prepared for:

Township of West Lincoln
318 Canborough Street, Smithville, ON L0R 2A0

2/24/2023

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1.0 Introduction

1.1 Study Overview

The Township of West Lincoln (The Township) has initiated a Master Community Plan Study to plan for future growth in the Community of Smithville. The Master Community Plan is being developed under the Planning Act, and supporting infrastructure planning is being conducted in accordance with the requirements of the Municipal Engineers Association's Municipal Class Environmental Assessment (EA) for Water, Wastewater and Roads (as amended in 2015) Master Plan Approach #4. This process includes the preparation of a Subwatershed Study (SWS), as a companion study being completed in parallel with the Master Community Plan Study. The overall purpose of this SWS is to:

a. Inventory, characterize and assess natural hazard, natural heritage and water resource features and functions within the study area (i.e., constraints to development);

b. Provide recommendations for the protection, conservation and management of natural hazard, natural heritage, and water resource features within the study area;

c. Provide sufficient detail to support the designation of NHS in Secondary Plans, through the refinement of the Regional NHS; and

d. Provide recommendations for a management strategy, implementation and monitoring plan to be implemented through the Secondary Plan(s) and future site/area specific studies.

The results of the SWS will be essential for informing the future Secondary Plan(s). The SWS will inform land use decision making so that it allows for urban systems to be integrated with natural systems in an area that is transitioning from predominantly rural to urban uses.

1.1.1 Planning Process for Community of Smithville

The Study Area for the Subwatershed Study is located along the perimeter of the existing urban boundary of the Community of Smithville, and is generally bounded by Young Street to the north, the North Creek to the south, S. Grimsby Road 6 to the west, and S. Grimsby Road 2 to the east (ref. **Figure 1.1.1**).

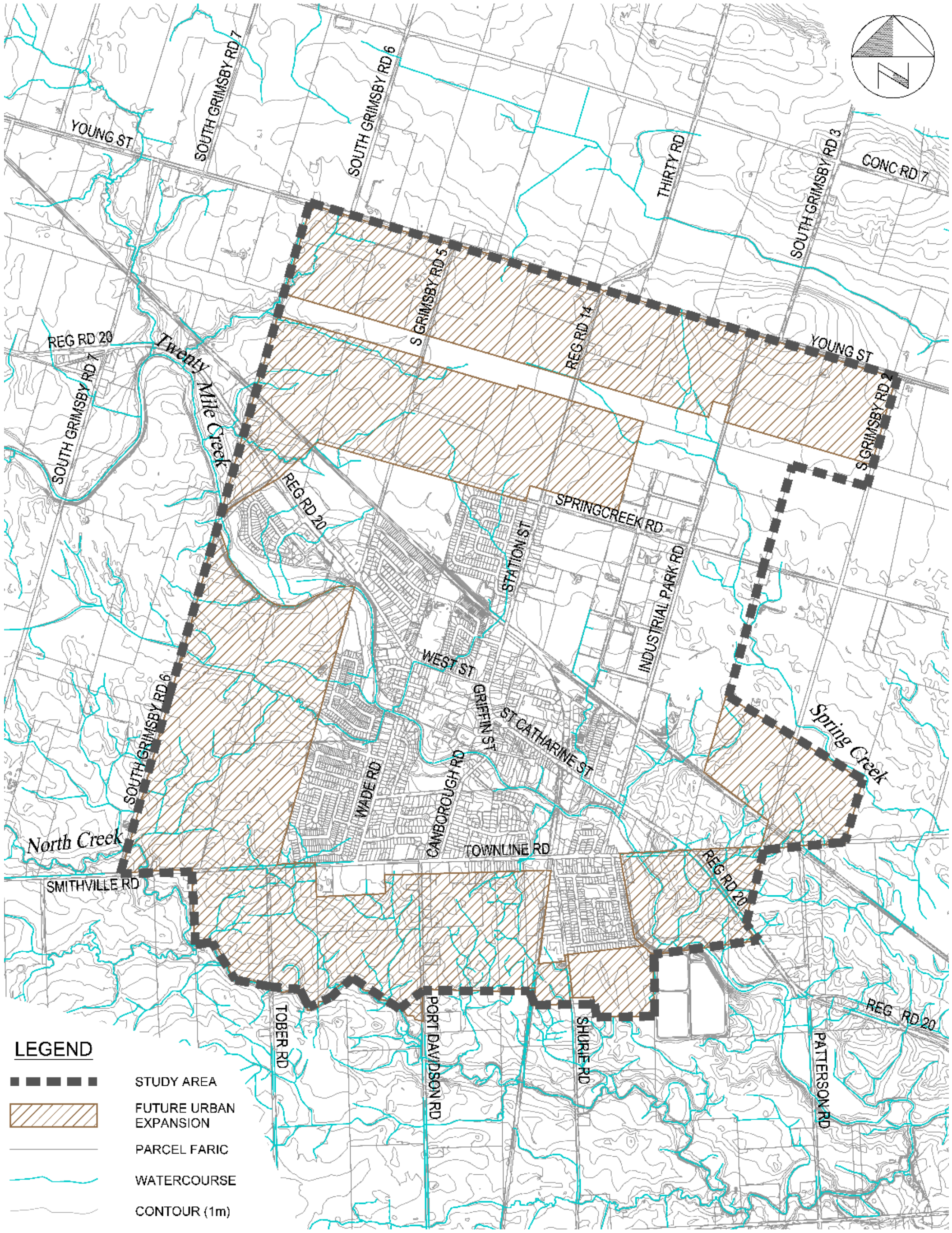

Figure 1.1.1. SWS Study Area Location Plan

The planning process includes the preparation of a subwatershed study, master transportation and servicing studies, and high-level land use studies as the basis for developing the Conceptual Master Plan. The Conceptual Master Plan provides a high-level community structure and the planning context for the future development of more detailed Secondary Plan(s) for smaller geographic areas including companion Master Environmental Servicing Plans (MESPs). The SWS study is being undertaken collaboratively and concurrently with the master transportation and servicing studies and the preparation of the Conceptual

Master Plan. The linkage between the Subwatershed Study and the companion studies is depicted graphically in **Figure 1.1.2**.

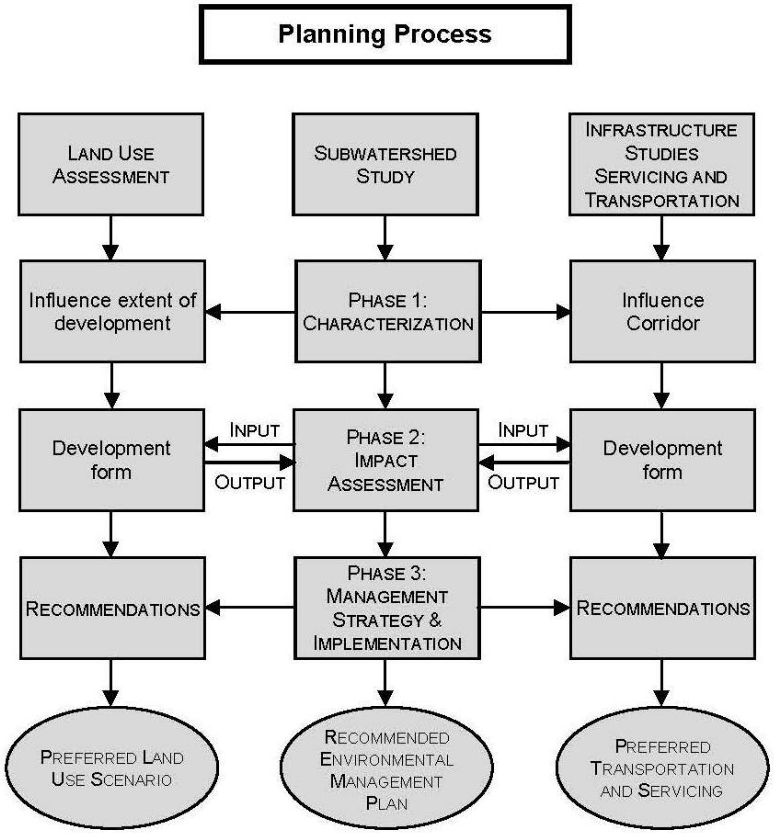

Figure 1.1.2. Integrated Land Use, Subwatershed and Servicing Plan Process

The SWS organization is being administered through a Steering Committee as part of the overall Master Community Plan, and directed by a Technical Advisory Committee (TAC). The Steering Committee is comprised of Senior Management in planning and engineering from the Township of West Lincoln, as well as senior representatives from the Region of Niagara, Niagara Peninsula Conservation Authority (NPCA), and area Landowners. The Technical Advisory Committee is comprised of representatives from the Subwatershed Study Team and relevant staff from the Township of West Lincoln, Region of Niagara, NPCA, and Landowner Representatives, with expertise in hydrology, hydraulics, hydrogeology, water quality, fluvial geomorphology, terrestrial, aquatics and land use planning.

1.2 Subwatershed Study Process

The SWS must ensure that all applicable Provincial, Regional and Municipal land use planning requirements, including Conservation Authority regulations, are achieved.

The initial step in the SWS process involved the collection and review of available data from the TAC. An inventory of the data provided for use in this study is included in Appendix A. The data were then reviewed for completeness and quality, and a gap analysis conducted to identify deficiencies in the available data. The Gap Analysis lists the available data and provides an assessment of data gaps and the degree to which the available data can and/or should inform the SWS. This has been done in consultation with the TAC. The findings of this gap analysis were used to refine the Work Plan, to allow for the collection of any required data to inform the SWS process. As a parallel initiative to the data collection and gap analysis, the Township, in cooperation with the Landowner Representatives, secured Permissions To Enter (PTE) to allow fieldwork to be completed on properties of interest within the study area. The Work Plan was finalized April 21, 2020, shortly following commencement of the fieldwork.

Following the gap analysis and Work Plan refinement, a preliminary constraint assessment was completed. This assessment was undertaken based on the interpretation of the data provided by the TAC, and was intended to provide initial guidance for the land use planning process to allow both initiatives to continue to proceed in parallel. The findings of this preliminary constraint assessment were documented in a Technical Memorandum (TM) which was submitted to the Township of West Lincoln May 15, 2020; a copy of this correspondence is included in Appendix A.

The core Work Plan of the SWS process has been structured to be carried out in three (3) phases, which will result in three (3) documents/reports, as follows:

- Phase 1: Subwatershed Characterization and Integration, (this document)
- Phase 2: Impact Assessment,
- Phase 3: Management, Implementation and Monitoring Plan,

The purpose of Phase 1 (Subwatershed Characterization and Integration) of the SWS is to gain a better understanding of the state, health and general character of the subwatershed. Reviews of existing studies and reports, fieldwork and, where appropriate, modelling has been undertaken, in order to understand the baseline of conditions related to the following key components: Hydrology/Hydraulics, Hydrogeology, Karst Features, Water Quality, Stream Morphology and Aquatic and Terrestrial Resources. These components have been considered and assessed as part of this report to characterize the Subwatershed area's of interest.

Phase 2 (Impact Assessment) involves evaluating the impacts of future planned urbanization of the land use plan, as prescribed by the Master Community Plan. This initial evaluation is intended to provide direction to the Land Use Team, who will then refine the Land Use Plan in accordance with the direction from the first iteration of testing. The refined Land Use Plan (after some integrated consultation amongst all team members) is then advanced for a second round of testing and assessment, as required, as part of Phase 3. Working Targets and preliminary management strategies to address potential impacts associated with future development, as related to the natural environment and stormwater, have been developed. Watercourses and natural heritage features have been assessed and given a constraint ranking, followed by an overall net rating. Any refinements to the Region's NHS have been identified and discussed through this phase.

Phase 3 (Management, Implementation and Monitoring Plan) formalizes the recommendations for water management, including traditional and low impact development practices, as well as specifics related to environmental management, including parameters for stream stability and terrestrial and aquatic system protection and enhancement. This process also includes developing an implementation and monitoring plan, to provide further direction on the implementation procedures related to the plan recommendations, including priorities, specific policies, need for follow-on studies and related study requirements.

In addition to the foregoing, the study includes the preparation of a Stormwater Management Master Plan for the future intensification and infill areas within urban Smithville. This component of the study has built upon the insight and guidance from the three phases of the Subwatershed Study, and has developed the stormwater management plan specific to the future intensification and infill areas, tailored to address local constraints within existing receiving infrastructure in Smithville.

At the conclusion of the SWS, the final reports are to be adopted by Council.

2.0 Policy and Study Context

2.1 Introduction

The protection of the natural environment and public health and safety in land use planning are fundamental principles enshrined in the policies, guidelines and practices of provincial, municipal and local levels of government. The following sections summarize some of the key plans and policies which require the completion of the SWS to support the land use planning process, and which will provide guidance in developing the management strategies and recommendations, as it related to subwatershed planning, the protection of the natural environment/public health and safety, through land use planning.

2.2 Province of Ontario

The following summarizes the key Provincial Policies, specific to the land use planning process and the SWS.

2.2.1 Provincial Policy Statement

On February 28, 2020, the Ministry of Municipal Affairs and Housing released the Provincial Policy Statement (PPS), 2020. The 2020 PPS came into effect on May 1, 2020, and replaces the previous PPS issued April 30, 2014.

The PPS (2020) is issued under Section 3 of the Planning Act. The PPS provides direction on matters of provincial interest related to land use planning and development. The PPS provides for appropriate development while protecting resources of provincial interest, public health and safety, and the quality of the natural environment. The PPS recognizes the complex inter-relationships among economic, environmental and social factors in planning and embodies principles of good planning for the creation of complete, healthy, and livable communities. All land use decisions (provincial and municipal) must be consistent with the PPS.

The PPS provides guidance for the long-term, wise use and management of resources including the protection and management of natural heritage and water resources, as well as the protection of public health and safety. The PPS provides specific policy direction on significant wetlands, endangered and threatened species, fish habitat, significant woodlands, significant valleylands, significant areas of natural and scientific interest (ANSI) and significant wildlife habitat. It also provides guidance for the protection, improvement and restoration of the quality and quantity of water resources. The PPS recognizes that the linkages and related functions among groundwater features, hydrologic functions, natural heritage features and areas, and surface water features are to be maintained. It states that watersheds are the ecologically meaningful scale for integrated and long-term planning, and provides for evaluating and preparing for impacts of climate change to water resources systems at the watershed scale.

The PPS also provides direction relating to natural hazards, so as to ensure that development is directed away from areas of natural hazards where there is an unacceptable risk to public health or safety or of property damage. It is also to ensure that development does not create new or aggravate existing hazards.

Natural Heritage Systems (NHS) are to be identified for the protection of natural features for the long term.

The Natural Heritage Reference Manual (OMNR 2010) and the Significant Wildlife Habitat Technical Guide (OMNR 2000, MNRF 2015) were prepared by the MNRF to provide guidance on identifying natural features and in interpreting the Natural Heritage sections of the PPS.

2.2.2 A Place To Grow: Growth Plan for the Greater Golden Horseshoe

On June 13, 2005, the Provincial Government passed the Places to Grow Act, which was enacted to help the Province plan for growth in a coordinated and strategic way. It gives the Province the authority to, among other things, designate any geographic region of the province as a growth plan area and develop growth plans in any part of Ontario. The Growth Plan for the Greater Golden Horseshoe, 2006 (Growth Plan, 2006) was the first growth plan to provide a framework for implementing Ontario's vision for building stronger, prosperous communities by better managing growth in this region. It established the long-term framework for where and how the region will grow, while recognizing the realities facing our cities and smaller communities and acknowledging what governments can and cannot influence. It also demonstrated leadership for improving the ways in which our cities, suburbs, towns, and villages will grow over the long-term. The Growth Plan was subsequently revised and amended since its release in 2006; the most recent revision was released May 2019, with an amendment in August 2020.

The 2020 Growth Plan introduced new policies related to the population and employment forecasts, a change to the Growth Plan horizon year, adjustments to the aggregates policy framework, new policies to address Major Transit Station Areas within Provincially Significant Employment Zones, and other policy revisions to support an increase in housing supply, job creation, and infrastructure alignment.

The Growth Plan identifies a NHS within the Greater Golden Horseshoe, outside the Greenbelt Plan area and settlement areas.

2.2.3 Greenbelt Plan

The Greenbelt Act, 2005 provided the authority for the creation of the Greenbelt Area and the Greenbelt Plan. The Act sets out the main elements and objectives for the Greenbelt, which are addressed in the Plan and to permanently protect about 1.8 million acres of environmentally sensitive and agricultural land in the Greater Golden Horseshoe from urban development and sprawl. It includes and builds on about 800,000 acres of land within the Niagara Escarpment Plan and the Oak Ridges Moraine Conservation Plan. The Greenbelt Act, 2005 requires that decisions made under the Ontario Planning and Development Act, 1994, the Planning Act and the Condominium Act, 1998 conform to the Greenbelt Plan. The Greenbelt Plan identifies where urbanization should not occur and provides policy direction for permanently protecting the agricultural land base and the ecological features and functions on the landscape.

The Greenbelt Act provides authority for the creation of a Greenbelt Plan, which originally came into effect in December 2004, and was amended by the Province in May 2017. The Greenbelt Plan identifies where development should not occur to ensure permanent protection of the agricultural land base, and the ecological and hydrological features and functions that occur in the rural landscape of the Greenbelt Plan Area.

The Greenbelt Plan provides policies specific to Natural Systems within the Protected Countryside (Natural Heritage System, Section 3.2.2; Water Resource System, Section 3.2.3), and polices which apply across the entire Greenbelt Plan Area for Key Hydrologic Areas (Section 3.2.4) and Key Natural Heritage Features and Key Hydrologic Features (Section 3.2.5). The Natural System within the Protected Countryside of the Greenbelt Plan Area is comprised of a Water Resource System and a Natural Heritage System. These two systems often overlap as a result of the interrelationship between hydrologic and ecological features and functions. The Natural Heritage System is made up of core areas and linkages. The Water Resource System is made up of groundwater and surface water features and areas which support ecological and human water needs.

The Natural Heritage System of the Greenbelt Plan Area connects to systems beyond the Greenbelt (e.g., the Growth Plan NHS); policies for these External Connections are also provided to ensure a connected landscape system

2.3 Regional and Municipal Official Plan

The Consolidated Regional Official Plan (2014) contains objectives, policies and mapping that implement the Region's approach to managing growth, growing the economy, protecting the natural environment, resources and agricultural land, and providing infrastructure. Chapters 7 and 8 of the Consolidated Regional Official Plan (ROP) contain policies specific to the managing the Natural Environment and Infrastructure respectively, which are directly pertinent to the completion of the SWS. Policies are included in other chapters of the ROP, which direct the planning and management of Growth (Chapter 4), Rural and Agricultural lands (Chapter 5), and Resources (Chapter 6); these other chapters include policies related to integrating the planning and management of these other lands and objectives with the planning, management, and protection of the natural environment.

In 2019, Niagara Region initiated a process to develop a new Niagara Official Plan, which was adopted by Regional Council on June 23, 2022 and forwarded to the province prior to the July 1st, 2022 submission deadline. The province approved the Niagara Official Plan on November 4th 2022. A key element of the new Niagara Official Plan are policies and mapping that incorporate Provincial requirements on natural environment and water resources planning. Through consultation with Niagara Region, the SWS appropriately reviewed and incorporated directions resulting from the Region's Natural Environment Work Program and Watershed Plan Equivalent, work that formed the basis for the Niagara Official Plan.

The Township of West Lincoln Official Plan (TOP), 1998, was most recently consolidated in 2019. The TOP must be in agreement with provincial policy direction, as well as the ROP. The TOP addresses its growth management strategy, which includes direction for the expansion of Smithville, and is to be undertaken through the municipal comprehensive review process on a Subwatershed/watershed scale. The TOP identifies a Core NHS for the "protection, maintenance, restoration, integration, and where possible the enhancement of the natural systems, ecological health, and biodiversity of the community" (Policy 5.6.e). Both the Region's Niagara Official Plan and the TOP promote a Healthy Landscape approach to protect the natural environment and distinctive natural character of the Township. Water resource policies are considered to protect, improve, and restore groundwater and surface water resources. Policies speak to the protection of Natural Heritage and Hazard Areas, including watercourses, wetlands and forested areas from incompatible development.

The study area includes portions of the Township's Core NHS. Potential corridors, as identified by the Township, are located outside the study area. The Township's NHS is depicted on Schedule C-1 of the TOP.

2.4 Niagara Peninsula Conservation Authority

Section 28 of the *Conservation Authorities Act* enables Conservation Authorities to develop and administer regulations relating to development and activities in or adjacent to river or stream valleys, Great Lakes and inland lakes shorelines, watercourses, hazardous lands and wetlands. In 2006, the Minister of Natural Resources and Forestry (MNRF) approved individual "Development, Interference and Alteration" Regulations for all Conservation Authorities consistent with Ontario Regulation 97/04 (i.e., Generic Regulation). It was at that time, that the Minister approved NPCA's regulation, Ontario Regulation 155/06. Ontario Regulation 155/06 prohibits development in, adjacent, or close to the shoreline of lakes and rivers that may be affected by flooding, erosion or dynamic beaches; hazardous lands; wetlands; or areas that could interfere with the hydrologic function of a wetland. In certain circumstances, approval for development in these areas may be approved by the NPCA's Board, as long as specific conditions are met.

2.5 Other Applicable Acts, Guidelines and Policies

There is a broad framework of legislation that regulates land use and other activities within a watershed and along streams. The following is a summary of legislations not discussed above that will need to be considered as part of this SWS.

Table 2.5.1. Summary of Acts, Guidelines and Policies

Level of Government	Name/Title	Type	Purpose
Federal	Federal Fisheries Act (I)	Act	Purpose is to ensure the conservation and protection of fish and fish habitat.
	Migratory Birds Convention Act (1994)(I)	Act	Purpose is to protect listed migratory bird species and their nests from persecution or destruction.
	Species at Risk Act	Act	Protection of Wildlife species at risk; recovery plans regarding federally regulated resources.
	Canadian Environmental Protection Act (1999)	Act	The goal of the Canadian Environmental Protection Act (CEPA) is to contribute to sustainable development through pollution prevention and to protect the environment, human life and health from the risks associated with toxic substances.
	Canada Water Act	Act	An Act to provide for the management of the water resources of Canada, including research and the planning and implementation of programs relating to the conservation, development and utilization of water resources
Provincial	Nutrient Management Act (OMAF) (2002)	Act	As part of the Ontario government's Clean Water Strategy, the Nutrient Management Act provides for province-wide standards to address the effects of agricultural practices on the environment, especially as they relate to land-applied materials containing nutrients.
	Lakes and Rivers Improvement Act (1990)	Act	The Lakes and Rivers Improvement Act gives the MNRF the mandate to manage water-related activities, particularly in the areas outside the jurisdiction of Conservation Authorities.
	Provincial Planning Act (D)	Act	The purposes of this Act is to promote sustainable economic development in a healthy natural environment
	Ontario Water Resources Act	Act	The Ontario Water Resource Act deals with the powers and obligations of the Ontario Clean Water Agency, as well as an assigned provincial officer, who monitors and investigates any potential problems with regards to water quality or supply. There are also extensive sections on Wells, Water Works, and Sewage works involving their operation, creation and other aspects.

Level of Government	Name/Title	Type	Purpose
	Environmental Protection Act	Act	The purpose of this Act is to provide for the protection and conservation of the natural environment. R.S.O.1990, c.E.19, s.3.
	Fish and Wildlife Conservation Act (1997)	Act	Fish and Wildlife Conservation Act enables the Ministry of Natural Resources and Forestry (MNRF) to provide sound management of the province's fish and wildlife.
	Municipal Act	Act	The Municipal Act sets forth regulations in regard to the structuring of municipalities in Ontario.
	Ontario Drinking Water Protection Regulation	Regulation	In August 2000, the Government of Ontario announced a new Drinking Water Protection Regulation (Ontario Regulation 459/00) to ensure the safety of Ontario's drinking water. The regulation issued under the Ontario Water Resources Act was a part of the comprehensive Operation Clean Water action plan. This regulation put the Ontario Drinking Water Standards into law, updating and strengthening the Ontario Drinking Water Objectives.
	Provincial Water Quality Objectives (MOE) (1994)	Guideline	Provides objectives for the protection of aquatic life.
	Significant Wildlife Habitat Technical Guide (2000, OMNR)	Guideline	Significant Wildlife Habitat has been identified as one of the natural heritage feature areas requiring protection under the PPS. This Guide provides guidance on identifying Significant Wildlife Habitat by Ecoregion.
	Ontario Drinking Water Standards (MOE) (2001)	Guideline	The purpose of the standards is to protect public health through the provision of safe drinking water.
	Technical Guideline for Private Wells: Water Supply Assessment (MOE) (1996)	Guideline	Guidance manual for the development of private wells.
	Drainage Act	Act	Provides for the regulation of drainage practices in Ontario.
	Endangered Species Act (2007)	Act	The Endangered Species Act (ESA) prohibits killing, harming, harassing or capturing Species at Risk (SAR) and protects their habitats from damage and destruction.

Level of Government	Name/Title	Type	Purpose
	Clean Water Act	Act	The Clean Water Act was implemented as a legislative measure to protect existing and future sources of drinking water.
	Conservation Authorities Act	Act	Conservation Authorities, created in 1946 by an Act of the Provincial Legislature, are mandated to ensure the conservation, restoration and responsible management of Ontario's water, land and natural habitats through programs designed to further the conservation, restoration, development and management of natural resources other than gas, oil, coal, and minerals.

2.6 Study Goals and Objectives

The overall goal for the SWS is to identify and assess opportunities and constraints to development, as well as refine the Region of Niagara's Natural Heritage System (NHS) (ROP, 2014), within the study area. It is also intended to provide an overall strategic management framework for natural heritage and water resources within the respective study area.

This SWS is to provide sufficient detail on the natural systems (form and function) to support the completion of future Secondary Plan(s) and any associated studies. It is expected that neighbourhood-level and site-specific stormwater and environmental management plans will need to be consistent with the recommended strategic direction of the SWS.

The specific goals and objectives for the SWS are as follows:

2.6.1 Natural Hazards

Goal:

To prevent, eliminate or minimize the risks to life and property caused by flooding and erosion hazards and not create new or aggravate existing hazards.

Objectives:

i. To ensure new development does not increase the frequency and intensity of flooding, the rate of natural stream erosion or increase slope instability;
ii. To establish development standards, land use planning and engineering practices that ensure future development is located outside of, and appropriately setback from, flooding and erosion hazards;
iii. To ensure that new development, including infrastructure, incorporates appropriate mitigation measures in order to avoid adverse impacts to natural features and areas as it relates to natural hazards; and
iv. To consider climate change adaptation measures as part of the development of flooding and erosion management strategies.

2.6.2 Natural Heritage

Goal:

To protect, restore or, where appropriate, enhance the biodiversity, connectivity and ecological functions of the natural heritage features and areas throughout the Study Area for the long term.

Objectives:

i. To ensure that natural heritage features and areas, associated with a refined NHS, including their ecological and hydrologic functions, are protected from potential adverse impacts of development;
ii. To ensure that buffers, corridors and linkages between natural features and areas, surface water features and groundwater features are maintained, restored or, where possible, improved through the establishment of the NHS;
iii. To establish innovative development standards and land use controls that will ensure future development does not negatively impact the NHS;
iv. To consider climate change mitigation and adaptation measures as part of the development of natural heritage management strategies;
v. To consider opportunities for maintaining and enhancing the aesthetic and recreational value of the NHS, as part the development of management strategies;
vi. To consider that NHS may vary in size and form among Settlement Areas, Rural Areas, and Prime Agricultural Areas; and
vii. To develop integrated stormwater management plans to help manage water balance with the intent to maintain both hydrological and ecological function of features within the adjacent NHS.

2.6.3 Water Resources

Goal:

To protect, improve or restore the quality and quantity of water resources within, adjacent to and downstream of the Study Area, including their associated ecological and hydrologic / hydrogeologic functions.

Objectives:

i. To ensure fluvial processes and stream morphology are maintained or improved to support important habitat attributes (pools, riffles, etc.), dynamic channel form and diversity which will contribute to maintaining a sustainable natural heritage system;
ii. To prevent nutrient enrichment and contamination of surface and groundwater resources from development and related activities;
iii. To ensure surface and groundwater features, including certain karst features, and their hydrologic functions are protected, improved or restored;
iv. To maintain important linkages and related functions among groundwater features, karst features, functional groundwater recharge, surface water features, hydrologic functions, and natural heritage features and areas;
v. To consider climate change mitigation and adaptation measures as part of establishing management strategies; and
vi. To ensure that the riparian rights of downstream landowners are respected.

2.6.4 Stormwater Management

Goal:

To mitigate negative impacts related to the quality and quantity of stormwater runoff within, adjacent to, and downstream of the Study Area.

Objectives:

i. To maintain/enhance baseflow to the receiving regulated watercourses to mimic existing hydrologic functions;
ii. To ensure that post- to pre-development peak flow control (as a minimum) achieves flood control objectives for all storm events (2 year to 100 year);
iii. To ensure that stormwater runoff controls maintain or enhance existing flow-duration exceedance characteristics and other erosion indicators in the receiving regulated watercourses;
iv. To ensure that the treatment of runoff mitigates surface water quality impacts due to development in accordance with Ministry of the Environment, Conservation and Parks (MECP) guidelines, to an *Enhanced* standard;
v. To mitigate thermal impacts from stormwater runoff to the extent possible;
vi. To consider Low Impact Development (LID), Green Infrastructure and Best Management Practices (BMPs) to treat stormwater at its source; and
vii. To consider climate change mitigation and adaptation measures as part of establishing stormwater management strategies.

3.0 Baseline Inventory and Characterization

3.1 General Data Collection

3.1.1 Background Information and Data Tracking

Background information has been provided by the Township of West Lincoln, Niagara Region, and the NPCA for use in this study. An inventory of the background information requested and provided is included in Appendix A.

3.1.2 Topographic Mapping and Orthophotography

LiDAR mapping has been provided by the Township for the Study Area, and topographic data for the balance of the Twenty Mile Creek Watershed has been provided by the NPCA. Orthophotos for the study area have been obtained by the Study Team from the Brock University Library.

3.1.3 Property Access

The Township of West Lincoln has coordinated securing Permissions To Enter from area residents, landowners and businesses to allow the SWS Team access to properties for field investigations.

3.1.4 Stormwater Management Inventory

Information has been reviewed for stormwater management facilities (SWMFs) within the Urban Expansion Area and the existing urban area. Drawing WR1 provides an overview of the locations and types of the SWMFs. A summary of the SWMFs is provided in **Table 3.1.1**.

Table 3.1.1. Summary of SWMF Review

SWMF ID	SWMF Name	Location	Contributing Drainage Area (ha)	Type	Volume (m^3)	Maximum Design Storm	Report Reference
A	Crossing On 20	Townline Rd & Anderson Cres	0.793	OGS	NA	NA	Ashenhust Nouwens March 14, 2013 & New Plans
B	Old Town Gateway	Hwy 20 & Dennis Dr	8.97	Quality Wet Pond	2964	-	Lamarre Consulting April 2012
C	2060 Industrial Park Road Tank	Industrial Park Rd & Skyway Rd	1.09	OGS + Quantity Storage Tank	209.6	100 year	Ibi Group June 2017 Rev 4
D	Griffin Place Tank	Shurrie Rd & Cherry Ave	1.78	OGS + Quantity Storage Tank	179.1	100 year	Upper Canada Consultants Rev February 2016
E	Vintage Collection Bungalows	West Street & Bartels Dr	1.03	OGS + Quantity Dry Pond	240	100 year	Upper Canada Consultants Rev June 2012

SWMF ID	SWMF Name	Location	Contributing Drainage Area (ha)	Type	Volume (m^3)	Maximum Design Storm	Report Reference
F	Streamside Estates	South Grimsby Road 6 & Hwy 20	12.75	Wet Pond (Quality; Erosion; and Quantity)	14095	100 year	MTE Consulting January 2006
G	Anastasio Ph2	Wade Road & Townline Rd	28.58	Wet Pond (Quality; Erosion)	4059	-	Ashenhust Nouwens April 21 2005 Report With Reference To Upper Canada Consultans Dwgs
H(1)	Smithville Estates;	Oakdale Blvd & Forestview Ct	3.94	Wet Pond (Quality; Erosion)	NA	NA	Ashenhust Nouwens April 21 2005 Report With Reference To Upper Canada Consultans
I(1)	Station Meadows	Station St & Hornack Rd	NA	Wet Pond	NA	NA	Odan Dtech Autocad Plan Sht 2 Of 7 Dated June 14/2020
J	Almas Ph3	Alma Drive & Paticia Ct	8.99	Culvert	NA	NA	Upper Canada Autocad Plan Dated May 2004 Located In 71044 Subfolder

Note: (1) Anastasio Ph2 and Smithville Estates contribute to one common SWMF.

Within the existing urban area, quantity control is currently provided in the form of storage tank, dry pond, or wet pond. Two quantity control SWMFs for residential subdivisions are located north of Twenty Mile Creek. One quantity control SWMF for industrial land is located north of the CNR near Industrial Park Road. One quantity SWMF is located at the south boundary of the existing urban area, which contributes to North Creek. Quality control is currently provided in the form of an OGS unit or wet pond for all SWMFs with available information. The OGS units were typically designed to provide stormwater quality control to an Enhanced standard of treatment (i.e. 80% TSS removal) and the wet ponds were typically designed to provide stormwater quality control to a Normal standard of treatment (i.e. 70% TSS removal). Two wet ponds are indicated to be able to provide erosion controls – The Streamside Estates SWMF and the the Anastasio Ph2/Smithville Estates SWMF. The Streamside Estates SWMF discharge to Twenty Mile Creek. The Anastasio Ph2/Smithville Estates SWMF is an online SWMF on a Twenty Mile Creek tributary near the west boundary of the existing urban area.

3.2 Climate

3.2.1 Importance and Purpose

Climate data are critical to developing and understanding of how water moves through a system. The hydrologic and hydrogeologic/groundwater system modelling are reliant on climate data for characterization of the surface and subsurface water conditions at key locations within the study area, as well as for the Twenty Mile Creek Watershed. Long-term and short-term meteorological data sets have been used and specifically collected as part of this study within and adjacent to the Community of Smithville for use in multi-year assessments. These datasets, in conjunction with data collected from future studies, may also provide a means for assessing shifting trends in meteorological patterns associated with climate change.

3.2.2 Background Information

Rainfall and precipitation data are available from monitoring stations maintained by Niagara Region and Environment Canada's Historical Weather and Climate Data. These datasets have been reviewed to characterize the meteorologic conditions (rainfall/precipitation and temperature) within the Smithville Subwatershed, as well as to assess the availability of meteorologic data for conducting long-term continuous simulations. Additionally, Wood has been collecting rainfall data at the temporary gauge set up at Smithville Arena as part of this study. The monitoring period started in March 2020 and extended till November 2020. The data sources, type, timestep and period of record are summarized in **Table 3.2.1**

Table 3.2.1. Summary of Precipitation Gauges and Sources

Gauge Location/Description	Source	Timestep	Period of Record
Smithville SPS Precipitation Station	Niagara Region Niagara Weather Information System Database (NWIS)	5 Minute	January 1998 – June 2019
Grimsby Mountain Station	Environment Canada	daily	August 2005 – December 2020
Temporary Station (Smithville Arena)	Wood	15 Minute	March 2020 – November 2020

The information in Table 3.2.1 indicates that the NWIS Smithville SPS station provides the longest period of record of all local stations. Recognizing that continuous simulation and frequency analysis requires a minimum of 20 years of rainfall for the hydrologic modelling, this gauge is the only station with a sufficient period of record for use in continuous simulation.

3.2.3 Methods and Analysis

The climate data have been reviewed for the common time periods of 2005 to 2019 and for the year 2020 to determine whether the data are appropriate for use in long-term continuous simulation and hydrologic model validation based upon the respective timeseries. The comparison of the data between the Smithville SPS station and the Grimsby Mountain Station suggests that data gaps in the form of missing rainfall data exist within the Smithville SPS station for approximately 5% of the days over the 22-year period. The missing data have been filled with 0 mm. The average annual precipitation is 720 mm at the Smithville SPS station compared to 956 mm at the Environment Canada Grimsby Mountain Station, which reflects that the Smithville SPS station provides rainfall data only, rather than precipitation data (i.e. rainfall and snowfall). **Table 3.2.2** summarizes the comparison of monthly rainfall and precipitation results. The discrepancies are considered insignificant giving the spatial distance and the amount of missing data.

Table 3.2.2. Comparison of Average Monthly Rainfall and Precipitation Data

Month	NWIS Smithville SPS Precipitation Station	Environment Canada Grimsby Mountain	Environment Canada Grimsby Mountain
	Total Precipitation (mm)	Total Precipitation (mm)	Total Rainfall (mm)
January	40.02	67.31	42.87
February	38.32	69.94	31.24
March	48.92	73.78	50.51
April	77.95	96.54	89.75
May	73.24	76.76	76.69
June	72.61	81.77	81.77
July	61.97	76.63	76.63
August	57.63	74.19	74.19
September	67.51	76.76	76.76
October	74.86	105.04	104.74
November	57.98	76.09	65.79
December	48.89	81.52	51.51

3.2.4 Interpretation and Findings

The analysis of the climate data indicates that the 22-year NWIS data (1998-2019) are suitable for long-term continuous simulation specifically for non-winter months (April – October), to analyze the frequency peak flows and erosion duration exceedances. The rainfall data collected at the Wood temporary rainfall gauge are appropriate for model validation purposes due to the short monitoring time period (March to November 2020). The rainfall data from the Environment Canada Station Grimsby Mountain is not of a sufficiently resolute timestep for use in hydrologic modelling, however may be used to characterize the magnitude/severity of storm events for the continuous simulation.

3.3 Hydrogeology

3.3.1 Importance and Purpose

The interrelationship between the hydrogeologic conditions, the ecosystem, and the use of groundwater for anthropogenic needs, is important in order to assess and manage potential impacts from future land use changes on the groundwater flow system.

The primary objectives of the Phase 1 hydrogeological characterization component of this study are to:

- Define the geological and hydrogeological setting within, and adjacent to, the urban expansion area.
- Identify and evaluate the functional relationship and interactions groundwater may have with the existing surface watercourses and terrestrial resources.
- Integrate overall groundwater function with the karst assessment.

3.3.2 Background Information

The following are the relevant groundwater sources of information used to characterize the groundwater system within the study area.

NPCA Source Water Protection

Updated Assessment Report-Niagara Peninsula Source Protection Area, November 28, 2013.

The report provides an overview of the regional characterization of surface water resources, the physiography, surficial and bedrock geology, bedrock topography, aquifer and aquitard units, water table and groundwater flow, recharge areas and potential groundwater discharge. The report assesses and provides mapping of Highly Vulnerable Aquifers (HVA) and Significant Groundwater Recharge Areas (SGRA).

Phase IV Bedrock Remediation Program

Contamination discovered at the former Chemical Waste Management Limited (CWML) site in 1985 led the Ontario Ministry of the Environment (MOE) to implement the Phase IV Bedrock Remediation Program in 1998. This program was a multi-phase investigation and assessment program to remediate the onsite surface contaminant sources, overburden and groundwater contamination. As part of the overall program the Phase IV Bedrock Remediation Program conducted intensive subsurface investigations, groundwater computer modelling and hydrogeological characterization. In all, the final recommendation report included 49 supporting documents. These reports were reviewed to varying extents for the current Subwatershed Study. The level of investigative detail and assessment carried out for the remediation program was quite extensive and is reflective of the contaminant assessment and remediation objectives related to the CWML site. The overall hydrogeological characterization presented in these reports has been incorporated into this Subwatershed Study. The following represent the more relevant reports:

Preliminary Site Conceptual Model (1997) Report, (Phase IV Project Management Team)

The Development of a Conceptual Model for Contaminant Transport in the Dolostone Underlying Smithville, Ontario, December, 2000 (Kent Novakowski, P. Lapcevic, G. Bickerton, J. Voralek, L. Zanini and C. Talbot),

Solution-Enhanced Features at the Smithville Site, August, 2001 (Acres & Associates),

Chemical Hydrogeology of the Carbonate Bedrock at Smithville, May, 1999 (S.R.H. Worthington and D.C. Ford),

Potential Discharge of Lockport Groundwater into Twenty Mile Creek Downgradient from the CWML Site, Smithville, September, 2000 (Kent Novakowski, Jamie Oxtobee, and Peter Kryger),

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

These reports provide various levels of information on groundwater levels and groundwater flow pathways and potential flux related primarily to the underlying bedrock, the hydraulic characteristics related to the fractured nature and enhanced channel nature of the bedrock, recharge through the overburden and the potential groundwater connection to Twenty Mile Creek and North Creek. They also provide borehole specific information related to overburden thickness and groundwater level trends.

Water Well Information System (WWIS)

The provincial Ministry of the Environment, Conservation and Parks (MECP) database has been incorporated to use the site-specific data provided in the water well records including overburden stratigraphy and groundwater levels. The WWIS database provides a quality control feature related to the accuracy of the location of the well. An additional review of the data and mapping presented on the original well records has also been carried out as part of the Subwatershed Study.

Permit To Take Water (PTTW) Database

MECP permits to take water have been reviewed. Eight groundwater sources related to one PTTW. Eight groundwater sources related to one PTTW exist and they are located at the CWML site related to groundwater remediation.

Geotechnical Investigations

Nine geotechnical investigations for various residential/commercial developments and sanitary infrastructure projects have been reviewed. Borehole log data presented in these reports provided technical information, to varying extents, on overburden stratigraphy, overburden thickness and potential locations of the water table.

Miscellaneous/Other

Geologic Hazard Mapping Study, Karst Topography, Phase 1 NPCA Watershed Area, April 2006 (Terra-Dynamics Consulting Inc.)

This report provided a preliminary assessment of major surficial karst locations in the NPCA Watershed and a general description at each location.

Preliminary Bedrock Resource Assessment – Urban Settlement Area Expansion, Township of West Lincoln, May, 2014 (MHBC)

This report provided Study Area specific aggregate resources and potential extraction capability.

3.3.3 Field Methods

Site reconnaissance was conducted on five (5) occasions (December 24, 2019, March 25, 2020, April 6, 2020, April 27, 2020, September 12, 2020) to assess potential sites for drilling and monitoring well installation, to determine sites for baseflow measurements, to inspect for potential seeps and springs, and to observe portions of the karst field survey.

A groundwater field program that includes drilling and monitoring well installation, groundwater level monitoring, and spot baseflow measurements has been conducted to supplement the existing knowledge base, refine the hydrogeological characterization, and establish baseline conditions within the Smithville area. The field program supports the overall goal of the groundwater characterization work to enhance the understanding of the regional and local groundwater flow system. This understanding supports the development and post-development objectives and targets that maintain groundwater function and will integrate considerations of hydrogeologic sensitivity during the evaluation of alternative land use and stormwater management plans.

3.3.3.1 Borehole Drilling and Monitoring Well Installation

In 2021, the SWS team coordinated and supervised a borehole drilling and monitoring well installation program. Five new monitoring wells (labelled "21-MW01 to 21-MW05"; Drawing GW-8) were completed within the Study Area, both north and south of Twenty Mile Creek, to provide additional information for minor refinements to the characterization of the local geology, overburden thickness, seasonal groundwater level variation, overall groundwater flow direction in the shallow bedrock, and potential hydraulic connections to creeks and karstic features. Water level data collected from these new wells supplements water level data collected from the existing six monitoring wells (OW2, OW3-5, OW3-10, OW4, OW5-4, and OW5-7) located in Rock Park (Drawing GW-8 [inset]), which were instrumented in June 2020 for this study.

Four of the boreholes were advanced and completed as monitoring wells (21-MW01, 21-MW02, 21-MW03, and 21-MW05; Drawing GW-8) between March 8 and 11, 2021. The fifth borehole could not be completed at the same time due to wet ground conditions preventing drill rig access to the location. This borehole was advanced and completed as a monitoring well (21-MW04; Drawing GW-8) on May 26, 2021.

Drilling was carried out using track-mounted drilling rigs operated by licensed drilling contractors (Aarvark Drilling Inc. of Guelph, ON and Landshark Drilling Inc. of Brantford, ON). Prior to drilling, the SWS team contacted Ontario One Call to notify registered utility owners of the upcoming work and request public locates. Field personnel also supervised a private locate sweep of each proposed borehole location on February 25, 2021 and inspected the sites for indications of non-registered buried infrastructure.

Boreholes were drilled using hollow stem augers with split spoon samples collected every 0.76 m to a minimum depth of 3.05 m below ground surface (mbgs) and then at least every 1.52 m to the end of the borehole. Field personnel were onsite to record observations on the geologic logs including lithology, colour, texture, structure, moisture, consistency and monitoring well completion details. For bedrock core, Rock Quality Designation (RQD) was recorded. RQD is the percentage of intact drill core pieces longer than 10 cm recovered during a single core run. When calculating RQD, fractures interpreted to occur during drilling were ignored. Geologic logs indicating borehole lithology and monitoring well installation details are provided in Appendix C.

The drilling subcontractors completed each monitoring well using 52 mm diameter slotted (10-slot) poly-vinyl chloride (PVC) screens and solid Schedule 40 PVC riser pipe. The annular space between the PVC pipe and the wall of the borehole was backfilled with a sand filter pack to approximately 0.10 to 0.30 m above the top of the screened section and a bentonite-based granular seal was installed in the remaining annulus to ground surface to prevent downward surface water migration. The monitoring wells were installed with riser pipes extending approximately 0.7 m above the ground surface and were covered with a protective steel surface casing, well cap, and lock. Field personnel developed each well by purging at least ten well volumes or until the well went dry using a dedicated Waterra inertial pumping system. The stick- up height at each well was measured from ground surface to the top of the PVC riser pipe. Ground elevations at each monitoring well were estimated using the 30 m Provincial Digital Elevation Model for the Study Area (MNRF 2018). Each newly installed well was instrumented with an automatic data logger recording water levels at one-hour intervals.

Four of the five boreholes were completed across the interpreted overburden/bedrock contact where drilling response indicated a weathered transition zone was present. One well (21-MW03) was completed entirely in the dolostone bedrock, across an interpreted karst feature at 9.4 m bgs. During bedrock advancement at 21-MW03, the drill rods suddenly dropped approximately 0.08 m at that depth and the rig lost circulation of drilling water. Monitoring well installation details are provided in Appendix C and Table 3.3.1.

Table 3.3.1. Summary of Monitoring Wells Installed in 2021

Well ID	Installation Date	Total Drilled Depth (mbgs)	Screened Interval (mbgs)	Screened Stratigraphy
21-MW01	March 9, 2021	4.57	2.11 - 3.61	Sand / Dolostone
21-MW02	March 11, 2021	6.02	3.74 - 5.26	Clay / Silt / Dolostone
21-MW03	March 10, 2021	9.96	8.28 - 9.8	Dolostone
21-MW04	May 26, 2021	6.10	2.96 - 4.49	Clay / Dolostone
21-MW05	March 10, 2021	7.01	4.95 - 6.47	Silt / Sand / Dolostone

Detailed descriptions of borehole lithology are presented on the borehole logs in Appendix C. The following general observations were noted:

- Overburden generally comprised of fine-grained deposits with variable silt and clay content, with trace to some sand
- Overburden deposits were typically brown with some evidence of oxidation and mottling, but no distinct colour change to gray was consistently observed in the overburden
- At several drilling locations (21-MW02, 21-MW03 and 21-MW05), fractures were observed in the clay overburden units. These fracture planes varied in orientation and depth (1.5 to 5 m bgs). The fracture planes were often discoloured (gray or oxidized) compared to the rest of the sample core and sometimes showed crystalline mineralization.
- Based on drilling response and returned samples, a transition/weathered zone between overburden and bedrock was observed at all locations, typically comprising increased sand and gravel content with angular bedrock fragments. This transition zone varied in thickness from 0.16 m to 1.05 m.
- In general, the cored dolostone bedrock was competent; in most cases the RQD was above 90% and aside from the lost-circulation zone at 21-MW03, no obvious evidence of larger karst features was observed
- The upper portion of the retrieved bedrock cores was more highly weathered and/or fractured; vugs (whether open or infilled) were consistently observed throughout the bedrock cores, but they tended to be larger and more frequent near to overburden/bedrock interface

3.3.3.2 Groundwater Level Monitoring

Groundwater level monitoring was carried out to provide information on baseline seasonal groundwater level variation within the shallow bedrock flow system. Groundwater levels were monitored at the five monitoring wells installed in 2021 and at six pre-existing monitoring wells starting in June 2020. The pre-existing wells are located within and adjacent to Rock Street Park in Smithville and are designated OW2, OW3-5, OW3-10, OW4, OW5-4 and OW5-7 (locations provided on Drawing GW-8 and Appendix C2). Four of these monitoring wells were completed in pairs (i.e., OW3-5/OW3-10 and OW5-4/OW5-7), which provided additional information on vertical hydraulic gradients. These wells were originally drilled and installed 2 to 6 m into the shallow bedrock in 1994 (Terraqua 1994). Monitoring well location and elevation details are summarized in Table GW-1 (ref. Appendix C1) and original well logs (Terraqua 1994) are provided in Appendix C2.

All of the monitoring wells were equipped with a Solinst™ Levelogger Model 3001 non-vented pressure transducer automatically recording groundwater levels every hour starting in June 2020 (existing monitoring wells in Rock Park) and in March or May 2021 (newly installed monitoring wells). Groundwater levels were also measured and recorded periodically in 2020 and 2021 at each well relative to the top of pipe using a Solinst™ electronic water level tape (Table GW-1 in Appendix C1). Prior to Levelogger installation, the Rock Park monitoring wells were developed by purging at least 3 times the well water volume. Data from a Solinst™ Barologger transducer recorded atmospheric pressure on site to correct the water level pressure recordings to gauge pressure. Groundwater elevations at each well were calculated by subtracting measured depths to water from the ground surface elevations (i.e., Rock Park - Terraqua 1994; newly installed wells – MNRF 2018). Hydrographs of manual and automatic groundwater levels are presented in Appendix C3.

3.3.3.3 Spot Baseflow Monitoring

Surface water spot baseflow measurements were collected to observe the seasonal and spatial variability of baseflow along watercourses. Baseflow conditions are present during periods when overland flow to a watercourse is absent and the watercourse has returned to its "dry" weather level. It is during these conditions that areas of potential groundwater discharge and recharge along the length of a watercourse can be evaluated. Dry weather conditions supporting baseflow conditions were considered to occur following any period of three consecutive days with less than 5 mm of cumulative rainfall. Surface water spot flow measurements were collected by the SWS Team during the spring (May 13), summer (July 31) and fall (November 5) of 2020 to capture seasonal variability.

Baseflow monitoring locations were selected at 26 locations in and around the urban expansion area boundary, along the main channels and supporting tributaries of Spring Creek, Twenty Mile Creek and North Creek (Drawing GW-10). Spot baseflow measurements were completed by securing a measuring tape across the banks of the stream and dividing the cross section of the stream into approximately 10 panels of equal width. A Son-Tek FlowTracker Acoustic Doppler Velocimeter (ADV) was used to record the width, water depth and flow velocity in each panel to produce a final discharge value for the stream at each monitoring location. Spot baseflow measurements are presented in Table GW-2 (Appendix C-1) and Drawing GW-10.

