Submitted to:
City of Hamilton

Elfrida Subwatershed Study

Final Phase 1 Report

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Reference: 65726

May 24th, 2018

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1 INTRODUCTION

1.1 General

On May 18, 2006, Hamilton City Council endorsed the GRIDS (Growth Related Integrated Development Strategy) which identified the preferred "Nodes and Corridors" scenario for future growth to the year 2031. The Elfrida study area, located in the southeast portion of the City, was included in the preferred growth scenario, which addresses the City's need for residential lands to the year 2031. Elfrida is Hamilton's next major mixed-use growth area. In support of this proposed future urban growth, the City of Hamilton is in the process of developing the Elfrida Growth Area Secondary Plan.

The Elfrida Subwatershed Study is one of several component studies which have been undertaken in support of the secondary planning process. The purpose of the Subwatershed Study is to develop a plan that allows sustainable development while ensuring maximum benefits to the natural and human environments on a watershed basis.

The study investigates and inventories the natural resources which could potentially be impacted by future urban development and identifies development limitations and opportunities associated with the proposed land use changes. The findings are then used to develop a comprehensive Subwatershed Management Plan, including stormwater management and natural heritage strategies, which will protect, rehabilitate and enhance the environment within the Elfrida study area limits, as well as downstream.

1.2 Subwatershed Planning

The process of Subwatershed Planning has evolved over the last 20-30 years. The typical Subwatershed Plan of the 1980s, which was commonly termed "Master Drainage Plan", was primarily concerned with two issues; flooding and erosion. In the latter part of the 1980s, the plan evolved and typically dealt with the above issues as well as water quality and occasionally aquatic resources.

Subwatershed Plans have continued to evolve and now deal with numerous inter-related environmental issues including:

- surface water flooding, erosion, and water quality;
- groundwater quantity and quality;
- water budget (groundwater recharge, base flows, and peak flows);
- terrestrial and aquatic habitat;
- wetlands and woodlands, including woodlots and forests;
- species-at-risk;
- environmentally sensitive areas; and,
- recreation and aesthetics.

Furthermore, the plans are ecosystem-based, with the potential interaction between each of the environmental features being strongly considered.

Integration of the Land Use Planning Process with Water Resource Management Planning has also evolved over the last 20-30 years. Whereas the historic practice in the mid-eighties involved the development of Official, Secondary and Draft Plans with nominal consideration of environmental consequences; present practice considers the two planning processes in unison.

The Subwatershed Plan, in this manner, becomes an integral part of the overall planning process, that provides a solid foundation such that the environmental features will be protected, enhanced or restored under present conditions, and as land use changes occur.

1.3 Study Area and Landuses

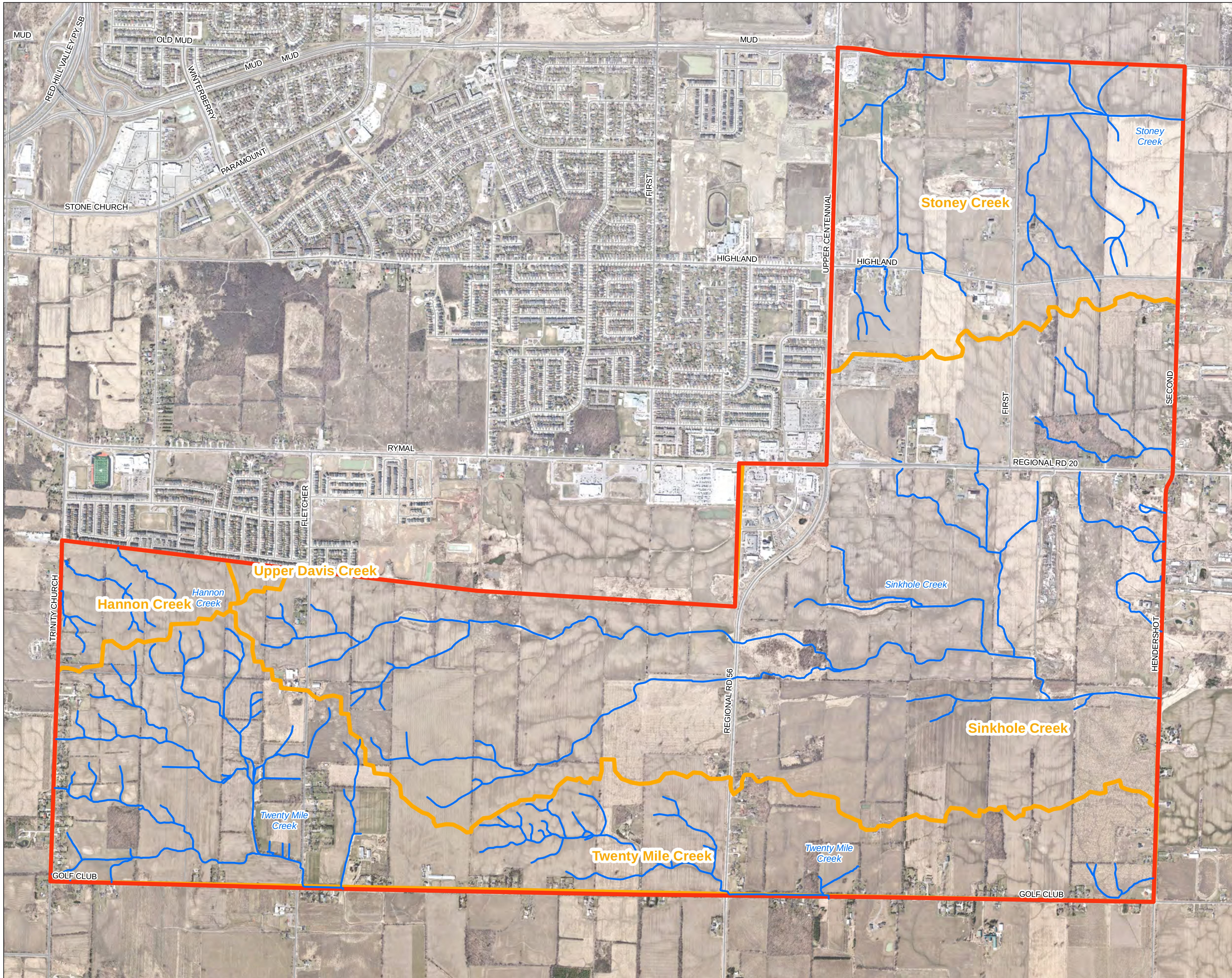
The Elfrida study area, illustrated in **Figure 1.1**, is approximately 1237 gross hectares in the southeast portion of the City. The study area is generally bounded by Mud Street to the north, Second Road/Hendershot Road to the east, Golf Club Road to the south, Trinity Church Road to the west, and follows the existing urban boundary to the northwest along the hydro corridor and Upper Centennial Parkway. The study area spans five (5) subwatersheds:

- Upper Davis Creek;
- Hannon Creek;
- Twenty Mile Creek;
- Sinkhole Creek; and
- Stoney Creek.

The Upper Davis, Hannon and Twenty Mile Creek subwatersheds originate within the Elfrida study area. The headwaters of Sinkhole Creek and Stoney Creek originate in the existing urbanizing lands to the west and drain into the Elfrida study area across Upper Centennial Parkway.

Current land uses within the study area are primarily agricultural with some small commercial lots along Upper Centennial Parkway. Just beyond the northwest-central boundary of the study area, industrial/commercial developments also exist, or are currently being constructed, near the Rymal Road and Swayze Road intersection. Residential developments also exist, more of which are currently being constructed along the northern and western boundaries of the study area.