3.3.4 Interpretation and Findings

3.3.4.1 Physiography

The physiographic description of an area commonly includes summaries of topography, landform, drainage and the occurrence of surface soil types along with an overview of the depositional and erosional history that created the landform. Geologic descriptions commonly detail the overburden and bedrock composition and form below the surface as well as the relationship of the geology to the physiography of that area. Together these two descriptions are used to characterize the physical setting of a study area and form the basis of any groundwater interpretation.

The variability of the bedrock surface, as well as the stratigraphy of the overburden, is a result of the repeated glacial advances and retreats, which occurred in southern Ontario. The most recent glacial advance and retreat formed much of the land surface and geology present in the area today. This event is referred to as the Wisconsin Glaciation, and was accompanied by various meltwater lakes and channels. The last glacial retreat ended approximately 12,000 years ago, blanketing the area in glacial sediments.

The study area lies within the Haldimand Clay Plain physiographic region (Drawing GW-1). The larger region generally consists of stratified clay related to glacial Lake Warren although the northern area, including Smithville, may consist of an intermixture of stratified clay and till (Chapman, L.J and Putnam, D.F., 1984). Modest till moraine ridges in this area (Drawing GW-1) control surface drainage creating a general easterly flow for surface water features such as Twenty Mile Creek, North Creek and Spring Creek. Soils are generally characterized by a heavy texture and poor drainage.

3.3.4.2 Bedrock Geology and Bedrock Topography

The bedrock underlying the study area consists of a sequence of bedded dolostones and shales. Paleozoic bedrock within the study area, found at the bedrock surface, is presented on Drawing GW-2 and includes the following:

Guelph Formation: This formation is characterized as a tan to brown, medium to very thick-bedded, fine to medium crystalline dolostone and overlies the Lockport Formation.

Lockport Formation:

- Eramosa Member - this member is characterized as a brownish grey, fine to medium grained dolostone containing frequent bedding plane fractures and gypsum filled vuggy zones. The thickness of this unit ranges from 6-19 m. The Eramosa Member is further characterized by an upper zone which is a weathered dolostone with open bedding partings and a lower zone unweathered dolostone with open bedding partings. In between these two zones is a thickly bedded massive dolostone.
- Vinemount Member - this member is characterized as a vuggy, gypsiferous, and argillaceous dolostone, medium grey and fine grained. The thickness may vary from 3-15 m. The upper Vinemount is high fractured and the gypsum filled vugs have been weathered out. The lower Vinemount remains unweathered and there are fewer bedding plane fractures.
- Goat Island Member – is a chert rich, fine to medium grained dolostone with less frequent bedding planes. The thickness varies from 5 – 7m.
- Gasport Member – a fine to medium dolostone with less frequent bedding planes. The thickness varies from 7-16 m.

Underlying the Lockport Formation is the Decew Formation characterized as a brownish-grey, fine grained, medium bedded argillaceous dolostone; and the Rochester Formation characterized as a massive, medium grey, fine grained, thin to medium bedded argillaceous and dark grey shaley dolostone.

The various bedrock characteristics related to fractures, bedding planes and weathering is discussed further in Sections 3.3.4.4 and 3.4.4.

A bedrock topography map (Drawing GW-3) was created using borehole information from: the wells installed as part of this study, previous reports in the study area, information from the Ministry of Environment, Conservation and Parks (MECP) WWIS, and from surficial geology mapping. Borehole information from the boreholes drilled as part of this project, as well as information from background reports, are considered relatively higher quality information where more detailed borehole logs have been prepared as part of geotechnical studies and the Phase IV Bedrock Remediation Program. Information available from the WWIS was also used to inform the bedrock elevation. This dataset has the benefit of having a greater number of datapoints; however, this information is considered relatively lower quality due to greater uncertainties in the database with respect to reported well locations and depths. Where the depth to bedrock was provided, this information was used directly from the WWIS. However, where only overburden information was provided, this depth information was used as "push down control points" to inform where the overburden thickness should be at least as thick as the depth of these wells and where the bedrock is at a lower elevation. Finally, surficial geology mapping (OGS 2010; Drawing GW-4) was used to inform where bedrock has been mapped at ground surface.

The bedrock generally slopes from north to south with an elevation range of approximately 25 m in the area of the proposed the urban expansion. Elevated bedrock areas exist south of Twenty Mile Creek in the southwestern portion of the urban expansion area and in the northern portion of the urban expansion area, as well further north beyond the urban expansion area. Twenty Mile Creek tends to follow a bedrock depression just west of, and through the Community of Smithville (Drawing GW-3). Trends in the bedrock topography influence, in part, the overburden thickness (Section 3.3.4.3) and the shallow bedrock groundwater flow directions (Section 3.3.4.4.2).

3.3.4.3 Surficial Geology, Overburden Thickness and Stratigraphy

The regional surficial geology mapping and data is provided by the Ontario Geological Survey (OGS 2010). The surficial geology (Drawing GW-4) consists primarily of fine-grained sediments characterized by the glaciolacustrine clay and silt throughout the majority of the urban expansion area and has been observed to include pebbles and cobbles which is discussed further in Section 3.4.7. Clay to clayey silt till (Halton Till) can be found in areas of the urban expansion area. Stream deposits are predominately clay and silt with some sand and gravel. The Eramosa dolostone is exposed in bedrock outcrops along portion of Twenty Mile Creek and areas northeast of the urban expansion area.

An overburden thickness map (Drawing GW-5a) was created utilizing the same dataset and methodology described in Section 3.3.4.2. A map of overburden thickness less than 6 m was also created (Drawing GW-5b). The significance of the 6 m overburden thickness relates to observations of the depth of fractures and root cast within the overburden and will be discussed further. The overburden is less than 6 m thick throughout the majority of the urban expansion area, with the least amount of overburden correlating with the bedrock highs and bedrock outcrops (Drawing GW-3). Overburden thickness generally increases south of the urban expansion area in a southerly direction correlated with the slope of the bedrock.

Ten stratigraphic cross-sections were completed (Drawings GW-6a through GW-6j) and their locations are found on Drawing GW-4. The cross-sections and geologic units shown on those cross-sections were developed using available data from borehole logs in the Study Area, except for the Guelph Formation-Eramosa Member contact surface. This surface was approximated using the Guelph Formation-Eramosa Member subcropping contact line from OGS bedrock mapping (Armstrong and Dodge 2007) as a starting point and then applying the same bedrock surface dip and trend as the underlying Vinemount Member surface that was interpolated using borehole data.

The undulating surface in the uppermost bedrock units, the Eramosa member and Guelph Formation, as seen on GW-3 and GW-6a-j, is generally a result of glacial erosion. The overall bedrock stratigraphy demonstrates a southerly regional dip of 0.5% with more local dips of up to 2% (ref. Novakowski, K., P. Lapcevic, G. Bickerton, J. Voralek, L. Zanini and C. Talbot, 2000) which is reflected in the bedrock topography presented on Drawing GW-3. The bedrock high areas north and south of Twenty Mile Creek can be seen on GW-6g (Section G-G'). Well depths and groundwater level trends presented on the cross-sections are discussed in Section 3.3.4.4.

The overburden generally exhibits the following characteristics (Phase IV Project Management Team, 1997; Worthington, S.R.H. and D.C. Ford. 1998; Amec, 2011):

- The upper portion of clay silt overburden is highly weathered and fractured,
- The uppermost 3 metres is heavily desiccated and brown in colour suggesting oxidation,
- In various test pits, fractures varied in size from several sub-millimetres to millimetre and have been observed to be up to 2 cm in width at the top of the overburden,
- Shallow fracture widths can vary seasonally,
- A transition zone of mottled brown leads to distinct grey with depth,
- Root casts along with soils pipes related to burrowing animals are present,
- Fractures and root casts exhibit oxidized halos to various depths,
- Sub-vertical fractures and root casts have been observed to extend through the entire thickness of the clay silt overburden with spacings of 0.2 to 0.6 m.

Discontinuous deposits of a mix of silty sand, gravel and cobbles can be found at the bedrock contact in various exploratory boreholes and water well logs. These deposits are considered to be localized and absent over large areas (Phase IV, 1997).

Within the bedrock, tectonic events have created structural characteristics on a regional scale including folding, faulting and uplift which have influenced fracture orientations and trends through the entire bedrock sequence. The shallower bedrock has fracture network characteristics that may relate more to loading and unloading cycles during glacial events (Phase IV, 1997) or possibly from mechanical forces (Worthington, S.R.H. and D.C. Ford. 1999). Fractures occur in lateral bedding planes and as vertical and sub-vertical fractures (joints) above and below the bedding planes. Joint spacing is noted to be more frequent in the uppermost portions of the bedrock and decreases with depth and exhibit preferential orientations (Novakowski, K., P. Lapcevic, G. Bickerton, J. Voralek, L. Zanini and C. Talbot, 2000).

3.3.4.4 Hydrogeologic Setting

Conceptually, water from precipitation percolates or infiltrates into the ground until it reaches the water table. Areas where water moves downward from the water table are known as recharge areas. These areas are generally in areas of topographically high relief. Areas where groundwater moves upward to the water table are known as discharge areas. These generally occur in areas of topographically low relief, such as stream valleys and discharge can occur in significant quantities when the stream valleys cut into permeable sediments. Discharge occurring as seeps and springs also occur in these areas as well as localized areas outside of major topographic lows where the stratigraphy controls groundwater flow. Groundwater that discharges to streams is the water that maintains the baseflow of the stream. Wetlands may be fed by groundwater discharge.

There are different types and rates of recharge and discharge. Water percolating into the ground at a specific location may discharge to a small stream a short distance away. This is local recharge and local discharge. Some water may recharge in a certain area and discharge to a larger river basin, a long way from the source of recharge. This is known as regional recharge and regional discharge.

Hydrostratigraphic units are developed by lumping or splitting stratigraphic units based on their hydrogeologic properties. The delineation of hydrostratigraphic units is completed using knowledge of the regional and local understanding of the spatial distribution of stratigraphic units where higher quality data is available, and carrying this interpretation outwards using lower quality data. Permeable geologic materials that can transmit significant quantities of water are known as aquifers. Aquifers are "water bearing" formations, meaning that water can be easily extracted from these units. The less permeable units are known as aquitards, and although water can move through these units, it moves slowly and it is difficult to extract water from these units. How these aquifers are connected within a hydrogeologic setting is what controls much of the movement of groundwater.

The delineation of the flow system will identify where groundwater originates, where it discharges, and the most prominent paths it travels between these points (e.g., pathways through aquifers or more permeable hydrostratigraphic units). From this delineation, the relative sensitivity of the linkage from the groundwater system to the aquatic or terrestrial systems can be assessed. Knowing the level of sensitivity of the receptor, the impacts of particular types and scales of land uses or land use changes on the groundwater flow system and other linked ecosystem components can also be assessed. Best management practices can then be developed to prevent unacceptable impacts from occurring.

3.3.4.4.1 Hydrostratigraphy

As mentioned previously, hydrostratigraphic units are developed by lumping or splitting stratigraphic units based on their hydrogeologic properties. Hydraulic conductivity is the main property of a stratigraphic unit that describes how easily water can move through it. Stratigraphic units are considered aquifers where the hydraulic conductivity is relatively high. Conversely, they are considered aquitards where the hydraulic conductivity is relatively low. Aquifer units are defined solely on the basis of the estimated ability of the unit to yield water and do not consider water quality or vulnerability to surficial sources of contamination. The hydraulic conductivity and ability to yield water which characterize the study area bedrock aquifers relates directly to the extent of fractures and the associated solution channels within these units. The main aquifer and aquitard units within the study area are described in Novakowski, K., P. Lapcevic, G. Bickerton, J. Voralek, L. Zanini and C. Talbot, (2000). Aquifer units include the Eramosa Member, particularly the upper Eramosa Member, which provides for the majority of the private domestic wells; the upper Vinemount Member which was previously the intake for the former municipal wells for the Town of Smithville, and the Goat Island and Gasport Members. These units can transmit significant quantities of water through the interconnected fracture and solution channel network. The clay/silt overburden would generally be considered an aquitard particularly when considering the unweathered portion and the lack of water wells. The discontinuous deposits of silty sand, gravel and cobbles that are found in pockets at the bedrock contacts may provide for a domestic water supply. Additional aspects of supply wells are described in Section 3.3.4.4.5.

A minor aquitard exists between the upper and lower portions of Eramosa Member. The lower Vinemount sub-member is an aquitard and the Rochester Shale is the major regional aquitard.

3.3.4.4.2 Groundwater Levels and Groundwater Flow

The clay silt overburden controls the shallow groundwater components of horizontal and vertical flow and subsequent local recharge to the underlying bedrock units. The overburden characteristics presented in Section 3.3.4.3 provide the hydraulic pathways for groundwater movement within the overburden. The following additional hydrogeologic factors and interpretations relate to varying levels of groundwater flow in the overburden:

- Frequency and depth of fractures can depend on the clay/silt/sand content, average precipitation and temperature,
- Secondary flow pathways that include fractures, root casts and animal burrows are more prevalent within the upper 2-3 m but occur, to various extents, through a 6 m thickness of the overburden, as observed in various excavations and test pits (Amec 2011, Phase IV, 1997, Worthington, S.R.H. and D.C. Ford. 1998). Drawing GW-5b presents areas where the overburden is less than 6m thick,
- Vertical groundwater flow in the overburden, as a result of secondary pathways, can be quite rapid and lead to relatively high fluxes (Phase IV, 1997, Worthington, S.R.H. and D.C. Ford. 1998),

- The lateral hydraulic connection within the upper clay/silt is limited but considered an active groundwater zone. Lateral flow in the zone reduces more quickly as the water levels drop due to less fractures and related hydraulic connection with depth (AMEC 2011),
- The zone of oxidation in the upper clay/silt represents the seasonal variation of the water table within the overburden.
- Subtle horizontal flow patterns in the upper clay/silt may be controlled by local depressional topography and restricted by underlying more massive and less permeable clay/silt matrix,
- Evapotranspiration will significantly reduce water levels in the upper 2-3 of fractured overburden,

It is currently proposed that the upper 2-3 m is a relatively active groundwater flow zone mainly due to the permeability contrast (2-3 orders of magnitude) between it and the underlying more massive clay/silt. It is interpreted that lateral flow in the upper active zone may be directed to the depressional features. Where water levels in this zone are high enough and where depressional features are connected at surface, (i.e. a ridge/swale system) minor amounts of groundwater discharge and overland flow may occur. The extent and distance of overland flow will vary but are likely very local. This flow may be more dominant immediately following a precipitation event and may only last for a short period of time. Although local, minor lateral groundwater flow exists on the clay/silt overburden, the primary component of groundwater flow is vertical to the bedrock.

Groundwater flow within the discontinuous sand/gravel/cobble deposits at the bedrock contact may also be significant on a local scale.

The organic sediments within the forested areas could provide significant storage of water on a local scale which could drain slowly to local reaches where connected and provide seasonal recharge when evapotranspiration is minimal.

Groundwater flow within the bedrock is governed by the horizontal and vertical hydraulic gradients as well as the general characteristics of the fracture network and solution channels presented in Section 3.3.4.3. Groundwater flow moves from the bedrock surface vertically through the vertical fractures (joints) to the bedding planes where the joints are connected. The vertical flux through the upper bedrock will depend on the spatial frequency of the joints, and their size, particularly related to the history of dissolution, and the water made available from ground surface through the overburden. The combined bedding plane/joint network provides for significant lateral flow and less frequent vertical flow conduits (Phase IV, 1997). High transmissivity bedding planes exist particularly within the Eramosa and the upper Vinemont allowing rapid movement of water (Worthington, S.R.H. and D.C. Ford. 1999). The interconnected network of fractures and conduits may only occupy a small fraction of the bedding planes (Worthington, S.R.H. and D.C. Ford. 1998) but are quite significant for flow. The relationship of the characteristics described above as they relate to a 'karst aquifer' characterization is discussed in more detail in Section 3.4. Based on the variety of studies carried out for the Phase IV Bedrock Remediation, groundwater flow within the bedrock has significant components related to more discrete open conduits and potentially less relative flow or flux related to smaller fractures.

Groundwater flow within the upper bedrock is considered to be the primary flow pathway potentially connected to Twenty Mile Creek and the majority of the domestic wells. A deep overburden/shallow bedrock potentiometric surface was prepared to characterize potential flow directions and hydraulic gradients for this characterization (Drawing GW-6a to GW-6j and GW-8) and was created using groundwater level information from monitoring wells from this study and from previous reports in and near the urban expansion area and MECP WWIS. Water level information from the monitored wells and background reports is considered relatively higher quality information where more detailed borehole logs and well screen information are available. As mentioned previously, the WWIS dataset has the benefit of having a greater number of datapoints; however, this information is considered relatively lower quality due to greater uncertainties in the database with respect to reported well locations and depths. Water levels taken from screens completed within 20 metres below ground surface (mbgs) were used to develop the overburden/shallow bedrock potentiometric surface (Drawing GW-8). Without the addition of surface water control points, the shallow potentiometric surface would exceed ground surface in areas of lower elevation (i.e., river valleys). Surface water control points were added to the surface along Twenty Mile Creek and Spring Creek to lower the potentiometric surface and intersect mapped riverbeds (Drawing GW-8).

A deeper bedrock potentiometric surface was also prepared for this preliminary characterization (Drawing GW-6a to GW-6j) and it was created using water level information from the WWIS where wells are screened deeper than 20 mbgs.

Groundwater flow in the upper bedrock generally flows from northwest to the southeast but within the Town of Smithville flow is directed towards Twenty Mile Creek from the north and from Townline Road in the south northward to Twenty Mile Creek (Drawing GW-8). There is a strong correlation between the horizontal flow direction the shallow bedrock and the bedrock topography (GW-3). It is expected that more local shallow groundwater flow will be controlled to varying extents by the fractured nature of the bedrock and particularly the larger solution channels and conduit flow. The orientation of these features may direct flow in directions not consistent with the larger scale hydraulic gradients. The karstic nature of the Eramosa Member as it relates to conduit flow is discussed in more detail in Section 3.4. The fracture orientation patterns which can influence groundwater flow are presented in Section 3.4.6.

Groundwater level trends within the clay/silt overburden vary seasonally within the upper 2-3 m with lower levels in the summer months. The seasonal overburden water table low levels are represented by the weathered oxidized zone within the overburden and generally reflects the zone with the prevalence of fractures. Groundwater levels within the upper Eramosa are generally above the bedrock/overburden contact but can drop below this contact such that unsaturated conditions exist within the upper bedrock while saturated conditions can still exist within the overburden. Groundwater levels below bedrock/overburden contact can be seen on GW-6g and GW-6h where the bedrock high areas exist both north and south of Twenty Mile Creek. Groundwater levels within the upper Eramosa are known to drop below the bedrock outcrops along Twenty Mile creek in the summer months and manifest in a lack of streamflow. At this time the majority of horizontal groundwater flow within the upper Eramosa Member is being transmitted beneath Twenty Mile Creek. The upper Eramosa provides for lateral flow to Twenty Mile Creek on a seasonal basis with the majority of flow passing beneath Twenty Mile Creek (Oxtobee, J.P.A. and K. Novakowski. 2002). Seasonal trends in the groundwater levels are reflected in the change in horizontal hydraulic gradient and the reduction in potential groundwater discharge to stream reaches. Local trends in groundwater levels (ie a groundwater trough) within the bedrock can reflect preferred drainage to highly conductive zones related to an open network of solution channels. Groundwater flow velocities within the fracture/solution channel network can be quite high. Groundwater velocities on the order of 15-120 m/day were measured in the study area (Worthington, S.R.H. and D.C. Ford. 1999).

Downward gradients generally exist within in the Eramosa Member (Novakowski, K., P. Lapcevic, G. Bickerton, J. Voralek, L. Zanini and C. Talbot, 2000., Worthington, S.R.H. and D.C. Ford. 1999) although there are times of upward gradients (Worthington, S.R.H. and D.C. Ford. 1999). In addition, upward gradients within the upper Eramosa provide groundwater discharge to Twenty Mile Creek. Downward gradients from the Eramosa Member and upward gradients from Goat Island Member and lower Vinemount sub-member converge on the upper Vinemount sub-member (Novakowski, K., P. Lapcevic, G. Bickerton, J. Voralek, L. Zanini and C. Talbot, 2000.). Water levels presented on various cross-sections (GW-6b to 6j) show a potential for neutral or downward gradients when comparing the deep potentiometric surface (lower Eramosa/upper Vinemount) to the shallow potentiometric surface (upper Eramosa) which is consistent with the previous Smithville Phase IV studies.

As was previously described, 11 monitoring wells screened within the upper bedrock (Drawing GW-8), were utilized to collect continuous groundwater levels across the Study Area. The hydrographs are presented in Appendix C3. Water level data indicates that groundwater flow is directed towards Twenty Mile Creek. Groundwater level trends in all of the wells reflect, to varying degrees, seasonal and precipitation events as well as diurnal fluctuations. Seasonally, the water levels decline during the summer months and begin to rise in response to the increase in precipitation in the fall season.

Groundwater levels were observed to rise to a greater extent in the fall of 2021 relative to 2020 in response to larger precipitation events (Precipitation data obtained from the Environment Canada Grimsby Mountain station; Environment Canada 2022). While total precipitation in 2021 (1,020 mm) is just 3% higher than the average annual precipitation between 2006 and 2021 (995 mm), it is 25% higher than the total precipitation in 2020 (815 mm). Further, the total precipitation over the last 1/3 of 2021 is 86% higher than the same period in 2020, explaining the observed increase in groundwater levels during that time. The increase in groundwater levels during this period is observed to be more distinct and to a greater extent in well 21-MW04, potentially as a result of its proximity to known karst features and thinning overburden in the area. The karst sinkhole in the wooded area adjacent to 21-MW04 receives significant quantities of water during precipitation events, which is expected to provide direct input to the upper bedrock.

Well pair OW5-4/OW5-7 generally shows a downward gradient, but switches to an upward gradient periodically throughout the year (e.g., June to October, 2020 and August to September, 2021. Well pair OW3-5/OW3-10 is laterally further downgradient in the flow system and closer to Twenty Mile Creek with respect to well nest OW5, and shows a stronger and more consistent upward gradient across the available 1.5-year record. This is a common characteristic when further downgradient and closer to a groundwater discharge zone.

The groundwater level response in the monitoring wells to precipitation events and seasonal trends was similar to the responses within monitoring wells established for the Phase IV CWML study. CWML multi-level monitoring wells located along Twenty Mile Creek and north of Spring Creek Road showed responses in various bedrock units including the Eramosa Member and upper Vinemount indicating relatively rapid hydraulic connection (Novakowski, K., P. Lapcevic, G. Bickerton, J. Voralek, L. Zanini and C. Talbot, 2000).

Drawing GW-7 shows a conceptual groundwater flow system adjacent to Twenty Mile Creek which presents some of the basic vertical and lateral groundwater flow components described above It must be noted that this represents general groundwater paths and local scale groundwater flow in the bedrock will follow discrete fracture paths, joints, bedding planes and related solution channels and conduits. The conceptual flow model demonstrates the basic flow patterns described above for the Eramosa Member and overburden.

3.3.4.4.3 Groundwater Recharge

Groundwater recharge occurs where water infiltrates the ground, often in topographically high relief areas, until it reaches and moves down from the groundwater table. Infiltration rates are governed to a large extent by the surficial geology and associated permeability. Other factors affecting groundwater recharge potential include vegetative cover, topography, spatial and temporal distribution of precipitation events and temperature. A long-term variation in frequency of the intensity of precipitation events may affect the overall recharge. High intensity, short duration events generally lead to more surface runoff and less infiltration whereas longer term low intensity events lead to more infiltration. Detail was presented above relating to hydraulic pathways in overburden clay/silt which can increase infiltration, flow and recharge to the underlying bedrock aquifers. Where the overburden is thinner (GW-5a, GW-5b) the prevalence of these secondary hydraulic pathways are more prevalent; and where the topography is more depressional; relative recharge to the upper bedrock is expected to be greater. Recharge water is transferred from the overburden to the upper bedrock where vertical fractures transmit water to the overall fracture/solution channel network. The spatial variation in upper bedrock recharge may be controlled by the spatial variation vertical fracture size and frequency.

The relative amount of recharge within the study area compared to the regional estimate for recharge in the Haldimand Clay Plain will be likely much higher given the extensive area where the overburden thickness is less than 6 m (GW-5b). Areas associated with the thinnest overburden (ie bedrock topographic highs) and areas with bedrock at ground surface are expected to provide the greatest recharge within the study area. Forested and wetland areas may provide seasonal recharge in the spring and fall when evapotranspiration is minimal and direct precipitation and surface runoff are collected.

Regionally, groundwater recharge was presented in the Updated Assessment Report Niagara Peninsula Source Protection Area (NPCA, 2011) for the Haldimand Clay Plain and estimated to be 53 mm/year. It is expected that groundwater recharge may be significantly higher (70-170 mm) based on other studies looking at recharge within clay/silt tills (Amec, 2011, Amec, 2015) as well as the reduced thickness of overburden within the study area.

Significant Groundwater Recharge Areas (SGRAs) as characterized through Source Water Protection were developed (NPCA, 2011) and are presented on Drawing GW-9. SGRAs only occur in the north eastern portion of the study area, outside of the urban expansion area.

3.3.4.4.4 Groundwater Discharge

Areas where groundwater moves upward to the water table are known as groundwater discharge areas. These areas can include wetlands, streams, seeps and springs and are particularly important where the discharge is critical to maintaining ecological function. Baseflow to stream reaches provides both a seasonal quantity of flow and a thermal refuge, cooler in the summer and warmer in the winter for various fish species. Spot baseflow measurements were carried out at various locations to see if there were any trends that would indicate groundwater discharge.

The spot baseflow measurements are summarized in Table GW-2 (Appendix C1) and Drawing GW-10. In general, most of the study area tributaries were not flowing during the spot baseflow surveys. The greatest amount of baseflow was observed along the main reach of Twenty Mile Creek in the spring season (e.g., maximum of approximately 250 L/s) at both the upstream (site ‘HWY20-00B’) and downstream (site ‘TL-01’) ends of the stream. This suggests very little overall net change in baseflow overall between these two sites. However, a baseflow measurement located mid-way on Twenty Mile Creek, (Site ‘C-00’) and downstream from an observed sinkhole feature (Cowell/Blackport) and surface water loss point (Oxtobee and Novakowski 2002), was observed to be significantly lower (145 L/s) in that same spring event. Just downstream of this location, a spring was observed (S1, Figure 3.3.4.1) and flow at site ‘C-01’ was measured to be back up to 250 L/s during the same spring event. The increase in flow (105 L/s) occurred over a distance of approximately 80 m. An increase in baseflow was also observed along a tributary to Twenty Mile Creek as a result of an observed spring between site ‘RSP-01’ and ‘RSP-02’ (S3, Figure 3.3.4.1) where flow increased from 0 to approximately 1 L/s (Drawing GW-10). In general, relatively lower baseflow rates were observed in the spring and fall months.

A field investigation into the groundwater/surface interactions within the study area along Twenty Mile Creek and North Creek was carried out in 1999 (Oxtobee, J.P.A. and K. Novakowski. 2002). Conclusions were made that relatively small amounts of groundwater were discharging into Twenty Mile Creek and estimates suggested that the majority of the groundwater flow through bedrock, 95%, flowed underneath Twenty Mile Creek. The timing and location of the 5% of groundwater flow was not quantified within the study. The 1999 study also noted that there were indications of groundwater discharge within North Creek in the vicinity of Shurie Road. The cool/warm water aquatic habitat designation, based on fish species, for Twenty Mile Creek and North Creek tends to indicate some level of groundwater discharge.. North Creek shows increases in baseflow from South Grimsby Road 6 through to Shurie Road on all 3 monitoring occasions. The anomalistic high reading at Tober Road TO-02, 44.8 L/s) on July 30, 2020 is suspect. The magnitude of the value is not supported by visual observations recorded during the visit where floating debris were hardly moving, suggesting very low flow. As such the actual baseflow flow at this location is expected to be much lower than 44.8 L/s. The baseflow values indicate consistent increase in baseflow moving downstream indicating some levels of groundwater discharge within these reaches of North Creek. In addition, observations of the substrate in various North Creek reaches indicate of a variety of silt, sand, gravel, cobble and clay (Section 3.9.4) which present circumstances for potential groundwater discharge

Twenty Mile Creek is known to have no flow through the study area at various periods in the summer months. Groundwater discharge may occur seasonally when the more regional groundwater levels are higher, thus feeding some amount groundwater discharge. Pools along Twenty Mile Creek also exist in the summer months indicating varying amounts of local discharge, likely through the discrete fracture/solution channel network. Substantive flow at S1 (Figure 3.3.4.1), which contributes to Twenty Mile Creek, was discussed above. Its source is related to a significant conduit connected to the Smithville Cave (Section 3.4). Springs were also noted at S2 and S4. S4 had a substantial amount of watercress along the reach, which eventually drains into Twenty Mile Creek. As noted in Section 3.3.4.4.2, the groundwater levels upgradient and downgradient of S4 showed consistent upward hydraulic gradients for groundwater discharge to occur. These springs and conduit flow will be discussed in more detail in Section 3.4.

The local wetlands within the study area are currently not considered to have any significant functional groundwater discharge associated with them based on the characteristics of the overburden and the groundwater flow system as presented in Section 3.3.4.4.2 the observations made during the terrestrial surveys (Section 3.8.4) did not note any groundwater discharge or seepage observations although it was noted that a pond in the north east portion of the study area (Section 3.8.4.2, Map NH-3b) was likely maintained by groundwater. It is assessed that this is a dug pond that intercepts the water table with no significant groundwater discharge given the 10 m thickness of clay/silt overburden in the vicinity of the pond.

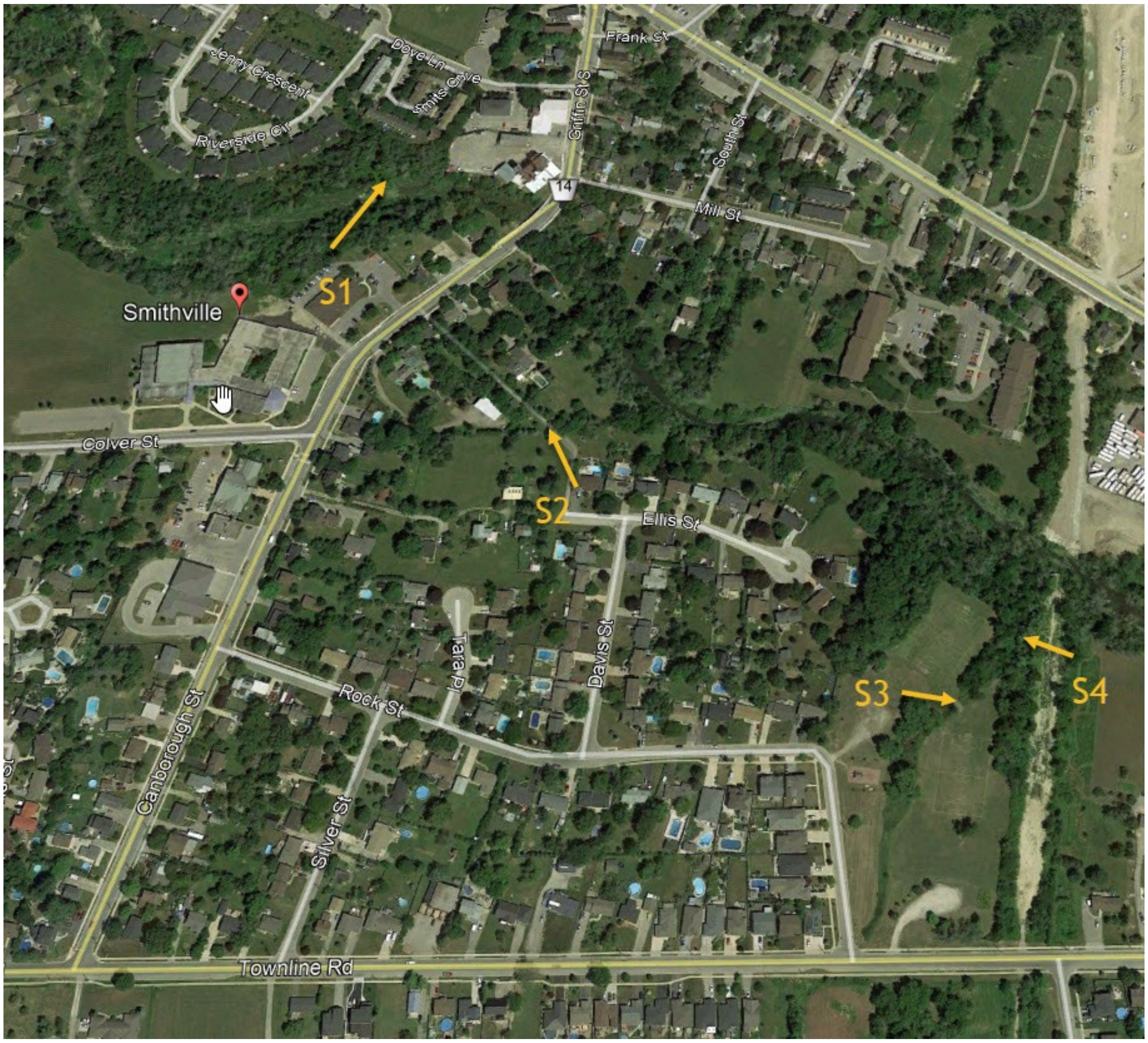

Figure 3.3.1. Observed Springs

3.3.4.4.5 Groundwater Use

The municipal water supply for the Community of Smithville is a lake-based supply. Outside of the existing urban area individual water supplies are provided through domestic wells and are inferred through data from the provincial WWIS. WWIS wells were further subdivided into those that are interpreted to be completed within overburden or bedrock based on whether a depth to bedrock was flagged for that record (Drawing GW-9). Where no depth to bedrock was flagged, the well was inferred to be completed in overburden. Where a depth to bedrock was flagged, the well was presumed to be completed in bedrock for the purposes of this assessment. These data indicate that the majority of the wells within the study area are completed within the bedrock. Wells completed in the overburden are generally completed in the silty sand, gravel and cobbles pockets located at the bedrock contact. The major aquifers were presented in Section 3.3.4.4.1. The majority of the bedrock wells are installed in the Eramosa dolostone or the Guelph Formation south of Twenty Mile Creek as can be seen on the stratigraphic cross-sections (Drawings GW-6a through GW-6j). Deeper wells below the Goat Island Member shown on the cross-sections reflect exploration and monitoring wells for the CWML study and domestic wells. The original municipal wells for the Town of Smithville were screened within the Goat Island Member.

The capacity or quantity of water that a well can provide depends on the hydrostratigraphic unit the well is installed in, the characteristic hydraulic conductivity adjacent to the well, the lateral extent and thickness of the unit and the size of the well bore and screen length among other characteristics. Wells within the overburden tend to have well capacities of less than one to 10's of gallons per minute depending on the permeable nature of the sediment; wells within the bedrock can have well capacities ranging from several to hundreds of gallons per minute depending on the fracture or solution channel prevalence as discussed in Section 3.3.4.4.2.

Drawing GW-9 presents areas where the aquifers are vulnerable. These areas are referred to as Highly Vulnerable Aquifer (HVA) and are developed through the Source Water Protection study (NPCA, 2011). The NPCA used an overburden thickness of less than 5 m to delineate these areas as the thinner overburden offers less protection of contaminants migrating to the shallow bedrock aquifers related to the Eramosa Member and the Guelph Formation. These HVA areas correlate well with the areas of overburden less than 6 m thick shown on Drawing GW-5b. This current subwatershed study presented less than 6 m as a more conservative general threshold based on site specific work done within the Phase IV study related to water residence time within the overburden and observations from test pits excavated to the bedrock.

3.4 Karst

3.4.1 Importance and Purpose

Karst is a geoscience that deals with the development of surface and subsurface landforms resulting from complex hydrological, hydrogeological and hydrochemical processes. Karst occurs only in certain types of rocks including limestone and dolostone ('carbonates'), gypsum, and halite (rock salt). The carbonates are the principal karst-forming rocks as higher mineral solubilities associated with gypsum and halite generally result in their complete removal where in direct contact with rainfall and groundwater.

Carbonates are chemically dissolved by weak acids (principally carbonic acid) contained in rainwater, snowmelt, and soil seepage. The acid weathers the rock by separating calcium (Ca) and magnesium (Mg) ions from carbonate (CO_3) anions creating dissolved constituents that freely move with flowing water. Water penetrates the bedrock via pores (primary permeability) and pre-existing weaknesses, such as fractures (secondary permeability). Continued recharge from precipitation, snowmelt, streamflow, etc. result, given sufficient time, in the preferential expansion of selected fractures creating concentrated pathways for groundwater to follow (tertiary permeability).

These tertiary pathways are referred to as "conduits" effectively increasing the hydraulic conductivity of the aquifer over time. The result is the formation of a karst aquifer whereby surface water enters the rock (recharge) via distinct solutionally-widened surface openings (sinkholes and exposed surface joints), passes through the rock in discrete conduits, then discharges at springs at lower elevations. Karst conduits typically develop along primary fractures that include both bedding planes and joints. The critical point in the development of a karst conduit occurs when fracture flow evolves from laminar flow to turbulent flow (Ford and Williams 2007). Such conduits can be only a few millimeters in width or large enough for human access ('caves').

Characteristics of a karst aquifer under vadose conditions (partially air-filled and subject to gravity flow) includes the absence of a continuous water table; dry wells located in close proximity to high-yielding wells; the presence of underground streams; a low density of surface streams; surface stream channels with significant changes in flow over the hydrological season (dry to flooded); rapid short-term changes in flow rates; and changing spring locations as flows in the connecting conduits increase or decrease. Variations in water table elevations are created by the presence of conduits which lower the water table in the vicinity of the conduit. In these cases, the presence of a conduit can be inferred by the presence of troughs within the piezometric surface.

3.4.2 Background Information

The background information utilized to characterize the karst features in the area includes various reportsand orthophotographs.

3.4.3 Methods and Analysis

The karst assessment investigations have included a review of the existing karst and hydrogeology literature; a reconnaissance site/area visit with Dr. Steve Worthington on December 24th, 2019; a detailed stereo aerial photo analysis (1:10,000 scale) of the entire study area and immediate surroundings; review of the orthophoto mosaic; a reconnaissance of selected air photo targets on March 10, 2020; and five days of site surveys on March 25th and 26th, April 24th and 25th, May 7th, 2020 and March 17th, 2021.

The December, 2019 reconnaissance with Dr. Worthington was conducted to view certain known karst features (i.e., Smithville Cave) and the area in general. Conditions were ideal at 10°C with a previous light snow cover under active melting.

The March 10th, 2020 reconnaissance was conducted to obtain a preliminary assessment of culvert/ditch flows and several of the air photo targets, again under ideal conditions with melting of residual snow and moderate to heavy rainfall.

The follow-up field surveys focused on direct ground observations of photo targets and sites referred to by the surface hydrology team. The range of dates also permitted re-visiting key features to observe situations under a variety of wet (e.g., snowmelt and rain) and drier conditions. All site work was limited to properties for which “Permission To Enter” (PTE) had been provided. One particularly interesting target was within an area for which PTE had not been provided and was not accessed during 2020. More detailed mapping showed that the adjacent property could be accessed allowing observation within approximately 20 m of the feature and this was undertaken in March 2021.

The available literature only referenced one karst surface feature within the study area, namely the Wade Road Sinkhole located immediately south of Twenty Mile Creek and west of Wade Road. This feature had been mapped by Oxtobee and Novakowski (2002), Novakowski et al. (2000) and was briefly described by Terra-Dynamics (2006). Terra-Dynamics also noted the presence of possible karst “targets” to the west, south and north of this sinkhole.

Karst hydrogeology within the Smithville area has been characterized by Worthington and Ford (1997, 1999) and Worthington (2002). This work is largely based on fracture mapping in a quarry north of the study area, subsurface conditions beneath the PCB storage site (as part of the CWML contaminant investigations) and characteristics of the Smithville Cave (see Section 3.4.4). That investigation did not investigate surface karst features or hydrogeological conditions associated with such features within, or near, the study area.

Novakowski (2000), also working on the CWML site investigations, developed a hydrogeological conceptual model and investigated groundwater/surface water interactions (Oxtobee and Novakowski 2002). Acres & Associated (2001) summarized chemical and physical evidence of bedrock solution including from previous studies and borehole descriptions. Potential discharges of Lockport bedrock water along an 8 km reach of Twenty Mile Creek was investigated by Novakowski et al. (2000) using conductivity measurements. Refer to Section 3.3 for a summary of the hydrogeological literature.

First Reconnaissance

During the December 2019 site reconnaissance, the SWS Team was able to observe flows in ditches and general field surface ponding. The SWS Team was accompanied by Dr. Worthington, who showed the location of the Smithville Cave which extends from immediately south of the new recreation/library complex to Twenty Mile Creek at Wade Road. The cave is not accessible as its upper end has been filled-in during development including the recreation center and a housing complex. Dr. Worthington pointed out the presence of sinkholes (not clearly visible at the time of the visit) on the south bank of Twenty Mile Creek immediately west of Wade Road and a large spring on the north bank, downstream of Wade Road. Dr. Worthington stated that he was not aware of any other surface karst features in Urban Boundary Expansion study area.

Aerial Photo Survey

Black and white 1978 aerial photograph at a scale of 1:10000 (Provincial series) were obtained prior to the field investigations. Stereo coverage was obtained and these were analyzed using a 2X to 10X Wild mirror stereoscope. Potential karst features were targeted based on position relative to channels, light colouration (possible bedrock), shape and topography (depressions). This analysis resulted in the mapping of 44 potential surface features for follow-up investigation. In addition, the other field teams (hydrology and ecology) were contacted and asked to report possible karst features.

Second Reconnaissance

The March 10, 2020 reconnaissance included observations (car and foot) of all the ditches within the study area and to the north of Young Street. Approximately 11 photo targets were viewed either directly on foot or indirectly from the road, including the presence of stream/channel flows downstream of these features and surface ponding.

Site Surveys

The second reconnaissance (March 10, 2020) and follow-up site visits (March 25th through May 7th, 2020 and March 17th 2021) were scheduled to ensure observations could be made during wet conditions when water would be flowing into any sinkholes and as the surface water conditions dried out to see low flow conditions. The large known sinkhole west of Wade Street was observed 3 times by the SWS Team under varying conditions and once more during a particularly high flow event.

Field studies including each of the 44 targets were located on lands for which the SWS Team had permission to access. Nine of the 44 targets were located on properties that the SWS Team did not have permission to access. The hydrology field team located two sinkholes, both of which were targets from the aerial photo analysis.

The following provides a brief summary of the various field visits:

March 10, 2020 – focused on the northwest corner at South Grimsby 6 and Young Street; targets to the west of Industrial and along the hydro right-of-way; and driving/walking most of the culverts and road-side channels to observe flow conditions.

March 25 and 26, 2020 – investigated the short channel flowing north from Townline to Twenty Mile Creek to the east of Rock Street; driving ditches and observing culvert flows; and extensive coverage of the area between Wade Street, South Grimsby 6, and Townline.

April 24 and 25, 2020 – investigated the area north of the railway and east of South Grimsby 6; two properties north of Highway 20 at Townline; revisited karst west of Wade Road; and searched for the location where Twenty Mile Creek disappeared into its south bank.

May 7, 2020 – investigated properties immediately north and south of the intersection of Highway 25 and Townline; reported sinkhole south of Townline Road; revisited karst west of Wade Street; and revisited sink point of Twenty Mile Creek

March 17, 2021 – viewed a prominent target (and vicinity) located at the downstream end of a small drainage that originated north of the railway immediately east of South Grimsby 6, terminating in a large sinkhole between the railway and Highway 20.

Surface Water

Areas of significant karst topography typically have little or no water at the surface. Ponds and streams may exist but their overall density is low and streamflow terminates downstream of sinkholes. Ditches are typically intermittent with losing flows in the downstream direction. These flow conditions are typically visible on aerial photos as dry reaches and/or reduced downstream flow.

Surface water observations, particularly on December 24, 2019 and in early March, 2020, did not provide any indication of significant surface karst capture. Flows are continuous, increasing in the downstream direction and surface ponding and saturated soils exist throughout the study area (Photo 1). Although the extent of surface ponding decreased between March 10 and March 25/26, 2020 despite mild weather and minimal precipitation over that period, ephemeral ponds continued to exist in virtually every low area observed and soils remained at saturation. Wet ponds and near-saturated soils continued to exist as of the last site visit on May 7, 2020.

The snowmelt period during 2021 was markedly different as a prolonged cold but sunny period resulted in significant sublimation greatly restricting seasonal runoff.

Surface Karst Features

The underground capture of surface water (ephemeral or permanent channels) occurs via 7 sinkholes located within the study area. Three additional sinkholes and a “losing” reach of a small creek occur immediately adjacent to the study area within the current urban area. No suffosion sinkholes – formed by piping and sloughing of sediment into karst voids without the presence of stream flow – were observed. In general, there is a relatively low incidence of surface karst in the study area.

Table 3.4.1 summarizes 11 karst features observed during the site investigations. Feature numbering refers to general areas (northwest, southwest and southeast, Figure 3.4.1) in which karst was found. Specific feature numbers and locations are shown in Figures 3.4.2 through 3.4.4. Features NW 1[1], NW 2, NW3, SW 1, SW 2, SE 1 and SE 3 are within the study area; SW 3, SW 4, SW 5, and SE 2 are located within the existing urban area.

1 NW 1 is located immediately west of South Grimsby Road 6 outside the study area, however drainage to the sinkhole is from within the Study Area and seasonal flooding affects the road.

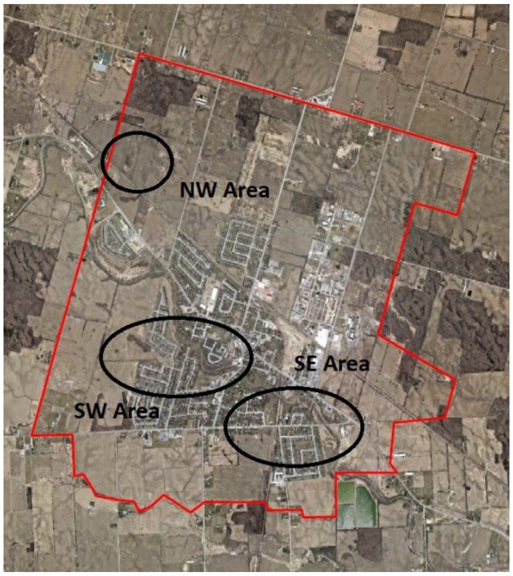

Figure 3.4.1. Karst Areas

Figure 3.4.2. Northwest Karst Features

Figure 3.4.3. Southwest Karst Features

Figure 3.4.4. Southeast Karst Features

Sinkholes range from a very small surface depression taking water from a culvert (SE 3) to a large, significant features (SW 2 and NW 3) draining unnamed tributaries of Twenty Mile Creek. SW 2 lies about 440 m due west of SW 4 which is known to drain into the Smithville Cave (Worthington 2002). Most streamsinks and the loosing stream (SE 2) are the result of opportunistic capture either naturally or due to human activities.

Smithville Cave was originally studied and mapped by Young (1981). Worthington (2002) further investigated the cave as part of the CWML site investigations. As part of this work he undertook dye trace investigation at two locations. Figure 3.4.5 shows the approximate location of the cave, 2 dye-traced flowpaths and an inferred flow path (this study). The major and minor joint orientations are also provided in an insert joint rose diagram prepared by Novakowski et al. (2000).

Smithville Cave is oriented approximately parallel to minor joint set "V" and each of the 3 flowpaths lie within the range of orientations of major joint set "I". These joint orientations are for the Eramosa Formation but are similar to those in the underlying Guelph Formation.

Sinkholes SW 2 and SW 3 and spring SW 5 (Figure 3.4.3) are all on the trend of the inferred flow pathway. As noted, known connections between the cave and the spring and sinkhole SW4 and the spring have been identified by dye tracing. It is important to note that the traced connections (and the inferred connection) do not necessarily represent precise underground routes. For example, it is possible that the cave to spring route and the inferred route converge at SW 4 before flowing to the spring.

The presence of the large Smithville Cave and its connection to both the large spring at SW 5 and the known sinkhole on the south edge of Twenty Mile Creek (SW 4) are anticipated to have a hydraulic influence on the karstification of the surrounding aquifer. It is our interpretation that study area sinkholes SW 2 and SW 3 and, likely, SW 1 are all hydraulically connected to the Smithville Cave drainage.

Although Worthington was able to access Smithville Cave during his investigations, more recent urban development (area of West Lincoln Arena & Community Centre) has resulted in partial in-filling of the upper (northern) portion of the cave. It is not certain what impacts/effects this in-filling has had on the hydrology of the cave and associated surface recharge.

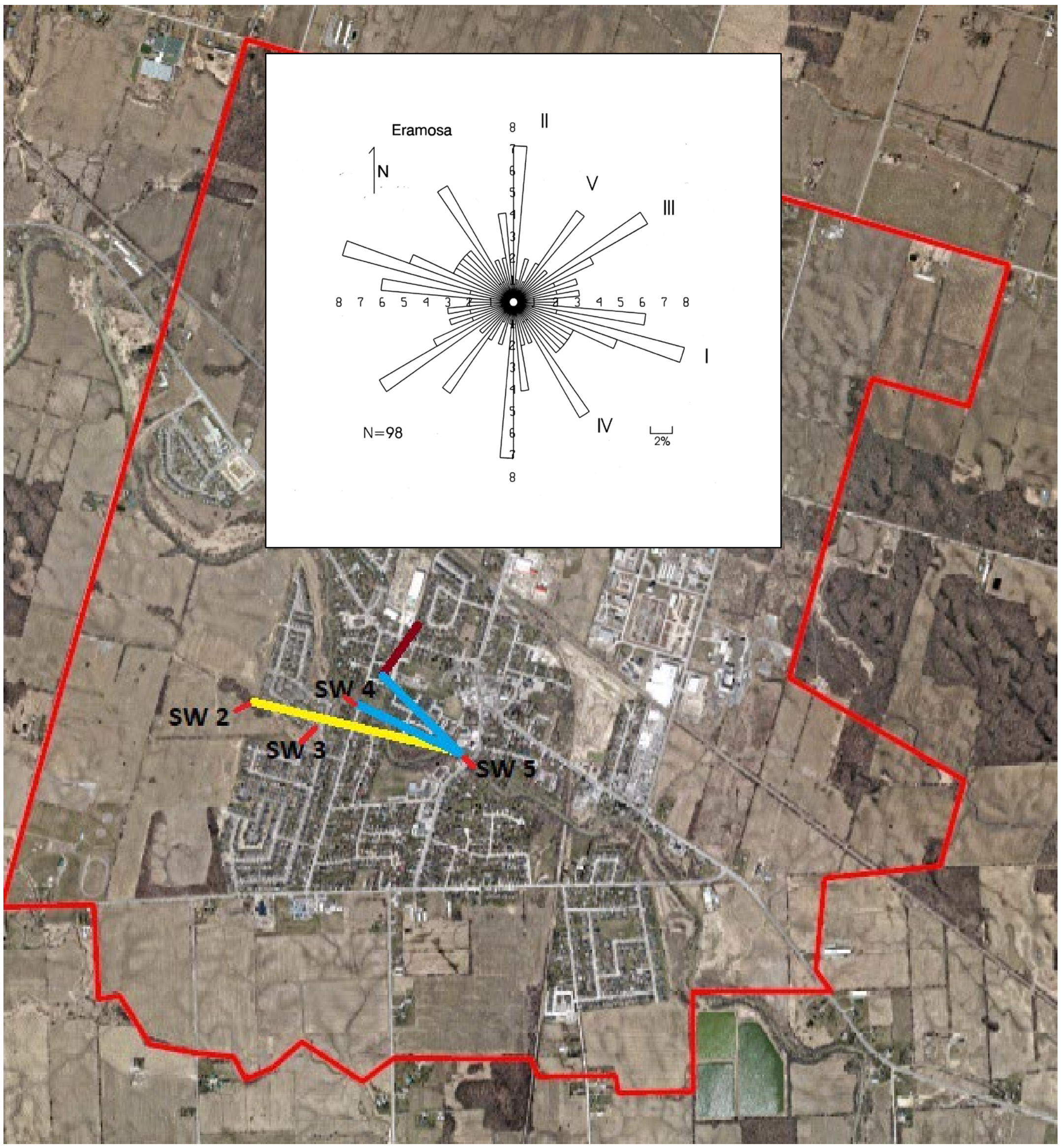

Figure 3.4.5. Approximate locations of the Smithville Cave (maroon); two traced flowpaths associated with the cave (blue); and an inferred flowpath (yellow, this study). The inset diagram shows the orientations of major and minor joints in the area (inset from Novakowski et al. 2000).

Table 3.4.1. Summary Description of Karst Surface Features Found within the Study Area (Feature numbers shown of maps in Figures 3.4.1 to 3.4.4. Preliminary constraint levels are shown as low (green); medium (yellow); and high (red). SW4 and SE5 are outside the study area (clear).

Feature Number	Description	UTM Coordinates (E/N)	HDF Reach (Drawing FG-1)	Depth[1] (m)	Distance to Creek (m)[2]
NW 1 (Photo 2)	Small intermittent streamsink upstream of railway culvert immediately west of South Grimsby Rd 6. Drains field channel from east.	616999/4774568	TM4(5)1-2	1.6	350
NW 2 (Photo 3)	Intermittent streamsink disturbed by vegetation removal/grading located near local high. Drains from south along a low ridge; overflow drains to NW1. At least two additional drains into feature within about 10 m of main feature.	617276/4774580	TM4(5)1-2-3	Partially filled	560
NW 3	Large streamsink and blind valley located between train tracks and Hwy 20. Flow is south/southwest with overflow channel visible.	617300/4774250[3]	TM4(5)2	Similar scale to SW 2[3]	349
SW 1 (Photo 4)	Small intermittent streamsink near edge of field displaying active downward sloughing on sides. Drains two field channels from east and southeast.	617253/4772596	N/A	1.2	475
SW 2 (Photo 5)	Large streamsink and blind valley in channel of unnamed tributary to 20 Mile Creek. Flow is west to east but downstream channel may reverse flow.	617345/4772768	TM4(2)2	2.3	310
SW 3	Intermittent streamsink in dug-out channel excavated beside stormwater pond. Drains overflow from SW2 and local precipitation.	617600/4772626	TM4(2)1	Filled with rip rap	205
SW 4	Located at south bank of 20 Mile Creek immediately upstream of pedestrian bridge. Not visible at high flow but otherwise has distinct flow from the creek.	617780/4772763	TM4	N/A	0
SE 5	Large spring draining Smithville Cave.	618155/4772564	TM3	N/A	0
SE 1 (Photo 6)	Intermittent streamsink draining surface flow and channel from field to the west.	618272/4771867	TM3(1)6	1.8	520
SE 2	Intermittent surface stream draining north to 20 Mile Ck. that loses flow in at least two reaches.	N/A	TM3(1)2	N/A	0 -350
SE 3 (Photo 7)	Small intermittent streamsink in upper field filled with quarry stone. Downstream of Highway 20 culvert that takes drainage from fields to the north.	6199349/4771998	TM1(2)3-2	filled	200

[1] Measured from lowest point in the throat to top of downstream wall.
[2] Measured to the closest channel reach.
[3] Approximate because sinkhole could not be accessed directly.

The surface karst features are all located within about 550 m of Twenty Mile Creek which forms the baselevel for surface streams and shallow groundwater in the study area. The average distance is 330 m (n=9). No karst was found north of the hydro right-of-way, south of Townline Road (with one exception), northwest of the Townline – South Grimsby Road 6 intersection, nor north of Highway 20 at its intersection with Townline Road. Two properties containing targets as identified on the aerial photos could not be directly accessed.

When first documented, only 3 of the sinkholes located within the Study Area were receiving runoff. The channel feeding NW 3 had a flow visually estimated to be less than ½ L/s immediately upstream of the sinkhole; NW 2 was receiving approximately ½ L/s; and the small in-line sink at SE 3 was flowing less than ¼ L/s.

Features NW 1, SW 1, and SE 3 likely developed as a result of human activities:

- NW 1 (Photo 2) lies immediately upstream of a culvert beneath the rail line. Evidence of back-flooding suggests that this culvert is undersized. In our experience, road and rail ditching and culvert sizing are often associated with the development of sinkholes due to changes in surface hydrology.
- SW 1 (Photo 4) is an active sloughing sinkhole draining two open field channels. The presence of the sinkhole is evident in the 1934 air photograph (Google Earth Pro 2018) however it appeared to be shallower and sediment filled. It is possible that this feature is an artifact of early settlement forest clearing.
- SE 3 lies immediately downstream of a small culvert beneath a field access road. It appears to have been present in the 1978 air photo but there is no evidence of this sinkhole (or the farm road) on the 1934 photo (the resolution of this photo makes interpretation difficult). It is clearly associated with the outlet of a culvert (Photo 7).

The air photo targets identified three circular closed depressions immediately south and southwest of SW 2. These have a very typical sinkhole shape and are the same ones noted by Terra-Dynamics (2006) and by David Samis (Phelps Homes, personal communication). They are not sinkholes but rather are stormwater management facilities (wet ponds). When first visited on March 10, 2020 the largest depression (617111/4772717) was actually overflowing to a field channel. They remained wet throughout our studies to at least May 7, 2020. These features represent some type of depressional landform[2] in the glaciolacustrine surface deposits.

Feature Constraints

Sinkholes are created by the removal of the underlying bedrock by chemical solution forming voids and flow pathways (karst conduits) within the bedrock. This creates potential hazards including instability through the potential for structural failure; flooding depending should the capacity of conduits to transmit water be exceeded; and potential for contaminant transport within the bedrock to springs.

Karst hazard assessments are required by the Provincial Policy Statement (PPS) under policy 3.1.1(c) (Karst Hazardous Sites). Hazardous sites are also regulated under the Conservation Authorities Act and the NPCA's specific regulation for development in these areas is Ontario Reg. 155/06. The specific hazard defined by the PPS is "unstable bedrock" related to solution and removal of bedrock potentially creating a geophysical hazard to development and/or the public. However, development in and around Karst

2 The depressions appear similar to glacial kettles, but kettles are not formed in glaciolacustrine sediments. However, the open fields surrounding these features have a significant content of rounded cobbles and stones mixed with the silty clay sediments. This suggests the possibility that these features originated as glacial kettles in a glaciofluvial environment (rounded cobble) but modified by seasonal ice and wave action in glacial Lake Warren.

Hazardous Sites can also result in problems associated with flooding (change in recharge capacity of the sinkhole/karst conduit) and/or loss of flow to connected springs. In our experience, karst hazards in SW Ontario are principally associated with the potential for flooding and/or loss of flow; direct physical instability occurs but is less common a hazard. Changes in surface flows and spring connections also have the potential to create ecological impacts.

In this regard, the assessment of hazard constraints depends on the size/depth of the karst solution and the capacity of the conduits to transport surface flows underground. Mitigation ranges from leave in place and buffer to accommodate potential flooding to complete removal and by-pass of the feature. In all cases, development should not result in increased flows to the feature. Depending on water balance/flow dynamics, the feature may be subject to excavation and grouting.

Table 3.4.1 provides a preliminary assessment of constraint level based on our extensive experience working on karst features in SW Ontario. Low (green) indicates the presence of little or no hazard and individual features can be left as is within their channel or removed (excavated and grouted). Medium level constraint (yellow) means the feature requires additional study, particularly considering potential water balance changes in the post-development scenario. A high constraint (red) indicates that development should avoid the feature and be buffered by at least 50 m from the upper rim of the depression(s), subject to NPCA hazardous sites policies and direction. Water balance studies are required to ensure that maximum post-development flows do not exceed pre-development.

Regional Constraint

In addition to the karst feature constraints, one can also apply a broad constraint based on depth of overburden over carbonate rock. There is no particular critical depth; this depends on local topography and the texture of the overburden. However, all else equal, the thinner the overlying deposits, the greater the opportunity for karstification.

In general, there are many exceptions to this but within the study area, streamsink NW 2 is found near the local topographic high and with a very limited upstream watershed area. Streamsinks occur in downstream or midstream locations which allow for surface water to accumulate and gather flow. However, NW 2 is located at the upper end of the local stream-shed within which it is located. This suggests the possibility of thinner overburden and this location at the local topographic high could indicate the presence of bedrock rise[3].

Drawings 5a and 5b map the overburden depth throughout the study area. These maps indicate that sediment depth is generally shallower in the area of feature NW 2. Hence, shallow overburden is a broad constraint overlay for potential karstification. This, in combination with the mapping of surface karst, provide the best constraint assessment.

3.4.4 Interpretation and Findings

The karst hydrogeology of the study area consists of two components: known discrete conduit flow from surface sinkholes toward Twenty Mile Creek; and postulated karst flow through bedrock conduits which are not directly mappable.

Surface karst associated with the Lockport Group is primarily the result of three conditions: rejuvenation of older karst features formed under a previous hydrogeological setting ('paleo-karst'); post-glacial sub-soil bedrock solution causing the downward subduction of overburden materials (suffosion sinkholes); or

3 One needs to consider the presence of paleo-karst (fossil karst) occurring at this location which would be more problematical.

the post-glacial capture of surface water opportunistically as contact with the fractured bedrock occurs. The latter could be direct contact with bedrock; enhanced infiltration due to locally higher permeability conditions (root channels, fractures, textural variation, etc.); or, as noted above, human activities such as directed infiltration, culvert placement and flooding.

Karst aquifers are defined by a variety of measures. Freeze and Cherry (1979) define a karst aquifer as limestones and dolostones having a hydraulic conductivity of at least 10^{-6} m/s. The presence of groundwater troughs within the piezometric surface are also evidence of karst flow. Worthington and Ford (1999) note the presence of a groundwater trough down-gradient (southwest) of the CWML site and report hydraulic conductivities within that defined by Freeze and Cherry (1979). Novakowski et al. (2000) report hydraulic conductivities in the order of $2x10^{-3}$ m/s. Acres & Associated summarized drilling results noting the occurrence of drill bit drops of between 10 cm and 1 m. They also noted that sediment, oil, rock flour and/or DNAPL were expelled from wells located up to 40 m distant during air drilling operations indicating direct fracture connections.

Further, Worthington et al. (2017), in reviewing definitions of the term ‘karst aquifer’, also consider the presence of an interconnected network of enlarged karst conduits (tertiary permeability); the presence of karst surface geomorphological features including sinking streams, sinkholes and springs; the presence of turbulent flow in conduits (generally having apertures ≥1 cm); and the presence of solutional caves as indicators of karst hydrogeological conditions. All these conditions are met within the Study Area: all features noted in the southwest area and the large spring on the north edge of Twenty Mile Creek are likely all interconnected as part of the Smithville Cave complex; karst geomorphic features have been documented in the study area; the aperture of conduits associated with the Smithville Cave and the sinking complex west of Wade Road are much greater than 1cm; and Smithville Cave is known to be a solutional cave (Young 1981).

Worthington and Ford (1999) note that karst conduits (in the area of the CWML site) are found primarily within the Eramosa and not in the underlying Vinemount unit, particularly the low-permeability lower unit (Novakowski 2000). In the Guelph area, Brunton and Brintnell (2011) map the Vinemount as the lower member of the Eramosa and consider this unit to serve as a regional aquiclude. The evidence is strong that the Eramosa Formation is a karst aquifer within the study area4. It is highly likely that the Eramosa Formation is recharged from the bedrock high in an area of shallow overburden north of the study area in the vicinity of the abandoned quarry, in addition to that derived from surface sinks within the study area, Preliminary Constraints to development from karst occur within three areas (Figures 3.2.1 – 3.2.4) and individually range from low (SW 3, SE 1, SE 2 and SE 3) through moderate (NW 1, and SW 1) to high (NW 2, NW 3and SW 2). Low constraint indicates the feature can be left as is or excavated and grouted. If left, stormwater runoff should not exceed existing maximum flows. Medium and high constraint features require water balance calculations (at least to the 100-year storm). Maximum post-development flows should not exceed existing maximum flows. High constraint features should be buffered by at least 50 m from top-of-bank. In all cases, additional runoff should not be directed toward sinkholes post-development.

Shallow overburden over bedrock represents a broad constraint. The silt-clay glaciolacustrine deposits in the study area generally restrict significant infiltration, particularly in the area of the hydro line right-of-way, along Young Street, and in the SW (Townline RD and South Grimsby Rd 6).

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4 The Gasport and Goat Island formations are also known to be karst aquifers within the vicinity of the Niagara Escarpment (Brunton and Brintnell 2011, Cowell 2020) and, although there is no direct evidence of karst in these units in the southern study area they are also likely karst aquifers.

All karst features occur with about 500 m straight line distance of Twenty Mile Creek, the longest (NW 2) being about 550 m. No surface karst was observed in the northernmost portion of the study area including along the hydro line and towards Young Rd. This suggests that the hydraulic gradient provided by the creek valley is playing a role in the initiation and development of the karst. Smithville Cave is known to be connected to the creek in terms of taking water directly from the creek (SW 4) and discharging within the creek valley (SW 5).

Several targets were on properties without PTE including immediately east of sinkhole NW 2 and north of sinkhole SE 3 in the area immediately north of Twenty Mile Creek.

The Eramosa Formation within the study area is a karst aquifer. This conclusion is principally defined on the basis of relatively high hydraulic gradients, the presence of at least one large cave, and several sinkholes.

3.5 Hydrology and Hydraulics

3.5.1 Importance and Purpose

The purpose of hydrologic and hydraulic studies is to provide a better understanding of the operative factors which influence the amount and movement of water in the system both under existing land use and proposed future land use conditions. By developing representative numerical models, which reasonably predict seasonal and storm-based runoff response (hydrology), the impacts of proposed future urbanization can be better quantified and thereby appropriate management strategies can be established in the future, as part of integrated management plans. Further, water levels and velocities in open watercourses can be predicted for a range of storm events including Regulatory conditions which will establish constraints and management requirements.

3.5.2 Background Information

Background information related to hydrology and hydraulics within the Smithville urban expansion area (study area) has been provided by the Township of West Lincoln, Region of Niagara, and NPCA for use in this study. A full list of provided data is included in Appendix A**.** The following provides an overview of the information pertinent to the hydrologic and hydraulic modelling and analyses:

Reports:

- Niagara Peninsula Conservation Authority Floodplain Mapping Twenty Mile Creek (City of Hamilton, Town of Lincoln, and the Township of West Lincoln, 2005, revised 2007)
- Twenty Mile Creek Watershed Plan (NPCA, 2006)
- Stormwater Management Reports (various sites, 2004 – 2020)

Mapping:

- 50cm aerial imagery (Niagara Region, 2018)
- 2010 topographic contour mapping (Niagara Region, 2010)
- 2018 topographic contour mapping for Smithville and surrounding areas only (Niagara Region, 2018)
- Contemporary mapping of watercourse: 1:2000 scale inventory of hydrologic mapping with feature characterization (NPCA, 2019)
- 1:2000 scale hydrography water lines (NPCA)
- 1:2000 scale Subwatersheds (NPCA)
- Existing storm sewer system and minor system capture points (Township of West Lincoln, 2015)

- Surficial Geology (Ontario Ministry of Energy, Northern Development and Mines, 2020)
- Soil Survey Complex (Land Information Ontario, Ontario GeoHub, 2019)
- NPCA regulated floodplains mapping (NPCA)

Meteorological Data:

- Continuous 5-minute precipitation data at Smithville SPS Precipitation Station from Niagara Weather Information Systems Database (1998 – 2019)
- Hyetographs for 12 hour AES design storms (2 year, 5 year, 100 year return periods) provided by NPCA.

Models

- HMS hydrologic model for Twenty Mile Creek Watershed (NPCA, 2007).
- HEC-RAS hydraulic model for Twenty Mile Creek (NPCA, 2007)

In addition to the foregoing information, Wood has collected additional rainfall and streamflow data as well as inventory data within the community of Smithville. The detailed data have been included in the data tracking sheet (ref. Appendix A). All the data have been reviewed for use in this study.

3.5.3 Methods and Analysis

3.5.3.1 Baseline Characterization

A baseline characterization of the hydrologic conditions within the urban expansion area and the existing urban area has been developed based upon a review of the background information provided for this study, to characterize the existing drainage systems, soils, slopes, and land use conditions.

Drainage Systems

The urban expansion area and the existing urban area fall within three watersheds – Twenty Mile Creek Watershed, North Creek Watershed, and Spring Creek Watershed. The main branch of Twenty Mile Creek runs west to east across the existing urban area. The main branch of North Creek runs west to east along the south boundary of the urban expansion area. A major tributary of Spring Creek runs northwest to southeast outside of the urban expansion area and through the existing urban area towards the east. The urban expansion area is characterized with mainly headwater drainage features (HDFs) along with several regulated watercourses. The existing urban area is characterized with open ditches and storm sewer drainage systems, overland flow drainage systems, and stormwater management facilities (SWMFs).

A portion of the urban expansion area (130 ha+/- of agricultural area between West Street and Smithville Road) drains to a tributary of Twenty Mile Creek which discharges at Twenty Mile Creek, west of Wade Road through a culvert. The portion of the urban expansion area adjacent to the existing urban area drains to the main branch of Twenty Mile Creek via urbanized storm sewer systems, agricultural drainage systems, and defined watercourses. The majority of the south portion of the urban expansion area drains to the main branch of North Creek via agricultural and open ditches, as well as defined watercourses. The northeast portion of the urban expansion area drains to a tributary of Spring Creek via various agricultural swales and open ditches. The existing urban area drains to Twenty Mile Creek mainly via urban drainage systems, overland flow drainage systems, and stormwater management facilities.

Regulated floodline mapping is available within the urban expansion area and the existing urban area for the Twenty Mile Creek main branch and tributaries, North Creek main branch, and the major Spring Creek tributary. The tributary of Twenty Mile Creek between West Street and Smithville Road is not defined and included in the current mapping.

Soils

Soils within the urban expansion area and the existing urban area have been characterized based upon a review of the surficial geology mapping information (Ontario Ministry of Energy, Northern Development and Mines, 2020). The soils are noted to consist of 93% of glaciolacustrine clay and silt, 4.7% of diamicton (predominantly clay to clayey silt), 1.9% of stream deposits (predominantly clay and silt), and 0.4% of paleozoic bedrock. Stream deposits and Lockport Formation are concentrated along Twenty Mile Creek (ref. Drawing WR3). Overall, the soils are with low permeability and low infiltration potential, with high potential for generating runoff.

The surficial geology soil characterizations within the urban expansion area and the existing urban area have been compared with the soil survey complex data. The permeability of the soils is consistent between the two datasets.

Slopes

The surface slopes within the urban expansion area and the existing urban area tend to be moderate between 1 and 2% (1.7% ave. +/-). There are slightly steeper areas along Twenty Mile Creek (3%+/-).

Land Use

The land use conditions within the urban expansion area and the existing urban area have been characterized based on the available aerial imagery. The existing land use conditions are shown in Drawing WR4. Within the urban expansion area, the land use conditions are primarily agricultural lands with headwater drainage features. Within the existing urban area, the land use conditions are a mixture of median to high density residential areas, park areas and open lands, industrial areas (along Industrial Park Road), and commercial areas (along West Street and St. Catherines Street).

3.5.3.2 Field Monitoring Program

A field monitoring program was implemented as part of the Phase 1 study to collect streamflow data to support the validation of the hydrologic modelling. The gauge locations are shown on Drawing WR-2. Level loggers were installed on April 2, 2020 at three sites proximate to the study area. The loggers collected continuous water level data at 15-minutes time intervals until November 27, 2020 at which time the loggers were removed prior to freeze-up. In addition, a rain gauge was installed on March 20, 2020 at the Smithville Arena. The rain gauge collected continuous rainfall amount data at 15-minutes time intervals until November 27, 2020 at which time it was also removed from the field.

Velocity metering was conducted to obtain in-stream velocities and corresponding water depths for the storm events of April 9, 2020, April 30, 2020, and June 3, 2020, to develop stage-discharge relationships. Flow areas have been determined at the monitoring locations using the surveyed cross sections and the measured flow depth at the time of velocity measurement. Observed flow rates have been established based upon the recorded velocities and corresponding flow areas. A stage-discharge relationship has been established at each monitoring location, using a simplified HEC-RAS model. The roughness coefficients have been adjusted to best reproduce the observed depth at the corresponding discharge values. The rating curves for the three monitoring locations are presented in Figures 3.5.1 to 3.5.3. The resulting rating curves have been used to convert the continuous depth readings at the gauges to corresponding continuous flow rates at the three flow monitoring sites.

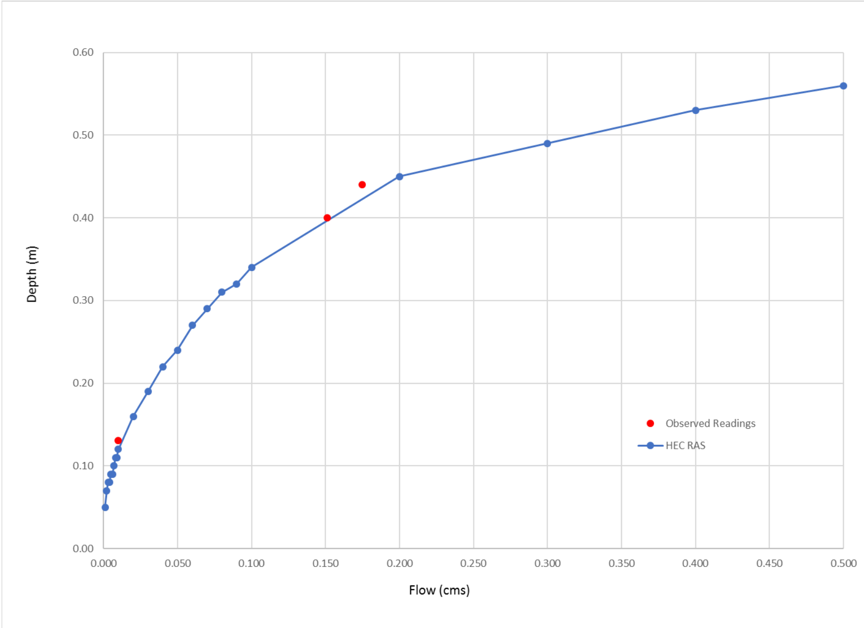

Figure 3.5.1. Rating Curve for Stream Gauge 1

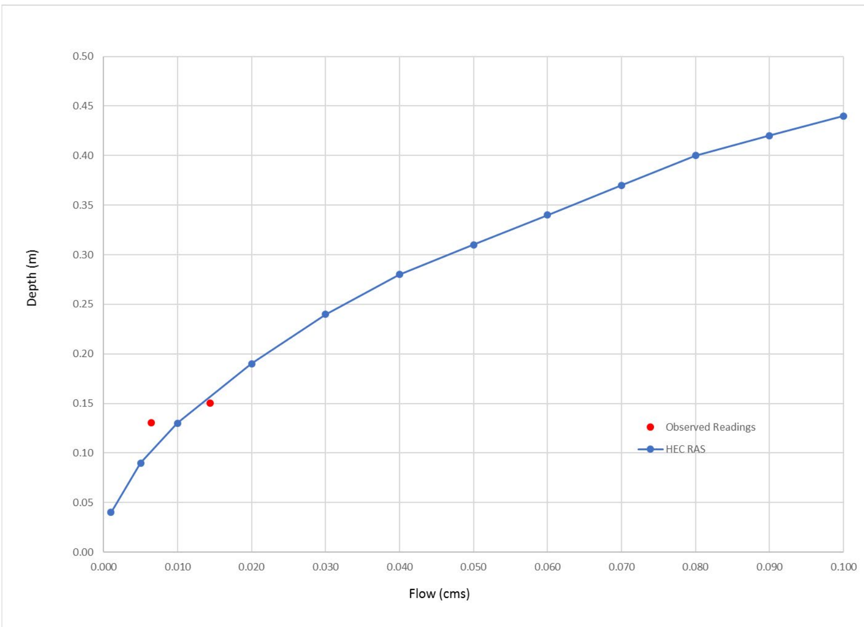

Figure 3.5.2. Rating Curve for Stream Gauge 2

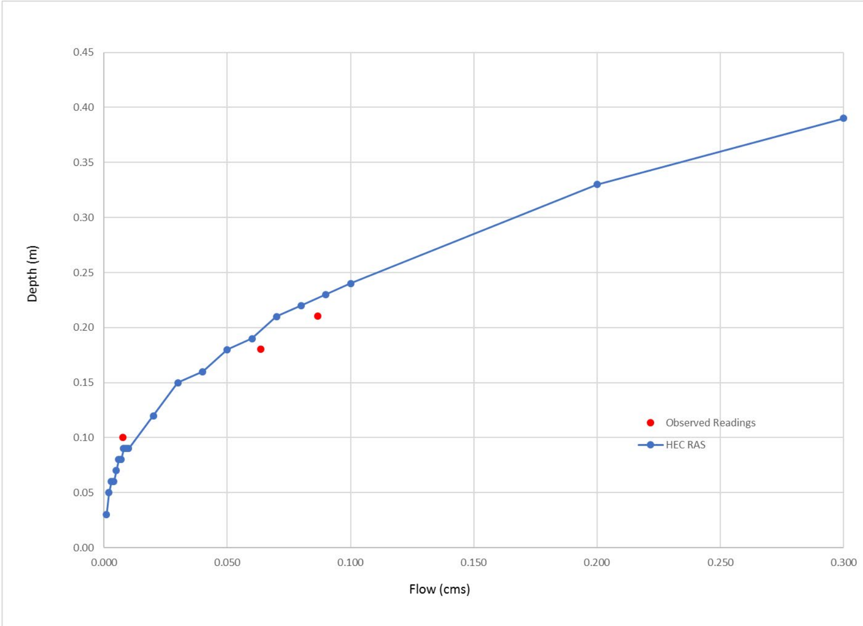

Figure 3.5.3. Rating Curve for Stream Gauge 3

The recorded water levels have been compared to the rainfall data in order to identify coincident storm events between the rainfall dataset and the streamflow responses at the temporary gauges, to thereby screen the rainfall and flow data to determine potential events for use in model validation. The findings of this assessment are presented in **Table 3.5.1**.

Table 3.5.1. Screening of Observed Storm Events at Monitoring Gauges for Coinciding Rainfall and Runoff Response

Event No.	Event Date	Duration (Hours)	Total Rainfall Depth (mm)	Rainfall Intensity (mm/hr)	Flow Reponses		
					Stream Gauge 1	Stream Gauge 2	Stream Gauge 3
1	2020-04-09	8.25	13.00	1.58	Yes	No	Yes
2	2020-04-13	13.50	14.40	1.07	Yes	Yes	Yes
3	2020-04-26	21.50	16.20	0.75	Yes	Yes	Yes
4	2020-04-30	7.75	8.40	1.08	Yes	Yes	Yes
5	2020-05-17	19.00	12.00	0.63	Yes	No	Yes
6	2020-06-23	1.25	12.60	10.08	No	No	No
7	2020-06-27	3.75	8.00	2.13	No	No	Yes
8	2020-07-09	2.50	19.60	7.84	No	No	Yes
9	2020-08-04	1.25	8.80	7.04	No	No	No
10	2020-08-17	4.00	8.40	2.10	No	No	No
11	2020-08-25	1.25	15.60	12.48	No	No	No
12	2020-09-13	3.25	19.60	6.03	No	No	No
13	2020-10-23	7.00	7.60	1.09	No	No	Yes
14	2020-11-22	7.5	12.60	1.68	Yes	No	Yes

The information in **Table 3.5.1** indicates that a total of fourteen storm events have been identified over the course of the monitoring program for 2020, for which only three events generated runoff at all three monitoring gauges. For the remaining events, five events recorded no runoff at any gauges and six events recorded runoff responses at only one flow monitoring station. The lack of response at the flow monitoring stations is considered potentially attributable to the dry conditions which prevailed over the course of 2020 monitoring period. Further, it has been recognized that the preponderance of karst features may have also influenced the runoff responses at Stream Gauge 2, and the wetland and forest areas upstream of Gauge 1, which may have potentially increased infiltration and evapotranspiration during the storm events. A field visit in August, 2020 confirmed that the watercourse was completely dry near Stream Gauge 1. As such, the lack of response at Gauges 1 and 2 during the summer periods is considered largely attributable to the properties of the natural features within the contributing drainage area to the monitoring stations.

The results of the 2020 monitoring program have been further reviewed to determine the runoff coefficient for the observed storm events, to further screen candidate events for model validation. The calculated runoff coefficients are summarized in **Table 3.5.2**.

Table 3.5.2. Summary of Calculated Runoff Coefficients for Observed Storm Events at Rainfall Gauge and Temporary Flow Gauges

Event No.	Event Date	Duration (Hours)	Total Rainfall Depth (mm)	Peak Rainfall Intensity (mm/hr)	Calculated Runoff Coefficient		
					Stream Gauge 1	Stream Gauge 2	Stream Gauge 3
1	2020-04-09	8.25	14.4	4.8	0.49	0.00	2.50
2	2020-04-13	13.50	16.2	4.0	0.94	0.04	1.69
3	2020-04-26	21.50	8.4	5.6	0.66	0.01	0.82
4	2020-04-30	7.75	12.0	3.2	0.53	0.01	0.83
5	2020-05-17	19.00	12.6	4.8	0.40	0.00	0.03
6	2020-06-23	1.25	8.0	38.4	0.00	0.00	0.00
7	2020-06-27	3.75	19.6	4.0	0.00	0.00	0.02
8	2020-07-09	2.50	8.8	41.6	0.00	0.00	0.01
9	2020-08-04	1.25	8.4	22.4	0.00	0.00	0.00
10	2020-08-17	4.00	15.6	16.8	0.00	0.00	0.00
11	2020-08-25	1.25	19.6	32.8	0.00	0.00	0.00
12	2020-09-13	3.25	7.6	20.0	0.00	0.00	0.00
13	2020-10-23	7.00	12.6	6.4	0.00	0.00	0.05
14	2020-11-22	7.5	14.4	4.0	0.02	0.00	0.02

The information indicates that the runoff coefficients are higher in the month of April (i.e. above 0.5), and are thus considered attributable to snowmelt conditions at the time of monitoring. Low and zero runoff coefficients have been noted at various stations over the summer and extending to the end of the monitoring period in November. As noted above, the low and zero runoff responses are considered attributable to the dry conditions which occurred over the course of the monitoring period, as well as the presence of natural features (i.e. karst, wetlands/forest) within the contributing drainage area to the gauge.

Based upon total observed rainfall and correlation between rainfall and runoff response, four (4) candidate storm events have been advanced for model validation and are summarized in **Table 3.5.3**. The events in April were not selected since from the runoff coefficient assessment it appears there might have been snowmelt influences on the peak flows and runoff volumes. The events represent storm volumes ranging from 7.6 to 12.6 mm and peak storm intensities ranging from 4 to 6.4 mm/hr.

Table 3.5.3. Summary of Observed Storm Events Advanced for Hydrologic Model Validation

Event Date	Duration (Hours)	Total Rainfall Depth (mm)	Rainfall Intensity (mm/hr)	Stream Gauge
2020-05-17	19.00	12.00	4.8	Stream Gauge 1 Stream Gauge 3
2020-06-27	3.75	8.00	4.0	Stream Gauge 3
2020-10-23	7.00	7.60	6.4	Stream Gauge 3
2020-11-22	7.5	12.60	4.0	Stream Gauge 3

3.5.3.3 Hydrologic Model Development

Hydrologic modelling has been completed in order to develop peak frequency flows and return period flows for existing land use conditions to serve as targets for future land use runoff management. For the purpose of this study, a PCSWMM hydrologic model has been developed for completing the hydrologic analyses locally within the existing urban area and the urban expansion area, as well as along downstream tributaries discharging to the major watercourses (i.e. Twenty Mile Creek Main Branch, Spring Creek, and North Creek). In addition, the HEC-HMS hydrologic model for the Twenty Mile Creek has been refined and used for the hydrologic analyses at the watershed and subwatershed scale along the major watercourses. The following sections provide a summary of the development of each hydrologic model.

Local PCSWMM Hydrologic Model

As noted above, a PCSWMM model has been created for hydrologic analyses and impact assessment at the local level within the urban expansion area and the existing urban area. The PCSWMM model combines hydrologic modelling with hydraulic modelling and is capable of completing hydrologic analyses using both continuous and event methodologies. The integrated hydrologic and hydraulic analyses can be used to assess storm sewer capacity, calculate flooding depths of overland drainage systems, and evaluate SWMF performance. . The integration modelling is well-suited for assessing dual drainage systems within the existing urban area. In addition, literature values are documented for key parameters such as Green-Ampt soil characteristics; although model calibration and validation are encouraged as a matter of practice, the literature values allow for the model to be applied without calibration, or with validation using relatively limited timeseries of data. Therefore, the PCSWMM model is considered appropriate to use for the local scale hydrologic analyses within the urban expansion area and the existing urban area. The model subcatchments within the urban expansion area and surrounding rural areas have been delineated using the 2018 topographic mapping provided by Niagara Region. The drainage areas have been calculated using the GIS geometry calculation tool within the PCSWMM hydrologic model. The subcatchments within the existing urban area have also been delineated based upon the 2018 topographic mapping, as well as the storm sewer plans provided for reference. The subcatchment boundary and key flow node locations plan are provided in Drawing WR5.

The PCSWMM hydrologic model has been discretized to provide 231 subcatchments and a total drainage area of 2192 ha. The drainage area of the model subcatchments range from 0.1 ha to 557 ha. The largest subcatchment of 557ha was delineated for the Spring Creek tributary beyond the north limit of the urban expansion area and does not influence the modelling results at the localized level. Within the urban expansion area, the model subcatchments range from 1.6 to 73.7 ha with the average size of 19.3 ha, which is considered appropriate for representing undeveloped and rural land use conditions. The subcatchments within the existing urban area have been delineated at a finer scale to account for the main storm sewers, overflow drainage systems, and existing SWMFs. Within the existing urban area, the subcatchments range from 0.1 to 35.4 ha with the average size of 3.5 ha, which is considered appropriate for representing the contributing drainage areas to urban sewer networks.

PCSWMM Hydrologic Model Parameterization

The existing land use conditions and impervious coverages have been determined based on the aerial imagery (Niagara Region, 2018) and background SWM reports. **Table 3.5.4** presents the resulting land use classifications and the associated impervious coverage values. Multiple previous projects and reports have been reviewed to verify that appropriate values have been applied for the land use conditions within the Smithville Community.

Table 3.5.4. Summary of Impervious Coverages by Land Use

Existing Land Use Condition	Impervious Coverage
Agricultural	5%
Open Space	10%
Park	10%
Low Density Residential	45%
Medium Density Residential	60%
High Density Residential	75%
Industrial	85%
Commercial	90%
High Imperviousness	95%
Rooftop	100%

The Green-Ampt Methodology has been applied for infiltration parameterization. The surficial geology mapping has been compared with surficial soils mapping to confirm any variations between the soils' characterization based on the two datasets. Although the surficial soils and surficial geology datasets do not provide a precise correlation, they nevertheless indicate generally lower permeability material within the Smithville Community.

Literature values for the parameterization of soils per the Green-Ampt methodology are provided in the PCSWMM User Manual; standard values are provided in **Table 3.5 5**. Although the surficial geology data provide textural descriptions which can be correlated to soil types provided in the literature values, the correlation based on surficial soils information is less direct. Therefore, the surficial geology data have been used to classify and parameterize the soils into the PCSWMM model. **Table 3.5.6** presents the Green-Ampt parameters assigned to the soils within the study area based on the surficial geology data, and the corresponding soils per the literature values prescribed in the PCSWMM User Manual.

Table 3.5 5. Literature Values for PCSWMM Model Green-Ampt Parameters

PCSWMM Soil Type	Hydraulic Conductivity (mm/hr)	Suction Head (mm)	Initial Deficit (fraction)
Sand	120.34	49.02	0.413
Loamy Sand	29.97	60.96	0.390
Sandy Loam	10.92	109.98	0.368
Loam	3.30	88.90	0.347
Silt Loam	6.60	169.93	0.366
Sandy Clay Loam	1.52	219.96	0.262
Clay Loam	1.02	210.06	0.277
Silty Clay Loam	1.02	270.00	0.261
Sandy Clay	0.51	240.03	0.209
Silty Clay	0.51	290.07	0.228
Clay	0.25	320.04	0.210

Table 3.5.6. Summary of PCSWMM Model Green-Ampt Parameters Applied for Surficial Geology Data

Soil Type	Corresponding PCSWMM Soil Type	Hydraulic Conductivity (mm/hr)	Suction Head (mm)	Initial Deficit (fraction)
Glaciolacustrine clay and silt	Clay	0.25	320.04	0.210
Diamicton (clay to clayey silt)	Silty Clay	0.51	290.07	0.228
Stream Deposits (clay and silt)	Clay	0.25	320.04	0.210
Paleozoic bedrock	Sand to Clay (Average) (1)	16.0(1)	184.45(1)	0.300(1)

Note: (1). The paleozoic bedrock within the Smithville Community is characterized by Dolostone (Limestone, Chert, and shale) and variable permeability. Average values of the eleven PCSWMM soil types have been applied as the parameters for Paleozoic bedrock.

Subcatchment slopes have been determined using the topographic contour data. The contour data were converted into a TIN surface, which has been combined with the subcatchment layer to calculate the average gradient across the subcatchment surface using ArcGIS 3D Analyst™ functions.

Overland flow lengths have been determined as the length of sheet flow for each subcatchment. For the subcatchments within the urban expansion area and the surrounding rural areas, flow lengths have been measured based on the topographic contour data. For the subcatchments within the existing urban area, a typical length of 40 m based on typical lot length has been applied.

Manning's roughness coefficients represent the type of surface for the subcatchment, and the associated friction applied to the flow across the subcatchment surface. Manning's roughness coefficients have been determined for the pervious and impervious portions of each subcatchment. Based on PCSWMM recommended values and common practice, a value of 0.013 has been applied to the impervious segment of each subcatchment and a value of 0.25 has been applied to the pervious segment of each subcatchment.

Depression storage represents the depth of rainfall which would be captured and detained in surface depressions within the subcatchment. Depression Storage values have been assigned to the impervious and pervious segments of each subcatchment. One (1) mm of depression storage has been assigned to impervious segments of subcatchments, while 5 mm of depression storage has been assigned to pervious segments of subcatchments based on PCSWMM recommended values and standard industry practice.

A summary of the subcatchment parameterization is included in Appendix B.

The Dual Drainage Creator tool within PCSWMM has been used to generate routing elements representing the minor and major system conveyance within the existing urban area. The minor drainage system has been characterized based on the GIS data for the storm sewer network (Township of West Lincoln, 2015). The data include shapefiles for storm sewers, maintenance holes, and catch basins. The data have been reviewed for the main sewers. Minor data gaps (i.e. missing pipe connections, invert elevations, sizes and lengths) have been filled based on the upstream and downstream pipe segments. In the PCSWMM model, storm sewer pipes have been represented as conduits and maintenance hole have been represented as junctions. A Manning's roughness coefficient of 0.013 has been applied for all the sewer pipes.

The major drainage systems within the existing urban area have been established based on various Right-of-Way (ROW) sections. Road classifications and the number of lanes within the ROW have been determined using the aerial imagery (Niagara Region, 2018) and Google Street ViewTM. The ROW cross sections are generally comprised of urban cross sections with curb and gutter and rural cross sections with roadside ditches. The cross sections have been developed based on standard ROW cross sections with an additional 2% cross-fall for the portion of cross section beyond the ROW, extending to the front of adjacent buildings or structures. The cross sections representing open drainage features within the urban expansion area and the existing urban area have been determined by extracting the transect profiles using the ArcGIS 3D Analyst™ function.

Runoff generated from each subcatchment is initially conveyed to the major system components and then routed to the minor system through orifices representing catch basins, catch basin leads and maintenance hole leads. The orifice opening sizes within the PCSWMM model have been determined to be equivalent to the sum of the open area of the inlet elements.

Seven (7) SWMFs have been incorporated into the PCSWMM model. Each SWMF has been represented using a storage element and an outlet component. The stage-storage-discharge relationships obtained from the background reports have been converted to storage curves (depth-area curves) for use in storage elements and rating curves (depth-outflow curves) for use in outlet components. The surface areas at each point of the depth-volume curve have been interpolated using the Trapezoidal Rule, which approximates the volume as the area under the curve as a trapezoid.. The interpolated depth-area curves have been adjusted to avoid negative and decreasing areas. Tables 3.5.7 to 3.5.12 present the original stage-storge-discharge relationships and the converted storage curves and rating curves.

Table 3.5.7. Storage-Discharge Relationships (Old Town Gateway)

Description	Stage (m)	Storage (m^3)	Discharge (m^3/s)	Depth (m)	Area (m^2)
Bottom	182	0	0	-	-
Permanent Pool	183.44[1]	1673	0	-	-
	183.441	0	0	0	2100
	183.83	943	0.012	0.39	2736
	183.9	1135	0.013	0.46	2750
Quality	184.5	2964	0.129	1.06	3347
Top	184.6	3316	1.000	1.16	3693

Table 3.5.8. Storage-Discharge Relationships (2060 Industrial Park Road)

Description	Stage (m)	Storage (m^3)	Discharge (m^3/s)	Depth (m)	Area (m^2)
Bottom	189.050	0	0	0	187.45
5 Year	189.427	74.089	0.098	0.377	187.45
100 Year	190.118	203.792	0.147	1.068	187.45
Top	190.168	209.570	1.000	1.118	187.45

Table 3.5.9. Storage-Discharge Relationships (Griffin Place)

Description	Stage (m)	Storage (m^3)	Discharge (m^3/s)	Depth (m)	Area (m^2)
Bottom	187.90	0	0	0	129.00
5 Year	188.52	89.6	0.092	0.62	129.00
100 Year	189.29	179.1	0.255	1.39	129.00

Table 3.5.10. Storage-Discharge Relationships (Vintage Collection Bungalows)

Description	Stage (m)	Storage (m^3)	Discharge (m^3/s)	Depth (m)	Area (m^2)
Bottom	187.95	0	0	0	134.00
	188.8	102.4	0.0105	0.85	134.00
	189	105.9	0.0117	1.05	134.00
	189.1	109.5	0.0123	1.15	134.00
	189.2	117.6	0.0129	1.25	134.00
	189.3	128.1	0.0134	1.35	134.00
	189.44	142.4	0.0141	1.49	134.00
	189.54	169.9	0.0146	1.59	134.00
	189.64	203.3	0.0263	1.69	134.00
100 year	189.74	240	0.0939	1.79	134.00

Table 3.5.11. Storage-Discharge Relationships (Streamside Estates)

Description	Stage (m)	Storage (m^3)	Discharge (m^3/s)	Depth (m)	Area (m^2)
Bottom	183.4	0	0	0	0
	183.9	0	0	0	0
	184.4	0	0	0	0
Permanent Pool	184.9	0	0	0	3725
	185.1	792	0.027	0.2	4195
	185.3	1713	0.0382	0.4	5015
Quality/Erosion	185.5	2763	0.0467	0.6	5485
	185.7	3899	0.5146	0.8	5875
	185.9	5114	0.5753	1	6275
	186.1	6409	0.6302	1.2	6675
	186.3	7785	0.6807	1.4	7085
	186.5	9241	0.7277	1.6	7475
	186.7	10777	0.7719	1.8	7885
	186.9	12395	1.2617	2	8295
Top	187.1	14095	2.1208	2.2	8705

Table 3.5.12. Storage-Discharge Relationships (Anastasio Phase 1 & Smithville Estates)

Description	Stage (m)	Storage (m^3)	Discharge (m^3/s)	Depth (m)	Area (m^2)
Bottom	NA	0	0	0	2050
Quality/Erosion	NA	4059	2.125	0.2	38540
5 year	NA	36160	4.300	0.5	175467
100 year	NA	80268	9.596	0.7	265613

Note: pond depth of 0.7m has been assumed based on contour data and incremental depth of 0.2m.

Model Validation and Parameter Refinement

Subsequent to the completion of the draft Phase 1 report, the soil parameters for the PCSWMM hydrologic model have been adjusted to improve upon the correlation between the observed and simulated runoff responses at the monitoring station. This exercise has focused upon the flow response at Gauge 3 within the southwest corner of the study area, as the runoff responses at Gauges 1 and 2 were both noted to be influenced by natural features in the area (i.e. karst features and significant woodlands) hence were not as suitable for determining required adjustments to soil parameterization for the hydrologic model. Through this exercise, it was determined that 20% reductions to the saturated hydraulic conductivity and suction head parameters provided the required improvement to the simulated runoff volumes from the PCSWMM model. A “hot start” file has been set up using the 24 hour 25mm storm simulated over 7 days. The “hot start” file provides initial flows for the model components to reduce model instabilities resulting from completely dry condition at the beginning of the simulation period. The model has been executed in continuous mode using the rainfall data collected during the monitoring period, and the simulated hydrographs have been extracted from the model output and compared with the observed hydrographs for peak flows and runoff volumes. Comparison of observed and simulated hydrographs for validation storm events, using the original and adjusted PCSWMM model parameters, are presented in **Figure 3.5.4**, **Figure 3.5.5** and **Figure 3.5.6**.

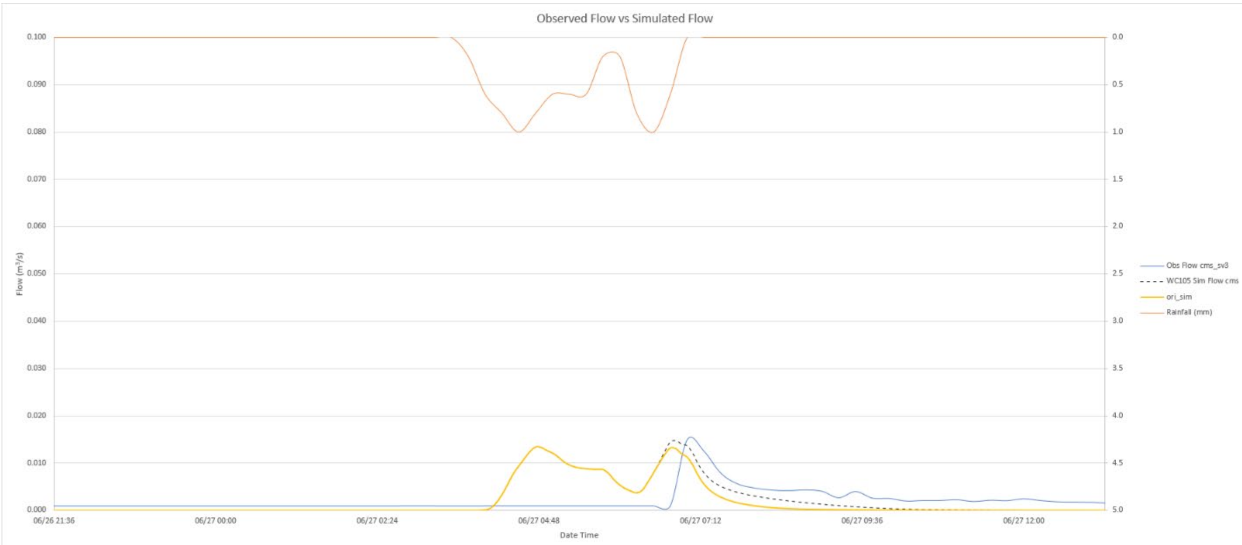

Figure 3.5.4. Comparison of Observed and Simulated Hydrographs for June 27, 2020 Storm Event

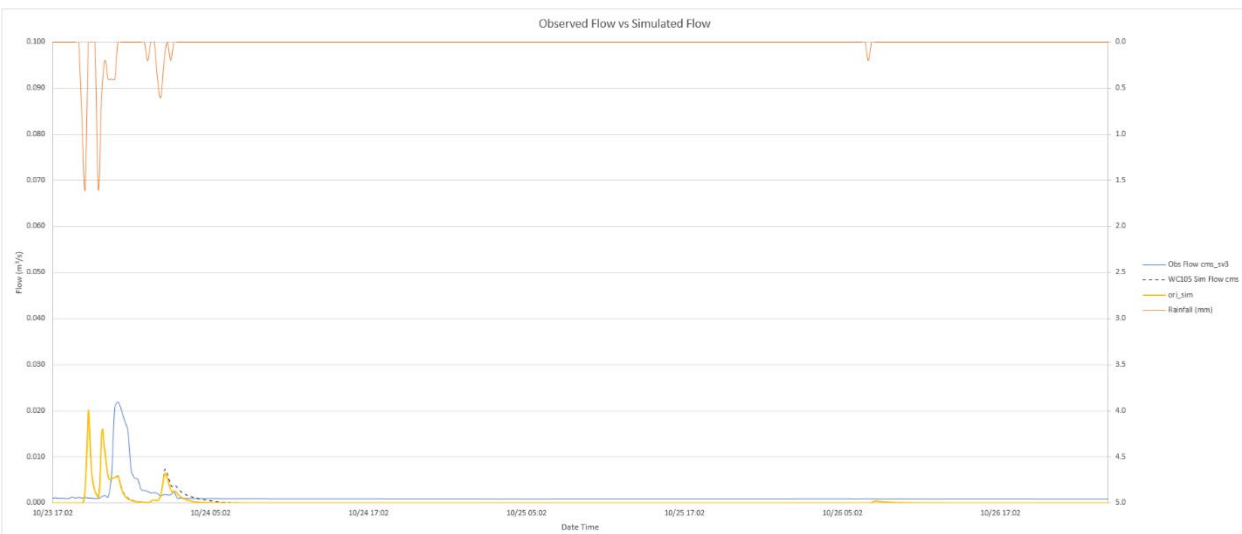

Figure 3.5.5. Comparison of Observed and Simulated Hydrographs for October 23, 2020 Storm Event

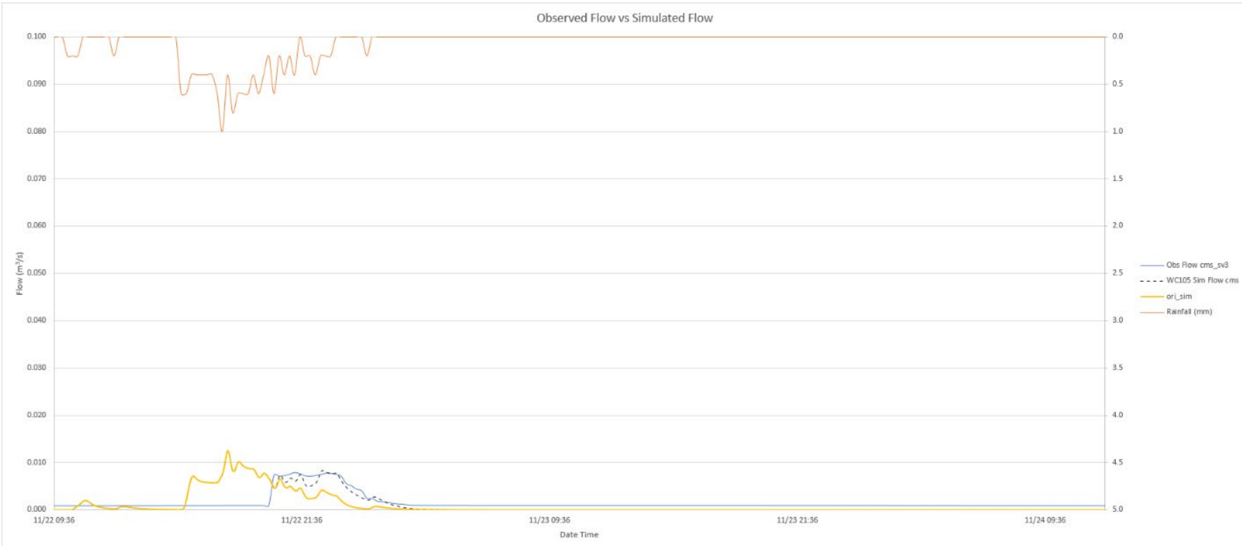

Figure 3.5.6. Comparison of Observed and Simulated Hydrographs for November 22, 2020 Storm Event

The comparisons of the selected storm events show that the overall shapes of the peak flow responses largely correspond to the observed runoff responses for the validation storm events.