Future land uses within the study area will ultimately be defined through the Elfrida Secondary Plan study, but the lands are expected to be developed primarily for community use with residential and supporting retail, schools, parks and community services.



Elfrida Subwatershed Study

Legend

- Study Area
- Subwatershed Boundary
- Watercourse

Figure 1.1

Elfrida Subwatershed Study Area

Date: February 2017
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

1.4 Subwatershed Goals, Objectives, and Study Phasing

As noted above, the Subwatershed Study goal may be defined as follows:

> "***Development of a management plan that allows sustainable urban growth, while ensuring maximum benefits to the natural and human environments on a watershed basis***"

The Subwatershed Study is undertaken in three phases. The objectives of this study are summarized below, according to the three study phases. ***This report has been prepared to present the results for Phase 1 of the process.***

Phase 1: Subwatershed Characterization

- identify and evaluate the location, extent, significance and sensitivity of the existing natural features of the study area, together with their potential interrelationship with other natural features;
- identify sensitive areas and natural hazard lands, together with recommended buffers and select preliminary management practices for these lands; and
- develop limitations and opportunities mapping to identify developable and non-developable lands.

Phase 2: Subwatershed Management Strategies

- identify potential land use impacts to natural features and functions;
- identify protective measure (best management practices, or BMP's) that, when implemented, will protect, enhance or restore the environmental features and functions;
- formulate alternative subwatershed management strategies;
- evaluate each Strategy, based on a range of environmental, social and cost considerations, together with stakeholder input; and
- select, among the alternatives, a recommended subwatershed strategy (or plan).

Phase 3: Implementation and Monitoring Plans

- develop an Implementation Plan to ensure the long-term integrity of the Recommended Plan, including the identification of issues and areas where further detailed studies may be required at the draft plan of subdivision stage of the planning process;
- identify any future recommended monitoring studies or contingency plans; and
- integrate the Subwatershed Study findings with the Secondary Plan and, if relevant, City Official Plan Policy.

1.5 Class Environmental Assessment (EA) Process

This Subwatershed Study is being conducted as a Master Plan under the Municipal Class Environmental Assessment (Class EA) process. In order to meet the intent of the Environmental Assessment Act, the study will need to satisfy Phases 1 and 2 of the Class EA process:

- Phase 1 – identification of the problem (deficiency) or opportunity; and
- Phase 2 – identification of alternative solutions to address the problem or opportunity by taking into consideration the existing environment, and establish the preferred solution taking into account public and review agency input.

The relationship between the components of the Subwatershed Study process (**Section 1.4**) and the Class EA process is depicted in **Figure 1.2**.

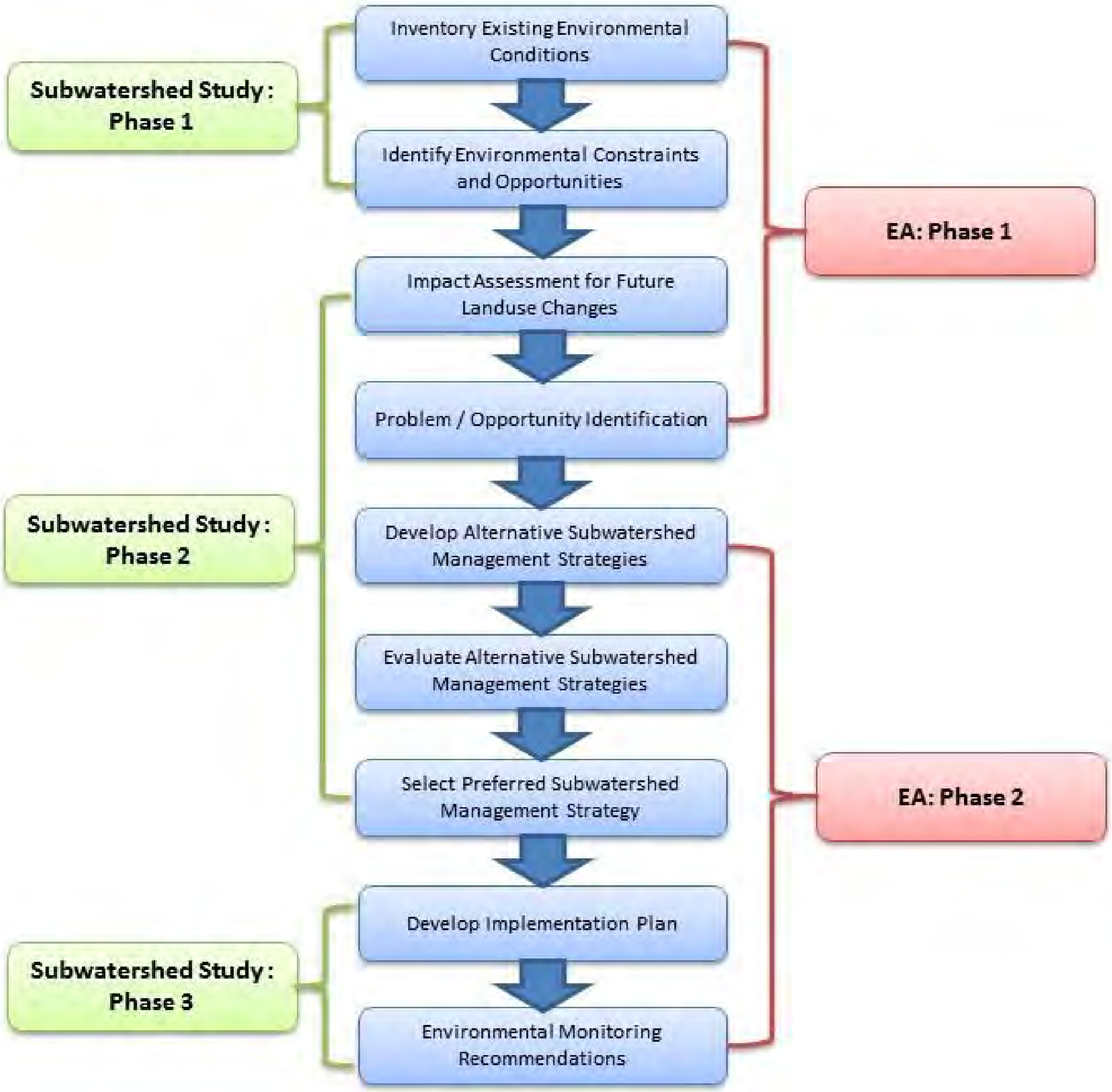
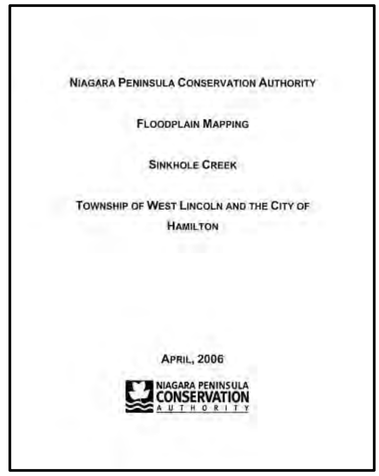


Figure 1.2: Subwatershed Study & Environmental Assessment Study Process

2 BACKGROUND INFORMATION

A series of historical study reports and background information was provided by the City of Hamilton, Niagara Peninsula Conservation Authority (NPCA) and Hamilton Conservation Authority (HCA) for background review and consideration during the Elfrida Subwatershed Study. Key documents are summarized below.