The local PCSWMM hydrologic model has been used to generate peak flows for the 2 year, 5 year, and 100 year return period design storms for comparison to the HEC-HMS hydrologic model and for further validation of the local PCSWMM hydrologic model. The unitary peak flows and unitary runoff volumes generated by the local PCSWMM model have been calculated and compared against the unitary peak flows and runoff volumes generated by the currently approved NPCA HEC-HMS model at common tributary outlets (ref. Drawings WR5 and WR6); this comparison has been completed to provide a further validation of the PCSWMM model performance. The 12 hour AES distribution has been applied for this comparison, consistent with the NPCA's HEC-HMS hydrologic model. Tables 3.5.13 and 3.5.14 summarize the comparison between the unitary peak flows and unitary runoff volumes generated by the PCSWMM and HEC-HMS hydrologic models.

Table 3.5.13. Comparison of Design Storm Unitary Peak Flows (PCSWMM vs. HEC-HMS Simulation Results)

PCSWMM Outlet Location	Location	PCSWMM Unitary Peak Flow (m^3/s per ha)	HEC-HMS Outlet Location	HEC-HMS Unitary Peak Flow (m^3/s per ha)	Unitary Peak Flow Difference (m^3/s per ha)	Percent Difference
2 Year 12 Hour AES Design Storm						
WC18	South of West St; 414 m +/- East of S Grimsby Rd 7	0.0056	TwCk-15	0.0069	-0.0014	-19.6%
WC39	60m+/- west of Wade Rd	0.0055	J-Tw-16	0.0071	-0.0016	-22.9%
JS1D	D/S of Townline Road; 125m+/- east of Alma Dr	0.0056	J-Tw-14	0.0078	-0.0021	-27.3%
OF11	480m+/- west of Patterson Rd	0.0058	J-Tw-13	0.0081	-0.0024	-28.9%
5 Year 12 Hour AES Design Storm						
WC18	South of West St; 414 m +/- East of S Grimsby Rd 7	0.0104	TwCk-15	0.0124	-0.0021	-16.6%
WC39	60m+/- west of Wade Rd	0.0108	J-Tw-16	0.0123	-0.0015	-12.1%
JS1D	D/S of Townline Road; 125m+/- east of Alma Dr	0.0099	J-Tw-14	0.013	-0.0031	-23.9%
OF11	480m+/- west of Patterson Rd	0.01	J-Tw-13	0.0134	-0.0035	-25.8%
100 Year 12 Hour AES Design Storm						
WC18	South of West St; 414 m +/- East of S Grimsby Rd 7	0.0243	TwCk-15	0.0263	-0.002	-7.6%
WC39	60m+/- west of Wade Rd	0.0228	J-Tw-16	0.0264	-0.0036	-13.6%
JS1D	D/S of Townline Road; 125m+/- east of Alma Dr	0.0212	J-Tw-14	0.0275	-0.0062	-22.7%
OF11	480m+/- west of Patterson Rd	0.0209	J-Tw-13	0.0279	-0.007	-25.1%

Table 3.5 14. Comparison of Design Storm Unitary Runoff Volumes (PCSWMM vs. HEC-HMS Simulation Results)

PCSWMM Outlet Location	Location	PCSWMM Unitary Runoff Volume (m^3 per ha)	HEC-HMS Outlet Location	HEC-HMS Unitary Runoff Volume (m^3 per ha)	Unitary Runoff Volume Difference (m^3 per ha)	Percent Difference
2 Year 12 Hour AES Design Storm						
WC18	South of West St; 414 m +/- East of S Grimsby Rd 7	124.55	TwCk-15	164.10	-39.55	-24.1%
WC39	60m+/- west of Wade Rd	159.95	J-Tw-16	169.08	-9.12	-5.4%
JS1D	D/S of Townline Road; 125m+/- east of Alma Dr	193.51	J-Tw-14	184.52	8.99	4.9%
OF11	480m+/- west of Patterson Rd	190.40	J-Tw-13	198.57	-8.17	-4.1%
5 Year 12 Hour AES Design Storm						
WC18	South of West St; 414 m +/- East of S Grimsby Rd 7	239.99	TwCk-15	284.20	-44.21	-15.6%
WC39	60m+/- west of Wade Rd	281.27	J-Tw-16	290.83	-9.56	-3.3%
JS1D	D/S of Townline Road; 125m+/- east of Alma Dr	314.65	J-Tw-14	310.84	3.81	1.2%
OF11	480m+/- west of Patterson Rd	312.25	J-Tw-13	326.51	-14.27	-4.4%
100 Year 12 Hour AES Design Storm						
WC18	South of West St; 414 m +/- East of S Grimsby Rd 7	555.93	TwCk-15	638.60	-82.67	-12.9%
WC39	60m+/- west of Wade Rd	603.78	J-Tw-16	648.41	-44.63	-6.9%
JS1D	D/S of Townline Road; 125m+/- east of Alma Dr	633.32	J-Tw-14	677.20	-43.88	-6.5%
OF11	480m+/- west of Patterson Rd	632.21	J-Tw-13	695.82	-63.61	-9.1%

The results indicate that design storm unitary peak flows and unitary runoff volumes generated by the PCSWMM hydrologic model are slightly lower than the results generated by the currently approved HEC-HMS model. It should be noted that the methodology and parameterization applied for soil infiltration differs between the PCSWMM model and the HEC-HMS model. Specifically, the PCSWMM model applies the Green-Ampt methodology for infiltration while the HEC-HMS model applies the SCS CN methodology. The PCSWMM applies flow length and width to each subcatchment while the HEC-HMS applies lag time to each subbasin. The PCSWMM subcatchments are also at a more discretized level compared with the HEC-HMS subbasins. Consequently, the differences in peak flow response generated by the PCSWMM model and the HEC-HMS model are considered attributable primarily to the different methodologies applied by each model for simulating soil infiltration.

Although the PCSWMM model has been noted to slightly under-estimate peak flows and runoff volumes for both observed storm events and design storm events, simulated by the approved HEC-HMS model, the differences are not considered to adversely affect establishing target flows for developing stormwater management criteria. Overall, the PCSWMM model is considered to be representative of the existing conditions of the lands proposed for urbanization and the existing urban area.

Watershed-Scale HEC-HMS Hydrologic Model Refinement

The existing NPCA's HEC-HMS model has as part of this study been refined within the urban expansion area and the existing urban area, based on the PCSWMM hydrologic model. The subcatchment boundary and key flow node location plan is provided in Drawing WR6. The parameterization for the refined HEC-HMS model subbasins has maintained consistency with the parameterization of the parent model.

The subcatchment boundary plan has been created from the Niagara Peninsula Conservation Authority Floodplain Mapping Twenty Mile Creek Report (City of Hamilton, Town of Lincoln, and the Township of West Lincoln, 2005, revised 2007), and refined within the within the urban expansion area and the existing urban area using the PCSWMM subcatchments as the base.

The SCS CN methodology has been retained from the parent model for simulating soil infiltration. Subbasin soil parameters of CN, Initial Abstraction (IA) and imperviousness have been based on the surficial geology data and aerial imagery.

The SCS Unit Hydrograph Transform Method has been retained from the parent model to establish time to peak. The subbasin parameters of lag time and time of concentration has been determined from flow lengths, slopes, and CN values, using the CN Lag Method.

Baseflow parameters have been retained from the parent model.

The Muskingum-Cunge Routing Method has been retained from the parent model. Routing elements have been refined and added based on the topographic mapping data.

The seven (7) SWMFs within the existing urban area have been added in the refined HEC-HMS model. The SWMFs are represented by reservoir with storage-discharge curves.

A comparison between the refined HEC-HMS model and the parent HEC-HMS model has been completed for the 2, 5, and 100 year return periods using the 12 hour AES storm distribution. The results are summarized in Table 3.5.15 to 3.5.17.

Table 3.5.15. Comparison of HEC-HMS Design Storm Peak Flows (2 Year)

HEC-HMS Reference Node	Location	Contributing Drainage Area (km^2)	Parent HEC-HMS Peak Flow (m^3/s)	Refined HEC-HMS Peak Flow (m^3/s)	Peak Flow Difference (m^3 per ha)	Percent Difference
J-Tw-20 (J-Tw-20)	Twenty Mile Creek between S Grimsby Rd 7 Grimsby Rd 8	157.62	13.1	13.1	0.0	0.0%
J-Tw-18 (J-Tw-18)	Twenty Mile Creek 370m+/- South of West Street	158.23	12.9	12.6	-0.3	-2.3%
J-Tw-17 (J-Tw-17)	Twenty Mile Creek 65m+/- South of West Street	162.05	13.3	13.1	-0.1	-0.8%
J218 (J-Tw-16)	Twenty Mile Creek 32m+/- west of Wade Rd	165.60	14	13.6	-0.40	-2.86%
J150 (J-Tw-14)	Twenty Mile Creek at Townline Rd	171.36	15	13.9	-1.1	-7.3%
J-No-4 (J-No-4)	North Creek between S Grimsby Rd 7 and S Grimsby Rd 8	17.96	10.6	10.6	0.0	0.0%
J192 (J-No- 2)	North Creek 390m+/- west of Tober Rd	28.30	15.3	14.3	-1	-6.5%
J-Tw-13 (J-Tw-13)	Twenty Mile Creek and North Creek Confluence	211.34	29.2	29.6	0.4	1.4%

Note: text in brackets represents parent HEC-HMS reference node.

Table 3.5.16. Comparison of HEC-HMS Design Storm Peak Flows (5 Year)

HEC-HMS Reference Node	Location	Contributing Drainage Area (km^2)	Parent HEC-HMS Peak Flow (m^3/s)	Refined HEC-HMS Peak Flow (m^3/s)	Peak Flow Difference (m^3 per ha)	Percent Difference
J-Tw-20 (J-Tw-20)	Twenty Mile Creek between S Grimsby Rd 7 Grimsby Rd 8	157.62	28.1	28.1	0.0	0.0%
J-Tw-18 (J-Tw-18)	Twenty Mile Creek 370m+/- South of West Street	158.23	28.2	27.9	-0.3	-1.1%
J-Tw-17 (J-Tw-17)	Twenty Mile Creek 65m+/- South of West Street	162.05	28.3	28.2	-0.1	-0.4%
J218 (J-Tw-16)	Twenty Mile Creek 32m+/- west of Wade Rd	165.60	28.9	28.7	-0.20	-0.69%
J150 (J-Tw-14)	Twenty Mile Creek at Townline Rd	171.36	30.8	28.9	-1.9	-6.2%
J-No-4 (J-No-4)	North Creek between S Grimsby Rd 7 and S Grimsby Rd 8	17.96	18.1	18.1	0.0	0.0%
J192 (J-No- 2)	North Creek 390m+/- west of Tober Rd	28.30	26.8	25.2	-1.6	-6.0%
J-Tw-13 (J-Tw-13)	Twenty Mile Creek and North Creek Confluence	211.34	57.3	57.2	-0.1	-0.2%

Note: text in brackets represents parent HEC-HMS reference node.

Table 3.5.17. Comparison of HEC-HMS Design Storm Peak Flows (100 Year)

HEC-HMS Reference Node	Location	Contributing Drainage Area (km^2)	Parent HEC-HMS Peak Flow (m^3/s)	Refined HEC-HMS Peak Flow (m^3/s)	Peak Flow Difference (m^3 per ha)	Percent Difference
J-Tw-20 (J-Tw-20)	Twenty Mile Creek between S Grimsby Rd 7 Grimsby Rd 8	157.62	94.5	94.5	0.0	0.0%
J-Tw-18 (J-Tw-18)	Twenty Mile Creek 370m+/- South of West Street	158.23	93.4	93	-0.4	-0.4%
J-Tw-17 (J-Tw-17)	Twenty Mile Creek 65m+/- South of West Street	162.05	93.7	93.8	0.1	0.1%
J218 (J-Tw-16)	Twenty Mile Creek 32m+/- west of Wade Rd	165.60	94.4	95.0	0.60	0.64%
J150 (J-Tw-14)	Twenty Mile Creek at Townline Rd	171.36	95.2	95.7	0.5	0.5%
J-No-4 (J-No-4)	North Creek between S Grimsby Rd 7 and S Grimsby Rd 8	17.96	39.5	39.5	0.0	0.0%
J192 (J-No- 2)	North Creek 390m+/- west of Tober Rd	28.30	60.1	56.9	-3.2	-5.3%
J-Tw-13 (J-Tw-13)	Twenty Mile Creek and North Creek Confluence	211.34	153.1	149	-4.1	-2.7%

Note: text in brackets represents parent HEC-HMS reference node.

The results indicate that there are nominal differences between the refined HEC-HMS model and the parent HEC-HMS model. The peak flow differences range from -4.1 m^3/s to 0.5 m^3/s (-7.3% to 1.4%). The average absolute difference is -0.55 m^3/s and the average percent difference is -1.7%. In general, the refined model produces slightly lower peak flow rates compared with the parent model. The differences are considered attributable to changes in subbasin sizes and parameterization, as well as incorporating SWMFs. Consequently, the refined HEC-HMS hydrologic model is considered to be representative for evaluating hydrologic impacts of the future development at the watershed scale.

3.5.3.4 Hydrologic Analyses

Peak Flow Analysis

The validated PCSWMM hydrologic model has been used to establish simulated peak frequency flows at key locations within the study area under existing land use conditions. The PCSWMM hydrologic model has been executed for a 22 Year continuous simulation (1998-2019) using the rainfall data at NWIS Smithville SPS Precipitation Station. Frequency analyses have been completed based on the simulated annual maximum peak flows, applying the Log Pearson Type III Distribution. The Log Pearson Type III Distribution has been applied based upon the review of the coefficient of skew, as well as visual inspection of the correlation between the best fit trendline and the sample population. The simulated peak frequency flows are summarized in **Table 3.5.18** for key locations within the urban expansion area and the existing urban area.

Table 3.5.18. Simulated Peak Frequency Flows (m^3/s)

Node	Location	Drainage Area (Ha)	Frequency (years)						
			1.25	2	5	10	20	50	100
Twenty Mile Creek Tributary									
WC17	confluence; north of CNR	119	0.81	1.39	2.23	2.80	3.32	3.99	4.47
WC18	south of West St; 414 m +/- East of S Grimsby Rd 7	159	1.05	1.79	2.84	3.52	4.14	4.91	5.46
WC20	trib, South of West Street	61	0.57	0.88	1.38	1.76	2.16	2.72	3.19
WC19	main stream, 410 m +/- U/S of S Grimsby Rd Six	224	1.56	2.66	4.22	5.22	6.15	7.28	8.09
WC116	810m+/- West of S Grimsby Rd 6	130	0.76	1.28	2.02	2.50	2.94	3.48	3.87
JS36D	between Forestview Ct and Golden Acres Dr	130	0.66	1.11	1.75	2.17	2.57	3.07	3.44
WC30	125m+/- u/s of Oakdale Blvd	163	1.84	2.54	3.41	3.95	4.43	5.01	5.43
JS43US	Las Road	19	0.22	0.35	0.54	0.67	0.80	0.98	1.11
DICBMH_418	Nornak Road	11	0.15	0.23	0.34	0.40	0.46	0.53	0.58
JS32D	D/S of Townline Road	30	0.63	1.00	1.45	1.70	1.91	2.14	2.29
JS1D	main stream at Townline Road	932	6.64	9.64	13.86	16.69	19.43	23.00	25.71
WC11	130 m+/- U/S of Hwy 20	27	0.20	0.30	0.48	0.62	0.77	1.00	1.20
WC12	140 m+/- D/S of Hwy 20	79	0.78	1.03	1.18	1.31	1.49	1.61	1.73
OF11	east study area boundary	1085	7.37	10.82	15.58	18.71	21.68	25.49	28.34
North Creek Tributary									
OF6	east of Port Davideson Rd	21	0.36	0.55	0.68	0.81	0.97	1.09	1.21
OF15+OF7	trib, west of Shurie Road	9	0.25	0.39	0.49	0.59	0.74	0.87	1.00
Spring Creek									
JS26D	Young Street	5	0.05	0.09	0.15	0.20	0.26	0.34	0.40
WC15	200m+/- S/E of South of Spring Creek Rd	263	1.53	2.54	3.97	4.91	5.79	6.88	7.66
WC38	520m+/- S/E of South of Spring Creek Rd	263	1.40	2.35	3.77	4.75	5.68	6.89	7.79
WC14	690m+/- S/E of South of Spring Creek Rd	315	1.63	2.70	4.24	5.26	6.22	7.43	8.31

The PCSWMM hydrologic model has been executed for the 2, 5, and 100 year return periods using the 12 hour AES storm distribution, to assess impacts at the localized scale of the Smithville Subwatershed. Peak flows have been extracted at the key locations for the respective synthetic design storms. The results of this assessment are presented in **Table 3.5.19**.

Table 3.5.19. PCSWMM Simulated Peak Design Flows (m^3/s)

PCSWMM Reference Node	Location	Drainage Area (ha)	Return Period (Years)		
			2	5	100
Twenty Mile Creek Tributary					
N52	west of S Grimsby Rd 6	56.41	0.34	0.64	1.44
WC41	Grimsby Rd 6; 400m+/- north of CNR	62.84	0.31	0.60	1.44
WC17	Confluence; north of CNR	119.25	0.64	1.22	2.86
WC18	South of West St; 414 m +/- East of S Grimsby Rd 7	158.77	0.88	1.65	3.86
JS20D	East of S Grimsby Rd 6; D/S of CNR	33.36	0.23	0.41	0.9
JS21D	D/S of West Street, West of S Grimsby Rd 6	44.37	0.26	0.50	1.17
WC20	Confluence; South of West Street	60.58	0.42	0.77	1.68
N57	U/S of Twenty Mile Confluence; west of S Grimsby Rd 6	64.87	0.45	0.84	1.84
N86	U/S of Twenty Mile Confluence; east of S Grimsby Rd 6	17.61	0.16	0.28	0.56
JS38D	D/S of S Grimsby Rd 6; 1230m+/- south of West Street	84.41	0.43	0.83	1.99
WC116	810m+/- West of S Grimsby Rd 6	130.42	0.65	1.26	2.99
JS36D	between Forestview Ct and Golden Acres Dr	130.42	0.56	1.14	2.82
WC30	125m+/- u/s of Oakdale Blvd	163.36	1.85	2.71	4.99
JS32D	D/S of Townline Road	29.97	0.32	0.5	0.99
N24	U/S of Twenty Mile Confluence; 274m+/- north of Townline Rd	43.10	0.49	0.75	1.54
N45	U/S of Twenty Mile Confluence; 390m+/- south of St Catherines St	79.2	0.61	0.93	1.66
N3	U/S of Twenty Mile Confluence; 530m+/- west of Patterson St	4.26	0.10	0.16	0.34
North Creek Tributary					
WC104	west of Smithville Sports Complex	25.95	0.19	0.34	0.73
OF2	317m+/- west of Tober Rd	7.71	0.07	0.12	0.25
OF3	D/S of Tober Rd Crossing	13.25	0.14	0.23	0.48
OF4	East of Tober Rd	47.37	0.33	0.60	1.31
OF5	west of Port Davideson Rd	35.09	0.33	0.56	1.12
OF6	east of Port Davideson Rd	21.28	0.15	0.27	0.59
OF7	west of Shurie Rd	5.18	0.04	0.08	0.16
OF8	east of Shurie Rd	7.37	0.08	0.12	0.26
Spring Creek					
JS29D	Industrial Park Road	129.24	0.82	1.58	3.55
JS30D	Spring Creek Road	186.05	0.90	1.77	5.10
WC15	200m+/- S/E of South of Spring Creek Rd	263.33	1.21	2.32	6.09
WC38	520m+/- S/E of South of Spring Creek Rd	263.33	1.18	2.28	6.03
WC14	690m+/- S/E of South of Spring Creek Rd	314.79	1.41	2.70	6.67

The refined HEC-HMS hydrologic model has been executed for the 2, 5, and 100 year return periods using the 12 hour AES storm distribution, to assess impacts at the broader watershed scale for Twenty Mile Creek. Peak flows have been extracted at key locations for the respective synthetic design storms. The results of this assessment are presented in Table 3.5.20.

Table 3.5.20. HEC-HMS Simulated Peak Design Flows (m^3/s)

HEC-HMS Reference Node	Location	Drainage Area (km^2)	Return Period (Years)		
			2	5	100
Twenty Mile Creek					
J-Tw-17	65m+/- South of West Street	162.05	13.1	28.2	93.8
J175	south of West St; 414 m +/- East of S Grimsby Rd 7	163.63	13.3	28.3	94.1
J174	west of S Grimsby Rd 6	164.28	13.3	28.3	94.2
J20586	east of S Grimsby Rd 6	165.03	13.3	28.4	94.3
J218	west of Wade Rd	168.65	13.6	28.7	95
J138	Canborough St	169.22	13.7	28.7	95.2
J136	280m+/- north of Shurie Rd	170.34	13.8	28.8	95.4
J150	Twenty Mile Creek at Townline Rd	171.36	13.9	28.9	95.7
J157	530m+/- west ofPatterson St	172.89	14.0	29.0	95.9
J-Tw-13	Twenty Mile Creek and North Creek Confluence	211.43	29.6	57.2	149
North Creek					
PRJ178	west of S Grimsby Rd 6	19.24	10.6	17.9	39.3
J192	North Creek 410m+/- west of Tober Rd	28.29	14.3	25.2	56.9
J193	365m+/- west of Tober Rd	28.97	14.3	25.1	56.9
J180	west of Port Davideson Rd	29.32	14.3	25.2	57
J1821	178m+/- east of Port Davidson Rd	29.53	14.3	25.1	56.9
J2032	155m+/- east of Shurie Rd	29.72	14.2	25.0	56.8
Spring Creek					
J144	Industrial Park Road	1.29	0.7	1.3	3.0
J141	Spring Creek Road	1.86	1.1	1.9	4.3
J185	200m+/- south of Spring Creek Rd	2.64	1.4	2.5	5.8
J184	943m+/- south of Spring Creek Rd	3.50	1.7	3.2	7.7

Duration Analysis

The results of the 22-year continuous simulation with the validated PCSWMM model have also been used to assess the erosion potential of the existing watercourse systems under existing land use conditions. The erosion sites have been determined as part of the fluvial geomorphologic component of this study. The locations of the erosion sites are presented in Drawing FG-2. Duration (in hours) of flows above the critical erosion flow rate has been determined for key locations. Since external drainage areas of North Creek are not included in the localized PCSWMM model, the critical erosion threshold flow of 0.472 m^3/s at the North Creek reach has been weighted based on drainage areas at the assessment locations. The results are presented in Table 3.5.21.

Table 3.5.21. Erosion Duration Analysis for Erosion Assessment

PSCWMM Reference Node	Location	Watercourse	Contributing Drainage Area (ha)	$Q_{critical}$ (m^3/s)	Total Hours Exceeded	Percent of Total Time	Total Volume Exceeded (m^3)
WC41	Grimsby Rd 6; 400m+/- north of CNR	Twenty Mile Creek Trib	62.84	0.159	974	0.5%	488,727
OF3	130m+/- west of Tober Rd	North Creek	13.25	0.034[1]	1441	0.8%	235,502
OF4	365m+/- west of Tober Rd	North Creek	47.37	0.120[1]	1161	0.6%	514,089
OF5	west of Port Davideson Rd	North Creek	35.09	0.089[1]	1377	0.7%	434,369
OF6	178m+/- east of Port Davidson Rd	North Creek	21.28	0.054[1]	1165	0.6%	234,842
WC15	200m+/- S/E of South of Spring Creek Rd	Spring Creek	263.33	0.385	1998	1.1%	3,385,332
WC38	520m+/- S/E of South of Spring Creek Rd	Spring Creek	263.33	0.385	1971	1.0%	3,294,963
WC14	690m+/- S/E of South of Spring Creek Rd	Spring Creek	314.79	0.385	2425	1.3%	4,532,056

Note: 1. Critical flow rate for North Creek Tributaries have been weighted based on contributing drainage areas and the critical flow rate for the Twenty Mile Creek Tributary

The duration analysis indicates that under the existing land use conditions, the erosive flows occurred for 0.5% of the 22 years along the Twenty Mile Creek tributary, 0.6 to 0.8% of the 22 years along the North Creek, and 1.0 to 1.3% of the 22 years along the Spring Creek reach.

3.5.3.5 Hydraulic Analysis

Hydraulic characterization of the regulated watercourses within and downstream of the study area has been completed using the HEC-GeoRAS hydraulic model. The HEC-RAS tool has been developed based on the U.S. Army Corp of Engineers HEC-2 hydraulic model, and uses energy and momentum equations to determine water surface elevations for given channel geometric cross-sections, crossings and boundary conditions.

Previous Hydraulic Modelling

Hydraulic models for the reaches of the Twenty Mile Creek and its tributaries through the study area have been completed recently by NPCA using the HEC-RAS methodology. Digital copies of the HEC-RAS hydraulic model representing the Twenty Mile Creek main branch and the contributing regulated watercourses have been provided by NPCA for use in the study.

Hydraulic Structure Inventory

Field reconnaissance has been conducted to obtain the geometry and dimensions of the hydraulic structures spanning the regulated watercourses within the study area, and along the receiving regulated watercourses. A photographic inventory of the culverts has been prepared, and Total Station Survey completed at the structures to establish the structure inverts and dimensions, as well as to obtain cross-sections of the open watercourses upstream and downstream of the structure. The hydraulic structure location plan is presented in Drawing WR-7, and the hydraulic structure inventory is presented in Appendix E.

Hydraulic Model Development

HEC-GeoRAS hydraulic models have been developed to conduct hydraulic analyses along the regulated watercourses within and downstream of the study area. The initial cross-section locations and alignments have been established based upon the cross-section locations provided by NPCA for the current HEC-RAS hydraulic models; the alignments and locations have been revised as appropriate in order to correspond to the contours within the LiDAR mapping provided for use in this study, as well as to extend the limits of the model to encompass all regulated watercourses based on flood hazard (i.e. watercourses with contributing drainage areas greater than 125 ha) not included within the current hydraulic modelling.

The low flow channel has been incorporated into the model cross-sections based upon the Total Station Survey information at the hydraulic structures. Standard values of Manning's roughness coefficient have been used at the cross-sections as 0.035 for the main channel. Overbank values have ranged from 0.050, where the overbank is predominately open field, to 0.10 where the overbank is dominated by thick brush and trees. based upon a review of available air photos . Expansion and contraction coefficients of 0.3 and 0.5 respectively have been used at all hydraulic structures. For the balance of the cross-sections, since the model has been executed under the subcritical flow regime, the coefficients of contraction and expansion have been set to 0.1 and 0.3, respectively. The reach lengths have been measured based on the standard practice of calculating the length of the anticipated path of the center of mass for the overbank flow. Model cross-sections and topographic data have been reviewed to account for ineffective flow areas in the model. Ineffective flow areas are predominantly found in the approaches to structures, as the flow converges near the opening, hence rendering a portion of the surrounding area as ineffective flow area.

The cross-section location and the resulting 100 year floodline mapping are provided on Drawing WR-8, along with the current regulatory floodline mapping developed by NPCA.

The results of the hydraulic analyses indicate that the floodline mapping along the main branches of Twenty Mile Creek and North Creek are generally comparable to the current floodline mapping. The variation are considered attributable to differences between the basemapping used for the NPCA floodline mapping and that used for the current study. The floodline mapping for the tributary of Spring Creek located toward the east limit of the site is noted to differ significantly from that which has been delineated by the NPCA. These differences are considered attributable to the differences in basemapping, as well as the significant difference in peak flowrates between the PCSWMM modelling and the HEC-HMS modelling as a result of the methodologies applied for infiltration (i.e. Green & Ampt for PCSWMM and SCS CN methodology for HEC-HMS). Nevertheless, recognizing that the purpose of the hydraulic analyses for the current study is to inform the impact assessment rather than to delineate Regulatory Floodlines for the study area, the hydraulic model developed for the Tributary of the Spring Creek is considered appropriate for completing the impact assessment for the Subwatershed Study.

Through the course of the hydraulic model development two additional reaches have been identified toward the west limit of the study area, which meet the NPCA drainage area criteria for delineating Regulatory Floodline Mapping, however which currently do not have floodlines delineated. The first creek is a tributary of the Twenty Mile Creek located toward the northwest and external to the study area, and the second is the reach which discharges toward the online stormwater management facility toward the middle and external to the study area. The hydraulic models and floodlines for these reaches are suggested to be retained for the purpose of this study to support the impact assessment along the receiving watercourses, however the floodlines for these reaches are provided for illustration and comparison purposes only, and are not intended to represent Regulatory Floodlines for the subject watercourses.

3.5.4 Interpretation and Findings

The hydrologic responses during the monitoring period were low potentially due to the influence of low seasonal rainfall, karst features, evaporation, and evapotranspiration due to area wetlands. A PCSWMM model has been developed for the urban expansion area and the existing urban area at the local level. The continuous simulation and the design storms simulation result in relatively lower peak flows and runoff volumes compared with the NPCA's HEC-HMS model. Overall, the PCSWMM model and the refined HEC-HMS model generate representative results considering the differences in subcatchment sizes, as well as modelling and parameterization approaches.

The erosive flows occurred for 0.5% of the 22 years along the Twenty Mile Creek tributary, 0.6 to 0.8% of the 22 years along the North Creek, and 1.0 to 1.3% of the 22 years along the Spring Creek reach.

HEC-GeoRAS hydraulic models have been developed for the regulated watercourses within and downstream of the study area. The resulting 100 year floodplain is contained within the current flood hazard defined by NPCA, hence the current 100 year floodplain developed by NPCA is considered to govern.

3.6 Fluvial Geomorphology

3.6.1 Importance and Purpose

The primary purpose of the fluvial geomorphology assessment and characterization component is to identify and characterize surface water features within and downstream of the study area to assess their sensitivity of the form and contributions of each feature to development, while also limiting risk to settlement areas from fluvial hazards. Each feature is evaluated in terms of form and function, erosion hazards (to adjacent lands), and erosion sensitivity of the feature themselves.

In order to identify and characterize watercourses and headwater drainage features (HDFs), a clear understanding on their definitions is required. The following definitions have been adapted from the guidance document *Evaluation, Classification and Management of Headwater Drainage Features Guidelines* (TRCA/CVC, 2014), and based on the existing understanding of drainage features within the Study Area from the background review, and professional experience in other jurisdictions.

Watercourses

Watercourses are defined as permanently to intermittent flowing drainage features with defined bed and banks. They exhibit clear evidence of active channel process including planform, profile, and material sorting, with evidence of a balance between erosion and deposition throughout the reach. They are often second-order or greater but may be first order when verified by the practitioner(s). Watercourses are currently identified as regulated features by the Conservation Authority, and fish are typically found within these features. The contributing drainage area is close to or exceeds 50 ha, but there may be instances where watercourses have smaller contributing areas.

Headwater Drainage Features (HDFs)

Non-permanently flowing drainage features that may not have defined bed or banks have been identified as HDFs. The presence of bed and bank definition within these features may be attributed to anthropogenic intervention (e.g. cutting a drainage feature into the surface), or seasonally as spring freshet concentrates flows in depressions, causing channel development into surfaces lacking vegetated cover. HDFs are first order and zero order intermittent and ephemeral channels, swales and connected headwater wetlands, but do not include rills or furrows. They are currently not identified as a regulated feature, and fish may or may not be found within them. The contributing drainage area is generally less than 50 ha.

The role of channel processes needs to be quantified such that guidance can be given to any proposed land use changes, thereby ensuring continued channel dynamics as well as ensuring any potential impact to downstream channels is minimized. This information will provide guidance to channel management and enhancements within the Study Area in relation to future development and infrastructure.

To achieve this objective, the assessment includes the following components:

- Collect and review any pertinent background information, such as topographic mapping, historic aerial photographs, and hydrologically informed watercourse mapping (shapefiles)
- Use available mapping to delineate channel reach boundaries for watercourses and HDFs, based on the definitions described above
- Characterize valley setting (confined or unconfined) on a reach basis based on available topographical data (e.g. DEM derived contours)
- Delineate the meander belt on a reach basis for watercourses with-in the study area
- Complete field reconnaissance to confirm existing geomorphic conditions, document evidence of active erosion and confirm desktop results for watercourses, and to execute seasonally based HDF Assessments by applying TRCA/CVC (2014) protocols

3.6.2 Background Information

Background Information Review

A background review of previous studies, policy documents and mapping information was undertaken to provide context for the stream morphology study. Key documents are summarized below.

Reports:

- Elfrida Subwatershed Study, Final Phase 1 Report. City of Hamilton, May 24, 2018.

  This study investigates and inventories the natural resources that could potentially be impacted by future urban development within the Elfrida Growth Area. A geomorphic evaluation of watercourses and headwater drainage features (HDFs) was undertaken which included an assessment of geomrophic limits to development and an erosion potential analysis.

- Natural Heritage Areas Inventory 2006-2009, Volume 1. NPCA, 2010.

  This study characaterizes the surficial geology, hydrology and natural heritage of the Twenty Mile Creek watershed. The Haldimand Clay Plain is found throughout the region which is composed of glacial till and loverlying lacustrine deposits. The area is poorly drainged due to the heavy clays. The plain is very level in general (flat to rolling hills) and rivers move sluggishly across it. Annual peak flows in Twenty Mile Creek are observed in March, decline quickly from April to June, and reach low flows by July. Low to no flows remain until mid to late fall. Flows are described as flashy.

- NPCA Policy Document: Policies for the administration of Ontario Regulation 155/06 and the Planning Act. NPCA, September 2018.

  The NPCA Policy Document (2018) outlines NPCA requirements for erosion hazard assessments and defines regulated valleylands as apparent valleys where the bank height is equal to or greater than 3 metres in height, the slope is steeper than 3 (horizontal) to 1 (vertical), and includes adjacent lands.

- Twenty Mile Creek Watershed Plan. NPCA, 2006.

  This study outlines key environmental characteristics and issues within the Twenty Mile Creek watershed, and provides a set of watershed objectives and restoration stretegies. The report notes that this subwatershed contains several regionally significant wetlands, that some sections of upper reaches of Spring Creek have been excavated and straightened, and that flow in this creek is intermittent especially during summer months. The North Creek subwatershed is described as predominantly rural, and baseflow drops to zero during summer months. Twenty Mile Creek in the vicinity of Smithville flows through relatively flat, predominantly agricultural land. Baseflow within the creek drops to zero during the summer months, and some water is retained in pools. An erosion-sensitive site was identified by modeling along Twenty Mile Creek upstream and downstream of Canborough Street. It is also noted that karstic features are found within the watershed.

  The Main Branch of Twenty Mile Creek Restoration Strategy recommends that opportunities to expand natural heritage areas within the Community of Smithville should be prioritized, and in rural areas, priority should be placed on establishing vegetated buffers (minimum 15-30 metres) along watercourses to enhance water quality. Along North Creek, restoration of the riparian corridor in agriculatural areas and landowner education is recommended. Along Spring Creek south of Yonge Street, it is also recommended that riparian buffer vegetation be established where there is no buffer.

- 20 Mile Creek Geomorphology Study, Dr. Keith Tinkler (for Hollington and Hoyle Limited), September 1999.

  This geomorphological assessment characterized Twenty Mile Creek and its tributaries throughout the watershed. A review of the channel profile, bankfull conditions and meander belt widths was provided. The longitudinal profile of Twenty Mile Creek is noted to be very flat between bedrock outcrops which serve as grade controls. Field assessments were completed at 31 sites, which included sites on Twenty Mile Creek and North Creek located upstream and downstream of Smithville. This study outlines restoration objectives including reduction of fine suspended solids in the creek and recommends conceptual channel restoration works, such as defining the floodplain, reducing channel size to ensure efficient sediment transport and improving wetland and forest cover.

The following mapping was reviewed:

- Niagara Region Orthophotography (2018)
- Niagara Region LiDAR digital elevation model (2018), reviewed as 0.5m contours
- NPCA Contemporary Watercourse Mapping shapefile
- NPCA 2k Hydrography and 2k Hydropoly watercourse and waterbody shapefiles
- NPCA 2k subwatershed shapefile

- NPCA Approximate Regulated Areas shapefile
- NPCA Top of slope delineation shapefile
- Historic aerial photographs of the study area from 1934, 1965, 1989, 2000, 2006 and 2015.

The NPCA 2k Hydrography Mapping, which was developed before the Contemporary Watercourse Mapping, was based on detailed hydrological modeling which produced drainage feature mapping that extends to the upstream limits of the subwatersheds. In contrast, the Contemporary Watercourse Mapping screened out surface water features that are not regulated by the NPCA and classified remaining watercourse segments by type at a high level. Both watercourse mapping sets were reviewed as part of the desk study to identify watercourses and headwater drainage features (HDFs) within the Study Area.

3.6.3 Methods and Analysis

3.6.3.1 Desktop Assessment

Reach Delineations and Feature Types

The parameters that influence channel form, amount and size of sediment inputs, valley shape, land use or vegetation cover vary over the length of a stream. Lengths of channel that exhibit similar characteristics with respect to these parameters are known as reaches. Reach lengths vary with the scale of the channel, often longer for a larger watercourse, while smaller watercourses exhibit more variability resulting in shorter reaches. Delineation of reaches is beneficial as it enables grouping and identification of general channel characteristics.

The process of delineating reaches considers external parameters such as local geology, topography and valley setting, hydrology, riparian vegetation, and land use. Consideration is also given to characteristics that reflect these external influences such as sinuosity, gradient, and dimensions. In some cases, reaches were defined based on changes in channel alteration or management and are best described as "management reaches" rather than geomorphic reaches. Such management reaches which account for historical land use variations are typically contained within larger geomorphic reaches that reflect the longer-term physical processes in the drainage network. Reach delineation is completed as part of the desktop assessment and used to guide the subsequent field program.

All reaches delineated within the Study Area were given a preliminary categorization during the desk study as either watercourse or HDF reaches. Potential HDF features were identified by overlaying the NPCA 2k Hydrography and Contemporary Watercourse Mapping map sets and selecting the features that had been screened out of the Contemporary Watercourse Mapping, as well as by selecting features that were classified in the Contemporary Mapping layer as swales, agricultural drainage, or agricultural drainage. As a general guide, tributary features initially categorized as watercourses during the desktop study had some or all of the following characteristics:

- Feature type noted to be "stream/creek" or "waterbody – river" on the NPCA Contemporary Watercourse Mapping;
- The feature appears in air photos to be subject to fluvial processes. For instance, the feature might have a meandering planform (which did not appear to be merely controlled by topography), a floodplain or distinct banks;
- The drainage network extended upstream a considerable distance from the reach;
- Drainage area >50 ha; where there were other indications that the feature might be a watercourse, smaller drainage areas were also considered.

The reach delineation and initial categorization into "watercourse" and "HDF" reaches was then verified during the field assessment. **Drawing FG-1** presents mapping of reach breaks for watercourses and headwater drainage features within the Study Area. **Drawing FG-1** also includes previously unmapped HDFs that were identified in the field.

Watercourse reaches have been further identified as being located within 'unconfined' or 'confined' valley systems based on the presence of a defined valley. This classification further assists the delineation of meander belt widths and erosion hazard limits along subject reaches. Unconfined systems have no discernable valley slope that can be detected from the surrounding landscape either by field investigation aerial photography and/or map interpretation. Typically, these types of systems are found in flat or gently rolling landscapes. Confined watercourses are ones in which the physical presence of a valley walls, with heights greater than or equal to 3 m (NPCA, 2018), are visibly discernible. For this type of system the location of the watercourse may be located at the base of a valley slope or in close proximity to it (MNR, 2002).

Due to the overall size of the Study Area, a naming convention has been used to identify watercourse and headwater drainage features reaches. The name indicates if the watercourse feature is a tributary and its general location within the subwatershed, from downstream to upstream. For example, the reach name "TM1" stands for "Twenty Mile Creek (reach 1)". This watercourse segment is the first downstream geomorphic reach identified for Twenty Mile Creek as part of this study. The reach name "TM4(6)1" indicates that this watercourse segment is the first reach (1) of the sixth tributary (6) to Twenty Mile Creek (reach 4).

Historical Assessment

Streams are dynamic, rather than static, landscape features. Over time their configuration and position within the floodplain changes as a result of meander evolution, development, and migration processes. These lateral and down-valley planform adjustments can be observed and often quantified by reviewing historic aerial photographs. Depending on photo quality and scale of the channel of interest, 100-year erosion rates may be determined by measuring the distance from known control points to a governing meander bend over the available historical record. Historic aerial photos are also analyzed to determine changes in surrounding land use which may have impacted channel migration. Historic photos of the Study Area from 1934, 1965, 1989, 2000, 2016, 2015 have been reviewed along with the orthophotograph from 2018.

Erosion Hazard Delineation – Meander Belt and Stable Top of Slope

The meander belt width defines the area that a watercourse currently occupies or can be expected to occupy in the future. Meander belt delineation is commonly used as a planning tool in order to protect private property and structures from future erosion due to fluvial action or geotechnical instability. Within a subwatershed study context, studies require the general identification of meander belt widths to facilitate the planning process. Therefore, for the purposes of this study, meander belt widths have been developed from a broad scale and are subject to refinement as part of future, more detailed, studies. For this study, meander belt widths have been delineated only for unconfined stream reaches that have defined bed and banks. For unconfined watercourses, limits of the meander belt have been defined by parallel lines drawn tangential to the outside bends of the laterally extreme meanders of the planform for each reach. Due to the broad-scale nature of this study and limited evidence of migration observed during the review historic photos, in lieu of calculating the 100-year migration rate for each reach, a factor of safety has been applied as 20% of the meander belt width (10% applied on either side of the meander belt width).

In addition to meander belt delineations for unconfined watercourse reaches, an erosion hazard limit has been determined for confined channel systems – the stable top of slope. For the confined systems within the Study Area, a stable top of slope limit has been delineated following Provincial Policy Statement (PPS) technical guidelines. Within the confined reaches of the Study Area, the watercourses typically meander back and forth between valley wall contacts, but some are more confined than others, and several are semi-confined on the reach scale with portions of the reach exhibiting confinement. The PPS requires that a toe erosion setback be applied where a watercourse is within 15m of the valley toe (MNR, 2002), plus a stable slope allowance (3:1, H:V), and erosion access allowance of 6m.

In some instances (e.g. Reach TM2) the valley form exhibited an intermittent definition longitudinally, resulting in partial confinement of the watercourse. The response for such instances was to combine the methodologies for delineating erosion hazards for confined and unconfined reaches as appropriate.

Watercourses are generally regulated features, and as such have management considerations and policy for the erosion hazard as outlined in the NPCA Planning Document (2018). These policies have been applied in the erosion hazard mapping (**Drawing FG-2**) and they include:

- The locaton of the stable top of slope or the physical top of slope, whichever is determined to be further landward on the tablelands;
- A slope stability allowance of 7.5 metres (25 feet) from the most landward locaton of either of the stable top of slope or the physical top of slope;
- The toe erosion allowance, where a watercourse is located less than 15 metres (49 feet) from the toe of slope.

3.6.3.2 Field Reconnaissance

Watercourses

Rapid Assessments

In order to provide insight into existing geomorphic conditions on a reach basis, field reconnaissance was completed in May of 2020. Rapid assessment techniques, Rapid Geomorphic Assessment (RGA) and the Rapid Stream Assessment Technique (RSAT) were applied to determine the dominant geomorphic processes affecting each reach.

The Rapid Geomorphic Assessment (RGA) was designed by the Ontario Ministry of Environment (MOE, 2003) to assess reaches in rural and urban channels. This qualitative technique documents indicators of channel instability. Observations are quantified using an index that identifies channel sensitivity based on the presence or absence of evidence of aggradation, degradation, channel widening, and planform adjustment. Overall the index produces values that indicate whether the channel is stable/in regime (score ≤0.20), stressed/transitional (score 0.21-0.40), or adjusting (score ≥0.40; **Table 3.6.1**).

Table 3.6.1. RGA Classification

Stability Index	Condition	Description
<0.20	In Regime or Stable (Least Sensitive)	The channel morphology is within a range of variance for streams of similar hydrographic characteristics – evidence of instability is isolated or associated with normal river meander propagation processes
0.21-0.40	Transitional or Stressed (Moderately Sensitive)	Channel morphology is within the range of variance for streams of similar hydrographic characteristics, but the evidence of instability is frequent
>0.41	In Adjustment (Most Sensitive)	Channel morphology is not within the range of variance and evidence of instability is widespread

The Rapid Stream Assessment Technique (RSAT) was developed by John Galli at the Metropolitan Washington Council of Governments (Galli 1996). The RSAT provides a more qualitative and broader assessment of the overall health and functions of a reach. This system integrates visual estimates of channel conditions and numerical scoring of stream parameters using six categories:

- Channel Stability
- Erosion and Deposition
- Physical In-stream Habitat
- Water Quality
- Riparian Conditions
- Biological Indicators

Once a condition has been assigned a score, the total of these scores produces an overall rating which is based on a 50-point scoring system. The result of the assessment then categorizes the stream as Low (<20), Moderate (20-35), or High (>35) stream quality.

While the RSAT scores streams from a more biological and water quality perspective than the RGA, this information is also of relevance within a geomorphic context. This is based on the fundamental notion that, in general, the types of physical features that generate good fish habitat tend to represent good geomorphology as well (i.e., fish prefer a variety of physical conditions – pools provide resting areas while riffle provide feeding areas and contribute oxygen to the water – good riparian conditions provide shade and food – woody debris and overhanging banks provide shade). Additionally, the RSAT approach includes semi-quantitative measures of bankfull dimensions, type of substrate, vegetative cover, and channel disturbance.

Detailed Characterization

To gain further insight into geomorphic processes, detailed field sites have been established based on the results of the rapid assessments. The sites selected are considered representative of the overall study area in terms of spatial and morphologic perspective. Sites also have been selected based on stability; areas that are most vulnerable to change need to be characterized in order to inform development planning.

The detailed field assessment uses standard protocols and known field indicators to quantify the bankfull geometry of the reach (i.e. bankfull depth, width, and gradient). The "bankfull" channel area generally represents the maximum capacity of the channel before flow spills onto the floodplain, and it is usually identified by obvious breaks, or inflections, in the cross-section profile and changes in vegetation along the channel margin. Generally, 5-10 cross-sections are measured to determine the bankfull channel geometry. At each cross-section, a modified Wolman (1954) pebble count has been completed to characterize the channel bed materials. Banks are also characterized at the cross-sections (height, angle, composition, degree of vegetative cover). A longitudinal profile has been surveyed to define the local channel gradient through the site and also included keys features along the channel bed (top and bottom of riffles, max pool depths, flow obstructions). These detailed channel measurements have then been used to estimate the hydraulic parameters at bankfull stage (i.e. Discharge, velocity, shear stress) and identify the shears stress and velocity needed to entrain sediment from the channel bed. Two detailed sites have been completed by the Subwatershed Study Team as part of Phase 1; additional sites have been completed by landowner consultants.

The data from the detailed field assessment has been used to complete the erosion threshold analysis. This analysis determines the hydraulics, such as discharge, channel depth, or average channel velocity, at which the channel produces sufficient shear stress to initiate the mobilization of sediment of a give size (D_{crit}). The analysis evaluates a reach's erosion sensitivity by comparing the boundary shear stress associated with modeled flows to the critical shear stress required to entrain sediment.

The general procedure for calculating erosion thresholds is to calculate a critical flow, shear stress, or velocity at which a sediment particle of a given size will just start to move. Once this value is found, a model is run that "fills" the channel incrementally until the depth and slope produce values equal to the critical values. A number of different established entrainment relationships are used to calculate erosion thresholds, including models based on critical shear stress and permissible velocity, in order to consider a range of results. The model results are examined for convergence and compatibility with field observations. Selection of appropriate thresholds is also based on an understanding of site conditions and the assumptions and ranges of conditions under which the entrainment equations are applicable.

Headwater Drainage Features

HDFs are, in general, poorly defined in nature. Within settled regions, many have been modified to facilitate drainage of the adjacent lands. The importance of the headwater channels is well recognised (i.e. water infiltration, attenuation, sediment and biota supply) with respect to the multiple functions they provide to the downstream subwatershed. Headwater systems are considered important sources of food, sediment, water, nutrients, and organic matter for downstream reached. The analysis of their formative requirements, basin contributions and the impacts of channel loss through development and land use change has come to the forefront of research and policy direction within Ontario.

The HDFs within the Study Area were first identified through a review of NPCA watercourse mapping and recent aerial photography. Potential HDF features have been identified by overlaying the NPCA 2k Hydrography and Contemporary Watercourse Mapping map sets and selecting the features that had been screened out of the Contemporary Watercourse Mapping, as well as by selecting features that were classified in the Contemporary Mapping layer as swales, agricultural drainage, or agricultural drainage. Following HDF assessment protocol (TRCA/CVC, 2014) a detailed field study has been undertaken to field verify potential features where access was available or from acceptable vantage points. The protocol requires three separate site visits; this is largely to characterize the hydrologic function under different seasonal conditions. The three separate visits also help determine the extent of fish habitat based on the amount of flow present. All features identified during the desktop phase have been assessed during the "first visit" which takes place shortly after spring freshet (late March or early April). Recording flow condition and feature type as outlined in the OSAP protocol (Stanfield, 2010) are the main focus of this visit. Based on the results, features may be classified as 'limited function' and receive the management recommendation of 'no management required' (TRCA/CVC, 2014). These features do not need to be assessed beyond the first visit. This process of screening based on the flow condition and feature type continues through the "second visit" to determine which features require the "third visit." The second visit is typically after the freshet is complete and before significant plant growth has occurred (late April to mid-May). The third visit is during the driest conditions of the summer, preferably after several days without significant rain, to determine which features continue to flow year-round (July to mid-September). In addition to the data on flow condition and flow type, other aspects of OSAP protocol (Stanfield, 2010) are employed. This includes assessment of riparian vegetation, fish habitat, and terrestrial habitat.

The HDF assessment visits occurred on three separate rounds and were conducted within the Study Area where property access was granted. The site assessments fell within the recommended timing window, with the exception of the final day of the Round 1 assessment which occurred in late April, and the Round 2 site visits that extended into June in order to accommodate property access permissions and health and safety requirements. Round 1 site visits occurred on April 3, 6, 9, 13 and 24, 2020. Round 2 visits occurred on June 2 and 9, 2020. Round 3 visits occurred on August 20 and 26, 2020. Approximately 75% of HDFs within the Study Area were field evaluated based on existing Permission to Enter (PTE) agreements. **Drawing FG-1** presents the location of HDF and watercourse reaches within the Study Area.

HDF Classification – Preliminary and Final Management Column

The above describes, in general, the field component of the HDF assessment. The collected HDF site assessment data has been used to determine a management classification for every reach as per the TRCA/CVC 2014 protocols. **Appendix G-4** includes a Table detailing the evaluation and classification of HDFs within the study area, with two columns for classification/management. One column displays the results of the HDFA per the CVC/TRCA protocols, and the next "final management" column which which will the recommended classification and management strategy by the SWS Team through Phases 2 and 3, where the recommended classification differs from that established per the CVC/TRCA guidelines based on site-specific nuances or modifiers as observed by the SWS Team. At present, this final management column has been populated with preliminary indications to note where further study is required to determine an appropriate classification and/or management recommendation. For the Phase 1 report, the HDF assessment and resultant classifications are intended for feature characterization only, and are not intended for feature management. Where it is known that future study or further evaluations are required following the Subwatershed Study, efforts have been made to identify these sites in Table G-4 in Appendix G, further discussion is provided in Section 3.6.3.3, below.

Monitoring

A monitoring program was initiated a part of this study. At two of the three newly established detailed geomorphic field sites surveyed (SC1(2) and TM4(6)1-1), one top of banks control cross-section was permanently installed in order to monitor future changes in morphology. The control cross-section typically represents a 'riffle' location within the reach when riffle-pool morphology is observed, and on a 'run' location in reaches without riffle-pool morphology.

3.6.3.3 Fluvial Geomorphology Analysis

Historical Assessment

In 1934, the Study Area was dominated by agricultural land use with associated rural residential dwellings. Occasional woodlots and sparsely treed hedgerows provided limited riparian buffer along some watercourse and HDF reaches. Most of the major roads present today were already established in 1934, but denser housing associated with the Town of Smithville was concentrated only along RR20 and Griffin Street / Canborough Street. Generally, channel planforms in 1934 closely match existing alignments however some minor increases in sinuosity was evident particularly within unconfined reached of the upper subwatersheds. Additional observations from the 1934 photo include:

- Twenty Mile Creek appears to have been wider than present near the west end of the current Study Area
- Floodplain scars of abandoned channels are visible on the north side of Twenty Mile Creek west of Griffin Street, and south of the creek near the intersection of RR20 and Townline Road.
- Many stretches of North Creek adjacent to and downstream of the study area did not have any riparian tree cover.
- Many of the larger HDFs still present today were visible in the 1934 air photo.
- Reach SC1(5) flowed north of its present planform from what is now Industrial Park Road.

By 1965, suburban housing within Smithville had expanded, but lands within the Study Area remained agricultural. A narrow woody riparian butter strip had become better established and more extensive along the main stem of Twenty Mile Creek.

- Floodplain grading or infilling may have taken place west of Griffin Street, as the floodplain scar north of Twenty Mile Creek is no longer observed.
- The Griffin Street bridge at Twenty Mile Creek also appears to have been widened.
- North Creek upstream of South Grimsby Road 6 was more visibly backwatered than in the 1934 photo.
- North Creek east of Port Davidson road (reach NC5) was straightened over a distance of approximately 200m, resulting in some loss of channel length.
- Alteration of the crossing of North Creek at Paterson Road appears to have been in progress.
- Many HDFs had been dredged but maintained the same overall planform as observed in 1934.
- Riparian tree cover along TM4(2)4 and TM4(2)4-1 east of South Grimsby Road 6 was lost due to clearing of a woodlot.
- Riparian tree cover along the main stem of Spring Creek and its tributaries appears to have matured or filled in since 1934 in areas.

Urban expansion within the Town of Smithville continued through 1989 to 2018, but the character of the Study Area remains predominantly agricultural to date.

- By 1989, the track southwest of the intersection of Station Street and Young Street had been constructed, impacting HDF reaches in that area.
- Between 1965 and 1989, a large meander along reach NC1 had been cut off, possibly due to channel realignment associated with road straightening at Sixteen Road. As well, the crossing of North Creek at Shurie Road (NC3) was moved to the north, and the channel was straightened near the roadway.
- By 1989, riparian cover along HDFs NC5(3)4-1, NC5(3)5 and NC5(3)6 north of Townline Road at Tober Road was lost due to partial clearing of a woodlot. As well, the public park land at Townline Road and South Grimsby Road 6 had been established.
- A large SWM facility had been constructed near the southeast corner of the Study Area by 1989.
- Between 2006 and 2010, a rail crossing of Twenty Mile Creek east of Griffin Street appears to have been removed.
- Between 1965 and 1989, vegetation cover was altered around reach TM3(1)1 and TM3(1)2 in the area that is now Rock Creek Park.

Over the period of historical record, confined reaches and their associated riparian (valley) extents have generally remained untouched. Much of the alteration to smaller tributaries and HDFs appear to have occurred before the start of the photographic record. Bank erosion at minor tributaries such as Reach TM4(6)1-1 has led to a reintroduction of small-scale sinuosity over time. The majority of HDFs are also visible over the course of historical record, however the influence of agricultural practices (i.e., ploughing and cultivation) as well as the likely influence of seasonal variation in the amount of rainfall and snowmelt experienced means that some features are not always visible.

Historical photos of the study area are presented in **Appendix G-1**.

Erosion Hazard Delineation

Table 3.6.2 and **Table 3.6.3** details the results of the erosion hazard assessment and **Drawing FG-2** present erosion hazard limits and the accompanying regulatory setbacks that are applicable to the Study Area. Due to the limited meander migration observed in the historic aerial photos, a factor of safety was calculated (10% of the meander belt width on either side of the channel) in lieu of calculating the 100-year migration rate. A 6m erosion access allowance was added to both sides of the belt width for unconfined watercourse reaches, as per MNRF guidelines. For confined settings 7.5 m setback has been applied to the erosion hazard limit, including the factor of safety/toe-erosion limit, the total extent of which is regulated by NPCA.

On mainstem reaches of North Creek some minor migration was observed during the period reviewed, however these adjustments were typically too small to measure. Adjustments included slight widening at bends and/or downstream migration. In reaches or portions of reaches where the natural planform had been modified, such as local realignments at road crossings, meander belt widths were extended from adjacent unmodified areas. In many areas, North Creek flows through low-lying wetland areas. Tributaries to North Creek were unconfined. Where there was no evidence of the natural planform, meander belt widths were extended from adjacent meandering reaches.

Meander belt limit was delineated on Spring Creek; however it is noted that these reaches are located near the headwaters of the watercourse. Observations made during the site visit indicated that the channel is typically poorly defined (refer to results for **Rapid Assessments**). Meander migration due to bank erosion may be less prevalent in these reaches. Nevertheless, the delineated belt width provides space for lateral expression (such as split flow, relocation of the low flow channel around organic debris, etc.) as well as providing room for modified reaches to adjust back to a more natural condition.

On mainstem reaches of Twenty Mile Creek there was very little evidence of active migration during the period reviewed. The watercourse planform is fixed to a certain degree by its valley, whose essential form has been in place since the beginning of the Holocene as noted by Tinkler (1999). Tributaries to Twenty Mile Creek were typically unconfined and varied in planform from straight to meandering. Where there was no evidence of the natural planform, meander belt widths were extended from adjacent meandering reaches, where available. Where unavailable, a 30m minimum preliminary meander belt width was applied as per the restoration strategies outlined in the Twenty Mile Creek Watershed Plan (NPCA, 2006).

Table 3.6.2. Meander Belt Widths for Unconfined Reaches

Reach	Meander Belt Width (m)	10% Factor of Safety Either Side of Channel (10% x 2)	Meander Belt Width + FOS (m)	Preliminary Meander Belt Width (m) (including 6m erosion access allowance)
North Creek				
NC5	56	11.2	67.2	79.2
NC6	56	11.2	67.2	79.2
NC7	68	13.6	81.6	93.6
Tributaries to North Creek				
NC5(2)1	30	6	36	48
NC5(3)1	30	6	36	48
NC5(3)2	30	6	36	48
Spring Creek				
SC1(1)	60	12	72	84
SC1(2)	60	12	72	84
SC1(3)	40	8	48	60
SC1(4)	40	8	48	60
SC1(5)	40	8	48	60
Tributaries to Twenty Mile Creek				
TM3(1)1	30	6	36	48
TM3(1)2	30	6	36	48
TM3(1)3	30	6	36	48
TM4(2)2	36	7.2	43.2	55.2
TM4(2)3	36	7.2	43.2	55.2
TM4(2)4	36	7.2	43.2	55.2
TM4(5)2	30	6	36	48
TM4(6)1-1	30	6	36	48
TM4(6)1-2	30	6	36	48
TM4(6)1-3	30	6	36	48
TM4(6)2	36	7.2	43.2	55.2

Table 3.6.3. Hazard Corridor Delineations for Confined Reaches

Reach	Valley Floor Width (m)	Average Slope Height (m)	3:1 Stable Top of Slope Setback (m)	Stable Slope Setback (m)	Toe Erosion Allowance (m)	Total Hazard Corridor (m)
Twenty Mile Creek						
TM2*	100-200	3	9	7.5	5	140 – 310
TM3	80-200	4	12	7.5	5	150 – 390
TM4	50-150	5	15	7.5	5	200 - 300
Tributaries to Twenty Mile Creek						
TM4(4)1*	<10	2.5	7.5	7.5	5	35-55

*Partially confined

Field Investigations

The reach delineation and initial categorization into "watercourse" and "HDF" reaches that was completed during the desktop assessment was verified during the rapid assessment and HDF field work. Reaches that may be subject to further consideration are noted in following section.

Rapid Assessments

The study area encompasses portions of the North Creek, Spring Creek and Twenty Mile Creek subwatersheds. **Appendix G-2** presents site photographs of each watercourse reach that was evaluated as part of the rapid reach assessment. **Table 3.6.4** provides a summary of the rapid assessment scoring results and a brief reach description. A summary overview of each creek system is provided below.

Assessed Watercourses of North Creek

North Creek meanders through a predominantly agricultural setting punctuated with woodlots, wetland areas and road crossings. The mainstem channel gradually becomes partially confined as it approached the confluence with Twenty Mile Creek, and near the confluence in reach NC1, it is backwatered. Portions of the watercourse have been realigned and in these areas the channel is often wide, featureless and aggradational. In some areas the channel consists of a low flow channel within wider high flow or bankfull channel. Wide, shallow pools and vegetated bank slumps are common. Riffles were not observed on mainstem reaches, and in general bedforms are poorly developed. Banks are cohesive due to their clay content. Organic debris is frequently present in the channel, and vegetation can encroach into the channel. There was evidence of flashy flows in early spring (such as overbank deposits and debris in branches), and dry conditions in late summer (vegetation establishment). The dominant geomorphic processes affecting the stability of the channel are often aggradation or widening.

The tributary to North Creek (NC5(3)1 and NC(5)3-2) was also aggradational where assessed. This tributary is considered to be near the boundary of being a watercourse or HDF, and may be subject to further review. The tributary has a well-defined channel and is recovering sinuosity after earlier straightening in reach NC5(3)2. Bank erosion was present on outer banks, and point bars with sorted sediment was observed on inside bends.

Assessed Watercourses of Spring Creek

The assessed reaches of Spring Creek include modified reaches with limited riparian cover interspersed with forested wetland reaches. In all cases the channel is poorly defined and displayed limited evidence of geomorphic activity. Where the RGA was applicable, processes affecting the stability of the channel included aggradation.

Reaches SC1(4) and SC1(5) are considered to be near the watercourse – HDF boundary and may be subject to further review. Both reaches have been substantially modified, which limits interpretation of field data, however these reaches drain over 125 ha and convey flow from an important network of HDFs. Spring Creek within the study area west (upstream) of Industrial Park Road were categorized as HDFs.

Assessed Watercourses of Twenty Mile Creek

The mainstem reaches of Twenty Mile Creek flows through a distinct valley with variable floodplain width. Observed flows within Twenty Mile Creek were turbid and sluggish during the site visit, and turbidity partially obscured the creek bed. Wide, shallow pools are common, and riffles were not observed except in reach TM3, which is confined and may be supplied with coarse material derived from the various forms of bank protection present. Banks are often stabilized at valley contacts through the town of Smithville. Not all areas could be accessed along the watercourse within the town due to steep banks and deeper water during May site visit. The dominant geomorphic processes affecting the stability of the channel are often aggradation or widening.

Tributaries to Twenty Mile Creek within the Study Area vary in character. Upstream tributary reaches often been impacted by agriculture and are considered to be near the boundary between watercourse and HDF reaches. In these areas channels are often ditched or poorly defined, while lower tributary reaches are better defined and display meandering tendencies. Regardless of their location, the observed tributaries typically lack well-developed bedforms. Dominant processes on tributary reaches include aggradation, widening, degradation and planimetric adjustment, or are too poorly developed to apply an RGA score.

Tributary TM4(2) is located in the southwest part of the Study Area. This feature develops from a ditched watercourse (reaches TM4(2)3 and TM4(6)4) into a well-defined meandering channel in reach TM4(2)2, and from there ponds into a sinkhole. Further downstream the tributary enters a grate (TM4(2)1) and is conveyed underground to Twenty Mile Creek.

Tributary TM4(4) passes through the valley slope of Twenty Mile Creek in the western part of the Study Area. The channel is well-defined, partially confined, and has point bars and undercut banks. Upstream of this reach the feature is a plowed swale and was not considered to have the characteristics of a watercourse.

Tributary TM4(5)2 was not evaluated in the field and may be determined to be an HDF. This reach has been highlighted for further evaluation in later stages of this study.

Tributary TM4(6)1 is located in the northwest part of the Study Area. It flows west through agricultural fields (TM4(6)1-2 and TM4(6)1-3) before entering a woodlot, where it a well-defined meandering channel with extensive bank erosion (TM4(6)1-1).

Tributary TM4(6)2 flows southwest in the northwest corner of the Study Area through a forested wetland. The watercourse drains HDF reaches upstream. The channel is well-defined, meandering and has a firm sand and gravel bed and moderate bank erosion.

Table 3.6.4. Rapid Assessment Results for the Study Area

Reach	RSAT Score	RSAT Condition	RGA Score	RGA Condition	Description
North Creek – Main Branch					
NC1	29	Moderate	0.13	In Regime	Dominant process: Aggradation. Estimated width: 17m. Channel has been realigned downstream of Patterson Road. It is now overwidened and sluggish and appears to be backwatered by Twenty Mile Creek. The channel is stabilized with riprap near the crossing of Patterson Road. The planform is meandering with limited riparian vegetation.
NC2	25	Moderate	0.18	In Regime	Dominant process: Widening and Aggradation. Estimated width: 8-12m. Channel is partially confined, generally stable except at valley contacts. Considerable vegetation grows in the channel, including trees, reeds, grasses and shrubs. Bed composed of silt with some cobble. Riparian buffer strip varies in width.
NC3	26	Moderate	0.18	In Regime	Dominant process: Widening and Aggradation. Estimated width: 15m. Straightened channel with meadow / tall grass riparian vegetation. Banks are typically stable with local erosion present on outer banks of bends. Turbid water with willow shrubs growing in the channel. Rail crossing at upstream reach extent.
NC4	30	Moderate	0.25	Transitional	Dominant process: Widening. Estimated width: 11-15m. Width varies, narrowing where locally confined and widening within the wetland area approaching rail crossing near downstream reach extent. Meandering reach, patches of riparian forest. Silt/clay bed with some gravel and cobble. Bed covered in black organic deposits. Pools were observed, but no riffles. Moderate woody debris. Muskrat holes observed on bank.

Reach	RSAT Score	RSAT Condition	RGA Score	RGA Condition	Description
NC5	23	Moderate	0.28	Transitional	Dominant process: Widening. Estimated width: 10-12. Meandering reach with local straightening in the vicinity of Port Davidson Road. In this area it is difficult to the distinguish bankfull channel: low flow channel is developing within widened corridor. Vegetated bank slumps common, evidence of high flows (grass and debris caught in branches where trees present). Bed composed of compact clay, in areas deep silt deposits present. Riparian vegetation generally grassy, little tree cover.
NC6	26	Moderate	0.21	Transitional	Dominant process: Widening and Aggradation. Estimated width: 12-14m. Upstream reach break occurs within a wetland area at the confluence with a small tributary from the south. The planform is quite straight upstream of Tober Road. The banks densely vegetated with reeds. Some tree cover along bank tops. Wetland vegetation predominant in the upper part of the reach. Soft silty channel bed, no bedforms.
NC7	17	Low	0.31	Transitional	Dominant process: Widening and Aggradation. Estimated width: 6-10m, widening downstream. Meandering. Passes through Township lands. Local widening near the outlet of the Smithville Road crossing. Limited riparian vegetation including mown grass, tall grasses and shrubs. Bank slumps frequent in mown areas. Overbank sand and gravel deposits. Downstream reach break occurs at confluence with tributary from southwest. Clay - silt bed with some gravel, some vegetation established in channel.
North Creek - Tributaries					
NC5(2)1	-	-	-	-	No site access.
NC5(3)1	-	-	-	-	No site access.

Reach	RSAT Score	RSAT Condition	RGA Score	RGA Condition	Description
NC5(3)2	23	Moderate	0.17	In Regime	Dominant process: Aggradation. Bankfull width: 2.2m. Straightened watercourse which is developing some sinuosity. The reach lacks a riparian buffer apart from a narrow swath of grass on east bank. Considerable input of fines from adjacent ploughed field, however some sediment sorting is still taking place. Banks are gentle to near vertical. No bedforms have developed. Feature was classified as an HDF upstream of this reach.
Twenty Mile Creek					
TM1	31	Moderate	0.21	Transitional	Dominant process: Widening and aggradation. Estimated width: 25-30m. Meandering main stem channel well connected to developed floodplain. Downstream reach break at confluence with North Creek. Sluggish turbid flow in May 2020. Sandy substrate with occasional cobble, sand deposits on floodplain. Forested riparian buffer among fields. Some emergent vegetation and in-channel willows. Widening observed at crossings. Poorly developed bed morphology (where visible). A beaver was observed in the creek.
TM2	30	Moderate	0.21	Transitional	Dominant process: Widening and aggradation. Estimated width: 20-25m. Partially confined reach with generally straight planform. Very limited riparian vegetation: occasional tree cover along top of banks, agricultural land on floodplain. Turbid flow in May 2020. Poorly developed bed morphology. Site access limited due to road construction.
TM3	32	Moderate	0.35	Transitional	Dominant process: Widening. Estimated width: 15m with locally wider areas. Confined meandering reach, valley opens and becomes less distinct near downstream reach break. Flow through central Smithville. Channel is narrower due to confinement.

Reach	RSAT Score	RSAT Condition	RGA Score	RGA Condition	Description
					Less evidence of aggradation on channel bed where visible; confinement prevents overwidening and may promote the flushing of fines. Patches of bank protection common throughout reach, varying in type and condition by property (riprap, boulders, concrete). Coarse material (likely sourced from banks) forms occasional riffles. Multiple stormwater outfalls are found on the banks near Griffin Street bridge. Minor emergent vegetation and grassy bank slumps observed. Portions of creek not accessible to due steep banks and/or deep water.
TM4	28	Moderate	0.22	Transitional	Dominant process: Widening. Estimated width: 20-30m. Confined reach within a wider valley. Planform characterized by large-scale meanders. Low energy reach characterized by in-channel vegetation and live in-stream trees, woody debris, a wide channel, and sluggish turbid flow in May 2020. Thin buffer of riparian forest and lawn along banks. Pipe passes through creek bed near pedestrian bridge. Reach extends through the western portion of the Study Area.
Twenty Mile Creek - Tributaries					
TM3(1)1	27	Moderate	0.09	In Regime	Dominant process: Widening. Channel width: 4m. Forested unconfined reach, outlets to Twenty Mile Creek. Runs near former railway embankment. Slightly entrenched, moderate slope and swifter flows as observed in May 2020. Firm gravel-cobble bed. Exposed tree roots, woody debris, steep banks and occasional bank erosion observed.
TM3(1)2	18	Low	0.11	In Regime	Dominant process: Aggradation with widening. Channel width: 2-4m. Unconfined reach located in Rock Park. Typically reed-choked, with a silty bed. Channel varies from poorly defined swampy

Reach	RSAT Score	RSAT Condition	RGA Score	RGA Condition	Description
					depression to well-defined. 300mm park crossing is stable. Mown lawn extends to bank tops, occasional shrubs and trees.
TM3(1)3	19	Low	N/A	N/A	Dominant process: N/A. Channel width: 1.5-2m, channel has been ditched. Straight unconfined reach running south of Townline Road. 950mm CSP at road is stable, protected with riprap. Densely vegetated with grass. Landowner adjacent to reach noted considerable flows occur in early Spring and back up at the culvert. Feature is an HDF upstream. RGA not applicable.
TM4(2)1	16	Low	0.29	Transitional	Dominant process: Widening and degradation. Channel width: 3.5m. Reach extends from sinkhole upstream, through a park and into a sewer grate which outlets to Twenty Mile Creek. Reach transitions from poorly defined with a grassy bed near upstream reach break, to an incised defined channel downstream (downstream of SWM pond input) with both banks eroding, grassy slumps. Channel is fenced off downstream of SWM pond. Bulrushes present. Failing gabion basket and riprap at downstream grate.
TM4(2)2	25	Moderate	0.32	Transitional	Dominant process: Planimetric Adjustment and Widening. Bankfull width: 3m. Meandering reach with a well-defined channel and forested riparian zone. Undercut and eroding banks common, channel moderately entrenched. Some chutes and split flow present. Substrate is fine grained with silty point bar deposits. Enters pond at downstream reach break and flows underground into a sinkhole.
TM4(2)3	17	Low	0.09	In Regime	Dominant process: Aggradation. Channel width: 2.5m. Historically straightened reach developing mild sinuosity. Watercourse flows along the margin of a

Reach	RSAT Score	RSAT Condition	RGA Score	RGA Condition	Description
					farm field, with scrub and meadow vegetation on the south bank and tilled land to the north. No bedforms, loose silty bed with algae, moderately defined banks. There has been a wash out around an old farm crossing at the downstream extent of the reach.
TM4(2)4	15	Low	0.13	In Regime	Dominant process: Aggradation. Channel width: 2.5m. Severely straight planform and poorly defined banks. Watercourse flows along the margin of a farm field, with scrub and meadow vegetation on the south bank and tilled land to the north. No bedforms, loose silty bed with algae. Considerable input of fine sediment from adjacent field.
TM4(4)1	24	Moderate	0.31	Transitional	Dominant process: Widening and Degradation. Channel width: 2m. Sinuous channel traversing the Twenty Mile Creek valley slope. Channel is increasingly incised upstream. Moderate gradient, undercut banks on outer bends, point bars present. Rill and gully input. Angular gravel in deposits possibly transported from roadway upstream. Pools in general not well-defined but present. Upstream of this reach, feature defined as HDF.
TM4(5)1	-	-	-	-	No site access
TM4(5)2	-	-	-	-	Unevaluated, partial site access
TM4(6)1	-	-	-	-	No site access

Detailed Assessments

Based on the results of the rapid geomorphic assessments, three detailed geomorphic field sites were established within or downstream of the Study Area. Results of the detailed field investigation can be used to characterize pre-development flow conditions, and to establish targets for stormwater management that may be required under future development scenarios.

Selection of the detailed sites focused on selecting an appropriate reach based on existing instability (sensitivity to land use change), representative spatial distribution, and extent of channel alteration. Reaches that are located further downstream, or reaches having a greater drainage area, are more frequently selected as they are more likely to be impacted by land use changes. Two of the selected sites were located on mainstem reaches of North Creek and Spring Creek downstream of the Study Area. However, the main stem of Twenty Mile Creek was considered to have too large a drainage area to sustain a measurable impact by potential changes in land use within the study area. As such, a site was not established on Twenty Mile Creek. Instead, following review of the drainage network and rapid field assessments results, a site was established on a smaller tributary to Twenty Mile Creek which was determined to be sensitive to erosion.

Channel alteration is also considered; unaltered reaches are preferred as they offer a more accurate depiction of channel processes under existing conditions. However, as established in earlier studies in the region (Aquafor Beech, 2018) and confirmed during the rapid site assessment, channels with drainage areas of less than 10km^2 in the region have typically been modified. In practice all three selected study reaches had undergone some form of previous modification and were in different stages of subsequent adjustment.

The detailed field assessments were completed on August 20 and 26, 2020 on reaches TM4(6(1-1), a tributary to Twenty Mile Creek, SC1(2) and NC5. Five to ten channel cross-sections were surveyed at each study reach along with a total station survey of the channel profile, which provides a measure of the local energy gradient and bed morphology. The three study reaches each had fairly uniform channel dimensions, and none had well-developed pool or riffle morphology. Where possible, bankfull dimensions were identified using known field indicators, such as changes in vegetation and inflection points in the bank profiles. The 'bankfull' channel area generally represents the maximum capacity of the channel before it spills onto the floodplain. The bankfull stage at reach TM4(6)1-1 was identifiable using typical indicators. However, channel alteration and in-channel vegetation at NC5 and SC(1)2 made it difficult to determine the 'bankfull' elevation in these reaches. All three watercourses are intermittent or ephemeral and all were dry at the time of the sit visit.

Bulk samples were collected at each site (1 sample per reach) and grain size analyses (including hydrometer) were completed to characterize the channel bed substrate materials. Laboratory grain size analyses were more appropriate than Wolman pebble counts to characterize the typically fine-grained channel substrate within the study area.

Geomorphic field conditions for the study reaches are presented in **Table 3.6.5**. Bankfull flow estimates based on the most representative measured cross-sections are provided in **Table 3.6.6**.

Reach NC5

North Creek through the study reach is a vegetation-dominated channel with an intermittent to ephemeral flow regime. The watercourse has a straight planform throught this reach, and appears to have been previously altered. There is no easily identifiable bankfull channel; the creek is instead comprised of a low flow channel within a wider corridor or high flow channel. The low flow channel is approximately two metres wide and is defined by slumping vegetated banks. The high flow channel is generally well-vegetated with grasses and is typically stable. For the purposes of this analysis the high flow channel was used as a proxy of the bankfull channel, but it has not been confirmed how frequently the channel overtops. The calculated channel characteristics in Table 3.6.6 should be considered rough estimates only, and may not correspond to a 2-year or 1.5-year flow. The channel has mixed substrate which includes predominently clay (21.5%), silt (10.8%), sand (30.5%) and gravel (37.3%). The erodibility of this channel is controlled by the cohesive clay substrate, the gravel fraction, the resistance of vegetation and the channel slope, which is extremely low (estimated 0.08%). Due to the vegetation in the channel, a roughness value of 0.04 was used.

The channel was 10.8 m to 11.8 m wide and 1.1 m to 1.3 m deep on average, and ranged up to 16.0 m wide and 1.5 m deep at a pool. Bankfull discharge within the representative run-type cross-sections was 1.59 m^3/s to 3.99 m^3/s (at 0.08% slope and n = 0.04). At the bankfull flow, the channel produces velocities of 0.38 m/s to 0.51 m/s and shear stresses of 3.13 N/m^2 and 4.78 N/m^2.

Figure 3.6.1. NC5 in August, 2020

Reach SC1(2)

SC1(2) is an ephemeral creek which has been previously straightened. While channel banks were discernable, the channel is more representative of a low flow channel rather than a bankfull channel, and banktops may represent an excavation limit. The channel runs through a wide grassy floodplain within the reach, and through forested wetland reaches upstream and downstream of SC1(2). The channel bed was composed of compact clay (51.1%) and silt (47.5%), and was densely vegetated with grasses and reeds at the time of the site visit. The slope is low (0.14%). Morphlogical controls include vegetation, the low slope, and clay content of the substrate which provide cohesion. The estimated roughness coefficient (Manning's N) was high (N = 0.07) due to the density of the vegetation in the channel.

The channel was 3.8 m wide and 0.3 m deep on average, and ranged up to 4.0 m wide and 0.5 m deep at a pool. Bankfull discharge within the representative run-type cross-sections was 0.12 m^3/s (at 0.14% slope and n = 0.07). At the bankfull flow, the channel produces velocities of 0.16 m/s and shear stresses of 2.14 N/m^2.

Figure 3.6.2. SC1(2) in August, 2020

Reach TM4(11-1)

This channel was well-defined and a bankfull stage was identifiable, although the bankfull channel may not correspond to the 2-year flow. The channel bed was composed of compact clay based on a visual inspection. A small amount of scattered gravels and occasional cobble was present intermittently throughout the reach. This material was not embedded into the clay and covered only a small portion of the creek bed where present. As such it was not included in the bulk sample for grain size analysis as it did not appear to contribute to channel stability. The grain size distribution indicates that the bed material is composed predominantly of clay (48.5%) and silt (31.9%) with smaller components of fine, medium and coarse sand, and less than 1% gravel (diameter >4.75mm). The channel did not have well-developed riffle and pool morphology. The bulk sample was taken from a cross-section with run-type morphology. Tree, shrub and grass roots provide some bank cohesion, and little vegetation is present within the channel. The cohesive clay-silt substrate is a controlling factor on critical thresholds in this reach.

The channel was 2.2 m to 3.0 m wide and 0.43 m to 0.53 m deep on average, and ranged up to 4.8 m wide and 0.6 m deep at a pool. Bankfull discharge within the representative run-type cross-sections was 0.57 m^3/s to 1.31 m^3/s (at 0.96% slope and n = 0.035). At the bankfull flow, the channel produces velocities of 0.92 m/s to 1.28 m/s and shear stresses of 17.86 N/m^2 and 28.94 N/m^2.

Figure 3.6.3. TM4(6)1-1 in April, 2020

Figure 3.6.4. TM4(6)1-1 in August, 2020

Table 3.6.5. Channel Characteristics for the Detailed Geomorphic Field Sites

Parameter	NC5	SC1(2)	TM4(6)1-1
Representative Channel Width (m)	10.8-11.8	3.8	2.2-3.0
Maximum Channel Width (m)	16.0	4.0	4.8
Representative Channel Depth (m)	1.1-1.3	0.3	0.43-0.54
Maximum Channel Depth (m)	1.5	0.5	0.6
Channel Width: Depth	9.1 – 9.8	12.7	5.1 – 5.5
Cross sectional Area (m^2)	6.71 - 7.86	0.77	0.62 – 1.03
Wetted Perimeter (m)	13.10 – 12.92	4.96	3.22 – 3.35
Hydraulic Radius (m)	0.40 - 0.61	0.16	0.19 - 0.31
D_{50} (mm)	2	<1	<1
Bed material	Clay, silt, sand and gravel	Clay and silt	Clay, silt and sand
Bank material	Clay soil, densely vegetated	Clay soil, densely vegetated	Clay soil, moderate vegetation density

Table 3.6.6. Bankfull Hydraulics for the Detailed Geomorphic Field Sites

Parameter	NC5	SC1(2)	TM4(6)1-1
Bankfull or 'Channelfull' Discharge (m^3/s)	1.59 – 3.99	0.12	0.57 - 1.31
Estimated Gradient (m/m)1	0.0008	0.0014	0.0096
Bankfull Velocity (m/s)	0.38 – 0.51	0.16	0.92 - 1.28
Stream Power (W/m)	12.53 – 31.33	1.65	53.24 - 123.57
Stream Power per unit Width (W/m^2)	1.26 – 2.65	0.34	18.06 - 41.81
Shear Stress (N/m^2)	3.13 – 4.78	2.14	17.86 - 28.94

[1]Values from DEM

Erosion Threshold Analysis

Data from the detailed field assessment is used to complete the erosion threshold analysis. This analysis determines the hydraulics (discharge, channel depth, average channel velocity) at which the channel produces sufficient shear stress to initiate mobilization of a representative particle size (D_{crit}), i.e., the 'threshold' condition at which sediment will start to mobilize typically the median grain size, or an equivalent force to erode cohesive or vegetation bound materials. It is then assumed that if this 'threshold' flow is sustained, erosion will eventually occur. Therefore, the flow is referred to as the 'erosion threshold'.

Several different established entrainment relationships are used to calculate the critical shear stress or velocity for each detailed field site. Once these values are established, an iterative approach using existing channel conditions is applied to evaluate the critical discharge, or erosion threshold. The erosion thresholds are determined by modelling a "dry" channel and increasing water levels in small increments (1 mm) until the average velocities or shear stresses exceed the critical values defined. The discharge under which the critical values are generated within each cross-section defines the critical discharge of the transect. Cross-sections that were considered the most representative of the reach were selected for use in the analysis.

Selection of the appropriate threshold is also based on an understanding of site conditions and the assumptions and ranges of conditions under which the entrainment equations are applicable. The goal of the erosion threshold analysis is to determine a threshold discharge for various reaches above which a critical fraction of the boundary materials is entrained. Where changes are to occur to the contributing drainage area of a channel, a typical objective is to ensure that the future hydrological conditions do not result in channel flow exceeding the threshold discharge more frequently than with existing conditions. This is done to minimize potential post-development channel impacts such as erosion or degradation.

For each study reach, a critical shear stress value was determined based on the Chow (1959) relation for cohesive material and based on permissible thresholds for vegetated channels as determined by Fischensich (2001). The Shields equation modified by Miller (1977) was also used as a reference for critical thresholds at reach NC5, as substrate at this site included a considerable fraction of non-cohesive coarse material. The recommended critical discharge values represent approximately one third of the bankfull or channel-full flow at sites NC5 and TM4(6)1-1, and three times the channel-full flow at reach SC1(2). The SC1(2) channel is a well-vegetated, stable low flow channel rather than a bankfull channel, and where unaltered the system tends to behave like a wetland. In such a system it is not unreasonable that the critical discharge rate would be greater than the channel discharge as it does not function as a conventional alluvial channel that is morphologically shaped to its annual or 2-year flood events. The actual critical discharge values for both SC1(2) and NC5 are likely greater than those presented in **Table 3.6.7** due to the significant role of vegetation in stabilizing both watercourses. As described in Tinkler (1999), vegetation may be particularly resistant in these watercourses because it can grow vigorously during the months when the channels are dry.

Table 3.6.7. Threshold Characteristics Estimated for the Detailed Geomorphic Field Sites

Parameter	NC5	SC1(2)	TM4(6)1-1
Bankfull Channel Geometry			
Channel Width (m)*[1]	10.8-11.8	3.8	2.2-3.0
Channel Depth (m)*[1]	1.1-1.3	0.3	0.43-0.54
Gradient (m/m)[2]	0.0008	0.0014	0.0096
Bed Material			
D_{50} (mm)	2	<1	<1
D_{84} (mm)	17	<1	<1
Manning's 'n'	0.04	0.07	0.035
Bankfull Channel Hydraulics			
Channel Discharge (m^3/s)	1.59 – 3.99	0.12	0.57 - 1.31
Channel Velocity (m/s)	0.38 – 0.51	0.16	0.92 - 1.28
Average Shear Stress (N/m^2)	3.13 – 4.78	2.14	17.86 - 28.94
Thresholds			
Recommended Critical Discharge (m^3/s)	0.472	0.385	0.159
Percent of Channel Discharge (%)	30 – 12	320	28 – 12
Critical Velocity (m/s)	0.28	0.22	0.71
Critical Shear Stress (N/m^2)	2	3.5	12
Critical Flow Depth (m)	0.54	0.47	0.22
Sources	Fischenich Permissible Shear Stress: Alluvial Silt = 2.2 N/m^2 Shields modified by Miller (1997): D50 (2.2mm) = 1.6 N/m^2 Chow (1959): Loose clay soil = 2.8 N/m^2	Fischenich Permissible Shear Stress: Firm Loam = 3.6 N/m^2 Chow (1959): Fairly compact clay soil = 3.4 N/m^2	Fischenich Permissible Shear Stress: Alluvial colloidal silt = 12.4 N/m^2 Fischenich Permissible Shear Stress: Stiff clay = 12.4 N/m^2 Chow (1959): Compact clay soil = 12.0 N/m^2

*Channel dimensions of selected representative cross sections
[1]Values based on detailed topographic survey
[2]Values from DEM

Headwater Drainage Feature Assessments

Headwater Drainage Features have been assessed with management classifications determined in accordance with TRCA/CVC (2014) guidelines and a historic classification and evaluation methodology developed for earlier subwatershed studies in Halton Region that was collaboratively reviewed and agreed to with Conservation Halton and Halton Region, as well as area landowners (ref. **Section 4.2.7** for discussion). The modified evaluation approach for the subwatershed study first applies the guidelines set by TRCA/CVC (2014) to determine a feature classification ("**HDFA Classification**"), which, through SWS

Phases 2 and 3, may then be carried forward to "**Final Management**" or altered based on site opportunities, or other constraints that the protocol may not capture (e.g. feature protection based on location within a significant valley or terrestrial feature). **Drawing FG-4** illustrates reach specific **HDFA Classification** for headwater features within the Study Area, and **Appendix FG-4** presents the evaluation and classifications (characterization) for these features.

Protection

Headwater reaches with the 'protection' designation offer important functions to both the upstream and downstream connected reaches as well as to the surrounding environment. Typically, headwater reaches of this nature can exhibit: perennial drainage through seeps or springs, have woody riparian cover, offer permanent fish habitat, offer amphibian breeding habitat and or provide habitat to SAR. Under the recommended 'protection' management

practices, these reaches must be protected and/or enhanced in-situ. Channel adjustments may be permitted at select locations given sufficient rationale, and as approved by Regulatory Agencies. For these reaches, the hydroperiod must be maintained, and use of natural channel design or LID techniques can be used to incorporate additional shallow groundwater and base flow protection as well as restore and enhance existing habitat features although not realignments can be performed. Future SWM systems are to be designed and located to avoid impacts to both sediment and temperatures to protection features.

Conservation

Headwater features with the 'conservation' designation offer valued functions to both the upstream and downstream connected reaches as well as to the surrounding environment. Typically, headwater reaches of this nature can exhibit: seasonal fish habitat with woody riparian cover, and/or amphibian breeding habitat. For these reaches, the feature must be maintained within its riparian zone corridor however relocations are allowed through the use of natural channel/corridor design principles and techniques such that the overall productivity of the reach is maintained or enhanced. Also, if a terrestrial linkage is present, this linkage must be maintained as a part of the realignment unless alternate linkages exist and have been assessed. Flows both on-site and external must be maintained or replaced and the feature must connect downstream. If any segment of the reach has been previously removed or will be removed; all lost functions must be restored through lot level controls.

In the current study, there are several instances where an HDF connects to small wetlands that may require further ecological and/or hydrological study to provide a complete and accurate HDF classification. In these instances, 'conservation' has been proposed for a "Final Management" recommendation in Phases 2 and 3, pending further investigations at the MESP stage or later, and are identified in Table G-4 of Appendix G. However, the current HDF classification rather than the final management recommendation is presented in the Phase 1 report for the characterization of existing conditions for these HDFs.

Mitigation

Headwater features with the 'mitigation' designation offer contributing functions to both the upstream and downstream connected reaches as well as to the surrounding environment. Typically, headwater reaches of this nature can exhibit: meadow vegetation within riparian corridor and contributing (i.e., sediment and nutrient transport through feature) fish habitat. For these reaches functions have to be replicated or enhances through lot level conveyance measures (i.e., vegetated swales, LID). Flows through the feature should initiate at the upstream extent in order to maintain functions and if any segment of the reach has been previously removed or will be removed; all lost functions must be restored.

No Management Required

Headwater features with the ‘no management required’ designation offer limited functions to both the upstream and downstream connected reaches as well as to the surrounding environment. Typically, features receiving this recommendation have no/or minimal flow, are within cropped land that is annually ploughed and cultivates with no riparian vegetation and do not offer fish or amphibian habitat. Within the Study Area, these reaches are designated as a result of a lack of observed flow during the first visit. These features were originally identified during the desktop assessment phase and field verified to confirm that no feature and/or functions associated with a headwater drainage feature are present on the ground. No management recommendations are required.

It is noted that the TRCA/CVC (2014) guidelines do not provide guidance on management of karst features associated with HDFs. The presence of karst throughout the region is an important element to consider in the development of HDFs and watercourse management recommendations. The absence of discussion on regionally specific features such as karst highlight that the TRCA/CVC (2014) document is only a guideline which must be interpreted in the context of each study area to which it is applied.

For watercourse and HDF characterization, the results presented in this report have been be approved in collaboration with the TAC. . Each feature that are understood to require further analysis (i.e. HDF assessments, karst, or ecological studies) have been identified in the tables in **Appendix G-3 and Appendix G-4,** and in **Drawings FG-3 and FG-4**.

Sediment Budget

Areas of erosion and deposition were identified during the field assessment program (reach walks and detailed characterization). In general, main stem watercourse reaches were quite stable, and no sites of excessive erosion were observed. Non-point source erosion is more prevalent within the Study Area due to actve farming in headwater areas.

The study area can be characterized by three typical areas of sediment erosion. The first area is along HDF features, particularly features that are seasonally ploughed and where vegetation has not developed. Erosion in headwater areas was the most widespread type of erosion observed within the Study Area. The types of erosion observed along HDFs was typically sheet flow and rill erosion. These features provide a source of fine-grained (clay and silt) to receiving watercourses. This fine-grained material is generally very mobile, and once in the system will be carried easily downstream as part of the wash load. During HDF assessment site visits, flow within these features was frequently turbid, indicating that material was being transported downstream. The slope of the fields where the HDFs are located likely has a direct effect on the volume of sediment contributed to the watershed, with higher slopes likely to contribute a higher volume of sediment than lesser slopes. As well, management practices such as ploughing and seeding cover crops may also affect the amount of sediment contributed.

The second area of sediment erosion identified is along the upper reaches of North Creek and along several tributaries to North Creek and Twenty Mile Creek that display active meandering processes within an unconfined floodplain. In the upper reaches of each tributary there is also a lack of floodplain vegetation to help stabilize channel banks from fluvial erosion. Bank erosion in Tributaries TM4(6)1-1, TM4(6)2, TM4(2)2 and NC5(3) contributes primarily fine-grained material into the subwatershed. Bank erosion within these systems was typically within a normal range of geomorphic adjustment for meandering systems, and no areas of excessive erosion were observed.

The third area of sediment erosion identified where the watercourse contacts the valley walls within the lower confined reaches of the Twenty Mile Creek and North Creek. While the available erodible material in the overburden is primarily glaciolacustrine silt and clay, bedrock outcrops occur along portions of Twenty Mile Creek which may contribute coarse grain particles into the system. It is noted that most valley contacts on Twenty Mile Creek that were observed within the urban boundaries of Smithville have been stabilized with various forms of bank protection.

Silt deposits were noted throughout many watercourse and HDF reaches, but were notably present at breaks in slope where features encounter flatter areas such as wetlands. One of the dominant geomorphc processes within surveyed watercourse reaches was aggradation. Farming in the watershed has likely increased the sediment load to the watercourses over time. Tinkler (1999) noted that fine-grained sediment limits bar-building, and the lack of coarse material has limited morphological channel adjustment.

3.6.4 Interpretation and Findings

Historical Assessment

The historical assessment indicated that lateral channel migration has been fairly limited since 1934. This corresponds with findings of the field assessment which found that mainstem watercourses appear to have low stream power throughout of the year (with occasional flashy flows) and are often aggradational.

While many reaches have been historically altered, much of this alteration (outside of dredging and maintenance) appears to have been generally unchanged through period of photographs reviewed. Local alterations occurred where crossings were altered or removed. Some grading and offline SWM pond works have also occurred on the Twenty Mile Creek floodplain in areas adjacent to the Study Area. Local changes also occurred with respect to riparian cover. Generally, riparian cover is poor through the Town and the Study Area, however some improvement has occurred along mainstem watercourses, while vegetative cover near HDFs has remained poor or worsened. Changes in riparian vegetation may play an important role in channel form and stability within the Study Area because of the relatively low stream power.

Meander Belt and Erosion Hazard Corridor Assessment

The study area contains unconfined (meander migration is not restricted by valley slopes), partially confined (valley slopes restrict migration in some parts of the reach) and confined reaches (valley slope restrict migration throughout the reach). Meander belts were assessed on all reaches that were categorized as watercourses within the Study Area and in adjacent areas where belt widths may intersect the Study Area. The erosion hazard setbacks associated with the Twenty Mile Creek valley intersects the west and southeast parts of the Study Area. The meander belt limits of several reaches of North Creek intersect the southwest limit of the Study Area. These reaches are unconfined. Due to limited channel migration along those reaches a factor of safety was calculated (10% of the meander belt width on either side of the channel) in lieu of calculating the 100-year migration rate. A similar approach was applied to delineate meander belt limits along watercourse reaches of Spring Creek. These intersect the easternmost limits of the Study Area. It is noted that meander migration is likely limited in Spring Creek, as it is a poorly defined, low energy system, however meander belt provides space for lateral expression and room for modified reaches to adjust back to a more natural condition.

Rapid Assessments

The Rapid Assessment of watercourses within the Study Area characterized dominant geomoprhic processes and evidence of instability. While local bank erosion occur throughout the study area, no areas of excessive erosion were observed. Mainstem reaches of Twenty Mile Creek are generally considered stressed/transitional indicating that channel morphology is within the range of variance of streams of similar hydrographic character but that evidence of instability exists. Spring Creek reaches were in regime, or were not suitable for rapid geomorphic assessment, and North Creek reaches varied from stressed / transitional to in regime. Dominant processes affecting the stability of the channel are typically aggradation and widening.

No watercourses within the study area have consistent year round flow. The majority of mainstem watercourses are intermittent and do not support connected flow in the late summer, but may have disconnected pools, as observed on North Creek in August, 2020. Tributary watercourses are similarly intermittent to ephemeral, with flow occurring only in early spring in some reaches. Depending on the drainage area, tributary watercourses can either be in regime, stressed/transitional, or not suitable for rapid geomorphic assessment.

Substrate within mainstem and tributary reaches is typically fine-grained. There is in general a limited supply of coarse sediment due to the clayey overburden. Fine-grained material sourced from headwater drainage features are typically carried through the system as wash load or suspended sediment.

Erosion Thresholds

Critical shear stress values were determined for the three detailed assessment sites based on several sources including relations for cohesive material, permissible thresholds for vegetated channel and, where applicable (NC5), relations for non-cohesive substrate, in relation to observed channel substrate. The three sites were selected due to their sensitivity to erosion relative to other reaches on their respective watercourses. The recommended critical threshold values were provided to inform the exceedence analysis for the purposes of developing a stormwater management plan that does not excarbate erosion in the watercourses. The results can be considered conservative, as in-channel vegetation provides additional resistance.

Geomorphic Constraint Ranking

Geomorphic constraint rankings were assigned to watercourse reaches following the classification presented in **Section 4.2.7**. Watercourse reaches within the Study Area represent High and Medium Constraint features. These features must either be maintained in place, along

with their erosion hazard setbacks (High Constraint) or can be relocated so long as their associated erosion hazard setbacks area maintained (Medium Constraint).

All reaches of the main branch of Twenty Mile Creek are considered High Constraint. Twenty Mile Creek is the most significant watercourse and valley system within Smithville, and the watercourse has a well-developed floodplain and a defined valley.

All reaches of the main branch of North Creek are considered High Constraint. North Creek is the second most significant watercourse within Smithville. It is generally unconfined within the study area and has a well-defined floodplain. The valley is defined downstream of the study area.

Spring Creek reaches within or adjacent to the study area were assigned a preliminary Medium Constraint ranking because they have a modified planform and/or poorly defined channel and lack a defined valley.

Several tributaries located within the Study Area have been assigned a Medium Constraint ranking as they have no defined valley or developed floodplain and have been straightened, have poor-quality riparian vegetation and could benefit from rehabilitation. Several other tributary reaches were given a High geomorphic constraint ranking because they have a well-defined active channel with material sorting and floodplain development.

Note that Medium constraint watercourse reaches may be subject to realignment and therefore erosion setbacks would need to be developed accordingly. Should these reaches be relocated, the corridor width (meander belt width/erosion hazard corridor) associated with each reach must, at a minimum, be maintained.

Drawing FG-3 presents mapping of the geomorphic watercourse reach constraints. These features will be further characterized based on management recommendations **(ref. Section 4.2.7)** of other team members.

Headwater Drainage Feature (HDF) Assessment

HDFs are found predominantly in agricultural settings within the Study Area. Many HDF features extend almost to the upstream limits of the subwatersheds, and in one case features linked across subwatershed boundaries due to channelization and low relief. Previously unmapped HDFs were identified on most properties that were visited. Several HDFs identified during the desk study were reclassified as watercourses based on field observations, and were included in the Rapid Assessments. The spring of 2020 was fairly dry, without a pronounced freshet. Consequently, many features were dry or contained standing water during the early spring site visit. All of the HDFs assessed were dry by the third site assessment in August. Feature types included channelized and ditched features, swales, wetlands, naturally defined features with sorted sediment and features that were poorly defined.

Several HDF features provide linkages to provincially significant wetlands (PSWs). In addition, several HDFs appear to be seasonally fed by small wetland pockets that are found in the middle of tilled agricultural fields (such as TM4(2)3-3, TM4(2)3-1a). In general, there were more wetland connections to HDFs in the northwest and northeast parts of the Study Area, in the Twenty Mile Creek and Spring Creek subwatersheds respectively. Other HDFs appear to have been created for altered by changes in drainage patterns caused by residential development. For instance, TM4(3)1, TM4(3)2 and TM4(3)2-2 currently drain north to Twenty Mile Creek, while historic air photos indicate that the land drained to the east prior to development.