Sinkhole Creek Floodplain Mapping - Township of West Lincoln and the City of Hamilton (NPCA, April 2006)


NIAGARA PENINSULA CONSERVATION AUTHORITY

FLOODPLAIN MAPPING

SINKHOLE CREEK

TOWNSHIP OF WEST LINCOLN AND THE CITY OF HAMILTON

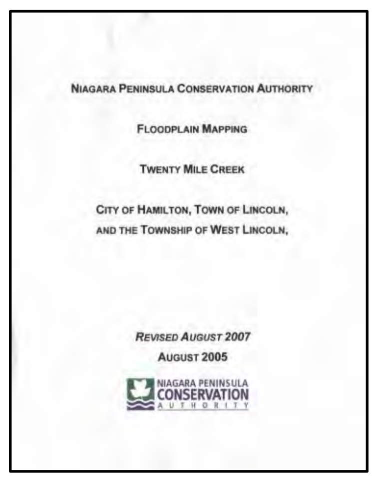
APRIL, 2006

NIAGARA PENINSULA CONSERVATION AUTHORITY

This study established 100-year Regulatory Floodplain Mapping for Sinkhole Creek. The HEC-HMS hydrologic model was used to estimate flood flows based on a 12-hour EAS design storm distribution. The HEC-RAS hydraulic model was then used to establish the 100-year Regulatory flood profile for the creek, and the resulting flood elevations were plotted onto topographic mapping over the subject creek reaches.

Within the Elfrida study area, Regulatory floodplain mapping extends along the Main Branch of Sinkhole Creek from Hendershot Road to approximately 500 m upstream of Regional Road 56, and along the north Tributary 1 from the confluence with the Main Branch to Regional Road 56.

Twenty Mile Creek Floodplain Mapping – City of Hamilton, Town of Lincoln, and the Township of West Lincoln (NPCA, August 2007)


NIAGARA PENINSULA CONSERVATION AUTHORITY

FLOODPLAIN MAPPING

TWENTY MILE CREEK

CITY OF HAMILTON, TOWN OF LINCOLN,
AND THE TOWNSHIP OF WEST LINCOLN,

REVISED AUGUST 2007
AUGUST 2005

NIAGARA PENINSULA CONSERVATION AUTHORITY

This study established 100-year Regulatory Floodplain Mapping for Twenty Mile Creek. The HEC-HMS hydrologic model was used to estimate flood flows based on a 12-hour EAS design storm distribution. The HEC-RAS hydraulic model was then used to establish the 100-year Regulatory flood profile for the creek, and the resulting flood elevations were plotted onto topographic mapping over the subject creek reaches.

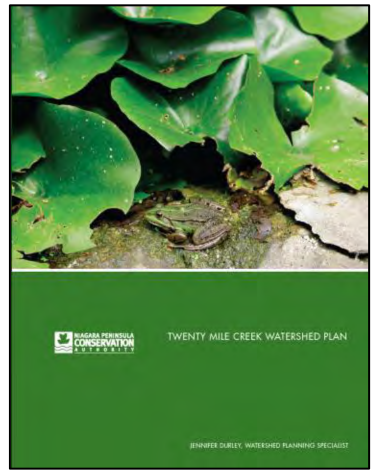
The southern limits of the Elfrida study area drain via several small tributaries to the Main Branch of Twenty Mile Creek. These small tributaries were not included in the hydraulic modeling, and therefore, the resulting Regulatory Floodplain Mapping from this study does not extend into the Elfrida study area.

Battlefield and Stoney Creeks Floodplain Mapping Study (M.M. Dillon Ltd., November 1976)

This study established Regulatory Floodplain Mapping for Battlefield and Stoney Creeks. The HYMO hydrologic model was used to estimate flood flows and the HEC-2 hydraulic model was then used to establish flood profiles for the creeks. The resulting flood elevations were plotted onto topographic mapping over the subject creek reaches. The floodplain mapping completed for this study does not extend into the Elfrida study area.

Twenty Mile Creek Watershed Plan (NPCA, 2006)

This study reviews the environmental character and issues of the Twenty Mile Creek watershed. Watershed objectives for the restoration of riparian, wetland and upland habitat were formulated.



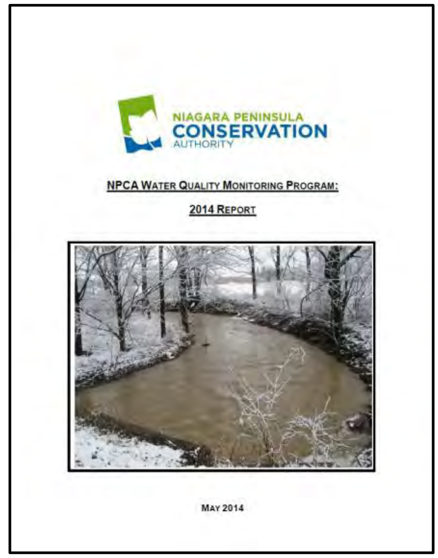
With respect to the Elfrida study area, the restoration strategy for the Twenty Mile Creek Main Branch recommends a Vegetation Protection Zone (VPZ) of up to 30 m on either side of the watercourse to protect from future development in the headwaters, including the Hamilton urban area. For the Sinkhole Creek Subwatershed, 15-30 m VPZ planting is recommended, together with wetland creation along the watercourse.

The study also recommends riparian restoration for watercourses along Regional Road 20 to lessen impacts from road salt on water quality and aquatic habitat.

The study also notes that, due to the exposed bedrock and karst formations in some areas, the groundwater system is susceptible to contamination. Further study is recommended to ensure karst formations are protected from future development, and to assess the feasibility of any wetland creation projects in the watershed.

NPCA Water Quality Monitoring Program 2014 Report (NPCA, May 2014)

The NPCA Water Quality Monitoring Program collects water quality samples at 73 surface water and 13 groundwater stations throughout the NPCA watershed. Chemical and biological analyses are used to evaluate the water quality and the general health of watercourses.

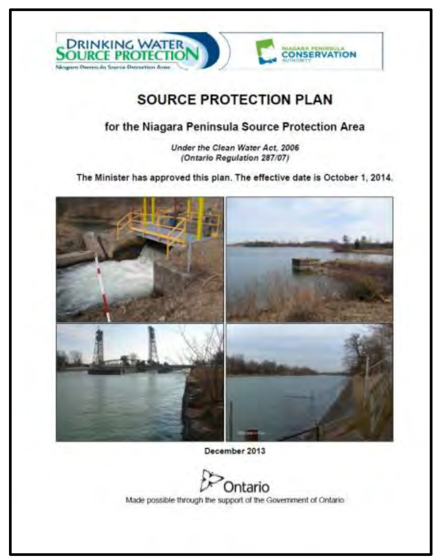


At sampling sites located on Twenty Mile Creek downstream of the Elfrida study area, the Water Quality Index is rated as "poor" and the BioMap rating is classified as "impaired".

Concentrations of chloride, copper, E. coli, lead, nitrate, phosphorus, TSS, and zinc frequently exceed provincial guidelines. Elevated concentrations of total phosphorus are of particular concern, and levels have been found to be increasing. Best Management Practices (BMPs) to reduce the phosphorus loads are recommended.

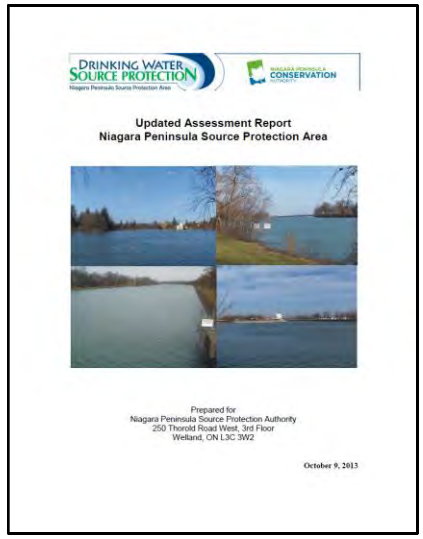
Source Protection Plan for the Niagara Peninsula Source Protection Area (NPCA, December 2013)

The Source Protection Plan was prepared to safeguard the study area's existing and future drinking water sources as part of an overall commitment under the Clean Water Act. The plan contains a range of policies that together reduce the risks posed by water quantity and quality threats.