HDFs within the study area are also influenced by karst. Two sinkholes were encountered during the HDF site assessment. One sinkhole (NW 2) is located between TM4(5)1-4 and TM4(5)1-3 in the northwest part of the Study Area, which are associated with “high constraint” karst features, and may attract a higher constraint HDF management recommendation as a result.. The other is located on TM3(1)6-2 in the southeast Study Area (SE 2), which is a “low constraint” karst feature, and has no implication on the HDF classification. The HDFs associated with “high constraint”features will require additional evaluation to deterimine an appropriate management recommendations through later planning studies (i.e. MESP).

In several cases where HDFs were dry but showed evidence of recent flow, such as fresh erosion or sorted sediment, the features were classified as ‘Mitigation’ to provide a conservative recommendation for this relativley dry year in 2020. As well, HDFs located downstream of ‘Conservation’ or ‘Protection’ reaches were assigned a higher management classification to ensure linkages are protected. Table G-4 in Appendix G summarizes the HDF assessment and characterization, and mapping is included in Drawing FG-4.

3.7 Surface Water Quality

3.7.1 Importance and Purpose

The surface water quality assessment provides an indication of the aquatic health of the watercourses and tributaries with respect to contaminant loadings under existing land use conditions, and thereby provides a baseline condition which can be used to verify the performance of the recommended stormwater quality management plan, as part of subsequent phases of study and monitoring.

3.7.2 Background Information

The water quality sampling results four (4) locations have been provided for use and reference to characterize the surface water quality within the Smithville Community.

3.7.3 Methods and Analysis

Water quality monitoring has been conducted by NPCA at the Twenty Mile Creek, North Creek, and Spring Creek. The locations of the NPCA water quality monitoring stations in the proximity of the study area are presented in Drawing WR-9. Station TN003A is located upstream of the study area on Twenty Mile Creek. Station NC001 is located downstream of the study area on North Creek. Station TN004 is located on Twenty Mile Creek further downstream of the study area. Since Station SP001 on Spring Creek is not within the proximity of study area, it has been excluded from this assessment. **Table 3.7.1** summarizes the water quality stations and the corresponding periods of record.

Table 3.7.1. Summary of Water Quality Sampling Stations

Water Quality Sampling Station	Location	Watershed	Period of Record
TN003A (Ontario Provincial Water Quality Monitoring Network Station)	Highway 20	Twenty Mile Creek	2010-04 to 2019-11 (Niagara Region Lab) 2010-04 to 2016-04 (YSI 200QS) 2016-05 to 2019-12 (YSI ProDSS) 2013-10 to 2019-11 (MECP-PWQMN)
TN004	Synder Road	Twenty Mile Creek	2003-06 to 2019-11 (Niagara Region Lab) 2003-06 to 2016-04 (YSI 200QS) 2016-05 to 2019-11 (YSI ProDSS) 2015-04 to 2016-11 (Maxxam Lab) 2017-03 to 2018-11 (ALS Lab) 2019-04 to 2019-11 (Eurofins Lab)
NC001 (MOE/MECP Multi-watershed nutrient study station)	Patterson Road	North Creek	2004-06 to 2019-11 (Niagara Region Lab) 2004-06 to 2016-04 (YSI 200QS) 2016-05 to 2019-11 (YSI ProDSS) 2015-04 to 2016-11 (Maxxam Lab) 2017-03 to 2018-11 (ALS Lab) 2019-04 to 2019-11 (Eurofins Lab)

The sampling data were collected on a monthly basis from June 2004 to November 2019 for Stations NC001 and SP 001, June 2003 to November 2019 for Station TN004, and April 2010 to November 2019 for Station TN003A. Wet weather conditions and dry weather conditions were not distinguished in the data. The samples were analyzed by different laboratories for the sixteen (16) years of records. The water quality parameters reported by the various laboratories are summarized for each location and presented in **Table 3.7.2**.

Table 3.7.2. Summary of Water Quality Parameters Monitored at Each Station

Water Quality Parameter	Water Quality Monitoring Station		
	TN003A	TN004	NC001
Alkalinity	x	x	x
Aluminum	x	x	x
Ammonia as N	x	x	x
Antimony		x	x
Arsenic		x	x
Barium	x	x	x
Beryllium	x	x	x
Bismuth	x	x	x
Boron	x	x	x
Bromide	x	x	x
Cadmium	x	x	x
Calcium	x	x	x
Cesium		x	x
Chloride	x	x	x
Chromium	x	x	x
Cobalt	x	x	x
Coliform	x		
Conductivity	x	x	x
Copper	x	x	x
Dissolved Oxygen	x	x	x
E_Coli	x	x	x
Fluoride	x	x	x
Hardness	x	x	x
Iron	x	x	x
Lead	x	x	x
Lithium	x	x	x
Magnesium	x	x	x
Manganese	x	x	x
Molybdenum	x	x	x
Nickel	x	x	x
Nitrate	x	x	x
Nitrite	x	x	x
ODO	x	x	x
ORP	x	x	x
pH	x	x	x
Phosphate	x	x	x
Phosphorus	x	x	x

Water Quality Parameter	Water Quality Monitoring Station		
	TN003A	TN004	NC001
Potassium	x	x	x
Rubidium		x	x
Selenium		x	x
Silicon	x	x	x
Silver	x	x	x
Sodium	x	x	x
Solids; suspended	x		
SpCond	x	x	x
Strontium	x	x	x
Sulfur		x	x
Sulphate	x	x	x
Sulphur	x	x	x
TDS	x	x	x
Tellurium		x	x
Thallium	x	x	x
Thorium		x	x
Tin	x	x	x
Titanium	x	x	x
Total Coliform	x	x	x
Total Kjeldahl Nitrogen	x	x	x
Total Solids	x	x	x
Total Suspended Solid	x	x	x
Tungsten		x	x
Turbidity	x	x	x
Uranium	x	x	x
Vanadium	x	x	x
Water Temp	x	x	x
Zinc	x	x	x
Zirconium	x	x	x

As evident, the water quality monitoring stations have not evaluated the same suite of water quality parameters. The parameters evaluated for a given station have varied over time (i.e. various periods of record, laboratories, and analysis techniques), hence the sample population of monitoring data for a given monitoring station varies amongst the water quality parameters.

Statistical analyses of minimum, maximum, mean, median concentrations of the contaminants have been completed for representative contaminants to characterize the surface water quality. A comparison of statistics was not available for the Twenty Mile Creek Watershed, North Creek Watershed, and Spring Creek Watershed. Comparisons among the sampling data analyzed by different laboratories showed that the evaluation results are generally consistent. The sampling data have been compared with current Provincial Water Quality Objectives (PWQO's) for various contaminants, to determine the number of exceedances under existing land use conditions. Contaminants have been listed when available guidelines have been provided within the PWQO's or within The Canadian Council of the Ministers of the

Environment (CCME): Canadian Water Quality Guidelines. The statistical summary and the PWQO exceedances results are summarized in Tables 3.7.3 – 3.7.5.

Table 3.7.3. Statistical Results of Water Quality (Station TN003A)

Contaminant	Statistical Results for Concentration of Contaminants			PWQO Exceedance		
	Mean[1.]	Median[1.]	Range[1.]	PWQO Limit	Number of Samples Exceeding PWQO	Percentage of Samples Exceeding PWQO
Arsenic (As) (ug/L)	-	-	-	100 ug/L	-	-
Beryllium (Be) (ug/L)	<0.85	<0.27	0.002 - <10	1100 ug/L	0	0%
Cobalt (Co) (ug/L)	<1.09	<0.49	<0.2 - <10	0.9 ug/L	14	20%
Copper (Cu) (ug/L)	<3.58	<2.47	<0.11 - <50	5 ug/L	7	10%
E_Coli (cfu/100ml)	1715.5	203.5	5 - 24197	100 cfu/100ml	40	56%
Iron (Fe) (ug/L)	909.65	376.5	29 - 13000	300 ug/L	44	63%
Lead (Pb) (ug/L)	2.92	2.01	0.29 - 23.4	25 ug/L	0	0%
Nickel (Ni) (ug/L)	3.47	2.97	0.01 - 20	25 ug/L	0	0%
Nitrate (mg/L)	2.54	1.43	0.04 - 18.82	-	-	-
Nitrite (mg/L)	0.12	0.07	0.01 - 0.47	-	-	-
Phosphorus (Total) (mg/L)	0.22	0.17	0.03 - 0.86	30 ug/L	29	100%
Silver (Ag) (ug/L)	<1.49	<0.77	<0.06 - <10	0.1 ug/L	43	61.4%
TSS (mg/L)	20.2	10	<3 – 134	-	-	-
Zinc (Zn) (ug/L)	15.28	12.55	4.25 - 60	30 ug/L	4	6%

NOTE: [1.] Water quality results for certain contaminants reported values less than the minimum detection limit. In these instances, the mean and median have been calculated assuming the minimum detection limit, however the reported results are recognized to be below the reported value.

Table 3.7.4. Statistical Results of Water Quality (Station TN004)

Contaminant	Statistical Results for Concentration of Contaminants			PWQO Exceedance		
	Mean[1.]	Median[1.]	Range[1.]	PWQO Limit	Number of Samples Exceeding PWQO	Percentage of Samples Exceeding PWQO
Arsenic (As) (ug/L)	<1.63	<1.35	<0.6 - 4.5	100 ug/L	0	0.0%
Beryllium (Be) (ug/L)	<1.47	<0.5	<0.1 - <20	1100 ug/L	0	0.0%
Cobalt (Co) (ug/L)	<1.31	<0.63	<0.2 - <10	0.9 ug/L	49	38.0%
Copper (Cu) (ug/L)	<3.71	<2.95	<1 - <50	5 ug/L	29	22.0%
E_Coli (cfu/100ml)	769.3	166	5 - 24500	100cfu/100 ml	76	63.9%
Iron (Fe) (ug/L)	1912.72	1257.5	<20 - 37000	300 ug/L	126	94.7%
Lead (Pb) (ug/L)	3.4	2	0.29 - 20	25 ug/L	0	0.0%
Nickel (Ni) (ug/L)	<4.61	<2.55	1 - <50	25 ug/L	2	1.6%
Phosphorus (Total) (mg/L)	0.27	0.22	0.05 - 0.99	30 ug/L	133	100%
Silver (Ag) (ug/L)	<1.6	<0.1	<0.05 - <30	0.1 ug/L	37	31.4%
TSS (mg/L)	46.3	30	4 - 431	-	-	-
Zinc (Zn) (ug/L)	<19.76	<13.25	<3 - <200	30 ug/L	29	22.1%

NOTE: [1.] Water quality results for certain contaminants reported values less than the minimum detection limit. In these instances, the mean and median have been calculated assuming the minimum detection limit, however the reported results are recognized to be below the reported value.

Table 3.7.5. Statistical Results of Water Quality (Station NC001)

Contaminant	Statistical Results for Concentration of Contaminants			PWQO Exceedance		
	Mean[1.]	Median[1.]	Range[1.]	PWQO Limit	Number of Samples Exceeding PWQO	Percentage of Samples Exceeding PWQO
Arsenic (As) (ug/L)	<1.42	<1.35	<0.1 - 2.17	100 ug/L	0	0.0%
Beryllium (Be) (ug/L)	<1.8	<0.55	<0.1 - <20	1100 ug/L	0	0.0%
Cobalt (Co) (ug/L)	<1.31	<0.76	<0.2 - 30	0.9 ug/L	35	32.7%
Copper (Cu) (ug/L)	<4.46	<3.75	<1 - 60	5 ug/L	23	20.4%
E_Coli (cfu/100ml)	<1544.25	<315.5	<5 - 48400	100cfu/100ml	87	79.1%
Iron (Fe) (ug/L)	2040.79	1060	<40 - 84300	300 ug/L	81	72.3%
Lead (Pb) (ug/L)	2.57	1.25	<0.14 - 30	25 ug/L	1	1.0%
Nickel (Ni) (ug/L)	<4.47	<3.07	<0.5 - 90	25 ug/L	1	1.0%
Phosphorus (Total) (mg/L)	0.31	0.26	<0.03 - 2.3	30 ug/L	114	99%
Silver (Ag) (ug/L)	<1.36	<0.1	<0.05 - 30	0.1 ug/L	26	25.2%
TSS (mg/L)	41.35	20	<3 - 1300	-	-	-
Zinc (Zn) (ug/L)	15.02	10	<3.2 - 310	30 ug/L	12	11.3%

NOTE: [1.] Water quality results for certain contaminants reported values less than the minimum detection limit. In these instances, the mean and median have been calculated assuming the minimum detection limit, however the reported results are recognized to be below the reported value.

The statistical results indicate that the concentration levels are high for E.coli, Nitrite, Iron, Cobalt, Copper and Silver for all water quality stations. Similarly, the exceedances of PWQO indicate that these contaminants frequently exceeded the PWQO limit. Nearly all water quality samples exceeded the PWQO concentration for iron. The concentrations of contaminants downstream of the Smithville community are higher than the upstream of the Smithville Community. However, silver at the upstream Twenty Mile Creek exceeded the PWQO concentration for two thirds of the total samples at this location. The maximum TSS concentration was more than 430 mg/L at the downstream Twenty Mile Station and 1000 mg/L at the North Creek station.

In addition to the foregoing, it is recognized that road salt, used for maintaining roads during winter conditions, represent an additional source of contamination for receiving watercourses. Typically, road salts are retained in the snowpack during winter conditions, and released during the spring freshet or during intervening snowmelt conditions over the winter period. It is also recognized that road salt can leach into the soils adjacent to roadways and accumulate over time if used continually. As such, management of road salt use is recognized to represent a key component to mitigating water quality impacts associated with increased chloride concentrations resulting from application of road salt.

3.7.4 Interpretation and Findings

The water quality monitoring samples received from NPCA indicate that the concentrations of typical contaminants in the proximity of the study area are generally in comparable ranges with relatively higher levels compared with similar land uses in other study areas. High concentrations of organics, nutrients, and metals are noted for Twenty Mile Creek and North Creek. The existing land uses condition are largely agricultural. Therefore, the high concentrations and exceedances are considered attributable to intensive farming activities and lack of formative water quality measures.

3.8 Terrestrial Resources

3.8.1 Importance and Purpose

The terrestrial resources assessment provides a characterization of the terrestrial ecology and natural heritage features within the study area and their sensitivity to anthropogenic disturbance in order to inform land use planning. The information collected through this analysis provides insight regarding the significance and connectivity between ecological systems and terrestrial features on the landscape, as well as the movement of wildlife through the study area and its environs. This understanding provides the foundation for developing a Natural Heritage System (NHS) and for informing the management of surface water and groundwater systems, in order to achieve an integrated and ecologically sustainable development. Information provided in the Draft Phase 1 Report was revised in the Draft Phase 2 report through consultation with the Technical Advisory Committee. Information as provided in the Draft Phase 1 report has been maintained in this Final Phase 1 Report for traceability, especially in regard for the comments and response matrix.

3.8.2 Background Information

Existing natural heritage information was gathered on terrestrial resources and reviewed to identify key natural heritage features and species that are reported from the study area. Background information pertaining to the natural environmental features within the study area has been collected from the Ministry of Natural Resources and Forestry (MNRF) Land Information Ontario (LIO) database, the MNRF Natural Heritage Information Centre (NHIC), Species at Risk (SAR) mapping, as well as from the Niagara Region (2014 and 2022) and the Township of West Lincoln (2019) Official Plan documents, and other files provided by the Township and the Region, including the *Environmental Screening Report for the Smithville Growth Management Study* (Colville 2008) and associated updated and addendum (Colville 2015a, 2015b). Additional background information has been provided by the NPCA, and relevant taxa-specific databases, as listed below.

To help inform suitable land-use concepts and identify areas to be protected, terrestrial natural heritage features are evaluated against the relevant policies and legislation described in Section 2.2.

Initial wildlife species lists were compiled to provide information on species reported from the study area and vicinity using various atlases including the Ontario Mammal Atlas (Dobbyn 1994), the Ontario Breeding Bird Atlas (BSC et al. 2006), the Ontario Reptile and Amphibian Atlas (Ontario Nature 2020), the Ontario Butterfly Atlas (Macnaughton et al. 2020), and the Ontario Odonata Atlas (NHIC 2020). As data from the atlases is based on 10x10km survey squares, information on species from the square that overlaps the study area was compiled (squares 17PH17 and 17PH27).

Based on these initial species lists, Species at Risk (SAR) and species of Conservation Concern (SCC) that have the potential to occur within the study area were compiled. For the purposes of this report, SAR are defined as species listed as Threatened or Endangered provincially which are afforded protection under the Endangered Species Act. Species of Conservation Concern refer to:

- species designated provincially or nationally as Special Concern,
- species that have been assigned a conservation status (S-Rank) of S1 to S3 or SH by the Natural Heritage Information Centre, and
- species that are designated federally as Threatened or Endangered by the Committee for the Status of Endangered Wildlife in Canada (COSEWIC), but not provincially by the Committee on the Status of Species at Risk in Ontario (COSSARO). These species are protected by the federal Species at Risk Act but not by the provincial Endangered Species Act.

A preliminary screening exercise was conducted to determine whether there are suitable habitats within the study area for these species. This involved cross-referencing the preferred habitat for reported SAR and SCC (OMNR 2000) against habitats known to occur in the study area. This was completed to ensure that the potential presence of all SAR and SCC within the study area was adequately considered and identified. The screening table was updated based on field investigations. Full results of the SAR and SCC screening are provided in Appendix H-I. SCC are discussed within the context of Significant Wildlife Habitat (SWH).

A preliminary screening for the presence of SWH was also completed for the study area. The Significant Wildlife Habitat Technical Guide (SWHTG) is a guideline document that outlines the types of habitats that the MNRF considers significant in Ontario as well as criteria to identify these habitats (OMNR 2000, MNRF 2015). The SWHTG groups SWH into four broad categories: seasonal concentration areas, rare vegetation communities and specialized wildlife habitat, habitats of species of Conservation Concern, and animal movement corridors. The SWH screening tables were updated based on field investigations. Full results of the SWH screening are provided in Appendix H-II.

3.8.3 Methods and Analysis

The study area represents the expansion boundary lands identified and described above and shown on all maps. Legacy data collected from and provided by agencies and the TAC included an area of approximately 1km around the study area to ensure that all surrounding natural features were considered. Field surveys were undertaken within the study area where property access was permitted (ref. Map NH-2). The natural heritage features have been characterized within the study area and adjacent lands (120m surrounding the study area). Where property access was not granted, natural heritage has been characterized based on observations obtained from the property boundary or road, and using air photo interpretation and background mapping.

The study area consists primarily of agricultural fields and rural properties surrounding the Community of Smithville. Isolated natural heritage features are found disbursed through the study area, and along Twenty Mile Creek, which bisects the Town. The study area borders numerous residential subdivisions, industrial and commercial lands comprised within the Community of Smithville. The natural features within the study area consist of woodlands, wetlands, and watercourses. The Twenty Mile Creek subwatershed comprises the central area, within the North Creek subwatershed located to the southwest, and the Spring Creek subwatershed located to the northeast. The study area and natural heritage features, as mapped by the province, are shown on Map NH-1A. Map NH-1B identifies the Township of West Lincoln's (TOWL 2019) and the Region of Niagara's Core NHS (ROP 2014).

Surveys were conducted for breeding birds, mammals, herpetofauna, insects, and vascular flora. This section identifies natural feature constraints in association with land use policy designations in order to inform the land use planning strategy. The study area is located within Ecoregion 7E. Existing information and field data was reviewed and analyzed in order to identify a preliminary Natural Heritage System (NHS).

Surveys were undertaken in accordance with provincial and local guidance documents as indicated below. Terrestrial monitoring station locations are shown on Map NH-2. Table 3.8.1 outlines the field surveys that were conducted during the 2020 field season.

Vegetation Surveys

Vegetation community delineation was completed using aerial photography and thorough investigations in the field on May 12 and 13, 2020, with refinements on subsequent field visits as required. The standard Ecological Land Classification (ELC) System for southern Ontario was applied (Lee et al. 1998). Details of vegetation communities were recorded including species composition, dominance, uncommon species or features, and evidence of human impact. A three-season detailed botanical survey was also undertaken with all observed species of vascular flora recorded during field surveys. Vegetation community mapping from the NPCA was also used to guide assessment and delineation of vegetation communities.

Table 3.8.1. Terrestrial Field Survey Summary

Survey Type	Protocol	Date	Start and End Time (24 hrs)	Air Temp. (°C)	Beaufort Wind Speed	Cloud Cover (%)	Precipitation	Observers
Vascular Flora Inventory (Spring) and Ecological Land Classification (ELC)	Lee et al. (1998), Systematic search by ELC polygon	May 12, 2020	07:00 – 17:00	8	2 - 3	20 - 60	None	P. Deacon E. Voogjarv
		May 13, 2020	08:00 – 15:00	10.5	1 - 3	50	None	
Vascular Flora Inventory (Summer) and ELC refinement		July 6, 2020	08:00 – 16:30	18	1 - 3	50	None	K. Burrell P. Deacon
		July 7, 2020	08:00 – 14:00	32	1 - 3	0 - 50	None	
Vascular Flora Inventory (Fall) and ELC refinement		September 22, 2020	09:00 - 17:00	9-21	0-2	0	None	K. Richter P. Deacon
		September 23, 2020	08:00 – 16:00	11	0	0	None	
Calling Anuran Survey #1	BSC (2009)	April 28, 2020	21:00 – 23:30	6 - 10.5	1 - 3	10 - 30	None	K. Richter
								K. Burrell
								N. Miller
								T. Brenton
Calling Anuran Survey #2		May 20, 2020	21:00 – 23:00	10 - 11	0 - 1	0 - 60	None	A. Reinert
								E. Gosnell
								E. Milne
								J. McCarter
Calling Anuran Survey #3		June 23, 2020	21:30 – 23:00	20 - 23	3 - 5	30 - 75	None	E. Milne
								S. Catry
								S. Turner
								T. Brenton
Breeding Bird Survey #1	10 minute point counts and area searches,	June 8, 2020	06:30 - 10:00	12 - 22	1 - 2	0 - 10	None	K. Richter
								K. Burrell
								N. Miller

Survey Type	Protocol	Date	Start and End Time (24 hrs)	Air Temp. (°C)	Beaufort Wind Speed	Cloud Cover (%)	Precipitation	Observers
Breeding Bird Survey #2	breeding evidence as per OBBA (2001)	June 23, 2020	06:30 – 10:00	21 - 25	2 - 3	10 - 95	None	K. Hoo J. Pickering
Snakeboard Surveys	Stationary boards installed in suitable habitat	April 28, 2020 (installed)	16:30 - 18:30	11 - 14	2	40	None	K. Richter K. Burrell N. Miller T. Brenton
		May 20, 2020	18:30 - 20:30	13 - 18.5	3 - 4	0 - 3	None	A. Reinert E. Gosnell E. Milne J. McCarter
		June 8, 2020	06:30 - 11:40	13 - 21	0 - 2	0 - 10	None	K. Richter K. Burrell N. Miller T. Brenton
		June 23, 2020	06:30 - 10:30	21	1 - 2	10 - 20	None	K. Hoo J. Pickering
		September 22, 2020	09:00 - 17:00	9 - 21	0 - 2	0	None	K. Richter P. Deacon
		September 23, 2020	08:00 – 16:00	11	0	0	None	K. Richter P. Deacon

Bird Surveys

Breeding bird surveys were completed on June 8 and 23, 2020, and data was recorded using standard OBBA call codes (OBBA 2001). Surveys consisted of 10-minute point counts at 22 locations within the various habitat types (ELC community) present within the study area. The surveys occurred between dawn and 1000hrs. All visual and auditory observations of birds were recorded, as well as the highest level of breeding evidence exhibited for each recorded species. Birds observed between point count locations were also recorded. Observations of birds during all field visits were recorded and stick nests were also identified, which indicate raptor, owl, or heron nesting.

Reptile Surveys

Snakes

Snake cover board surveys were conducted at suitable locations within the study area, particularly focusing on field and woodland edges in meadow and scrubland habitat. Coverboards measured 1.0m by 1.0m and were black on the top side. Boards were placed on April 20, 2020 and checked on May 20, June 8, and June 23, 2020 in association with other field surveys.

Visual encounter surveys and active searches were also undertaken to identify snake species present within the study area. Surveys were conducted during each terrestrial site visit while walking throughout the study area. The visual encounter surveys involved biologists approaching suitable basking areas (i.e. sunny, open grassy or rocky habitats) quietly and scanning the area with binoculars. Active searches involved turning over rocks or other suitable cover objects.

Turtles

Similarly, visual encounter surveys were undertaken to search for turtle species present within the study area. Surveys conducted in early spring were targeted at identifying turtle overwintering areas, while surveys conducted later in the season were focused on identifying general species presence. This involved biologists approaching suitable basking areas (i.e. wetlands, watercourses, ponds) quietly and scanning the area with binoculars. Visual surveys occurred on sunny, warm (>10ºC) days, although biologists were watching for turtles during all travel throughout the study area. During each visual encounter survey detailed notes were taken which described the habitat searched, level of effort, weather conditions, and species observed.

Anuran Call Surveys

Evening anuran (frog and toad) call surveys were conducted on April 28, May 20, and June 23, 2020 using the Marsh Monitoring Program protocol (BSC 2009) at 11 stations. Monitoring focused on calling frogs and toads during 3 minute call counts, which included call intensity and an estimated number of individuals. Additional information, including survey time, air and water temperature, wind speed, and cloud cover were recorded at each survey station as applicable.

Insect Surveys

Butterfly and Odonata Surveys

Visual encounter surveys for butterfly and odonata were conducted throughout the study area in conjunction with all other terrestrial and aquatic field surveys, which involved area searches in a variety of habitats. During each survey, detailed notes were taken that described the habitat searched, level of effort, weather conditions, species observed, and number of individuals. Notes were also taken on any habitat associations (e.g. nectaring or ovipositing on specific plants), larva, pupa, etc.

Mammal Surveys

Observations of all mammals were documented on all field visits. This included direct observations of individuals, as well as signs of animal presence, such as tracks, scat, dens, etc. Searches for high quality cavity trees, suitable for bat maternity colony roosting were conducted together with other field work, primarily vegetation inventories.

3.8.4 Interpretation and Findings

The existing conditions are characterized in the following sections.

3.8.4.1 Designated Natural Areas

A regionally significant Life Science Area of Scientific and Natural Interest (ANSI), the East Smithville Slough Forest, is located just east of the Town of Smithville and just beyond the eastern extent of the study area (Map NH-1A). The features captured within the ANSI are considered regionally significant.

The Lower Twenty Mile Creek Provincially Significant Wetland Complex extends through the study area. Provincially significant wetlands, as mapped by the MNRF, are shown on Map NH-1A.

The provincial Greenbelt is located immediately to the north of the study area, bordering Young Street. The Niagara Escarpment is located 3.5km north of the study area. Both areas are also shown on Map NH-1A. Recent changes to the Greenbelt in December 2022 did not effect this area.

3.8.4.2 Vegetation

Vegetation Communities

The subject lands consist of agricultural fields, meadows, woodlands, marshes and swamps, as well as rural and urban residential areas. A summary of ELC communities identified within the study area is provided in Table 3.8.2. ELC communities are described below and shown on Maps NH-3A to -3F. A woodland that appears on air photos and background mapping was removed between July 2018 and January 2020, as evidenced by the most recent aerial photography available. This woodland was located on the northwest of the study area, between the hydro corridor to the north and the railway tracks to the south (Map NH-3A) (in the vicinity of an observed karst feature, NW 2).

Table 3.8.2. Vegetation Communities Identified Within the Study Area

Cultural	
CUM	Cultural Meadow
CUT	Cultural Thicket
CUT1-4	Gray Dogwood Cultural Thicket
CUW	Cultural Woodland
Disturbed	Recently graded lands (bare soil/early successional)
Deciduous Forest	
FOD4-1	Dry – Fresh Beech Deciduous Forest Type
FOD5-2	Dry – Fresh Sugar Maple – Beech Deciduous Forest Type
FOD6-5	Fresh – Moist Sugar Maple – Hardwood Deciduous Forest Type
FOD7	Fresh – Moist Lowland Deciduous Forest
FOD7-4	Fresh – Moist Black Walnut Lowland Deciduous Forest Type
FOD9	Fresh – Moist Oak – Maple – Hickory Deciduous Forest Ecosite
FOD9-1	Fresh – Moist Oak – Sugar Maple Deciduous Forest Type
FOD9-3	Fresh – Moist Bur Oak Deciduous Forest Type
FOD9-4	Fresh – Moist Shagbark Hickory Deciduous Forest Type

FOD	Deciduous Forest
H	Hedgerow
Wetland	
MAM2	Graminoid Mineral Meadow Marsh
MAM2-2	Reed-canary Grass Graminoid Mineral Meadow Marsh Type
MAM3	Graminoid Organic Meadow Marsh Ecosite
MAS2	Graminoid Mineral Shallow Marsh Ecosite
SAS	Submerged Shallow Aquatic
SWT2	Mineral Deciduous Thicket Swamp Ecosite
SWT3	Organic Deciduous Thicket Swamp Ecosite
SWD3	Maple Mineral Deciduous Swamp Ecosite
SWD3-1	Red Maple Mineral Deciduous Swamp Type
SWD4	Mineral Deciduous Swamp Ecosite
SWD4-2	White Elm Mineral Deciduous Swamp Type
SWD	Deciduous Swamp
Constructed	
SWM Pond	SWM Pond Infrastructure

Cultural

Cultural Meadow (CUM)

Meadow habitat is present throughout the study area and includes areas of recently cleared land, fallow agricultural land, a hydro line right-of-way and periodically grazed livestock pasture. These communities often contain a high proportion of non-native cool season grasses including Smooth Brome (*Bromus inermis*) and Reed-canary Grass (*Phalaris arundinacea*). The diversity of forbs includes Canada Goldenrod (*Solidago canadensis*), Grass-leaved Goldenrod (*Euthamia graminifolia*), New England Aster (*Symphyotrichum novae-angliae*), Lance-leaved Aster (*S. lanceolatum*), Frost Aster (*S. pilosum*), Common Yarrow (*Achillea millefolium*) and Ox-eye Daisy (*Leucanthemum vulgare*).

The meadow communities generally contain a variety of species that provide pollinator habitat including Common Milkweed (*Asclepias syriaca*) which is the host plant for the Monarch butterfly (*Danaus plexippus*). The largest areas of meadow are located to the east of Industrial Park Road on both the north and south side of the rail line. Two areas of meadow in the western portion of the study area (Map NH-3C), were likely agricultural fields prior to the development of the adjacent subdivisions and are now complimentary natural features along the treed Twenty Mile Creek corridor. The larger areas of meadow, along with perch trees at the edges, provide good forage habitat for raptor species. In many locations, cultural meadow transitions to areas of cultural thicket where shrubs have established or Reed-canary Grass marsh where soils are wetter.

Cultural Thicket (CUT)

Gray Dogwood Cultural Thicket (CUT1-4)

Cultural thicket communities represent an early stage in natural succession between meadow and woodland habitat and the areas of thicket within the study area are the result of past clearing activities. Within the study area these habitats exist as openings at the edges of woodlots, infrequently grazed pasture, and lands beneath the hydro line corridor and along rail lines. Many of the hedgerow features identified within the study area contain sections of thicket between stands of trees. A complex of thicket, meadow and marsh is present to the east of Industrial Drive Road, east of London Road (Map NH-3D) in an area that was cultivated historically but has been left fallow for numerous years.

The two dominant thicket species are Gray Dogwood (*Cornus racemosa*) and non-native European Buckthorn (*Rhamnus cathartica*). Other shrub species that occur in smaller numbers include the non-native Tartarian Honeysuckle (*Lonicera tatarica*) and a variety of native species such as Manitoba Maple (*Acer negundo*), Staghorn Sumac (*Rhus typhina*), and Hawthorns (*Crataegus* spp.). Where forest is present nearby, Ash trees (*Fraxinus* spp.) and Trembling Aspen (*Populus tremuloides*) often seed into the thicket and these trees facilitate a transition toward woodland conditions.

Cultural Woodland (CUW)

A small area of cultural woodland exists to the northeast of the sewage lagoons (Map NH-3F). This community is outside of the study area boundary and was assessed from the Highway 20 roadside. The area is comprised of Trembling Aspen which have established in a wet section of a pasture where surface water is directed toward Twenty Mile Creek.

Disturbed

The rail line junction in the northeast portion of the town (Map NH-3D) was graded in 2017 and now exists as bare soil with little or no vegetation present.

Deciduous Forest

Dry – Fresh Beech Deciduous Forest Type (FOD4-1)

Within the large treed feature in the far northwest corner of the study area (Map NH-3A), there are three upland areas of forest adjacent to the road right-of-way dominated by American Beech (*Fagus grandifolia*). Other trees present include Hop Hornbeam (*Ostrya virginiana*) and American Basswood (*Tilia americana*). American Beech also comprises much of the shrub layer with abundant regeneration throughout. The groundcover is a rich assemblage of spring ephemerals including Yellow Trout Lily (*Erythronium americanum*), White Trillium (*Trillium grandiflorum*), Virginia Spring Beauty (*Claytonia virginica*), Virginia Waterleaf (*Hydrophyllum virginianum*), and Wood Anemone (*Anemone quinquefolia*). The right-of-way to the west appears to be used by ATVs periodically but rutting and damage to vegetation is not evident.

Dry – Fresh Sugar Maple – Beech Deciduous Forest Type (FOD5-2)

A small area of forest dominated by Sugar Maple (*Acer saccharum*) and American Beech is present in the southwest portion of the study area (Map NH-3E) in the 'U-shaped' treed feature to the east of the Smithville Sports Complex. Hop Hornbeam is common in the understorey while the groundcover includes Pennsylvania Sedge (*Carex pensylvanica*), Wood Anemone, Wild Geranium (*Geranium maculatum*), and Blunt-leaved Sandwort (*Moehringia lateriflora*). Although small in size, this community is situated on well-drained soils which are uncommon within the study area. A Red-tailed Hawk (*Buteo jamaicensis*) nest that was active in 2020 is present in this community.

Fresh – Moist Sugar Maple – Hardwood Deciduous Forest Type (FOD6-5)

There are several areas of fresh-moist Sugar Maple – hardwood forest located in the northwest portion of the study area (Map NH-3A), as well as a small area near the eastern boundary of the study area along Spring Creek Road (Map NH-3B). In addition to Sugar Maple, Red Oak (*Quercus rubra*) and American Beech are common in the canopy and sub-canopy, with Blue Beech (*Carpinus caroliniana*) and American Elm (*Ulmus americana*) present in the understorey. Herbaceous species include common spring ephemerals as well as Spinulose Wood Fern (*Dryopteris carthusiana*), Yellow Violet (*Viola pubescens*), Jack-in-the-pulpit (*Arisaema triphyllum*), and Poison-ivy (*Toxicodendron rydbergii*). The periphery of these habitats transitions to deciduous swamp with wetter soil conditions and a mixture of upland and wetland species.

Fresh-Moist Lowland Deciduous Forest (FOD7) /

Fresh – Moist Black Walnut Lowland Deciduous Forest Type (FOD7-4)

Fresh-moist forest comprised of Black Walnut (*Juglans nigra*), American Elm, Green Ash (*Fraxinus pennsylvanica*), Manitoba Maple, and Crack Willow (*Salix fragilis*) are present along much of the riparian area of Twenty Mile Creek (FOD7-4). A similar community without Black Walnut (FOD7) is present in several locations in the northern portion of the study area. These lowland habitats have relatively low diversity with non-native species including Garlic Mustard (*Alliaria petiolata*) and Dame's Rocket (*Hesperis matronalis*), as well as Reed-canary Grass which is the dominant groundcover in canopy openings.

These communities are likely subject to spring flooding on a regular basis, and some contain vernal pools between April and June before drying up. The contiguous cover of lowland forest along Twenty Mile Creek is likely a main corridor for wildlife movement across the landscape. The cultural meadow areas along Twenty Mile Creek that are adjacent to these forest types will likely transition toward a similar composition in time. The feature to the north of Anderson Crescent (Map NH-3D), contains extensive ATV and vehicle trails with multiple camper trailers set up during the 2020 surveys.

The FOD7-4 community has a provincial rank of 'S2/S3's, thereby making it provincially imperiled (S2) and vulnerable (S3) with a high (S2) to moderate (S3) risk of extirpation. However, the Black Walnut Lowland Deciduous Forest (FOD7-4) within the study area is of fairly low quality.

Fresh – Moist Oak – Maple – Hickory Deciduous Forest Ecosite (FOD9)

Lowland forest dominated by Bur Oak (*Quercus macrocarpa*) and Shagbark Hickory (*Carya ovata*) with small amounts of Red Maple are present in the north of the study area (Map NH-3B), as well as small isolated features within agricultural fields in the west (Map NH-3C) and along the decommissioned rail line in the south (Map NH-3F). With the exception of patches of non-native Reed-canary Grass and European Buckthorn along the forest edges, these communities are generally intact with limited invasive species cover. Chokecherry (*Prunus virginiana*), Nannyberry (*Viburnum lentago*), and Wild Black Currant (*Ribes americanum*) are common shrub species and the groundcover includes Jack-in-the-pulpit, May-apple (*Podophyllum peltatum*), Fowl Manna Grass (*Glyceria striata*), and Graceful Sedge (*Carex gracillima*). During surveys it was noted that the community in the south along the former rail line was recently grubbed with all young trees and shrubs reduced to mulch. The canopy is intact within this feature and a population of the provincially rare Slightly Hirsute Sedge (*Carex hirsutella*) is thriving with the reduction in competition. This southern FOD9 community very likely contains a snake hibernaculum. The southern FOD9 community was removed in October 2021. The Phase 2 Report provides additional details and discussion.

Forests with large amounts of mast producing trees (oaks and hickories) provide valuable forage opportunities for mammals. Oak trees are also known to support a high diversity of moth and butterfly species and in turn high numbers of caterpillars which support bird populations (Tallamy 2009, Valencia-Cuevas & Tovar-Sánchez 2015). Oak trees have also been identified as one of the species preferred for maternity roosting of the provincially Endangered roosting Tri-colored Bat (*Perimyotis subflavus*), where they may roost in hanging clusters of leaves (Veilleux, Whitaker Jr. and Veilleux 2003, Perry and Thill 2007).

Fresh – Moist Oak – Sugar Maple Deciduous Forest Type (FOD9-1)

Forest with a canopy of Red Oak with smaller amounts of Shagbark Hickory and Sugar Maple is present in several areas on the north end of Smithville (Maps NH-3A and -3B). Chokecherry and Hop Hornbeam are present throughout the understorey alongside regenerating oak and hickory. The groundcover is comprised of common species: Yellow Trout Lily, Virginia Spring Beauty, White Trillium, Wooly Blue Violet (*Viola sororia*), and Large-leaved Aster (*Eurybia macrophylla*). Logging trails in some of the features have allowed Garlic Mustard to spread and create localized patches. A Red-tailed Hawk nest was observed on the eastern edge of the woodland southwest of 30 Road and Young Street.

Fresh – Moist Bur Oak Deciduous Forest Type (FOD9-3)

Two small areas of lowland Bur Oak forest are present within the study area. In the northwest (Map NH-3A), an isolated stand of trees within an agricultural field was documented. The soils are presumably too wet for cultivation. In the southeast (Map NH-3F), a stand of mature Bur Oak is present along Twenty Mile Creek, to the north of the sewage lagoons. Reed-canary Grass is abundant where canopy gaps are present and it is likely that this area is subject to flooding or ice scour in the spring. The root systems of the oak trees along the watercourse provide bank stability and help to control erosion.

Fresh – Moist Shagbark Hickory Deciduous Forest Type (FOD9-4)

Forest dominated by Shagbark Hickory with American Elm and Bur Oak throughout occurs in numerous areas within the study area. Due to the level clay soils that characterize much of the study area, this community was likely the dominant cover in upland areas prior to settlement. Although Hop Hornbeam, Chokecherry, and American Prickly-ash (*Zanthoxylum americanum*) are common shrubs in the understorey, non-native Honeysuckles (*Lonicera* spp.) are common along edges and in canopy gaps. The groundcover typically includes Yellow Trout Lily, White Trillium, Virginia Spring Beauty, Wild Geranium, May-apple, and White Avens (*Geum canadense*). Garlic Mustard occurs sporadically in many of these communities but is never abundant and is likely limited by the dense tree canopy.

The FOD9-4 community has a provincial rank of 'S3', making it provincially vulnerable with a moderate risk of extirpation.

Deciduous Forest (FOD)

Several areas of deciduous forest were identified at or just beyond the study area limit. These communities were identified from roadsides or property lines as access was not permitted. Details pertaining to species composition could not be determined aside from the absence of Red Maple (*Acer rubrum*) or Swamp Maple (*Acer* x *freemanii*) that would suggest the presence of a swamp community. The extent of these communities was refined through a desktop review of available NPCA wetland mapping, aerial photography, and topographic mapping.

Hedgerow (H)

The study area contains a number of linear hedgerows comprised largely of native trees and shrubs and often reflecting the composition of nearby forest communities. Tree and shrub species that occur in many of the hedgerows include American Elm, Shagbark Hickory, Red Oak, Bur Oak, Chokecherry, Gray Dogwood, European Buckthorn, and Hawthorns. Although some hedgerows contain remnant patches of spring ephemerals, most are characterized by Canada Goldenrod and Smooth Brome growing along the edges adjacent to agricultural fields. Many of the hedgerows provide a connection of natural cover between larger features in the study area that are otherwise separated by agricultural fields or development.

Wetland

Graminoid Mineral Meadow Marsh Ecosite (MAM2) /

Reed-canary Grass Graminoid Mineral Meadow Marsh Type (MAM2-2)

Graminoid-dominated marsh communities, in particular Reed-canary Grass marsh, are widespread throughout the study area. This early successional community is often the result of land clearing in low-lying areas such as the area east of Industrial Park Road (Map NH-3D), or along the watercourses in the southern half of the study area. Red-canary Grass generally excludes native wetland forbs, but many species persist in small numbers among the dense stands of grass. Common wetland species found in these marshes include Panicled Aster (*Symphyotrichum lanceolatum*), Spotted Joe-pye Weed (*Eupatorium maculatum*), Perfoliate Thoroughwort (*E. perfoliatum*), Blue Vervain (*Verbena hastata*), Swamp Milkweed (*Asclepias incarnata*), Turtlehead (*Chelone glabra*), Dark-green Bulrush (*Scirpus atrovirens*), and Woolgrass (*Scirpus cyperinus*). Less common species such as Foxtail Sedge (*Carex alopecoidea*) are also found in these habitats. Many of these habitats contain sparse tree and shrub cover and left undisturbed the marsh will transition toward thicket swamp and ultimately swamp conditions. The problematic invasive species Common Reed (*Phragmites australis* ssp. *australis*) occurs in some sections of roadside ditch as well as within the complex of marsh habitats to the southeast of the Industrial Park Road – Spring Creek Road intersection (Map NH-4D).

Graminoid Organic Meadow Marsh Ecosite (MAM3)

There are two small organic marsh features within the northern portion of the study area (Maps NH-3A and -3B). Despite their small size, these wetlands contain a notably high concentration of native species, many of which are conservative and do not occur elsewhere in the study area. Species present include Floating Manna Grass (*Glyceria septentrionalis*), Fringed Sedge (*Carex crinita*), Northern Blue-flag iris (Iris versicolor), Tufted Loosestrife (*Lysimachia thyrsiflora*), Water Parsnip (*Sium suave*), Nuttall's Bur-reed (*Sparganium americanum*), and patches of Highbush Blueberry (*Vaccinium corymbosum*), Winterberry (*Ilex verticillata*) and Swamp Rose (*Rosa palustris*). These features, as well as a nearby swamp thicket, are the only organic soil wetlands in the study area and as a result, they are unique and of natural heritage significance within the vicinity of Smithville.

Graminoid Mineral Shallow Marsh Ecosite (MAS2)

A small shallow marsh feature is present in the northwest corner of the study area (Map NH-3A). This feature contained standing water into the mid-summer. The fringe is comprised of Broad-leaved Cattail (*Typha latifolia*) and Reed-canary Grass with Lesser Duckweed (*Lemna minor*) present in the standing water and persisting on saturated substrates once the water level had dropped. The hydro-period of this feature and inundated vegetation provides good anuran breeding habitat. Spring Peeper, American Toad, and Western Chorus Frog were noted calling in the vicinity of MAS2 during anuran breeding surveys in April and May, 2020.

Submerged Shallow Aquatic (SAS)

A farm pond (that has naturalized) surrounded by lowland forest and marsh in the north of the study area (Map NH-3B) contains deep water with some submergent vegetation present. Topography and the proximity to a watercourse to the east suggest that the pond may receive intermittent flow, but the water depth is likely maintained by groundwater. This feature was likely excavated, as it does not exist on 1934 aerial photography. The pond is surrounded by Reed-canary Grass and the species growing within the pond were not able to be identified. A mowed trail leads to the edge of the pond where a viewing platform has been constructed by the landowner. Similar to the shallow marsh discussed above, this feature provides suitable anuran breeding habitat.

Mineral Deciduous Thicket Swamp Ecosite (SWT2)

Swamp thicket situated on mineral soil is generally associated with the riparian areas of North Creek and Twenty Mile Creek within and adjacent to the study area. The groundcover within these areas resembles the Reed-canary Grass marsh (MAM2-2) community, but has a greater cover of shrubs including Silky Dogwood (*Cornus amomum*) and Grey Dogwood. Young to mid-age Green Ash, Willow (*Salix* spp.), and Black Walnut occur sporadically in some of the swamp thickets.

Organic Deciduous Thicket Swamp Ecosite (SWT3)

An area of organic swamp thicket is present near the northern end of Thompson Avenue (Map NH-3B). Similar to the organic marsh communities (MAM3), this feature contains numerous conservative species found nowhere else in the study area. The herbaceous vegetation is similar in composition to the MAM3 communities, but Highbush Blueberry and Winterberry form a dense colony within this wetland. Past evidence of rubbish dumping and Marijuana (*Cannabis sativa*) cultivation was observed along the southern edge of this feature.

Maple Mineral Deciduous Swamp Ecosite (SWD3) /

Red Maple Mineral Deciduous Swamp Type (SWD3-1)

Swamp communities with a canopy comprised of Red Maple or Swamp Maple are common in the study area. These swamps generally contain mature trees with deadfall, root tip-ups, and hummocky topography. Many of the maple swamps contain shallow standing water in the spring, although defined vernal pools are relatively rare in this community. The canopy often includes American Elm and Bur Oak in small numbers. The shrub layer includes regenerating American Elm and Shagbark Hickory, as well as Narrow-leaved Meadowsweet (*Spiraea alba*). The groundcover includes Sensitive fern (*Onoclea sensibilis*), Spotted Jewelweed (*Impatiens capensis*), Fowl Manna Grass, Calico Aster (*Symphyotrichum lateriflorum*), Canada Bluejoint (*Calamagrostis canadensis*), Spinulose Wood Fern, Dwarf Clearweed (*Pilea pumila*), and Purple Cress (*Cardamine douglassii*). The provincially rare tree Black Gum (*Nyssa sylvatica*) occurs within the SWD3-1 feature in the northwest of the study area, on the east side of South Grimsby Road 5 (Map NH-3A) where about 50 mid-age trees were observed at the edge of a vernal pool. This woodlot has a large amount of rubbish dumping in the southwest corner extending out to the edge of the field. A roosting Great-horned Owl (*Bubo virginianus*) was observed in the maple swamp beyond the northern end of Thompson Road during the surveys. This owl's nest was within the woodland to the north, where 2 young owlets were observed in the spring (SWD3 next to the SAS). Within the former woodlot, and applicable to other treed features as well, congregations of snags and cavity trees may provide suitable habitat for bat roosting.

Mineral Deciduous Swamp Ecosite (SWD4) /

White Elm Mineral Deciduous Swamp Type (SWD4-2)

Swamp communities comprised of American Elm with Green Ash and Willow occur largely along the watercourses in the southern half of the study area. Black Walnut and Shagbark Hickory are present in small numbers as this community often occurs alongside areas of lowland forest dominated by those species. Both American Elm and Green Ash are in decline due to Dutch Elm Disease and Emerald Ash Borer (*Agrilus planipennis*) respectively, resulting in the stands being mid-age with deadfall and snags throughout. Where the canopy has declined, shrubs including Silky Dogwood and Eastern Buttonbush (*Cephalanthus occidentalis*) are thriving, as well as patches of the non-native Reed-canary Grass. The feature to the west of Forestview Court (Map NH-3C) is overrun with non-native Honeysuckle in the understorey with a fort and dumping present at the west end of the feature. A corrugated steel culvert crossing between fields near the western end is undersized and/or perched and has led to extensive erosion. Further north towards Creekview Drive, stands of the provincially rare Lizard's Tail (*Saururus cernuus*) are present along the bank of Twenty Mile Creek.

Vascular Flora

A total of 259 species of vascular plants were recorded during the three-season vegetation inventory within the study area and surrounding lands. A complete list of these species is included in Appendix H-III.

A total of 52 non-native species (20%) were documented. Notable non-native invasive species include: Common Reed, European Buckthorn, Garlic Mustard, Multiflora Rose, Purple Loosestrife, Tartarian Honeysuckle, and Bell's Honeysuckle. All of these species are considered somewhat aggressive and can overtake intact natural habitats resulting in decreased plant diversity and habitat value for wildlife. Reed-canary Grass, which is common along watercourses and floodplains within the study area is considered to be a non-native and invasive genotype where it occurs in southern Ontario (Lavergne & Molofsky 2004). Within the study area, non-native species are most common in disturbed features including meadows, hedgerows and forest edges, along trails and within floodplain areas that are subject to spring flooding. In general, forests and swamps have retained a good diversity of native plant cover, while marshes are largely dominated by Reed-canary Grass.

Background information and the SAR/SCC screening exercise (Appendix H-I) indicates that several significant plant species are reported from the study area that were not observed during field work. These include White Wood Aster (*Eurybia divaricata*), Butternut (*Juglans cinerea*), Cucumber Tree (*Magnolia acuminata*), and Perfoliate Bellwort (*Uvularia perfoliata*). Suitable habitat for all of these species is present, but none were observed during the surveys. The Study Team documented three SCC including Black Gum, Lizard's Tail, and Slightly Hirsute Sedge. Vegetation surveys in 2020 also documented 13 species that are considered regionally rare and 19 species that are considered uncommon (Oldham 2010). These include species such as Cardinal Flower (*Lobelia cardinalis*), Blunt-leaved Bedstraw (*Galium obtusum*), Foxtail Sedge (*Carex alopecoidea*), Drooping Wood Sedge (*C. arctata*), Mosquito Bulrush (*Scirpus hattorianus*) and Nuttall's Bur-reed. Of the 207 native species documented, 27 have a coefficient of conservatism of 7 or higher indicating that these species require high quality intact habitats. The majority of rare or conservative plant species are found in areas of higher quality swamp or forest habitat with limited disturbance. The significant species are listed in Appendix H-III.