Updated Assessment Report – Niagara Peninsula Source Protection Area (NPCA, October 2013)

The purpose of the Assessment Report (AR) was to assess the quality and quantity of municipal drinking water supplies and to identify threats to drinking water sources. The AR was used as a basis to prepare NPCA's Source Protection Plan.



The study compiles the findings of several other background studies, including:

- NPCA Groundwater Study Final Report (2005);
- Groundwater Vulnerability Analysis (2009);
- Water Availability Study for the Twenty Mile Creek Watershed Plan Area (2009)
- Significant Groundwater Recharge Area Delineation (2009)
- Niagara Peninsula Tier 1 Water Budget and Water Quantity Stress Assessment (2010)

As part of the study, intake protection zones (IPZ) were mapped for six water treatment plant intakes located in the study area, and vulnerability scores were assigned to each. The Elfrida study area is located outside of the identified water treatment plant IPZs.

There are no municipal groundwater systems in the NPCA area, and therefore, no municipal well head protection areas (WHPAs) were identified.

The study also mapped highly vulnerable aquifers (HVAs) and significant groundwater recharge areas (SGRAs). The study notes that the Haldiman Clay Plain soils limit interaction between surface and groundwater in much of the NPCA area, however, interaction does occur in areas such as the Niagara Escarpment and karst locations.

The study identifies the following water budget components for Twenty Mile Creek, which includes the Sinkhole Creek subcatchment:

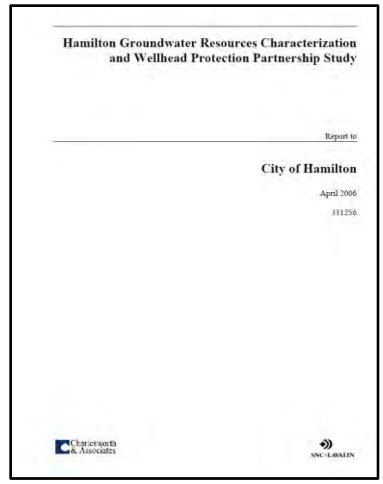
- annual precipitation: 897 mm/yr
- annual evapotranspiration: 547 mm/yr
- interflow: 39 mm/yr
- baseflow: 39mm/yr
- runoff: 271 mm/yr

Mapping from the study also indicates the following range of annual groundwater recharge rates in the Elfrida study area:

- Twenty Mile Creek: 0-50 mm/yr
- Sinkhole Creek: 50-100 mm/yr

Hamilton Groundwater Resources Characterization and Wellhead Protection Partnership Study (SNC-Lavalin, April 2006)

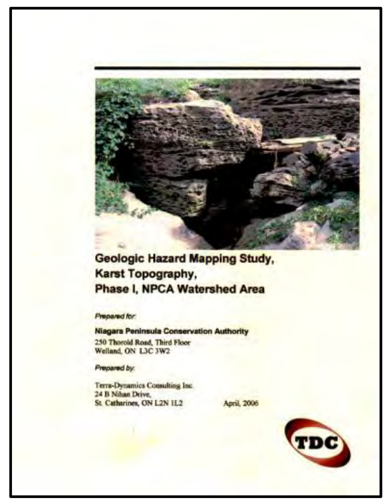
This study completed a regional groundwater resources characterization and mapped aquifer vulnerability and wellhead protection areas for the City of Hamilton.



Within the Elfrida study area, the study's mapping illustrates a shallow overburden thickness and a shallow depth to the water table. A zone of Eramosa karst is also mapped in the northwest portion of the Elfrida study area. Because of the shallow depth to the water table, groundwater susceptibility over much of the Elfrida study area was classified as medium to high. There were no municipal wells or wellhead protection areas within the Elfrida study area.

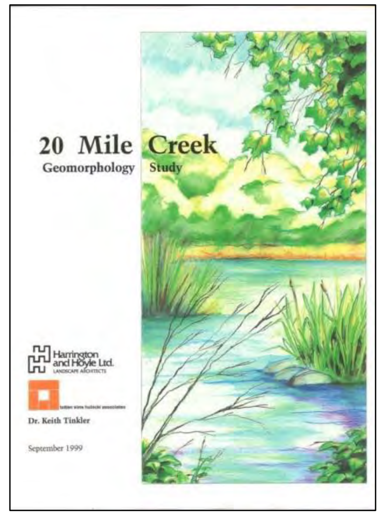
Geologic Hazard Mapping Study, Karst Topography, Phase 1, NPCA Watershed Area (Terra-Dynamics Consulting Inc., April 2006)

This study compiled a map of known and potential karst hazard areas based on a review of existing maps, reports and limited field investigation. An area of Eramosa karst is identified just northwest of the Elfrida study area near the intersection of Rymal Road East and Trinity Church Road. The karst has developed through a combination of thin (or no) soil cover and erosion of the dolomite rock from surface water runoff. Additional karst features are located on Sinkhole Creek downstream of the Elfrida study area, near Westbrook Road, south of Regional Road 20.



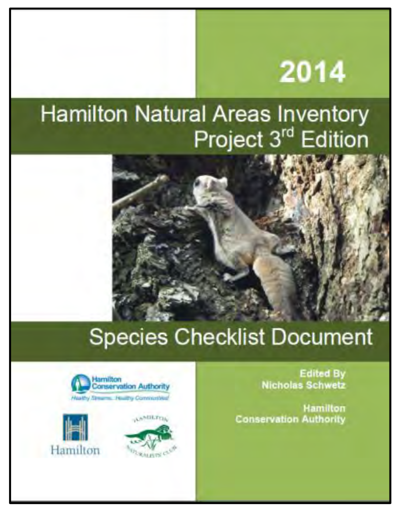
Twenty Mile Creek Fluvial Geomorphology Study (Harrington and Hoyle Ltd., September 1999)

This watershed fluvial geomorphology assessment study was completed by Dr. Keith Tinkler (Brock University) to characterize Twenty Mile Creek and a number of its tributaries from the headwaters to Lake Ontario. The geomorphological characterization includes a review of watershed surface geology, drainage patterns, and stream profiles, as well as detailed field assessments of 31 sites to document bankfull channel conditions, substrate, vegetation/roughness, and corridor meander belt widths. The study provides some comment on the hydrological interactions between the stream channels and the underlying karstic limestone bedrock. In addition, the study includes conceptual recommendations for stream rehabilitation and general restoration strategies within the watershed.



Nature Counts Project – Hamilton Natural Areas Inventory (2014)

The Species Checklist Document of the 3rd Edition of the Hamilton Natural Areas Inventory (NAI) contains a list of vascular plants, vegetation communities, butterflies, odonates, fishes, herpetofauna, breeding birds, and mammals known or previously known to occur within Hamilton. The document contains information on the rarity status of each species. The Site Summaries Document of the NAI was not referenced for this study, as lands surveyed in support of that document are not located within or adjacent to the Elfrida study area.



3 EXISTING SUBWATERSHED CONDITIONS

The following sections provide an overview of the environmental features and functions of the Elfrida study area. The natural ecosystem that existed prior to human settlement has been altered. Activities that have resulted in change include agricultural practices, construction of roads, highways, buildings, and industries.

Defining the current state of the environment, as well as the relationship between each feature is necessary in order to characterize key environmental functions, define opportunities and limitations associated with future development, and to ultimately establish alternative strategies to protect, enhance, or restore the environmental features over time.

3.1 Groundwater Resources

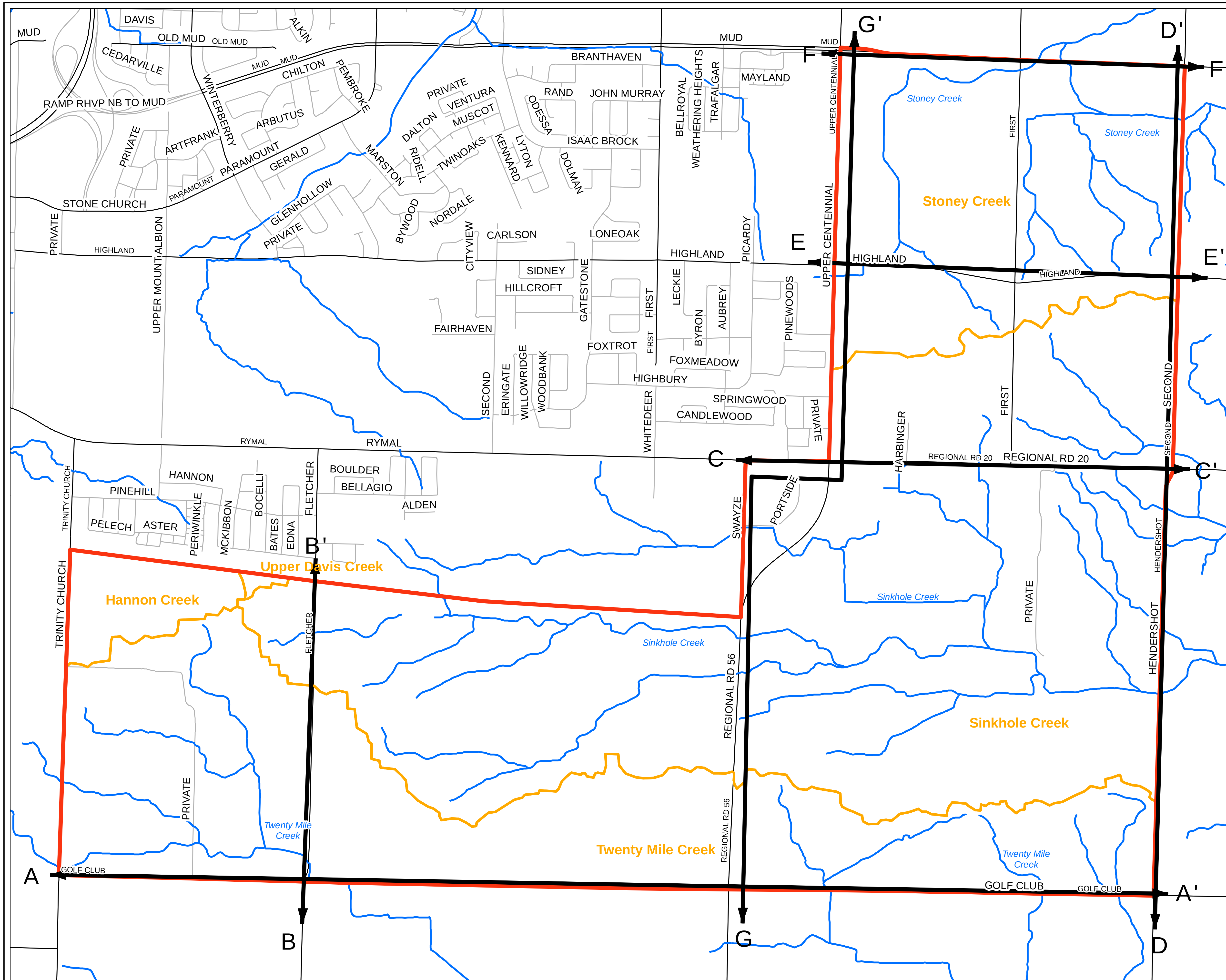
3.1.1 Geology/Hydrogeology

The geology of the Elfrida tudy area is relatively simple and is comprised of a low permeability glaciolacustrine clay and silt overlying a dolostone bedrock aquifer. Feenstra (1975) describes that the clay and silt deposits are from proglacial Lake Warren, which formed a vast lake-plain south of the Niagara Escarpment. Chapman and Putnam (1984) state that the clay deposits are part of the Haldimand Clay Plain, which covers most of the Niagara Peninsula above the Niagara Escarpment.

The deposits consist predominantly of interstratified clay and silt which partially cover the Niagara Falls Moraine. The Niagara Falls Moraine is expressed as a gently sloping ridge which traverses the study area from approximately Highland Road East in the east to just south of Rymal Road East in the western end of the study area. The Niagara Falls Moraine consists of the low permeability Halton clay till. The small ridge associated with the Niagara Falls Moraine acts as a surface water flow divide between streams and creeks flowing towards Hamilton Harbour and Lake Ontario to the north, and streams and creeks that form the upper reaches of Twenty Mile Creek which flows in a southwesterly direction.

Geologic cross-sections were derived over the study area using information obtained from the Ministry of Environment and Climate Change (MOECC) water well records. A map of the study area showing the location of geologic cross- sections is provided on **Figure 3.1**. **Figure 3.2** through **Figure 3.8** illustrates these cross-sections. As shown, the thickness of the low permeability clay ranges from 2 to 3 m on Highland Road East near Centennial Parkway, to greater than 10 m along Highway 20 near 2nd Road East.

The underlying dolostone forms the regional aquifer for the study area. The dolostone is from the Guelph Formation and the Eramosa Member of the Lockport Formation from the Silurian Era. The Eramosa Member is described as light brown to black in colour and is thin to moderately layered. It is known to be both fossiliferous and bituminous (Armstrong and Carter, 2010).