3.8.4.3 Birds

A total of 105 birds are reported from the study area based on the OBBA (BSC et al. 2008). During field surveys, 81 bird species were documented within the study area, of which 58 exhibited signs of breeding (72%). Of the species observed from the study area, 16 were not reported from the OBBA. Refer to Appendix H-IV for a list of bird species found in the study area and vicinity.

Two bird SAR were observed in the study area: Bobolink (*Dolichonyx oryzivorus*) and Eastern Meadowlark (*Sturnella magna*); as well as four bird SCC: Barn Swallow (*Hirundo rustica*), Caspian Tern (*Hydroprogne caspia*), Eastern Wood-Pewee (*Contopus virens*), and Rusty Blackbird (*Euphagus carolinus*). Table 3.8.3 provides a summary of significant species observed in the study area, their current status ranks, and preferred habitats. Barn Swallow was downlisted to Special Concern in January 2023, but was previously classified as Threatened in Ontario.

Bobolink and Eastern Meadowlark were both observed within the study area during breeding bird surveys. Bobolink were observed at four locations across the northern portion of the study area. Bobolink exhibited probable breeding evidence at BMB-04 and BMB-08, and were observed with no evidence of breeding at BMB-02 and BMB-11. Eastern Meadowlark were observed at BMB-08, BMB-09, and BMB-17 exhibiting possible breeding evidence at each station. This species was also noted from BMB-15 in early June 2020, but there is no suitable breeding habitat at the Leisureplex. Both of these species favour large contiguous grassland habitats (OMNR 2000) which are not generally present in the study area. However, depending on the crop and management of agricultural fields, these two species may breed in the study area depending on conditions during a given year. Based on survey results, Bobolink and Eastern Meadowlark may be breeding within the study area, depending on the crop and management of the agricultural fields.

Suitable habitat is particularly found in the northern portion of the study area, generally north of Spring Creek Road as well as in the southwest corner in the vicinity of North Creek.

Barn Swallows were observed widely throughout the study area during breeding bird surveys on June 8 and June 23, 2020, as well as during other field work. Nesting was not confirmed within the study area as biologists did not have access to barns or other agricultural structures in order to document nests. Barn Swallow were observed foraging primarily over agricultural fields. Nesting habitat for Barn Swallow is present within the broader study area in the form of barns, outbuildings, garages, houses, and culverts.

Eastern Wood-Pewee were observed at six locations during breeding bird surveys. They exhibited possible breeding evidence at BMB-02, BMB-03, BMB-07, BMB-10, and BMB-19 (woodland to north of station); and probable breeding evidence from BMB-05. This species favours deciduous forests, but can be found breeding in parks, small woodlots (OMNR 2000), and plantations (Nol 2015).

Caspian Tern and Rusty Blackbird were observed outside of the breeding season and are not breeding within the study area. The observations of these species represent migratory individuals. Caspian Tern breed mostly on Lake Erie and Lake Ontario; Rusty Blackbird breeds in central and northern Ontario.

Although no notable observations were made during field surveys on site, the sewage lagoons just outside the study area, to the southeast of Smithville, are considered a hotspot for birds.

Table 3.8.3. Significant Bird Species Observed from the Study Area

Common Name	Scientific Name	SRANK[1]	COSEWIC[2]	SARO[1]	Regional Status[4]	Habitat Preference	Background Source	Suitable Habitats Within Subject Property
Barn Swallow	*Hirundo rustica*	S4B	SC	SC	Significant	Foraging habitat in Ontario includes farmland, lakeshore and riparian habitats, road right-of-ways, clearings in wooded areas, parkland and urban and rural residential areas, wetlands and tundra (Heagy et al. 2014; OMNR 2000; COSEWIC 2011). Nest sites often occur on human structures including buildings, barns, bridges, culverts, wells and mine shafts. Natural nest sites include caves, cliffs or other ledges (Heagy et al. 2014).	BSC 2006	Residential Ag fields CUM MAM2 MAM2-2 MAM3 MAS2 SAS
Bobolink	*Dolichonyx oryzivorus*	S4B	T	THR	Significant	Large, open expansive grasslands with dense ground cover; hayfields, meadows or fallow fields. This species generally requires habitat >10ha in size although use of these areas may be influenced by other landscape attributes such as topography and patch shape (McCracken et al. 2013). In Ontario, hayfields and pastures are preferred but they are usually absent from grain fields and row crops (COSEWIC 2010).	BSC 2006 NHIC 2013	Ag fields (depending on crop) CUM Suitable grasslands of sufficient size were not located within the study area in 2020.

Common Name	Scientific Name	SRANK[1]	COSEWIC[2]	SARO[1]	Regional Status[4]	Habitat Preference	Background Source	Suitable Habitats Within Subject Property
Eastern Meadowlark	*Sturnella magna*	S4B	T	THR	Significant	Open, grassy meadows, farmland, pastures, hayfields or grasslands with elevated singing perches. The minimum required grassland size is approximately 5ha (McCracken et al. 2013). This species breeds in Ontario, and favours well concealed grasslands and prairie habitats for nesting (Jaster et al. 2012).	BSC 2006	Ag fields (depending on crop) CUM Suitable grasslands of sufficient size were not located within the study area in 2020.
Eastern Wood-pewee	*Contopus virens*	S4B	SC	SC	-	Open, deciduous, mixed or coniferous forest; predominated by oak with little understory; forest clearings, edges; farm woodlots, parks (OMNR 2000). Breeds in virtually every type of wooded habitat in the east (Peck and James 1987). Size of forest fragments does not seem to be an important factor in habitat selection (Freemark and Collins 1992).	BSC 2006	FOD FOD3-1 FOD4-1 FOD5-8 FOD6-5 FOD7 FOD7-4 FOD9 FOD9-1 FOD9-3 FOD9-4 SWD SWD3 SWD3-1 SWD4 SWD4-2
Rusty Blackbird	*Euphagus carolinus*	S4B	SC	SC	-	Within the non-breeding range, found predominantly in swamps and wet woodlands. Breeds in northern Ontario in openings in coniferous woodlands bordering bodies of water; tree-bordered marshes, beaver ponds, muskegs, bogs, fens or wooded	BSC 2006	Suitable nesting habitat is not present in the study area. The observation represents a migrant.

Common Name	Scientific Name	SRANK[1]	COSEWIC[2]	SARO[1]	Regional Status[4]	Habitat Preference	Background Source	Suitable Habitats Within Subject Property
						swamps; stream borders with alder, willow; wooded islands on lakes (OMNR 2000).		
Caspian Tern	*Hydroprogne caspia*	S3B	NAR	NAR	-	Open habitat near large lakes or rivers, beaches, shorelines, rocky or sandy beaches, offshore islands; negatively affected by elevated water levels during nesting season; feeds on fish; found in association with Ring-billed Gulls.	BSC 2006	Suitable nesting habitat is not present in the study area. The observation represents a migrant.

[1]MNRF 2023, [2]Government of Canada 2021, [4]NPCA 2010

Herpetofauna

According to the Ontario Reptile and Amphibian Atlas (Ontario Nature 2019), 22 species of herpetofauna are reported from the study area; however, the majority of these records are historic. NRSI field investigations confirmed the presence of 12 species within the study area including American Toad (*Anaxyrus americanus*), Gray Treefrog (*Hyla versicolor*), Northern Green Frog (*Lithobates clamitans melanota*), Northern Leopard Frog (*Lithobates pipiens*), Spring Peeper (*Pseudacris crucifer*), Western Chorus Frog (*Pseudacris triseriata pop.1*), Dekay's Brownsnake (*Storeria dekayi*), Eastern Gartersnake (*Thamnophis sirtalis sirtalis*), Northern Watersnake (*Nerodia sipedon sipedon*), Midland Painted Turtle (*Chrysemys picta marginata*), Snapping Turtle (*Chelydra serpentina*), and Blue-spotted Salamander (*Ambystoma laterale*).

A complete list of herpetofauna reported from the study area, based on background information and observations made as part of this study, is included in Appendix H-V. The results of species-specific surveys are detailed below.

Anurans (Frogs and Toads)

During anuran call surveys, five species of anurans were recorded: American Toad, Gray Treefrog, Northern Green Frog, Spring Peeper, Western Chorus Frog. The results of the monitoring are shown in Table 3.8.4. Species were generally well-distributed throughout the study area and anurans were heard calling at all monitoring stations during at least one of the three surveys. Western Chorus Frogs were heard calling at all but one of the monitoring stations including full choruses at three stations (ANR-05, ANR-07, and ANR-08). Spring Peepers and American Toads were both noted at seven of the 11 stations with full choruses of Spring Peepers noted at four stations (ANR-02, ANR-04, ANR-06, and ANR-11), and American Toads at one station (ANR-08). Gray Treefrog and Green Frog were heard at the fewest monitoring stations, calling at four and three stations, respectively.

Table 3.8.4. Anuran Monitoring Results

Anuran Station (ANR)	April 28	May 20	June 23
1	AMTO 2(4) CHFR 2(3) SPPE 2(8)	SPPE 1(4)	*None*
2	CHFR 2(2) SPPE 3	CHFR 1(1) SPPE (2)	*None*
3	AMTO 2(3) CHFR 2(6) SPPE 2(6)	CHFR (2)	GRTR 1(1)
4	CHFR 2(3) SPPE 3	CHFR (2) SPPE 1(1)	GRTR 1(2)
5	AMTO 2(3) CHFR 3	AMTO 1(4) CHFR 1(4)	*None*
6	AMTO 1(2) CHFR 1(2) SPPE 3	CHFR 1(1) SPPE 2(8)	*None*

Anuran Station (ANR)	April 28	May 20	June 23
7	CHFR 3	*None*	GRFR 1(2) GRTR 1(2)
8	AMTO 3 CHFR 3	AMTO 1(1) CHFR 1(2) GRTR 2(3)	GRTR 2(5)
9	*None*	*None*	GRFR 1(1)
10	AMTO 2(6) CHFR 2(6) SPPE 1(2)	AMTO 1(1) CHFR 1(1)	*None*
11	AMTO 2(4) CHFR 2(3) SPPE 3	*None*	GRFR 1(6)

Legend
AMTO – American Toad
CHFR – Western Chorus Frog
GRFR – Green Frog
GRTR – Grey Treefrog
SPPE – Spring Peeper
First # indicates call code/level, second #, in brackets, indicates number of individuals.
Call Level 1. Calls can be counted; not simultaneous
Call Level 2. Some simultaneous calls; yet distinguishable
Call Level 3. Calls not distinguishable; overlapping (i.e. "full chorus"); number of individuals cannot not estimated

Snakes

During snake coverboard surveys and area searches, two species of snakes were recorded. A single Dekay's Brownsnake was observed under SNK-18 and a single Eastern Gartersnake was observed under SNK-03. One Eastern Gartersnake was also observed near SNK-17. A single Eastern Gartersnake was also observed within the Shagbark Hickory forest (FOD9-4) southwest of Spring Creek Road and Industrial Park Road.

Blackport & Associates staff observed approximately 20 Gartersnakes in the vicinity of SNK-16 on April 6, 2020. The snakes were observed both in the agricultural field, as well as on the former rail line, indicating a hibernaculum nearby.

One additional species, Northern Watersnake, was observed incidentally during aquatic field surveys on September 1, 2020. A single individual was observed within Twenty Mile Creek below the walking bridge crossing of Wade Road.

No snake SAR or SCC, nor any regionally significant snake species were observed within the study area.

Turtles

Two species of turtles were observed within the study area: Midland Painted Turtle and Snapping Turtle. A single Midland Painted Turtle was observed within North Creek at the crossing of Townline Road. Snapping Turtle is a SCC and was observed during aquatic field surveys on September 1, 2020. A single individual was observed swimming in Twenty Mile Creek below the walking bridge crossing of Wade Road. This species inhabits permanent, semi-permanent fresh water; marshes, swamps or bogs; rivers and streams with soft muddy banks or bottoms and often uses soft soil or clean dry sand on south-facing slopes for nest sites (OMNR 2000). These conditions are found within the study area and particularly along the Twenty Mile Creek corridor.

Salamanders

A single species of salamander, Blue-spotted Salamander, was observed at SNK-10 during snake coverboard surveys.

No salamander SAR or SCC, nor any regionally significant salamander species were observed within the study area. Species specific surveys were not conducted and are outside the scope of the current study.

Mammals

According to the Mammal Atlas of Ontario (Dobbyn 1994), eight mammal species are reported from the study area, with several historic records. NRSI observed a total of 12 mammal species: American Mink (*Mustela vison*), Coyote (*Canis latrans*), Eastern Chipmunk (*Tamias striatus*), Eastern Cottontail (*Sylvilagus floridanus*), Eastern Gray Squirrel (*Sciurus carolinensis*), Meadow Vole (*Microtus pennsylvanicus*), Northern Raccoon (*Procyon lotor*), Red Fox (*Vulpes vulpes*), White-footed Mouse (*Peromyscus leucopus*), White-tailed Deer (*Odocoileus virginianus*), and Woodchuck (*Marmota monax*), as well as a mole species. Appendix H-VI provides a complete list of mammal species reported from the study area.

No mammal SAR or SCC, nor any regionally significant mammal species were observed within the study area.

Butterflies and Odonata

Butterflies

According to the Ontario Butterfly Atlas (Macnaughton et. al. 2020), 37 butterfly species are reported from the study area. NRSI biologists observed 9 species during surveys completed in 2020. These species include Black Swallowtail (*Papilio polyxenes*), Cabbage White (*Pieris rapae*), Canadian Tiger Swallowtail (*Papilio canadensis*), Clouded Sulphur (*Colias philodice*), Common Ringlet (*Coenonympha tullia*), Monarch (*Danaus plexippus*), Mourning Cloak (*Nymphalis antiopa*), Orange Sulphur (*Colias eurytheme*), and Viceroy (*Limenitis archippus*). A complete list of species observed and reported from the area is provided in Appendix H-VII.

Monarch is a SCC and was observed on several occasions during surveys. Adult Monarchs were observed on July 6 associated with ELC community FOD9-4, southwest of Forestview Crescent, and communities FOD9/SWD3 southwest of Young Street and Industrial Park Road. An individual adult was also observed along the North Creek riparian corridor east of Tober Road, associated with MAM2-2 on September 2, 2020 and one was observed along the Twenty Mile Creek corridor north of the sewage lagoons, associated with FOD9-3/SWD4/CUM. This species feeds exclusively on Milkweeds (*Asclepias spp.*) which are found throughout the study area and adjacent lands. No regionally significant butterfly species were observed.

Dragonflies and Damselflies

According to the Ontario Odonate Atlas (Ontario Odonata Atlas Database 2019), 13 odonate species are reported from the study area. NRSI biologists observed two species during surveys completed in 2020: Eastern Pondhawk (*Erythemis simplicicollis*) and Widow Skimmer (*Libellula luctuosa*). A complete list of species observed is provided in Appendix H-VIII.

No dragonfly or damselfly SAR or SCC, nor any regionally significant odonate species were observed within the study area.

3.8.4.4 Wildland Fire Screening

Wildland fires are defined as fires that burn in treed or forested areas. In natural ecosystems, fires can be necessary for natural regeneration and an important process for maintaining ecosystem heath. However, fires have the potential to cause property damage and impact public health and the safety of individuals when in close proximity to development. Wildland fire hazards are created when development encroaches into areas containing hazardous forest types for fire as the likelihood of fire occurring increases with the introduction of human caused sources of ignition.

A Wildland Fire Screening was conducted for the subject lands following the methods outlined in the *Wildland Fire Risk Assessment and Mitigation: A Guidebook in support of the Provincial Policy Statement, 2014* (MNRF 2016) document. The screening was conducted to determine if there is a potential risk for wildland fire within the subject lands and if so, what the level of risk may be.

A review of generalized wildland fire hazard mapping was conducted. The dataset *Fire – Potential Hazardous Forest Types for Wildland Fire*, was created by MNRF and provides a coarse scale assessment identifying areas that at one point may have contained potential hazardous forest types for wildland fire. These data are intended to indicate areas with the greatest potential for risks associated with high to extreme wildland fire.

A broadscale or municipal wide assessment of potential hazardous forest types is suggested by the MNRF if local planning authorities have undertaken a broad level/municipal-wide wildland fire assessment. The Niagara Region has not yet completed this assessment. The Niagara Region Natural Environment Background Study (NSEI et al. 2019) identifies that the Region should determine the need for undertaking a region-wide wildland fire assessment, as per the Wildland Fire Risk Assessment and Mitigation Reference Manual, including the need for a detailed dataset and to consider how wildland fire policies should be implemented.

A site-level wildland fire assessment for the study area was conducted in two phases. The level 1 site assessment consisted of screening the study area for the presence of forest cover to determine if there is a risk for wildland fire. Previous ELC mapping and aerial imagery were reviewed to confirm the presence of forest cover within the study area. Since forest cover is present within the study area, a level 2 site assessment was undertaken to determine the level of risk. The level 2 site assessment was conducted in conjunction with ELC surveys completed in 2020, and involved the evaluation of forest characteristics that may make an area unsafe for development from a wildland fire perspective. The following characteristics were documented for each forested area where possible:

- Forest composition and predominant vegetation;
- Forest condition (e.g. presence of disease, storm or insect damage);
- Forest arrangement and density (i.e. trees close to each other); and
- Presence of ladder fuels (i.e. conifer species with branches within 2m of the ground) and ground fuel accumulation.

The above characteristics of each forested area were assessed against the listed characteristics of high to extreme hazardous forest types presented in the MNRF Guidebook (MNRF 2016) to determine if any of the forested areas within the study area have a high to extreme wildland fire risk level.

Based on the level 1 site assessment, which involved a review of previous ELC mapping and aerial imagery, coniferous forest cover is present within the study area, therefore creating a potential risk for wildland fire within the study area. The initial review of MNRF wildland fire hazard mapping indicated that the study area contained low and moderate potential hazardous fuel types (Map NH-5).

A level 2 assessment refined results from the wildland fire hazard mapping. This assessment indicates that coniferous species do occur within the study area, including Eastern Red Cedar and Eastern White Pine. However, the overall composition of these species within woodland features is less than 25% across the study area, indicating a low risk of wildland fire. Conditions that could lead to high or extreme fire risk were not observed. ELC mapping and vegetation surveys indicate woodlands dominated by Maple, Oak, Beech, and Shagbark Hickory.

Although no areas were identified to pose a high threat for wildland fire within the study area, the meadow areas in close proximity to subdivisions have potential to carry a fire. A fire could be ignited due to the dumping of embers or use of a fire pit, smoldering pieces of fireworks reaching the ground, or cigarettes being discarded into the grassy thatch during times of drought.

3.9 Aquatic Resources

3.9.1 Importance and Purpose

The aquatic resources assessment provides a characterization of the aquatic ecology along the open watercourses and streams within the study area. The information collected through this analysis provides insight regarding the significance and contributions of the watercourses and streams toward supporting and sustaining aquatic habitat within and downstream of the study area. This understanding provides the insight toward establishing the watercourse and stormwater management plans for the future development, including integration with the NHS.

3.9.2 Background Information

Existing natural heritage information on aquatic resources was gathered and reviewed to identify key natural heritage features and species that are reported from the study area. Background information on the natural environmental features within the study area was gathered from the Ministry of Natural Resources and Forestry (MNRF) Land Information Ontario (LIO) database, the MNRF Natural Heritage Information Centre (NHIC), Fisheries and Oceans Canada (DFO) Species at Risk (SAR) mapping, as well as information provided by the TAC regarding the Niagara Region and the Township of West Lincoln (2018) Official Plan documents, and other files gathered from the Township and the Region, including the *Environmental Screening Report for the Smithville Growth Management Study* (Colville 2008) and associated updated and addendum (Colville 2015a, 2015b). Additional background information was gathered from the NPCA, including fish species occurrence data.

To help inform suitable land-use concepts and identify areas to be protected, aquatic natural heritage features are evaluated against the relevant policies and legislation described in Section 2.2.

3.9.3 Methods and Analysis

The aquatic ecology of the study area has been characterized using existing information and data collected through aquatic habitat assessments and fish community surveys undertaken in 2020. The watercourses occurring within the study area are located within the Twenty Mile Creek, North Creek, and Spring Creek subwatersheds. Most of the watercourses lie within the Twenty Mile Creek subwatershed and functionally collect and convey the majority of water from within the study area to the main branch of Twenty Mile Creek, which flows southwest from the western boundary to the southeast corner and bisects the Community of Smithville. Watercourses within the southern portion of the study area, and generally south of Smithville, flow south to North Creek. The main branch of North Creek runs along the southern boundary of the study area, coinciding within the study area at its southwestern corner. North Creek flows eastward and into the Twenty Mile Creek approximately 1.5km southeast of the study area. The northeast corner of the study area occurs within the Spring Creek subwatershed, which collects and diverts flow southeast toward Spring Creek, which lies outside of the study area boundary.

The watercourses, as mapped through existing sources, are shown on Maps NH-1A and -1B. Aquatic habitat assessment locations are shown on Map NH-4, which focused on permanent watercourses within the study area. The watercourse mapping layer was refined as appropriate based on observations during field work conducted by the Study Team and findings from a review of recent air photos. The revised watercourse mapping is shown on all subsequent mapping and reach designations from the fluvial geomorphological assessment have been integrated into the characterization of the area watercourses (see Figures 1a through 1n).

The Study Team has conducted surveys to assess the aquatic ecology during spring and summer conditions. During these site visits a detailed characterization of aquatic habitats was completed, as well as a fish community assessment within the watercourses that flow through the study area where property access was granted. These surveys are described in further detail in the following sections. Monitoring station locations are shown on Map NH-4. Table 3.9.1 outlines the field surveys that were conducted in 2020.

Aquatic Habitat Assessment

An aquatic habitat assessment was conducted in association with fish sampling locations on May 20, September 1, and September 2, 2020 to assess existing aquatic conditions and to identify and characterize key habitat areas for watercourses within the study area under spring and summer conditions.

The habitat assessment utilized modified OSAP methods (Stanfield 2013) to characterize basic channel morphology, channel substrates, bank stability, instream habitat and cover, aquatic vegetation type and abundance, adjacent lands, and flow conditions to determine general quality and availability of habitat for fish. The assessment also noted any barriers to fish movement, existing on-line ponds, sources of stream baseflow and groundwater discharge (e.g. seeps and springs), and water temperature measurements.

Watercourse Classification

Utilizing the MNRF watercourse classification (OMNR 2000), the watercourse features within the study area were classified as Critical, Important, and Marginal habitats. Existing MNRF watercourse classification mapping has been refined based on results from the aquatic habitat assessment and fish community surveys, which included an assessment of permanency (e.g. permanent, intermittent, HDF). This has been completed in conjunction with the HDF assessment conducted by the Study Team fluvial geomorphologists. Watercourses also have been assigned a cold, cold-cool, cool, cool-warm, or warm water designation based on summer temperature measurements (Chu et. al. 2009) and fish presence.

Thermal Regime Analysis

Permanent watercourses have been classified based on the priority of habitat type and were assigned a cold, cold-cool, cool, cool-warm, or warm water designation, based on surveys and background information. The designation of thermal regime has been based on water temperature readings taken during summer aquatic habitat surveys (September 1 and 2) as well as results from fish community surveys (May 20, September 1-2). Although the timing and date for some of the water temperature readings were not consistent with sampling guidelines (Chu et al. 2009), thermal regime has been inferred based on the temperature readings and the fish community present for each location. Water temperature data have been supplemented by summer surface water temperature readings collected during stream baseflow field work completed by the Study Team on July 30, 2020 as part of the surface water monitoring program.

Table 3.9.1. Aquatic Field Survey Summary

Survey Type	Protocol	Date	Start and End Time (24 hrs)	Air Temp. (°C)	Beaufort Wind Speed	Cloud Cover (%)	Precipitation	Observers
Fish Survey	OSAP (Stanfield 2013)	May 20, 2020	8:30 - 15:30	15	1	20	None	G. MacVeigh A. Cantwell
Fish Survey	OSAP (Stanfield 2013) and non-standardized sampling	September 1, 2020	12:00 - 16:30	20 - 30	2 - 3	0	None	S. Burgin A. Reinert
		September 2, 2020	9:30 - 16:30	26 - 30	1 - 4	50 - 100	Light Rain	S. Burgin A. Reinert
Aquatic Habitat Assessment	Modified OSAP (Stanfield 2013)	May 20, 2020	8:30 - 15:30	15	1	20	None	G. MacVeigh A. Cantwell
		September 1, 2020	12:00 - 16:30	20 - 30	2 - 3	0	None	S. Burgin A. Reinert
		September 2, 2020	9:45 - 16:20	26 - 30	1 - 4	50 - 100	Light Rain	S. Burgin A. Reinert

Fish Community Sampling

Backpack electrofishing has been conducted utilizing the OSAP single-pass methodology (Stanfield 2013), which targets the various habitat types (water depth, vegetation, cover etc.) within an area. Fish community sampling was also conducted utilizing non-standardized seine net, and dip net survey methodologies, where appropriate, to characterize the fish community within aquatic habitats in the study area. A spring electrofishing survey was conducted on May 20, 2020, which focused on sampling headwater drainage features within the study area. Summer fish sampling was completed on September 1 and 2, 2020 to document the fish community within the permanent watercourses. Summer surveys included backpack electrofishing, seine net, and dip net surveys. All surveys were undertaken by a two-person crew at locations shown on Map NH-4. Backpack electrofishing was completed using a Smith-root LR-20B backpack unit. Seine netting was completed using a 20m long by 1.5m high net.

Sampling conditions during aquatic surveys are summarized in Table 3.9.2. All fish species were identified to species in the field and returned to the water at the point of capture. Minimum and maximum lengths were collected for each species to identify the range of sizes present within the study area.

Table 3.9.2. Aquatic Sampling Conditions Summary

	Station EMS-01	Station EMS-02	Station EMS-03	Station EMS-04	Station EMS-05	Station EMS-06	Station EMS-07	Station EMS-08	Station EMS-09	Station EMS-10	Station EMS-11	Station EMS-12	Station EMS-13	Station EMS-14	Station EMS-15	Station SEN-01	Station SEN-02	Station DIP-01	Station DIP-02
Date	20-May-20	20-May-20	20-May-20	20-May-20	20-May-20	20-May-20	20-May-20	20-May-20	20-May-20	20-May-20	1-Sep-20	2-Sep-20	2-Sep-20	2-Sep-20	2-Sep-20	1-Sep-20	2-Sep-20	20-May-20	1-Sep-20
Sampling Start Time	8:30	9:10	9:50	10:30	13:00	14:30	15:10	15:45	16:10	17:08	12:00	8:20	9:10	15:30	15:50	14:50	11:24	8:30	14:40
Sampling End Time	9:00	9:35	10:30	11:20	13:45	15:02	15:30	16:00	16:52	17:42	12:40	8:25	9:40	15:40	15:55	14:57	12:02	9:00	14:50
Air Temperature (°C)	15	16	16	DNC	21	15	16	17	17	DNC	30	24	26	28.5	28.5	30	29	15	30
Water Temperature (°C)	10.7	11.7	24.2	DNC	18.7	24.4	26.8	26.3	24.3	DNC	24.7	19.3	18.2	14	21.5	23.4	24.8	11.1	22.5
Time Water Temp. Taken	9:27	10:10	14:25	DNC	13:00	14:30	15:10	15:45	16:15	DNC	12:40	8:20	9:45	15:30	15:50	15:30	12:30	8:30	14:40
Conductivity (ms/cm)	933	552	709	DNC	775	705	230	860	135	DNC*	DNC*	DNC*	DNC*	DNC*	DNC*	DNC*	DNC*	DNC*	DNC*
Dissolved Oxygen (ppm)	88.8%	100.6%	109	DNC	123%	121%	181	158.4	175.4	DNC*	DNC*	DNC*	DNC*	DNC*	DNC*	DNC*	DNC*	DNC*	DNC*
Electrofisher Type	Smith-root Backpack Unit (LR-20B)															N/A	N/A	N/A	N/A
Number of Netters	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	N/A	N/A	2	N/A
Voltage (V)	150	150	150	150	100	100	100	100	150	100	100-200	100	100	100	100	N/A	N/A	N/A	N/A
Pulsating Frequency (Hz)	80	60	60	60	60	60	60	60	60	60	70	80	80	80	80	N/A	N/A	N/A	N/A
Shocking Time (sec.)	227	314	142	260	285	399	81	109	N/A	123	533	35	435	95	30	N/A	N/A	N/A	N/A

DNC – Did Not Collect
DNC* – Equipment malfunction; readings were not accurate
N/A – Not Applicable

3.9.4 Interpretation and Findings

3.9.4.1 Aquatic Habitats

The permanent and intermittent watercourses within the study area are described in this section, whereas the headwater drainage features are described in the Fluvial Geomorphic section. Aquatic monitoring station locations are shown on Map NH-4. Reach mapping is shown on Figures 1a through 1n.

Permanent Watercourses

Three watercourses have been confirmed as permanent within the study area during field surveys completed on September 2 and 3, 2020. These include the main channel of Twenty Mile Creek (TM3/TM4), main channel of North Creek (NC6/NC7), and a small portion of an inflowing tributary to Twenty Mile Creek (TM3(1)1), located at AHP-005 on Map NH-4. Water was present within each of these features, but was only observed flowing at TM3(1)1. Portions of the channels within Twenty Mile and North Creek were dry, isolating the existing wetted portions of each feature.

Twenty Mile Creek

The main channel of Twenty Mile Creek was characterized at AHP-001 and AHP-004, although conditions were noted to be similar to other locations within Twenty Mile Creek within the study area as well. Wetted widths ranged from approximately 4m to 19m, although bankfull widths were much wider, ranging from 16m to 40m, indicating substantial variations in water levels throughout the year. Bank height was measured up to 2m with areas of erosion noted. Water depths ranged from 0.05m to 0.63m at the time of assessment. Substrates were variable, including silt, gravel, and cobble with smaller areas of sand and occasional boulders throughout. Bedrock was also observed throughout, but was particularly evident in the vicinity of the Wade Road crossing, downstream from the walking bridge where the channel was observed dry. Two concrete weirs exist at this location, which were acting to pool water upstream and maintain aquatic habitat. The flows within Twenty Mile Creek are influenced heavily by karst features in the area. One feature in particular (Smithville Cave) occurs approximately 100m upstream (west) from Canborough Street on the north side of the river. Water exits the feature and contributes to, and helps to sustain, baseflow downstream from this location throughout the year. The channel upstream from this location was noted to be dry at several locations, and in particular east from the cross-channel weirs at Wade Road. A sinkhole has also been identified at this location, which diverts water to the Smithville Cave.

Aquatic vegetation was observed throughout the wetted areas of the channel, associated primarily with finer substrates including silt and muck. Vegetation occurred in moderate to high abundance and included a variety of floating, emergent, and submergent species. Floating species included White Water Lily (*Nymphaea odorata*), Yellow Pond Lily (*Nuphar lutea*), and duckweed spp. (*Lemna spp.*). Emergent species included Cattail (*Typha spp.*), Burreed (*Sparganium spp.),* Arrowhead (*Sagittaria spp.*), and Water Smartweed (*Persicaria amphibia*). Submergent species included Coontail (*Ceratophyllum demersum*), Milfoil (*Myriophyllum spp.*), and Pondweed (*Potamogeton spp.*).

As indicated on Maps NH-3A to -3F, the riparian zone consists of a variety of ecotypes including both wetland and forest types, with wetland areas occurring along the western and eastern portions of the creek and deciduous forest primarily associated with the urbanized section of the creek. Riparian areas are variable in size and composition along Twenty Mile Creek and differ depending on adjacent land uses. Within the study area boundary, western and eastern portions of the creek run adjacent to agricultural fields, which limit the riparian area to a minimum of 5m at a few locations and generally restrict the riparian zone as a whole where they border the creek. Where the creek exists adjacent to residential and commercial lands within the Community of Smithville, the riparian zone varies from 0m up to roughly

100m, with a general width of approximately 30m. Several properties abut the top of bank where manicured lawn has been maintained to the edge, although the majority of the riparian zone throughout this stretch is treed, which offers a moderate amount of shading to the creek. In addition to the adjacent trees, a variety of forbs and shrubs overhang the creek.

Twenty Mile Creek is confirmed fish habitat and provides nursery, rearing and foraging habitat for the local fish community, including warm and coolwater species. The habitat present within the creek includes emergent, submergent, and floating aquatic vegetation; rocky substrates including gravel, cobble, and boulder; overhanging bank vegetation (shrubs and trees) and occasional large woody debris; pools and backwater areas. Under higher flow conditions, riffles would also occur at various locations within the creek, but during low flow conditions many sections of the creek are dry, which isolate pools and result in limited flow through the study area.

North Creek

The main channel of North Creek was characterized at AHP-002 and AHP-007, where the channel occurs within the study area boundary. The channel was also assessed at AHP-003 where the channel occurs along the perimeter of, but just outside of, the study area at Tober Road. The channel was noted to be dry at several locations where observed on September 1, but water was observed within small standing pools under the South Grimsby Road 6 culvert, within a large, isolated pool at the Townline Road culvert, and at the Tober Road crossing, where some flow was noted. Wetted widths ranged from approximately 0.75m to 2.3m, with bankfull widths ranging from 5m to 15m. Bank height was measured up to approximately 1.5m with areas of erosion noted, particularly at the Townline Road crossing. Where present, water depths ranged from 0.02m to 0.53m. Substrates were variable, including cobble, gravel, sand, silt, and clay, with occasional boulders. Substrates were generally finer (silt and sand) at the Townline Road crossing and more course at the Tober Road crossing. Aquatic vegetation occurred in low to moderate abundance and included a variety of floating, emergent, and submergent species. Floating species included Yellow Pond Lily and Duckweed spp. Emergent species included Cattail spp., and submergent species included Milfoil. Filamentous algae was noted to be abundant, particularly at Tober Road.

As indicated on Map NH-3E, the riparian zone is primarily comprised of Reed Canary Marsh (MAM2-2), which consists primarily of grasses and forbs with occasional shrubs and trees. This provides some, but generally limited, shading to the watercourse. North Creek runs along the southern edge of the study area, which consists of rural properties and agricultural lands. The riparian zone is generally limited along this stretch, varying between approximately 5m and 30m.

North Creek is confirmed fish habitat and provides nursery, rearing and foraging habitat for the local fish community, including warm and coolwater species. The habitat present within the creek includes emergent, submergent, and floating aquatic vegetation; rocky substrates including gravel, cobble, and boulder; overhanging bank vegetation (shrubs and trees) and occasional large woody debris; pools, and backwater areas. Under low flow conditions many sections of the creek are dry, which isolate pools and result in limited flow, although enough water still occurs to support a diverse fish population.

Watercourse Reach TM3(1)1

Water was observed flowing within a portion of Watercourse Reach TM3(1)1 at station AHP-005 on September 2. Water was exiting the ground as a seep and flowed for approximately 75m to Twenty Mile Creek. The channel upstream from this location was noted to be dry. This feature was observed flowing over a moderate gradient with a wetted width of 0.85m to 1.4m and bankfull width of 2.0m to 3.0m. Water depths were measured at 0.04m to 0.13m and bank height ranged from 0.4m to 1.2m. The substrates are dominated by cobble and gravel with areas of silt and clay. Watercress was observed in moderate abundance, in addition to filamentous algae and the water temperature was measured at 14°C on September 2, 2020. The riparian zone consists of lowland deciduous forest (FOD7), which provides nearly 100% shade to the channel.

This feature provides habitat features in the form of small pools, riffles, cobble, woody debris, and vegetation, but due to the gradient of the feature and abrupt changes in elevation due to cobble in the lower end it would be difficult for fish to access the entire channel. Further, fish sampling did not capture fish within the feature, indicating that it is unlikely to be utilized as direct fish habitat, but rather acts to provide indirect habitat and coldwater contribution to Twenty Mile Creek throughout the year.

Intermittent Watercourses

Several watercourses were identified within the study area by Matrix Solutions Inc. during their watercourse analysis that do not fall into the category of Headwater Drainage Feature, but were not permanent. These are indicated on Map NH-4. These features were generally noted to exhibit a more channelized form and provided some instream cover and habitat; primarily bank vegetation and undercut banks, where they occurred within undisturbed forested and wetland habitat while exhibiting less defined form and little to no cover or habitat where they flowed across agricultural lands. Several of these features appear to provide seasonal habitat for fish during the spring when water is present within the channels, but do not provide suitable habitat year-round due to the fact that they become dry during the summer and fall. During surveys in May, 2020 fish were captured at several locations, but were primarily found within small, isolated or partially isolated pools. Fish presence is discussed in the following section, which includes the identification of those features that were noted to have fish within them in 2020, including HDF, intermittent and permanent features.

Ponds

One pond exists within the wetland/woodland feature at the northeast portion of the study area (SAS, Map NH-3B), which is a created feature based on historical imagery, and is presumed to have been utilized for agricultural purposes. This feature connects to the HDF system that drains the northeastern portion of the study area to Twenty Mile Creek and was "on-line" during the spring. During spring fish sampling, a variety of species were captured within the connecting HDF reaches, which suggests that the pond is likely to provide year-round refuge for fish, particularly during times when the HDF are dry. Several other small off-line ponds are also present throughout the study area, which are generally associated with rural residential and agricultural properties.

3.9.4.2 Fish Community

Fish community surveys were conducted in May and September, 2020 to provide current fish species information for the watercourses within the study area. Surveys completed in May 2020 assessed fish presence as part of the HDF assessment, while September 2020 surveys provided species data on the permanent watercourses within the study area. Water levels were low during summer fish and habitat surveys in early September. The majority of features within the study area were dry on September 1 and 2, 2020, with the exception of the main channels of Twenty Mile Creek, North Creek, and a small inflowing channel to Twenty Mile Creek, located at Reach TM3(1)1.

A total of 22 fish species have been reported from the study area based on historical data from 2000 and 2008 for Spring Creek, North Creek, and Twenty Mile Creek. During 2020 field surveys, 19 fish species were observed within the study area, including one new species for the area: Iowa Darter (*Etheostoma exile*). All other species captured during the 2020 field program had been previously identified from the vicinity of the study area. Seven species were observed within Spring Creek, including its tributaries; 11 were observed in North Creek including its tributaries; and 17 species were observed within Twenty Mile

Creek, including its tributaries. Table 3.9.3 lists the fish species observed at each monitoring station. A complete list of fish species reported from the study area, based on background information and observations made as part of this study, is included in Appendix I-I

The fish community observed within the study area is considered to be fairly diverse and is characterized by a variety of small-bodied and larger-bodied fish, including recreationally valuable species such as Largemouth Bass (*Micropterus salmoides*), Northern Pike (*Esox lucius*), Pumpkinseed (*Lepomis gibbosus*), Bluegill (*Lepomis macrochirus*), and White Crappie (*Pomoxis annularis*). The highest fish diversity and abundance was observed within the main channel of Twenty Mile Creek, which is the largest watercourse of the three, and which provided the most wetted habitat and highest habitat diversity during the summer months. Young-of-year (Age-0 fish), juvenile, and adult fish were captured during both spring and summer surveys within all three subwatersheds indicating the presence of suitable spawning, rearing, and feeding habitat throughout the study area. All species captured exhibit either warm or cool thermal preferences, with 10 of the species exhibiting a warm thermal preference and nine exhibiting a cool preference. Thermal regime is discussed below.

The DFO Species at Risk distribution mapping (2019) indicates that Grass Pickerel (*Esox americanus vermiculatus*), a species of Special Concern, has the potential to occur in Twenty Mile Creek and North Creek, although, these systems do not include Critical Habitat for the species (DFO 2019). No Grass Pickerel were captured during field surveys but suitable habitat was present in the form of backwater and slow-moving areas with relatively warm, clear, shallow water and an abundance of aquatic (Eakins 2020, MECP 2019). Preferred water temperature for the species is approximately 25.5°C, which is slightly higher than the summer water temperatures that were observed within Twenty Mile Creek, which ranged from approximately 23 to 25°C and several degrees higher than summer temperatures within North Creek, which ranged from approximately 18 to 22.5°C.

Table 3.9.3. Fish Community Presence/Absence

Scientific Name	Common Name	Station ID																		
		EMS-01	EMS-02	EMS-03	EMS-04	EMS-05	EMS-06	EMS-07	EMS-08	EMS-09	EMS-10	EMS-11	EMS-12	EMS-13	EMS-14	EMS-15	SEN-01	SEN-02	DIP-01	DIP-02
Collection Date		May 20										September 1 and 2							May 20	Sept 1
Cyprinidae	**Carps and Minnows**																			
Pimephales notatus	Bluntnose Minnow		X									X		X			X	X		
Pimephales promelas	Fathead Minnow					X				X				X			X			X
Semotilus atromaculatus	Creek Chub											X								
Notemigonus crysoleucas	Golden Shiner					X			X			X		X			X	X		
Cyprinus carpio	Common Carp																X			X
Esocidae	**Pikes**																			
Esox lucius	Northern Pike													X						
Catostomidae	**Suckers**																			
Catostomus commersonii	White Sucker													X			X	X		
Umbridae	**Mudminnows**																			
Umbra limi	Central Mudminnow				X		X		X	X		X		X			X			X
Ictaluridae	**North American Catfishes**																			
Noturus gyrinus	Tadpole Madtom																	X		
Ameiurus nebulosus	Brown Bullhead											X					X			X
Gasterosteidae	**Sticklebacks**																			
Culaea inconstans	Brook Stickleback					X	X													
Centrarchidae	**Sunfishes and Basses**																			
Micropterus salmoides	Largemouth Bass																	X		
Lepomis gibbosus	Pumpkinseed			X		X						X		X			X	X		
Lepomis cyanellus	Green Sunfish	X				X			X			X		X			X	X		X
Pomoxis annularis	White Crappie																	X		
Lepomis macrochirus	Bluegill					X												X		
Ambloplites rupestris	Rock Bass											X						X		
Lepomis spp.	Sunfish spp. (yoy)					X			X									X		
Percidae	**Perches and Darters**																			
Etheostoma exile	Iowa Darter																	X		
Etheostoma nigrum	Johnny Darter													X			X	X		
	Total	**1**	**1**	**1**	**1**	**7**	**2**	**0**	**4**	**2**	**0**	**8**	**0**	**9**	**0**	**0**	**10**	**13**	**0**	**5**

4.0 Integration

4.1 Integration Approach

The foregoing investigations and discussions of the existing natural systems proceeded on a discipline-specific basis, working toward an integrated characterization and assessment of the features, functions and form related to the existing systems. This integration allows for a fuller understanding of the fundamental environmental components and systems within the study area. An integrated characterization and assessment of each study discipline generally occurs on two levels, namely: i) integrated characterization to validate or confirm the findings of respective disciplines, and ii) an integrated characterization of key environmental features and systems to define the functions, attributes, and interdependencies, and to thereby provide guidance for establishing management opportunities and requirements based on future land uses.

Primary environmental elements stemming from the discipline-specific characterization work described in the previous report sections include:

- Natural Heritage (including wetland/woodlot features/areas)
- Watercourses (including headwater drainage features)
- Recharge and Discharge Areas

Each of these elements to varying degrees requires an integrated assessment in order to establish the significance and associated sensitivity of the features, particularly in the context of the proposed urbanizing setting; the following provides some associated guidance in this regard:

i. Natural Heritage Units
    - diversity and significance of species (flora and fauna)
    - potential for corridor linkage and benefits to key biota
    - presence/absence of fluvial unit
    - local catchment area (size and land use)
    - groundwater influence to sustainability of habitats and functions
    - feature size, plant community diversity, and proximity to other features

ii. Watercourses and Headwater Drainage Features
    - presence/absence of form/stability
    - baseflow /intermittent/permanent
    - groundwater discharge (reach specific)
    - presence/absence of riparian corridor vegetation
    - presence/absence of karst features and associated function
    - bankfull/riparian/flood flows
    - floodplain
    - sediment transport
    - fish habitat (direct/indirect)
    - temperature/water quality

iii. Recharge and Discharge Areas
    - rate of infiltration/recharge
    - location of functional recharge areas
    - influence of karst features
    - functional relationship to watercourse, wetland or terrestrial feature

- quantity of groundwater flux

The foregoing factors/considerations (and others) have been summarized as they relate to the respective environmental features and systems. The following sections provide insight regarding these features and systems, which will be used in subsequent study stages to inform the land use and infrastructure (road and services) planning process in an iterative manner.

4.2 Principles of Integration

The field work and accompanying assessments, associated with the subwatershed characterization, has been used to establish various principles, unique to the overall study area. These principles reflect the properties and characteristics of the respective subwatersheds, which depending on their nature, have implications related to future management.

The following sections have been organized by discipline and the integration principle is stated, followed by the management implications, where relevant (italics). It should be noted that by their very nature there are overlaps between the respective disciplines, which essentially lead to the integrated understanding of how the subwatersheds function.

4.2.1 Groundwater Characterization and Functions

The study area is covered with a varying thickness of clay overlying bedrock. The clay reduces the amount of water that can move downwards to the bedrock except where open fractures, rooting channels and animal burrows allow for greater movement of water. These pathways are more prevalent where the clay is less than 6 m thick which allows for more 'recharge' to bedrock. The underlying bedrock consists of a network of vertical and horizontal fractures and solution channels. The solution channels form when water moving through the fractures dissolves the rock. Water that moves through the clay enters into the bedrock flow system through these fractures and solution channels, generally moving horizontally from north to south in the shallow bedrock with a limited amount of groundwater discharging to Twenty Mile Creek. Groundwater also moves vertically to the deeper bedrock and follows similar fractures and solution channels. The fractures and solution channels that are more common in upper 15 m provide the water for the majority of the household wells outside of the existing urban area. Stream reaches and wetlands that sit on top of the clay receive very limited amounts of groundwater compared to overland flow and direct precipitation. Areas where the clay is thin, 6 m or less, allow for a greater potential for water born contaminants from ground surface to enter the bedrock groundwater system

i. The fractured nature of clay/silt overburden, provides the main pathway for infiltration and movement of groundwater to the bedrock throughout the majority of the study area study area. A reduction in infiltration can reduce the local groundwater levels and available groundwater for storage and potential discharge where it exists. Infiltration can be reduced through urbanization by increased impervious area and compaction of the shallow till and glaciolacustrine silt/clay.

Maintain or enhance infiltration where functionally significant and minimize compaction of the shallow overburden.

ii. Reduced water levels may impact terrestrial communities dependent on a high water table and reduce groundwater discharge where it exists in stream reaches and effect aquatic resources.

Maintain or enhance infiltration where functionally significant. Also implement best management practices for underground servicing to minimize water table lowering.

iii. A reduction in recharge may reduce available water in local water wells.

Maintain or enhance infiltration where functionally appropriate and minimize compaction of the shallow overburden.

iv. The fractured nature of the clay/silt overburden can provide an additional capacity to infiltrate and store precipitation when the shallow water levels are sufficiently low and may buffer runoff for rainfall events.

Compaction or removal of the shallow overburden may reduce this buffering capacity

v. Smaller scale depressional topography can focus local shallow groundwater and may increase local recharge.

Efforts should be made to maintain or create where functionally important.

vi. Shallow groundwater levels adjacent to terrestrial features may act to buffer the amount of infiltration/recharge out of these features as part of the natural water balance.

Maintaining infiltration within the buffer areas surrounding these features may maintain the natural groundwater levels and local groundwater balance.

vii. The upper fractured bedrock network and its associated karstic features allow for localized discharge to Twenty Mile Creek and contributes to baseflow.

The interception storage function of certain karst features should be appropriately managed by protecting key karst features or replicating the function within the drainage system. The water balance function of the karst features and the contributing drainage area should be appropriately managed to ensure the groundwater functions where necessary.

viii. The upper fractured network within the Eramosa Member and Guelph Formation provides groundwater flow to Twenty Mile Creek and the majority of the local water wells. Installation of various infrastructure within this unit may occur where the overburden is thin and groundwater flow system impacts are possible with respect to the quantity and direction of groundwater flow.

Infrastructure trenches should be designed using best management practices to minimize water table lowering and redirection of shallow flows.

4.2.2 Surface Water Characterization and Functions

i. Drainage systems located within or adjacent to terrestrial units to be protected, such as woodlots and wetlands, may contribute overland drainage to the terrestrial units on a frequent basis; therefore, depositing sediments and nutrients is important for sustainability.

Drainage features with floodplains that include woodlots and wetlands should continue to contribute drainage, sediments and nutrients by appropriately managing the existing alignment or by being realigned in a manner that does not impact the terrestrial unit.

ii. Wetlands and woodlots provide temporary flood storage when located within drainage system floodplains.

The flood storage function of the area wetlands and woodlots should be appropriately managed either within the terrestrial units or replicated locally within the drainage system. The water balance function of the area wetlands should be appropriately managed to ensure the hydrological and ecological form and functions are maintained to pre development conditions. The use of woodlots that do not currently provide flood storage should not be considered for flood storage, unless it is *demonstrated that there will be no implications to the hydrologic period, water quality and habitat quality/health.*

iii. Certain karst features within and downstream of the study area intercept surface runoff and convey it directly to subsurface systems, thereby reducing peak flows and runoff volumes downstream.

The interception storage function of certain karst features should be appropriately managed by protecting key karst features or replicating the function within the drainage system. The water balance function of the karst features and the contributing drainage area should be appropriately managed to ensure the hydrological form and functions are maintained to pre development conditions.

iv. If unmitigated, the conversion of agricultural lands to urban land uses will increase the rate and volume of storm runoff locally, and potentially further downstream.

Stormwater management systems should be implemented to manage the increased rate and volume of runoff from future development and no increase water levels within identified downstream flood-prone properties.

v. Drainage systems contribute runoff to riparian vegetation along the drainage system corridor, therefore contributing to the formation and sustainability of the riparian vegetation.

Existing drainage systems, whether altered through realignment, form or other alterations, should be appropriately managed to maintain and improve upon existing riparian vegetation communities.

vi. The watercourses within the study area exhibit moderate erosion potential.

The flow regime within the channel system post development should be managed to mitigate potential impacts to the channel system stability. Stormwater management and natural channel design techniques will be required to provide for long-term and sustainable channel stability. Source controls should be implemented on-site to appropriately manage groundwater recharge and work toward replicating pre-development water budget.

In addition to the above, an integrated assessment has been completed to identify the components of the water resource system within the study area and its environs. The components of the water resource system are defined by Provincial Policy, specifically the 2020 Growth Plan for the Greater Golden Horseshoe and the 2017 Greenbelt Plan. The requirement for a Water Resource System (WRS) includes the identification of features and functions which are necessary for the ecological and hydrological integrity of a watershed and include:

- Groundwater features
- Hydrological functions
- Natural heritage features and areas
- Surface water features including shoreline areas

In particular, the Growth Plan for the Greater Golden Horseshoe provides the following definitions for key hydrologic features and key hydrologic areas:

Key hydrologic features: "Permanent streams, *intermittent streams*, inland lakes and their littoral zones, *seepage areas and springs*, and *wetlands*."

Key hydrologic areas: "*Significant groundwater recharge areas*, *highly vulnerable aquifers,* and *significant surface water contribution areas* that are necessary for the ecological and hydrologic integrity of a *watershed*."

Identifying the water resource system provides for the long-term protection the key hydrologic features and key hydrologic areas, and their functions. The key hydrologic features requiring protection within the study area consist of the watercourses, terrestrial features (i.e. wetlands and woodlots), and karst features identified as representing a high constraint which require protection in-situ based upon the findings from the discipline-specific and integrated characterization. While other key hydrologic features may not require protection in-situ, it is nevertheless recognized that the function of the hydrologic, hydraulic, and ecological function of the feature is to be replicated post-development.

Similarly, it is recognized that the function and contributions of the key hydrologic areas are to be recognized in developing the drainage and stormwater management plan for the future development.

4.2.3 Watercourse and Headwater Drainage Feature Characterization and Functions

Watercourse Principles of Integration

I. Land use changes such as the removal of headwater drainage features or vegetation and increases in imperviousness, typically increase flow discharges and diminish the development of resisting forces.

Headwater drainage features may be critical to maintaining proper flow and sediment conveyance across the landscape. It is necessary to ensure that all important functions of the headwater drainage features are adequately characterized as they are often removed or consolidated as a result of land use changes. Maintaining appropriate hydrologic and sediment regimes will be necessary to preserve the function of the headwater channels and their role in maintaining stream health in downstream areas.

II. Channel erosion is a necessary natural process; however anthropogenic pressures such as uncontrolled stormwater runoff, may accelerate and exacerbate natural erosion processes resulting in a loss of property, threats to infrastructure and environmental degradation.

Erosion and deposition within a channel can occur as a result of an imbalance between the sediment supply and the hydrologic regime. An imbalance between the two will result in increased erosion or deposition. Erosion thresholds can be applied to provide insight regarding the capacity of each watercourse system to accommodate an altered land use or flow regime. Application of appropriate thresholds as stormwater best management practice targets should limit rates of erosion to acceptable levels.

III. The incorporation of the meander belt width and associated setbacks into the stream corridor allows the lateral migration of the channel across its floodplain while also ensuring the maintenance of stream form and function. Through the identification of constraints, mitigation of risk to property or proposed infrastructure is achieved.

The meander belt width and associated setbacks represent a constraint to development and land use planning.

Watercourse Feature Constraints – Classification

Stream morphology is a key component of the Watercourse and Headwater Drainage Feature Classification and Management Recommendations (**ref. Table 4.2.1**). The Watercourse and Headwater Drainage Features – Integrated Assessments section below provides more detail on the development of this methodology and how it is integrated. Through the application of this classification methodology, appropriate constraints and management recommendations have been determined for watercourses and HDFs, respectively. In addition to geomorphology, this classification and management structure incorporates the disciplines of: Surface Water, Fisheries, and Terrestrial Ecology. Karst constraints were also incorporated into the Classification and Management Recommendations.

Stream management is approached on a reach or feature basis as these units display relative homogeneity with respect to form, function, and habitat. Key management practices, in terms of stream morphology, are recommended according to the geomorphic constraint ranking. Management strategies may include several options, or specific guidance. A brief summary of the geomorphological components of the constraint ranking/classification management strategy for watercourses is provided below.

High Constraint - Red Classification (Solid Red Line on Map)

- *Definition*: These corridors contain a defined active channel with well-developed channel morphology (i.e., riffle-pool), material sorting, floodplain development, and/or a well-defined valley. These corridors offer both form and function and have been identified as 'no touch' reaches that must be maintained undisturbed in their present condition, except for select locations where rehabilitation may be of benefit to the system. They have usually been deemed high-quality systems that could not be re-located and replicated in a post-development scenario.
- *Management*: Watercourse to be protected with meander belt in current form and location. Minor modification through rehabilitation/enhancement may be acceptable in select locations where it is a benefit to the system, or to allow for critical servicing as permitted by regulatory agencies. Options:
  - Do nothing: Corridors must remain where they are in the landscape. Delineate meander belt or erosion hazard corridor depending on valley classification. Determine additional regulatory setbacks as required.
  - Channel adjustments may be permitted at select locations given sufficient rationale (e.g. addressing an immediate high-risk erosion hazard, or an essential infrastructure for servicing issue such as road crossings or channel lowering). Natural channel design to be implemented for any adjustments.
  - Degraded (channelized and straightened) portions may by realigned using natural channel design, if realignment does not negatively impact rehabilitation.

Medium Constraint - Blue Classification (Solid Blue Line on Map)

- *Definition*: These reaches have well-defined morphology (defined bed and banks, evidence of erosion/sedimentation, and sorted substrate). These reaches maintain geomorphic function and have potential for rehabilitation. In many cases, these reaches are presently exhibiting evidence of geomorphic instability or environmental degradation due to historic modifications and land use practices.
- *Management:* Watercourse to be protected with applicable meander belt and setbacks. Realignment may be acceptable when deemed appropriate for restoration and enhancement or to address an essential infrastructure for servicing issue. Options:
  - Do nothing: Leave the corridors in their present condition and develop outside of their boundaries: Delineate appropriate meander belt or erosion hazard corridor depending on valley classification. Determine additional regulatory setbacks as required.
  - Enhance existing conditions: maintain the present location of the corridor but enhance the existing conditions (e.g. bank stabilization, re-establish a meandering planform, connect channel to functioning floodplain). Natural channel design to be implemented for any adjustments. Channel adjustments may be permitted for essential infrastructure for servicing (e.g. road crossings or channel lowering). All proposed works are to include sufficient rationale and be approved by regulatory agencies.

- Re-locate and enhance existing conditions: many of the reaches within the study area have undergone extensive straightening and modification for agricultural drainage purposes. As such, they are not as sensitive to re-location and would benefit from enhancements such as the re-establishment of a meandering planform with functioning floodplain and development of a riffle-pool morphology (i.e. natural channel design). In the event that these reaches are re-located, the corridor width (meander belt width/hazard corridor) associated with each reach must, at a minimum, be maintained. For reaches that have been straightened, appropriate surrogate reaches or empirical methods should be applied to determine the meander belt corridor. Natural channel design to be implemented for any realignment or adjustments.
- For features with realignment opportunities around roads, consideration should be made to select appropriate locations for realignment with respect to the road location, and to reduce the number of road crossings, where appropriate. This should reduce overall environmental impacts from roads Such changes require approval by regulatory agencies.

It should be noted that, within some reaches, the constraint ranking for another discipline may dictate the outcome (e.g. surface water, fisheries, terrestrial). Several features are protected by virtue of their location within a significant valley or terrestrial feature.

HDFs

The classification and evaluation methodology presented in **Table 4.2.1** has been used to classifiy and provide management recommendations for individual HDFs. In Phase 1, the focus is on the classification (characterization) rather than management recommendations. The approach first applies the guidelines set by TRCA/CVC (2014) to determine a feature classification ("**HDFA Classficiation**"), which, through Phases 2 and 3, may then be carried forward to "**Final Management**" or tailored to the landscape based on site opportunities, or other constraints that the protocol may not capture (e.g. feature protection based on location within a significant terrestrial or karst feature). The following briefly summarizes feature function and management strategies for HDFs.

Protection feature (mapped as red-white dashed lines)

- Important Functions: e.g. swamps with amphibian breeding habitat; perennial headwater drainage features; seeps and springs; SAR habitat; permanent fish habitat with woody riparian cover
- Protect in place and maintain contributions to and from feature, to be incorporated into the NHS. Channel adjustments may be permitted at select locations given sufficient rationale, and as approved by Regulatory Agencies.

Conservation feature (mapped as solid yellow lines)

- Valued Functions: e.g. seasonal fish habitat with woody riparian cover; marshes with amphibian breeding habitat; or general amphibian habitat with woody riparian cover.
- Realignment permitted provided important ecological functions are maintained, including linkage functions if the existing feature provides a linkage function. Conservation features providing important linkage functions may be incorporated into the NHS. Also, realignment may be permitted within existing buffer areas, provided that the feature realignment/creation supports the objectives of the buffer.

Mitigation feature (mapped as solid green lines)

- Contributing Functions: e.g. contributing fish habitat with meadow vegetation or limited cover

- Maintain function to downstream features. These features are typically highly modified but provide some downstream function (e.g. supply of sediment and/or water, or seasonal fish habitat). Some complexities like the function of tile drains, where important, can be replicated through SWM, while fish habitat may be replicated within another nearby feature, or downstream in the floodplain (e.g. pond creation).

No management required (mapped as green-dashed lines)

- Limited Functions: e.g. features with no or minimal flow; cropped land or no riparian vegetation; no fish or fish habitat; and no amphibian habitat.
- Feature can be removed from the surface without any implication to the system.

Appendix G-4 details the HDF evaluation and management recommendations following the TRCA/CVC protocols. It also highlights features which are anticipated to require a different final management recommendation based on site conditions. These features have been mapped as "Requiring further consideration in **Drawing FG-4.**

The classifications and constraint rankings established under Phase 1 are intended for characterization purposes only and are subject to Final Management recommendations based on site specific details.

Watercourse and Headwater Drainage Features – Integrated Assessments

The integration principles outlined in the preceding section have been applied to develop a constraint ranking for the watercourses and headwater drainage features (HDF) within the study area. Each watercourse has been assigned a ranking of high, or medium on a reach-by-reach basis, based upon various environmental factors and considerations, with individual rankings per discipline. A final constraint ranking was then determined established, conservatively, by utilizing the most limiting constraint observed for the feature, which may be suggested by all, few, or even one discipline. The findings of the assessment will ultimately provide guidance regarding the management opportunities and requirements for each watercourse feature within the study area. If during this integrated watercourse classification a watercourse was found to be of low ranking, then it was re-evaluated as an HDF.

The constraint ranking classification and evaluation methodology is based on a classification system that was developed and applied to recent subwatershed studies in Halton Region. This system provides a standard system to classify all surface water features (watercourses and HDFs) whereby each feature was assessed by contributing disciplines (i.e. hydrology, geomorphology, hydrogeology, fisheries, and terrestrial ecology), with a constraint ranking of "high", "medium" or "low" provided by each. Low rated features are typically headwater drainage features. This system incorporates the *Evaluation, Classification and Management of Headwater Drainage Features Guideline* (TRCA/CVC, 2014), and the resulting HDF classes, as determined by the 2014 HDF Guidelines, represent an integrated multi-discipline assessment of individual HDF segments.

In general, this evaluation approach builds upon the recommendations from TRCA/CVC protocols and includes management recommendations for watercourses, with corresponding colour coding/symbolism to represent each feature type, constraint ranking/classification, and corresponding management recommendation. **Table 4.2.1** provides further details regarding evaluation approach, and of feature and constraint definitions and corresponding management strategies. This classification system was collaboratively reviewed and agreed to by the TAC in a meeting held on March 11, 2020.

For HDFs, the evaluation has been completed first by following the 2014 HDF Guidelines to determine the management recommendation. Then, through an understanding of existing and proposed site conditions, features that require further consideration have been flagged. Further consideration is required in these cases to determine "final" recommendations that may differ from the outcome of the HDF Guidelines.

Watercourse and HDF reaches that intersect with Karst features have been flagged for further consideration, and the classification strategy has been adjusted to incorporate karst constraint rankings provided in **Section 3.4.3** of the report:

"Low (green) indicates the potential for the feature to be removed (excavated and grouted) and by-passed by runoff. Medium level constraint (yellow) means the feature requires additional study including water balance analysis and potential dye tracing. A high constraint (red) indicates that development should avoid the feature which should be buffered by at least 30 m from the top-of-bank and water balance/flow dynamics would dictate buffer requirements but these should be a minimum of 30 m."

It is noted that karst features located on watercourse and HDF reaches typically do not encompass the entire reach.

Table 4.2.1 summarizes the definitions for each constraint ranking and management implications.

Table 4.2.1. Watercourse and Headwater Drainage Feature Classification

Discipline	Definition	Management Strategy
Red Stream Classification (solid red lines). These features are high constraint watercourses that have attributes (e.g. floodplains, unstable banks) that attract NPCA regulations. They must remain open and protected in their present condition and location, with the exception of select locations where rehabilitation may be of benefit to the system.		
Surface Water	These corridors contain a well-defined channel within a well-defined and established valley system, with large contributing drainage areas (i.e. 200 ha or more).	Watercourse and corridor to be protected in current form and location, with applicable regulatory setbacks and ecological buffers.
Geomorphology	These corridors contain a defined active channel with well-developed channel morphology (i.e., riffle-pool), material sorting, floodplain development, and/or a well-defined valley. These corridors offer both form and function and have been identified as 'no touch' reaches that must be maintained undisturbed in their present condition, except for select locations where rehabilitation may be of benefit to the system. They have usually been deemed high-quality systems that could not be re-located and replicated in a post-development scenario.	Watercourse to be protected with meander belt in current form and location. Minor modification through rehabilitation/enhancement may be acceptable in select location where it is a benefit to the system. Options • Do nothing: Corridors must remain where they are in the landscape. Delineate meander belt or erosion hazard corridor depending on valley classification. Determine additional regulatory setbacks as required. • Channel adjustments may be permitted at select locations given sufficient rationale (e.g. addressing an immediate high-risk erosion hazard, or an essential infrastructure for servicing issue such as road crossings or channel lowering). Natural channel design to be implemented for any adjustments. • Degraded (channelized and straightened) portions may by realigned using natural channel design, if realignment does not negatively impact rehabilitation.
Fisheries	Permanently wetted (flowing or standing water over most of watercourse length) that is generally associated with continuous or seasonal groundwater discharge, or with wetland storage and/or pond flows. Fish community (or the	Watercourse to be protected/enhanced in current form and location. Minor modification through rehabilitation/enhancement may be acceptable in select location where it is a benefit to the system.

Discipline	Definition	Management Strategy
	potential for) is present and natural habitat is usually fully developed. Either habitat and/or flow source characteristics may be difficult to replicate or maintain. -and/or- Habitat occupied by species at risk.	Options • Preserve the existing drainage feature and groundwater discharge or wetland in-situ. Key features of this are: 1) Maintain existing water source: e.g. incorporation of shallow groundwater and base flow protection techniques such as infiltration treatment; examine need to incorporate groundwater flows through infiltration measures (i.e. third pipes, etc.) to ensure no net loss or, if appropriate, potential gain. 2) Drainage feature must connect to downstream watercourse/habitat. 3) Stormwater management (e.g. extended detention outfalls) are to be designed and located to avoid and/or minimize impacts (i.e. sediment, temperature) to fish habitat. • Channel adjustments may be permitted at select locations given sufficient rationale (e.g. addressing an immediate high-risk erosion hazard, or a critical servicing issue), and habitat features can be restored. Natural channel design to be implemented for any adjustments. • Degraded (channelized and straightened) portions may by realigned using natural channel design if realignment does not negatively impact rehabilitation potential. For example, a more rigorous investigation may be required to ensure realignment does not result in a reduction in groundwater inputs.
Terrestrial	The watercourse segments that are within terrestrial features that are of high ecological quality; are determined to be provincially, regionally, and/or locally significant; and/or are determined to provide critical habitat functions	Watercourse to be protected/enhanced in current form and location.

Discipline	Definition	Management Strategy
	for wildlife (e.g. consistent with criteria for Significant Wildlife Habitat).	
	Red HDF Classification (dashed red-white lines). These features, classed as [1]Protection, must remain open and, in general, remain protected in their present condition and location. They may have attributes that attract NPCA regulations.	
Surface Water	These are drainage features for which the application of the HDF Guidelines (TRCA/CVC, 2014) result in a "Protection" management strategy.	For drainage features in this category, follow the HDF management guidelines for "Protection".
Geomorphology	same as above	same as above
Fisheries	same as above	same as above
Terrestrial	The drainage feature reach segments that are within terrestrial features that are of high ecological quality; are determined to be provincially, regionally, locally significant, and/or are determined to provide critical habitat functions for wildlife (e.g. consistent with criteria for Significant Wildlife Habitat).	Drainage feature to be protected/enhanced in current form and location.
Blue Stream Classification (solid blue lines). These features are medium constraint watercourses that have attributes (e.g. floodplains, unstable banks) that attract NPCA regulations. They must remain open but they can be realigned using natural channel design.		
Surface Water	These reaches have relatively smaller contributing drainage areas (i.e. between 50 ha and 200 ha), and typically are not located within defined valley corridors.	Watercourse to remain open. Realignment may be acceptable. Reconstructed watercourse and corridor would be protected by applicable regulatory setbacks and ecological buffers.
Geomorphology	These reaches have well-defined morphology (defined bed and banks, evidence of erosion/sedimentation, and sorted substrate). These reaches maintain geomorphic function and have potential for rehabilitation. In many cases, these reaches are presently exhibiting evidence of	Watercourse to be protected with applicable meander belt and setbacks. Realignment may be acceptable when deemed appropriate for restoration and enhancement or to address an essential infrastructure for servicing issue. Options

Discipline	Definition	Management Strategy
	geomorphic instability or environmental degradation due to historic modifications and land use practices.	• Do nothing: Leave the corridors in their present condition and develop outside of their boundaries: Delineate appropriate meander belt or erosion hazard corridor depending on valley classification. Determine additional regulatory setbacks as required. • Enhance existing conditions: maintain the present location of the corridor but enhance the existing conditions (e.g. bank stabilization, re-establish a meandering planform, connect channel to functioning floodplain). Natural channel design to be implemented for any adjustments. Channel adjustments may be permitted for essential infrastructure for servicing (e.g. road crossings or channel lowering). All proposed works are to include sufficient rationale and be approved by regulatory agencies. • Re-locate and enhance existing conditions: many of the reaches within the study area have undergone extensive straightening and modification for agricultural drainage purposes. As such, they are not as sensitive to re-location and would benefit from enhancements such as the re-establishment of a meandering planform with functioning floodplain and development of a riffle-pool morphology (i.e. natural channel design). In the event that these reaches are re-located, the corridor width (meander belt width/hazard corridor) associated with each reach must, at a minimum, be maintained. For reaches that have been straightened, appropriate surrogate reaches or empirical methods should be applied to determine the meander belt corridor. Natural channel design to be implemented for any realignment or adjustments.

Discipline	Definition	Management Strategy
		• For features with realignment opportunities around roads, consideration should be made to select appropriate locations for realignment with respect to the road location, and to reduce the number of road crossings, where appropriate. This should reduce overall environmental impacts from roads Such changes require approval by regulatory agencies
Fisheries	Seasonally wetted (flowing or standing water) that is generally associated with seasonally high groundwater discharge or seasonally extended contributions from wetlands/ponds (no perennial flow). May provide an extended seasonal migration route for fish. Fish community (or the potential for) is present for an extended seasonal period. Potential permanent refuge fish habitat may be provided by naturally occurring storage features such as channel pools, wetlands, and other water bodies.	Watercourse to remain open. Realignment may be acceptable if habitat features and/or flow source can be maintained, replicated, or enhanced. Options • Watercourse remains open and in place, while maintaining (or replicating if appropriate) existing flow source from seasonal groundwater, surface or wetland flows. • Watercourse may be realigned using natural channel design techniques to provide habitat features to maintain or enhance overall fish productivity of the reach. Existing seasonal groundwater, surface, or wetland flows must be maintained (or replicated if appropriate), and drainage feature must connect to downstream habitat.
Terrestrial	Watercourse segment that is within terrestrial features that are determined to be of low or moderate ecological quality; are determined to be not provincially, regionally, and/or locally significant; and/or are determined to not provide critical habitat functions for wildlife (e.g. consistent with criteria for Significant Wildlife Habitat). -and/or-	Follow management strategies outlined for fisheries and fluvial, and ensure that the corridor is sufficiently wide and has appropriate restored habitat that supports movement of wildlife.

Discipline	Definition	Management Strategy
	Watercourse segment that is determined to provide significant linkage function for wildlife (as per Significant Wildlife Habitat).	
Yellow Classification (solid yellow lines). These features are HDFs classed as [1]Conservation, must remain open but can be realigned using natural channel design. They do not have attributes that attract NPCA regulations. The classification and management of terrestrial functions will result from being classed [1]Maintain or Replicate Terrestrial Functions.		
Surface Water	These are HDFs for which the application of the HDF Guidelines (TRCA/CVC, 2014) result in a "Conservation" management strategy.	For HDFs in this category, follow the HDF management guidelines for "Conservation".
Geomorphology	same as above	same as above
Fisheries	same as above HDFs classed as "Conservation" may provide an ephemeral aquatic linkage2 that flows for a very short period (typically in the early spring) that may provide a migration route for fish to move upstream to a valued permanent water storage feature, over a period of hours to a few days. 2An ephemeral aquatic linkage does not provide habitat in which fish may take up residence, though fish may become trapped in minor features and persist for a while until they perish.	same as above
Terrestrial	HDF classification guidelines result in a “Maintain Terrestrial Linkage – Terrestrial Functions” management strategy.	Follow HDF management guidelines for “Maintain Terrestrial Linkage – Terrestrial Functions”

Discipline	Definition	Management Strategy
Green Classification (solid green lines). These features are HDFs classed as [1]Mitigation, and do not have attributes that attract NPCA regulations. They need not remain open, but their function to the watershed system must be maintained or replicated.		
Surface Water	These are HDFs for which the application of the HDF Guidelines (TRCA/CVC, 2014) result in a "Mitigation" management strategy.	For HDFs in this category, follow the HDF management guidelines for "Mitigation".
Geomorphology	same as above	same as above
Fisheries	same as above	same as above
Terrestrial	HDF classification guidelines result in a "Replicate Terrestrial Linkage – Terrestrial Functions" management strategy.	Follow HDF management guidelines for "Replicate Terrestrial Linkage – Terrestrial Functions"
Green Classification (dashed green lines). These are HDFs classed as [1]No Management Required.		
Surface Water	These are HDFs for which the application of the HDF Guidelines (TRCA/CVC, 2014) result in "No Management Required".	For HDFs in this category, follow the HDF management guidelines for "No Management Required".
Geomorphology	same as above	same as above
Fisheries	same as above	same as above
Terrestrial	same as above	same as above

Note: 1. Based upon the Evaluation, Classification and Management of Headwater Drainage Features Guidelines (TRCA/CVC, 2014).

A consolidated constraint ranking for each watercourse has been established based upon the findings of each subject discipline. The proposed watercourse constraint rankings, including comments and rationale, are presented in **Appendix G-3** and are depicted graphically in **Drawing FG-4**. A summary of constraint rankings is provided in **Table 4.2.2**.

Of note, reaches TM3, TM3(1)1, TM3(1)2, TM4 and TM4(2)2 require further consideration due to the presence of karst features. Reach TM4(5)2 also requires further consideration regarding its status as a watercourse or HDF, and regarding its constraint ranking, as a High constraint was triggered by its Terrestrial classification alone and may be subject to further refinement.

The classifications and constraint rankings established under Phase 1 of the study will be subject to further review by the Technical Advisory Committee (TAC), and a sub-TAC meeting will be convened to review areas of disagreement and reach consensus.

Table 4.2.2. Watercourse Constraint Rankings

Reach	Surface Water	Fluvial	Terrestrial	Fisheries	Karst and Groundwater	Proposed Watercourse Classification
NC1	High	High	High	High	Low	High
NC2	High	High	High	High	Low	High
NC3	High	High	High	High	Low	High
NC4	High	High	High	High	Low	High
NC4(2)1	Low	Unevaluated (Medium)	High	Unevaluated (Medium)	Low	High
NC5	High	High	High	High	Medium	High
NC5(3)1	Low	Unevaluated (Medium)	Unevaluated (Medium)	Unevaluated (Medium)	Low	Medium
NC5(3)2	Low	Medium	Low	Low	Low	Medium
NC6	High	High	High	High	Medium	High
NC7	High	High	High	High	Medium	High
SC1(1)	Medium	Medium	Low	Medium	Low	Medium
SC1(2)	Medium	Medium	High	Medium	Low	High
SC1(3)	Medium	Medium	High	Medium	Low	High
SC1(4)	Medium	Medium	Low	Medium	Low	Medium
SC1(5)	Medium	Medium	Low	Medium	Low	Medium
TM1	High	High	High	High	High	High
TM2	High	High	High	High	High	High
TM3	High	High	High	High	High	High
TM3(1)1	Low	Medium	High	Medium	High	Medium
TM3(1)2	Low	Medium	Low	Low	Low	Medium
TM3(1)3	Low	Medium	Medium	Low	Low	Medium
TM4	High	High	High	High	High	High
TM4(2)1	Medium	Medium	Low	Low	Low	Medium
TM4(2)2	Medium	High	High	Medium	High	High
TM4(2)3	Low	Medium	High	Medium	Low	High
TM4(2)4	Low	Medium	Low	Medium	Low	Medium

Reach	Surface Water	Fluvial	Terrestrial	Fisheries	Karst and Groundwater	Proposed Watercourse Classification
TM4(4)1	Low	High	High	Low	Medium	High
TM4(5)1	Low	Unevaluated (Medium)	Low	Low	Medium	Medium
TM4(5)2	Low	Unevaluated (Medium)	High	Low	Low	High
TM4(6)1	Medium	High	Unevaluated	Medium	Medium	High
TM4(6)1-1	Low	High	High	Medium	Low	High
TM4(6)1-2	Medium	High	Low	Medium	Low	High
TM4(6)1-3	Medium	High	High	Medium	Low	High
TM4(6)2	Low	High	High	Medium	Low	High

4.2.4 Water Quality Characterization and Functions

i. Existing water quality is generally of moderate quality, with several PWQO exceedances.

   Based on future land use conditions within the study area, stormwater management infrastructure should be designed to provide stormwater quality control for future developments in accordance with MECP Enhanced standard of treatment and potentially improve the current water quality conditions to the greatest extent possible.

ii. The headwater areas provide a hydrologic function, nutrients, sediment, and/or particulate matter and organic matter to the downstream aquatic habitat.

   The headwater area aquatic habitat support function should be maintained through implementing a drainage system that can include the use of Low Impact Development best practices, open swales and ditching or other mitigation in a strategic manner consistent with the management guidance for Headwater Drainage Features.

iii. The main permanently flowing watercourses support diverse fish communities.

Stormwater management practices that maintain the quality of the permanently flowing watercourses should be implemented within the study area.

4.2.5 Terrestrial Characterization and Functions

This section of the report provides an overview of the important natural heritage features in the study area. Analysis of the significance and sensitivity of existing natural features was used to identify those features and habitats that are sensitive to disturbance and those that have been previously disturbed, impacted, or contain no natural features. Results of this analysis are intended to protect the form and function of the natural heritage features in a Natural Heritage System in order to protect these from future development impacts.

Significant Wetlands

Wetlands are important for many reasons including collecting and storing surface water and groundwater and providing habitat for plants, wildlife, and fish. Wetlands operate on a water balance, where the hydrologic character of the wetland is determined by the combination of water inflow and outflow, topography, and groundwater conditions (Mitsch and Gosselink 1993). Wetlands receive water through precipitation, surface water inflow, and groundwater discharge; and they lose water through evapotranspiration, surface water outflow, and groundwater recharge.

The Lower Twenty Mile Creek Wetland Complex is provincially significant (Map NH-1A) and runs the entire length of Twenty Mile Creek. It has been designated by the MNRF as an area of high biodiversity for aquatic and related terrestrial functions (NPCA 2006). The wetland complex as a whole includes 11% marsh and 89% swamp communities (Yagi 2005). The wetland complex is comprised of 129 wetland units, for a total area of 1,908.82ha. The following wetland units are located within the study area or in close proximity: 41-43, 46, 50-52, 56, 57, and 65-67. Several large wetland features exist within the study area, including four distinct features across the northern portion of the study area, and two towards the eastern extent of the study area. Wetland features also comprise portions of the Twenty Mile Creek riparian zone, at the eastern and western extents of the study area, as well as the riparian zone for North Creek to the south.

Field surveys undertaken in 2020 identified wetland habitat within the study area. Wetlands vary in size, ranging from small pockets of approximately 0.06ha to larger features of approximately 17.97ha. Twelve different types of wetlands have been identified in the study area: Graminoid Mineral Meadow Marsh (MAM2), Reed-canary Grass Graminoid Mineral Meadow Marsh (MAM2-2), Graminoid Organic Meadow Marsh (MAM3), Mineral Deciduous Thicket Swamp (SWT2), Organic Deciduous Thicket Swamp (SWT3), Maple Mineral Deciduous Swamp (SWD3), Red Maple Mineral Deciduous Swamp (SWD3-1), Mineral Deciduous Swamp (SWD4), White Elm Mineral Deciduous Swamp (SWD4-2), Deciduous Swamp (SWD), Graminoid Mineral Shallow Marsh (MAS2) and Submerged Shallow Aquatic (SAS).

The PSW boundary within the study area was refined through field surveys in 2020. The wetland boundaries are shown on Maps NH-3A to NH-3F. Certain areas of mapped PSW are not wetland, whereas other areas not previously identified as wetland were identified as wetland based on the vegetation inventories. At the time of the Draft Phase 1 Report, all wetlands within the study area are considered provincially significant, as they fall within the Lower Twenty Mile Creek Wetland Complex catchment area. However, later study work identified small wetland units separate from the provincially mapped PSW complex as "wetland for further review". The Phase 2 report provides more detail and discussion on this (see. for instance, Section 4.6.1.8 'Small Wetland Units' and Section 4.6.2.1). The PSW complex is shown on Maps NH-1A and NH-6. Map NH-6 also maps the wetlands identified by the SWS Team. The wetland boundaries were not surveyed for this large scale study.

Significant Woodlands

Consistent with the ROP (2014), the Township OP (2018, Policy 10.7.2.e) identifies woodlands as significant if they meet one or more of the following criteria:

i. Contain Threatened or Endangered species or species of concern
ii. Are ≥2ha in size if located within or overlapping Urban Area Boundaries (≥10ha if located outside an urban area)
iii. Contain interior woodland habitat ≥100m in from the woodland edge
iv. Contain older growth forest and ≥2ha in area
v. Overlap or contain one or more of the other significant natural heritage features that comprise Environmental Protection Areas or Environmental Conservation Areas
vi. Abut or be crossed by a watercourse or water body and ≥2ha in area.

A 'species of concern' is defined by the Township OP (2018, p. 202) as "*any species that is listed or categorized as a special concern species on the Ontario Ministry of Natural Resources* [and Forestry] *official Species at Risk list or that is designated as a special concern species by the Committee on the Status of*

Wildlife in Canada (COSEWIC) or that is not included on those lists but has been given a ranking of S3 imperiled or higher by the Ontario Natural Heritage Information Centre, as updated from time to time."

Given that the urban area will be expanded, all woodlands within the study area were assessed using the 2ha size criterion. Most of the woodlands within the study area are significant based on the Township's criteria as listed above, predominately because of their size and their connection to a watercourse or PSW. Significant woodlands are shown on Map NH-6.

Significant Valleylands

Twenty Mile Creek and North Creek valleylands are significant for the following reasons:

- They have large catchment areas
- They provide a valuable interplay between groundwater and surface water, with both recharge and discharge functions within their corridors
- They are prominent features on the landscape, with sizeable floodplains
- They contain significant natural heritage features, including PSW, significant woodlands, SWH, and significant and rare species
- They provide a wildlife linkage through the landscape.

Significant Wildlife Habitat

The results of information collected through a background review, agency consultation, vegetation community mapping, and focused wildlife surveys were used to identify SWH within the study area. Results of the SWH screening are found in Appendix H and discussed below. Confirmed SWH is shown on Maps NH-7A through NH-C.

Seasonal Concentration Areas

Wildlife seasonal concentration areas are defined as areas where animals occur in relatively high densities for all, or portions, or their life cycle (OMNR 2000). These areas are generally relatively small in size, particularly when compared to areas used by these species during other times of the year. Confirmed SWH was identified for Turtle Wintering, Reptile Hibernacula, and Deer Winter Congregation Areas, while Bat Maternity Colonies and Raptor Wintering are considered Candidate at this time. These habitats are described in further detail below.

<u>Confirmed Seasonal Concentration Areas</u>

A Snapping Turtle was observed within Twenty Mile Creek, leading to the river being identified as Confirmed Turtle Wintering Area SWH. The SWH within the river would be limited to the deep-water pools where turtles would suitable wintering conditions would be present. However, since these areas cannot be readily identified, the entire river has been mapped as Confirmed Turtle Wintering Area (Map NH-7C).

Reptile hibernacula are likely to be present in the Fresh-Moist Oak-Maple Hickory Deciduous Forest (FOD9) at the southeast corner of the study area, located along the west side of the railway. A congregation of approximately 20 Eastern Gartersnakes was observed immediately north of the forest on April 6, although a specific hibernaculum location was not identified. The FOD9 feature has been characterized as Confirmed SWH due to the fact that the congregation of Eastern Gartersnakes was in close proximity to the forest and no other suitable areas were observed (Map NH-7C).

Mapping provided by the MNRF confirms Deer Winter Congregation Areas associated with several deciduous forest/swamp features across the study area (Map NH-7A).

<u>Candidate Seasonal Concentration Areas</u>

The following two SWHs remain as candidate since confirmation of these types of habitats requires extensive targeted field surveys which was considered beyond the scope of the SWS.

Candidate Bat Maternity Colonies SWH may occur in any mature deciduous or mixed woodland or swamp community (e.g. FOD, SWD) where there are more than 10 large diameter wildlife trees per hectare. Bat maternity colony SWH could not be confirmed as bat surveys and cavity assessments were outside the scope of this project. Most woodlands, and likely all that provide suitable habitat for Bat Maternity Colonies, are protected as Significant Woodlands and PSW, thereby protecting this candidate SWH as well.

Raptor Wintering habitat is largely absent from the study area due to the lack of a combination of woodland and adjacent suitable upland habitat of sufficient size. Most woodlands are bordered closely by agricultural fields. A single area of Candidate Raptor Wintering habitat is present largely outside of the study area east of Industrial Park Road and north of the rail line within the milieu of woodland, forest, meadow, and thicket habitat. Further studies would be required during the winter season in these areas in order to confirm significance.

Rare Vegetation Communities

The SWHTG (OMNR 2000) identifies rare vegetation communities as those which are designated provincially rare or rare within a planning area. Vegetation communities with the poorest representation within the planning area may also be considered significant, and those that are rare or could be lost due to development are considered highly significant. The highest priority sites are those that contain S1-S3 ranked vegetation communities. A vegetation community may also be considered locally rare if it represents less than 3% of the remaining natural area or if it is found at 5 or fewer sites within the local area. Higher quality sites are relatively undisturbed. Rare communities supporting other SWH are considered the most significant.

Two vegetation communities are considered SWH: FOD7-4 (Fresh – Moist Black Walnut Lowland Deciduous Forest) and FOD9-4 (Fresh – Moist Shagbark Hickory Deciduous Forest) are ranked as S2/S3 and S3, respectively, thereby making them provincially imperiled (S2) and vulnerable (S3) with a high (S2) to moderate (S3) risk of extirpation. The Black Walnut Lowland Deciduous Forest (FOD7-4) is of fairly low quality. It is located along the southern banks of Twenty Mile Creek west of Wade Road to the edge of the study area (Map NH-7A). The Shagbark Hickory Deciduous Forest (FOD9-4) is located in numerous areas throughout the study area, as shown on Map NH-7A. This includes the Horseshoe Woodland and some of the treed stands that are very small, such as communities along West Road to the west of the study area, and another small area located between the Horseshoe Woodland and the Significant Woodland/wetland/karst (SW2) to the north.

Specialized Wildlife Habitat

Specialized habitats include those that support wildlife species with highly specific habitat requirements, areas with exceptionally high species diversity, and/or areas that provide habitat that greatly enhances a species' chance of survival (OMNR 2000). The SWHTG indicates that most specialized habitats have not been formally identified or mapped by any agency (OMNR 2000). A single Specialized Wildlife Habitat (Amphibian Breeding Habitat - Wetland) was confirmed, while one habitat (Turtle Nesting Area) is considered candidate.

Although anurans were abundant within the study area and often calling throughout the day, even from flooded/moist fields, especially in the northern part of the study area, the criteria significance for Amphibian Breeding Habitat (Woodland) was not met. One station, ANR-08 (Map NH-2), located west of Forestview Court, meets the criteria for Amphibian Breeding Habitat (Wetland), with a full chorus of

American Toad and Western Chorus Frog observed in April. This SWH is shown on Map NH-7C along with an Amphibian Movement Corridor to the woodland and wetland community located to the south.

Midland Painted Turtle and Snapping Turtle were observed within the study area and vicinity, within North Creek and Twenty Mile Creek, respectively. Turtle nesting surveys were outside the scope of this study, but nesting areas must be present. Hence, Candidate Turtle Nesting Area SWH is located along both watercourses, in areas of exposed mineral soil.

Habitat for Species of Conservation Concern

Confirmed habitat for SCC is considered SWH (OMNR 2000). Several SCC were observed within the study area, including Black Gum, Lizard's Tail, Slightly Hirsute Sedge, Eastern Wood-Pewee, Snapping Turtle, and Monarch. SWH for these species is shown on Map NH-7B. Barn Swallow was identified as a SCC in January 2023. It is unlikely that Barn Swallow habitat in anthropogenic structures would be identified as SWH, but this should be addressed through an Environmental Impact Study.

Black Gum was noted from the northern woodland to the east of South Grimsby Road 5; Lizard's Tail is growing along Twenty Mile Creek; and Slightly Hirsute Sedge was identified from a small woodland in the southern portion of the study area adjacent to an abandoned rail line.

Suitable breeding habitat for Eastern Wood-pewee is found throughout the study area within deciduous and mixed forested habitats. However, confirmed SWH was only identified from the woodland located northeast of 30 Road and Spring Creek Road where Eastern Wood-pewee was noted as a 'probable' breeder.

Snapping Turtle was confirmed within Twenty Mile Creek. As such, the creek is identified as SWH for this species. It is also identified as Turtle Wintering Area SWH.

Individual adult Monarchs were observed at several locations within the study area. SWH is not mapped for this species within the study area since large clusters of Milkweed were not noted within high quality meadow habitat. Monarch habitat is found anywhere where Milkweed and nectaring plants are present (e.g. Asters, Goldenrods). Habitat for this species will be provided within the proposed NHS and it is recommended that Milkweed plants (*Asclepias* species) be seeded in natural areas, buffer areas and open spaces.

Caspian Tern and Rusty Blackbird are also SCC that were observed within the study area, but SWH for these has not been identified as these species no not breed within the study area.

Terrestrial Crayfish SWH was confirmed along the north bank of Twenty Mile Creek near South Grimsby Road 6. A single chimney, associated with Chimney Crayfish (*Fallicambarus fodiens*), was observed on September 2, 2020 associated with the Reed-canary Grass Mineral Meadow Marsh (MAM2-2), which was mapped west of the road. The Mineral Deciduous Swamp (SWD4) that extends east from the crossing has also been mapped as SWH based on the connection along the north shoreline of the creek, which provides contiguous suitable habitat (Map NH-7C).

Animal Movement Corridors

Animal movement corridors are only addressed within Ecoregion 7E when Amphibian Breeding Habitat (Wetland) is confirmed. The pond associated with ANR-08 (Map NH-2) that is located within a small mineral meadow marsh (MAM2) was confirmed as Amphibian Breeding Habitat (Wetland). Movement corridors for amphibians are typically associated with watercourses or wetlands. The pond that is considered SWH is isolated from such habitats by agricultural fields and residential development, however, it is likely that some overland movement of amphibians occurs between this feature and the deciduous swamp (SWD4-2) located approximately 130m to the south. As such, a movement corridor is shown on Map NH-7C connecting the two habitats, and is considered confirmed SWH. The Amphibian Breeding Habitat (Wetland) SWH is located approximately 500m south of the Twenty Mile Creek vegetated corridor.

Wildlife linkages are addressed separately below.

Significant Areas of Natural and Scientific Interest

There are no provincially significant ANSI's within the study area or vicinity, but there is a regionally significant ANSI. The East Smithville Slough Forest regionally significant Life Science ANSI is located east of the study area, less than 50m from its boundary (Map NH-1A).

Habitat of Endangered and Threatened Species

A detailed screening was carried out for SAR with the potential to occur in the study area based on habitat requirements and availability of these habitats within the study area (Appendix H). Field surveys were conducted to assess which SAR are found within the study area.

Bobolink and Eastern Meadowlark were both observed within the study area. Both species are considered Threatened provincially and nationally (MNRF 2023; Government of Canada 2021). Although breeding evidence is considered 'probable' and 'possible' respectively for these species, suitable habitats were not identified that corresponded with these observations. No suitably sized open country habitats were identified that would likely support these species, although it is possible that Eastern Meadowlark, in particular (which favours smaller fields), may breed within the study area. Regardless, suitable habitats may shift from year to year due to changes in agricultural practices, and both species will need to be considered under the Endangered Species Act in the future.

It is likely that Little Brown Myotis and Northern Myotis (*Myotis septentrionalis*) are be found within the study area based on their extent through southern Ontario and the presence of potentially suitable habitat within the study area. Both species are Endangered provincially and nationally (MNRF 2023; Government of Canada 2021). Targeted surveys for bats were not conducted as part of this study, but may be required in the future, especially for development activities where tree removal is proposed.

Wildlife Linkages

Linkages that are ecologically functional and maintain natural interactions between plants and animals are required to maintain the ecological health of a landscape. Ideally a linkage should contain high quality habitat that is suitable for the species that are intended to use the linkage, but may also provide lesser quality habitat for movement or as a "stepping stone" to higher quality habitats. Many of the natural heritage features within the study area are isolated, but connected through an agricultural matrix, which wildlife can cross to get from one habitat unit to another. Once the area is developed, these open country connections are lost, so it is important to ensure a connected natural heritage system is provided for prior to development. Entirely isolated features will lose their ecological integrity and degrade over time if not connected to other features. Watercourses, and to a lesser extent HDF, provide additional connectivity between features that may be utilized to create linkages. The Twenty Mile Creek and North Creek valleylands currently provide good ecological connections through the landscape. Linkages to connect core natural heritage features are recommended as part of the NHS.

4.2.6 Aquatic Characterization and Functions

Twenty Mile Creek and North Creek provide critical year-round habitat for the local fish community, but were noted to have relatively long stretches of channel that were dry in the summer. Fish were isolated to larger pools of water, which prevented complete upstream and downstream movement through the study area in both major features. However, the majority of these pools still provided suitable water depths, water temperatures, and available habitat to support the diverse fish community within them. Several intermittent watercourses and HDF were noted to hold fish in the spring, indicating a likely connection to Twenty Mile Creek and North Creek. These features have been characterized as important due to the fact that fish are utilizing them in the spring, even though the majority of features dry up in the summer. The remaining features provide marginal fish habitat. Fish habitat classifications are shown on Map NH-8, which includes the classifications identified by the MNRF, defined in Table 4.2.3

Table 4.2.3. MNRF Classification of Fish Habitat Types

Classification Type	Description
Type 1	Habitats have high productive capacity, are rare, in space and/or time, are highly sensitive to development, or have a critical role in sustaining fisheries (e.g., critical spawning and rearing areas, migration routes, overwintering areas, habitats occupied by sensitive species).
Type 2	Habitats are moderately sensitive to development and, although important to the fish population, are not considered critical (e.g., feeding areas for adult fish, unspecialized spawning habitat). These areas are considered ideal for enhancement or restoration projects.
Type 3	Habitats have low productive capacity or are highly degraded, and do not currently contribute directly to fish productivity. They often have the potential to be improved significantly (e.g., a portion of a waterbody, a channelized stream that has been highly altered physically).

The main channel of Twenty Mile Creek has been designated as a cool-warmwater system, while North Creek has been designated a coolwater system. A small inflowing channel to Twenty Mile Creek, located within Rock Street Park originates as a seep and is designated as a coldwater system. Intermittent channels were dry during summer months and could not be classified based on water temperature. However, both warm and coolwater fish species were captured within several of these features during spring sampling and as such, have been classified as cool-warmwater features. These designations are shown on Map NH-9.

4.2.7 Natural Heritage System

Policy Background

The Provincial Policy Statement (2020, p.47) defines a Natural Heritage System (NHS) as,

> "*a system made up of natural heritage features and areas, and linkages intended to provide connectivity (at the regional or site level) and support natural processes which are necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species, and ecosystems. These systems can include natural heritage features and areas, federal and provincial parks and conservation reserves, other natural heritage features, lands that have been restored or have the potential to be restored to a natural state, areas that support hydrologic functions, and working landscapes that enable ecological functions to continue.*"

The Province has identified several NHS, which include the Greenbelt, Niagara Escarpment, and the Growth Plan NHS.

The Greenbelt is located immediately to the north of the study area. The Niagara Escarpment is located approximately 3.5km to the north. The Growth Plan NHS is located partially within the study area, both to the west, along Twenty Mile Creek, and to the east. These large-scale NHS are shown on Map NH-1A.

The current Niagara Region Official Plan (ROP, 2014) identifies a Core NHS that consists of natural areas of special significance. The Core NHS is shown on Schedule C of the ROP, and policies related to the Core NHS are 7.B.1.1, 7.B.1.3, 7.B.1.4, and 7.B.1.6. The Region's Core NHS is shown on Map NH-1B.

Natural vegetation and wildlife outside the Region's Core NHS is to be maintained, enhanced, and restored where possible, as part of the Region's Healthy Landscape approach (Policy 7.A.1.B).

The Township of West Lincoln OP (2018) is consistent with the ROP (2014). The Core NHS consists of the following (Policy 10.7.2.a):

- Core Natural Areas
  - Environmental Protection Areas (EPA) (Policy 10.7.2.c):
    - Provincially *and regionally*[5] significant wetlands
    - Provincially *and regionally*[5] significant Life Science ANSI
    - Habitat of Endangered and Threatened species
    - [EPA's within the Greenbelt NHS also include other features not listed here as they do not apply to the study area]
  - Environmental Conservation Areas (ECA) (Policy 10.7.2.d):
    - Significant woodlands (see Policy 10.7.2.e for criteria)
    - Significant Wildlife Habitat (SWH)
    - Significant habitat of Species of Concern
    - Regionally significant Life Science ANSIs
    - Wetlands
    - Significant valleylands
    - Savannahs and tallgrass prairies
    - Alvars
    - Publicly owned conservation lands
- Potential Natural Heritage Corridors connecting Core Natural Areas
- Greenbelt Natural Heritage and Water Resources Systems [not within the study area]

[5] italicized text added to identify difference to ROP (2014)

- Fish habitat.

Natural Heritage Corridors are natural and open space linkages between Core Natural Areas. They include naturally vegetated stream corridors, valleylands, woodlands; wetlands; and other natural vegetation communities (Township OP 2019).

Key hydrologic features include (Policy 10.7.2.f):

- Permanent and intermittent streams
- Lakes and their littoral zones
- Seepage areas
- Springs
- Wetlands

Key hydrologic features are included in the Core NHS where they constitute fish habitat.

Natural heritage features, vegetation, and wildlife within the Township are to be maintained, enhanced and restored (Policies 2.4.d and 10.3.1.b). The Township's target it to achieve 30% of its land area as forest or wetland cover, with a minimum of 10% in each subwatershed as wetland (Policy 10.3.2.i). Along watercourses, 70% of the 30m wide buffers are to be comprised of natural vegetation (Policy 10.3.2.ii).

The Township's Core NHS is mapped on Schedule B-4 and Schedules C-1 to C-4. Map NH-1B shows the Township's Core NHS (TOWL, 2019) along with the Region's Core NHS (ROP, 2014) mapping.

The study area contains EPA lands, ECA lands, fish habitat, a regionally significant Life Science ANSI, significant woodlands, and publicly owned conservation lands (i.e. Rock Street Park in Smithville).

Buffers

The Township OP (2018), in accordance with the Regional OP (2014) identifies the following buffers:

- 30m from Critical Fish Habitat (Policy 10.7.2.p)
- 15m from Important or Marginal Fish Habitat (Policy 10.7.2.p)
- 15m from a Municipal Drain (Policy 10.7.2.r)
- Policy 10.7.2.v relates to lands within the Greenbelt area, therefore does not apply to the Study Area
- Although not directly related to natural heritage, Policy 4.11 requires a 150-400m buffer from the Smithville Sewage Lagoon
- No other specific buffer dimensions are prescribed. Buffers are to be determined through an Environmental Impact Study (Policy 10.7.2.s).

The Growth Plan (2019) requires 30m Vegetation Protection Zones (i.e. buffers) from key hydrologic features (i.e. permanent streams, intermittent streams, inland lakes and their littoral zones, seepage areas and springs, and wetlands), fish habitat, and significant woodlands (Policy 4.2.4.1.c).

30m are recommended from all Significant Woodlands and wetlands within the study area. Type 1 fish habitat is also to be protected with a buffer of 30m on both sides of the watercourse, whereas Type 2 and 3 watercourses (refer to Map NH-8) are to have buffers of 15m on either side of the watercourse. Significant Valleylands will be protected within the NHS (see below). SWH is to be protected with a 30m buffer, which generally falls within the protected woodlands and wetlands.

Preliminary NHS

A preliminary NHS has been identified for the study area and Smithville based on the policy direction discussed above, in addition to the work completed for the SWS in 2020, including field surveys and the identification of significant and sensitive features within the landscape. The NHS for Smithville includes Significant Wetlands, Significant Woodlands, Significant Valleylands, SWH, fish habitat, and habitat for endangered and threatened species, as well as linkages between these core features.

A preliminary NHS for the study area was developed during the Draft Phase 1 Reporting stage, which was based on background mapping and results from field studies, which refined the wetland and woodland layers for the study area based on ELC vegetation community delineation. The Draft Phase 1 Report stated the following:

> *The core features are to be linked, thereby enhancing the NHS as a whole and ensuring its sustainability. The two primary watercourse features are Twenty Mile Creek and North Creek, which are identified as Significant Valleylands, and provide a linkage for wildlife through the landscape. These should be protected in wide corridors, such as 200m. Other general linkages are shown on Map 10* [now included in Appendix J]. *Certain HDF require protection or conservation within the study area, and have been included in the NHS. Depending on the management recommendations for individual HDF, some features may be moved. This may provide the ability to enhance other existing features, for instance by widening another corridor. Buffers have been included within the NHS, which are to be cut off at roads.*
>
> *Habitat for Endangered and Threatened species is partially protected within the NHS. Open country habitat for Bobolink and Eastern Meadowlark is not protected, but must be addressed through the Endangered Species Act. Habitat for SAR bats is protected within the Significant Woodlands, although individual trees and buildings need to be considered for SAR bats as well.*
>
> *Restoration Areas have generally been identified where an area is surrounded by a Core Area or NHS component and are thus generally landlocked.*

The preliminary NHS was refined through Phase 2 of the SWS.

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Appendix A

Background Data / Information, Consultation and Response Matrix

Appendix B

Climate

Appendix C

Hydrogeology

Appendix D

Karst

Appendix E

Hydrology and Hydraulics

Appendix F

Surface Water Quality

Appendix G

Stream Morphology

Appendix H

Terrestrial

Appendix I

Aquatics

Appendix J

Preliminary Natural Heritage System (Draft Phase 1)