Elfrida Subwatershed Study

Legend

- Cross-section Location
- Study Area
- Subwatershed Boundary
- Watercourse

Figure 3.1

Location of Geologic Cross-sections

Date: May 2016
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

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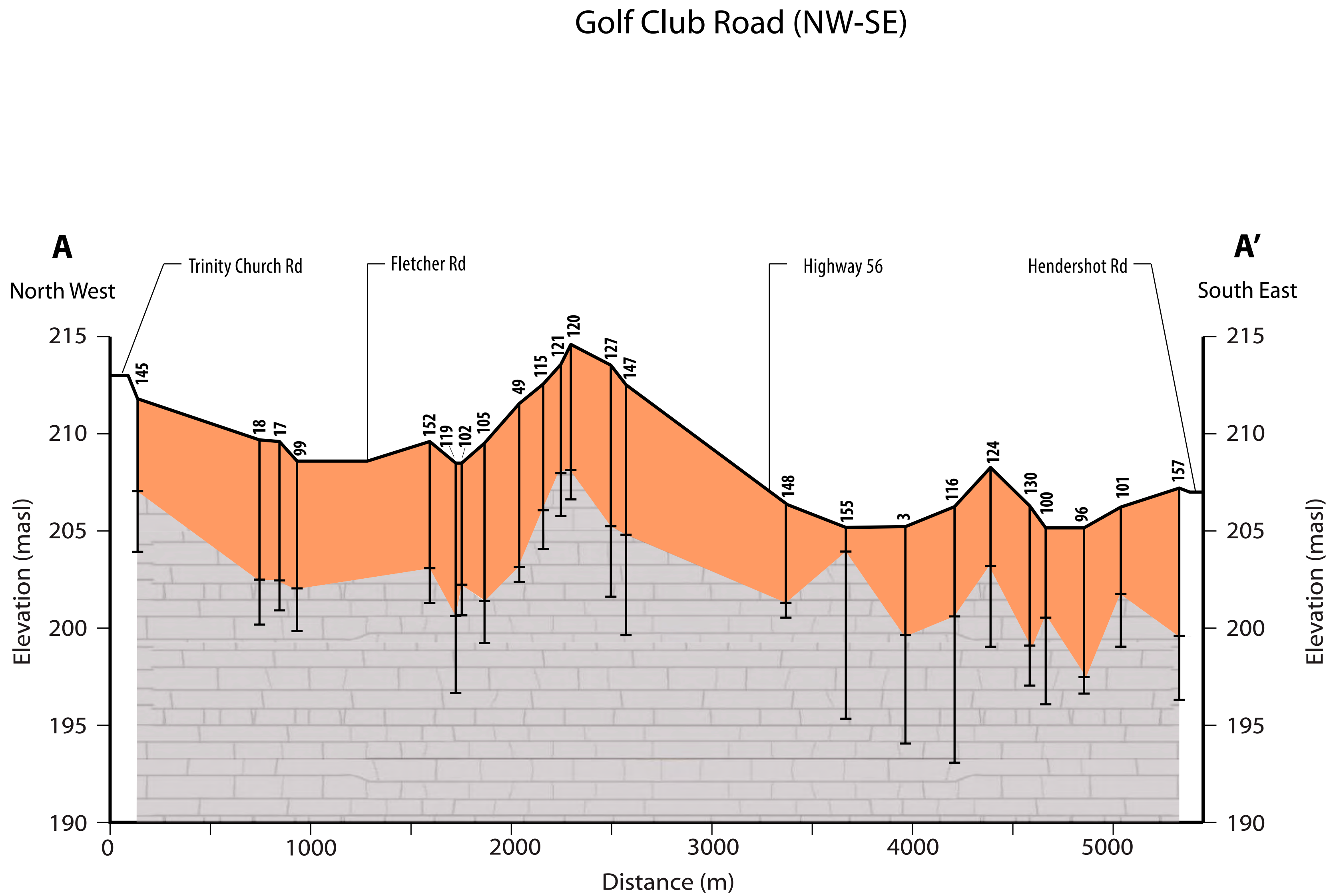
Hamilton

Aquafor Beech Limited

Elfrida Subwatershed Study



Legend

- Clay Overburden
- Dolostone Bedrock
- Well Number and Location

Figure 3.2

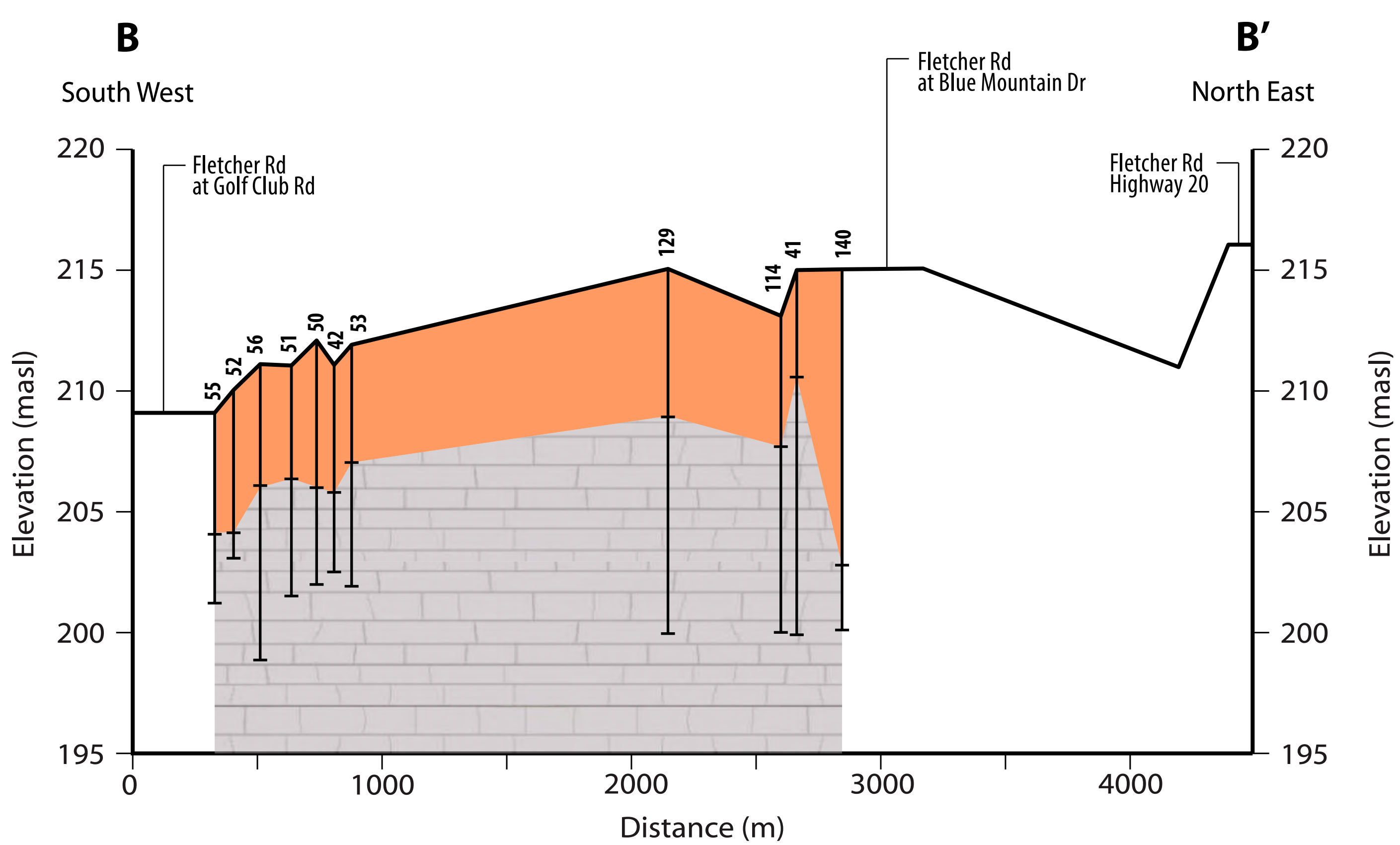
Geologic Cross-section A - A'

Hamilton

Aquafor Beech Limited

Elfrida Subwatershed Study

Fletcher Road (Southwest - Northeast)



Legend

Clay Overburden

Dolostone Bedrock

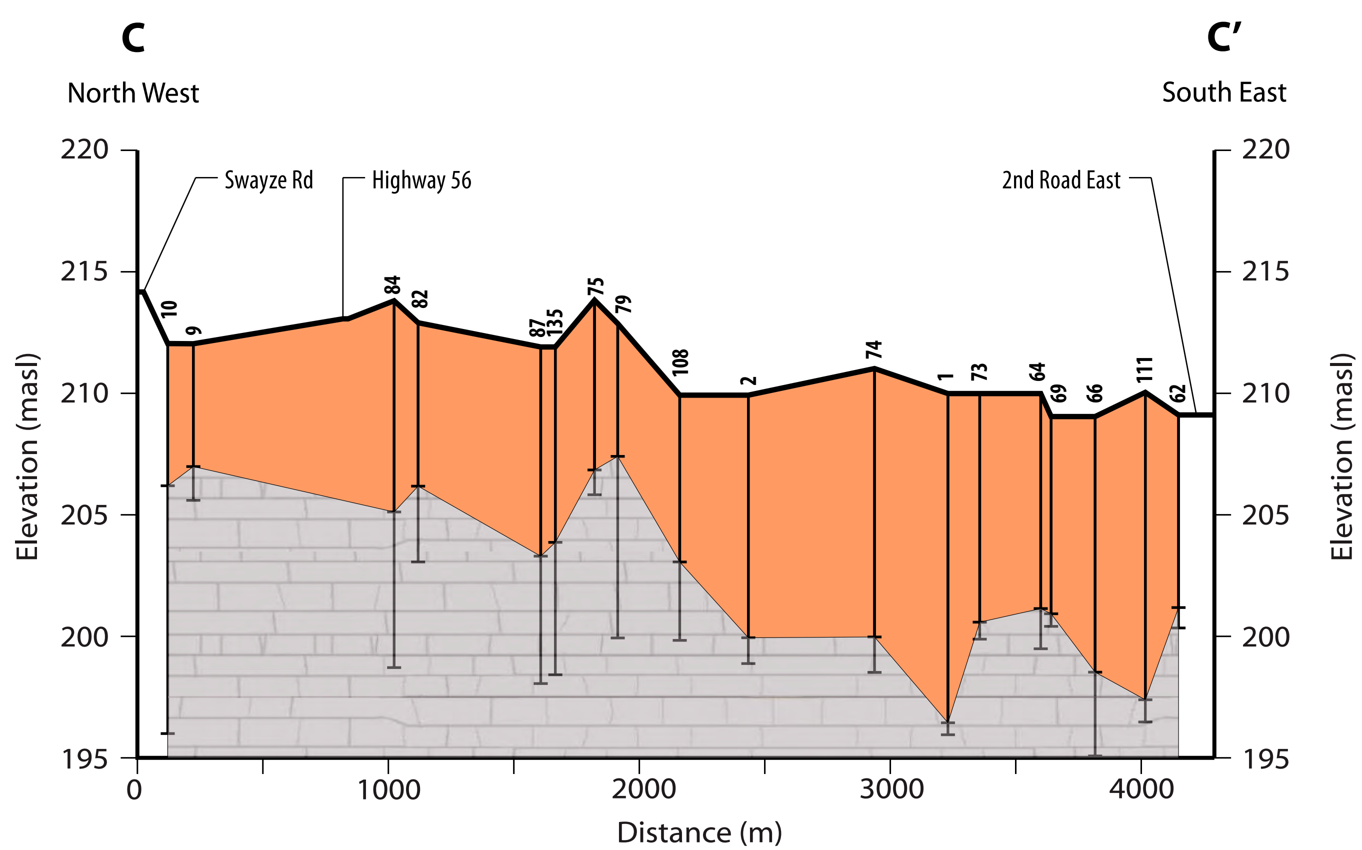
Well Number and Location

Figure 3.3

Geologic Cross-section B - B'

Elfrida Subwatershed Study

Highway 20



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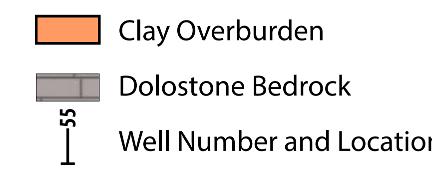

Figure 3.4

Geologic Cross-section C - C'

Hamilton

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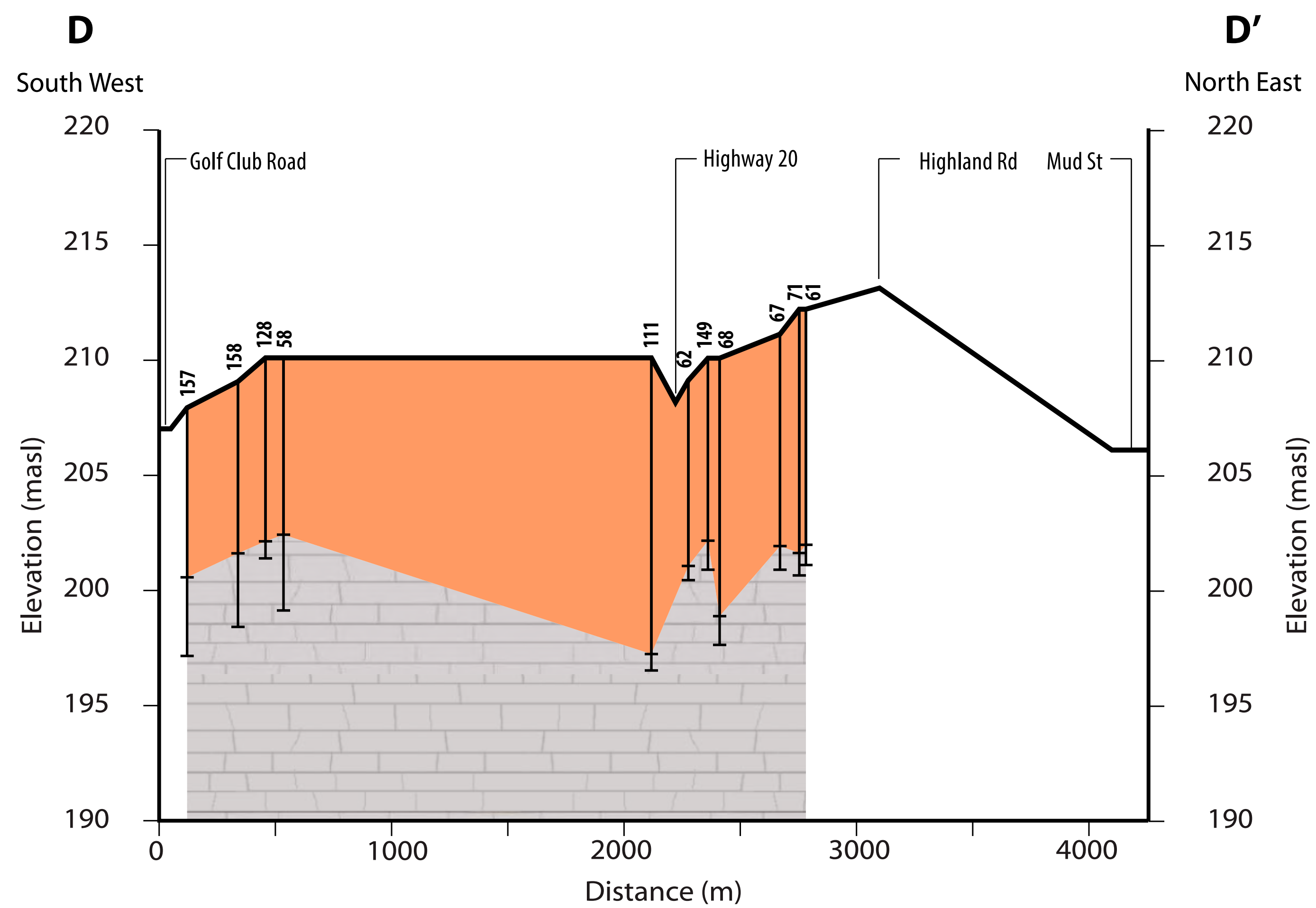
Elfrida Subwatershed Study

Hendershot Road / 2nd Road East



Legend

- Clay Overburden
- Dolostone Bedrock
- 55 Well Number and Location

Figure 3.5

Geologic Cross-section D - D’

Hamilton

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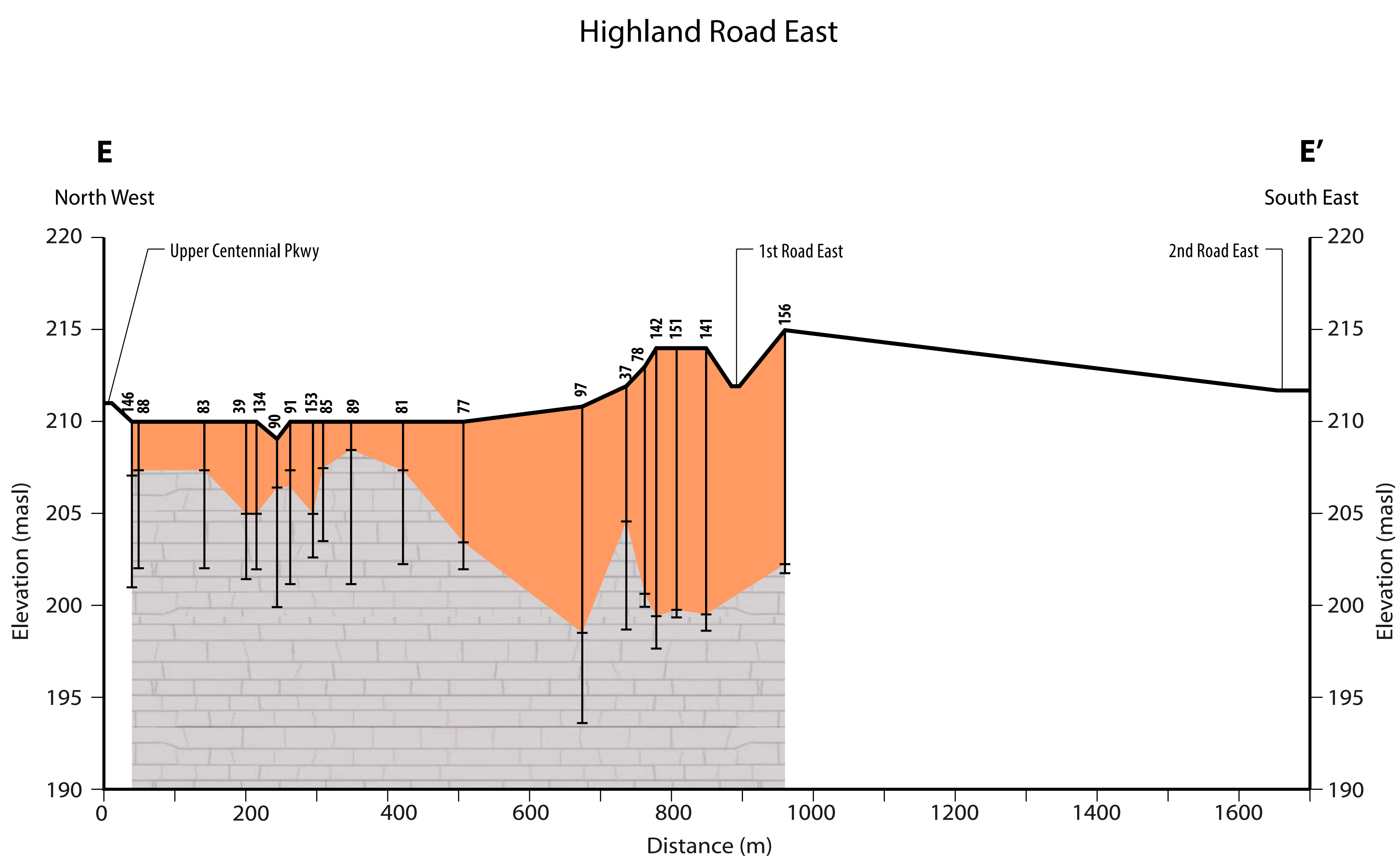
Elfrida Subwatershed Study



Legend

Clay Overburden

Dolostone Bedrock

Well Number and Location

Figure 3.6

Geologic Cross-section E - E'

Hamilton

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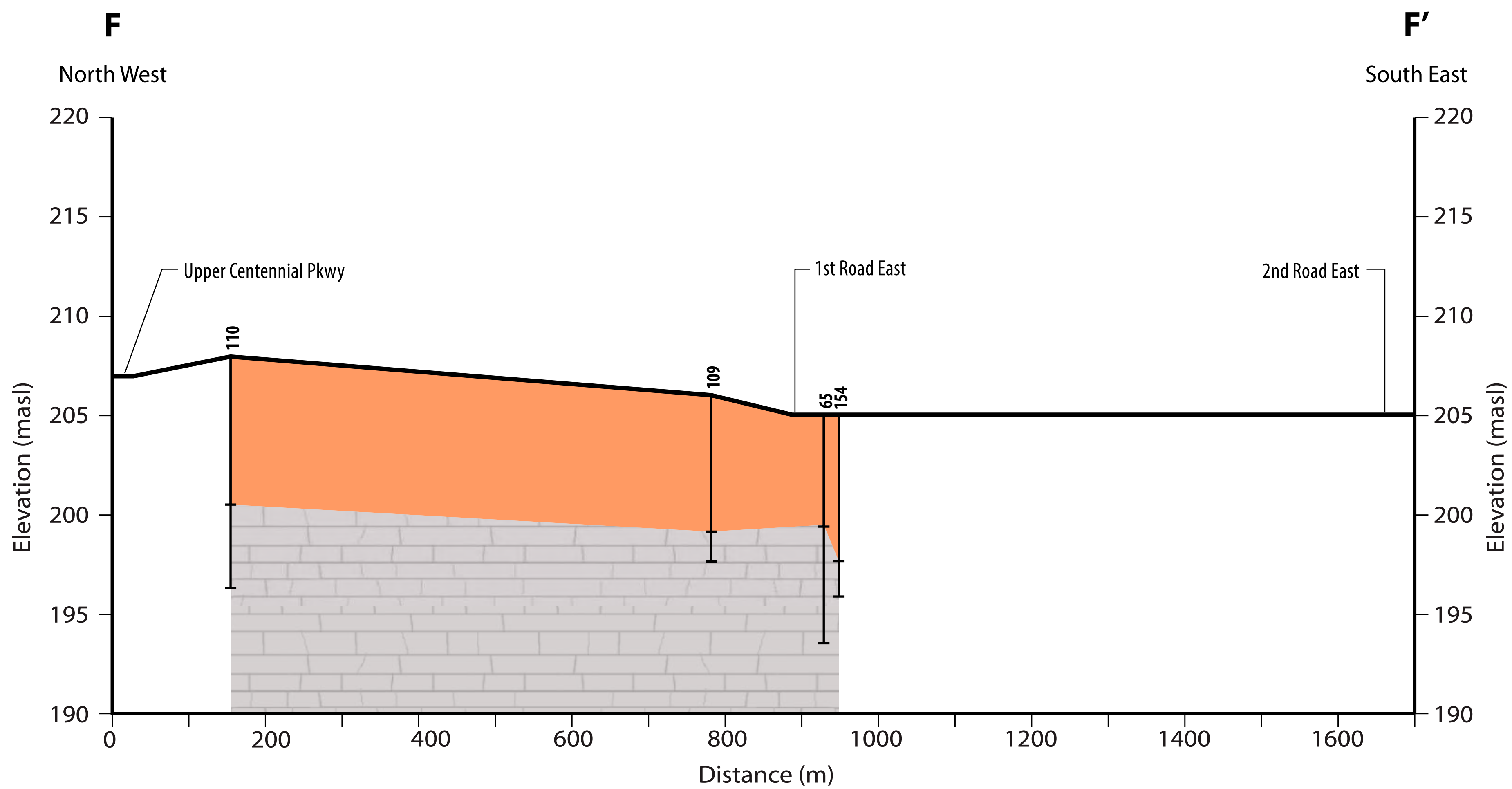
Elfrida Subwatershed Study

Mud Street



Legend

- Clay Overburden
- Dolostone Bedrock
- 55 Well Number and Location

Figure 3.7

Geologic Cross-section F - F'

Hamilton

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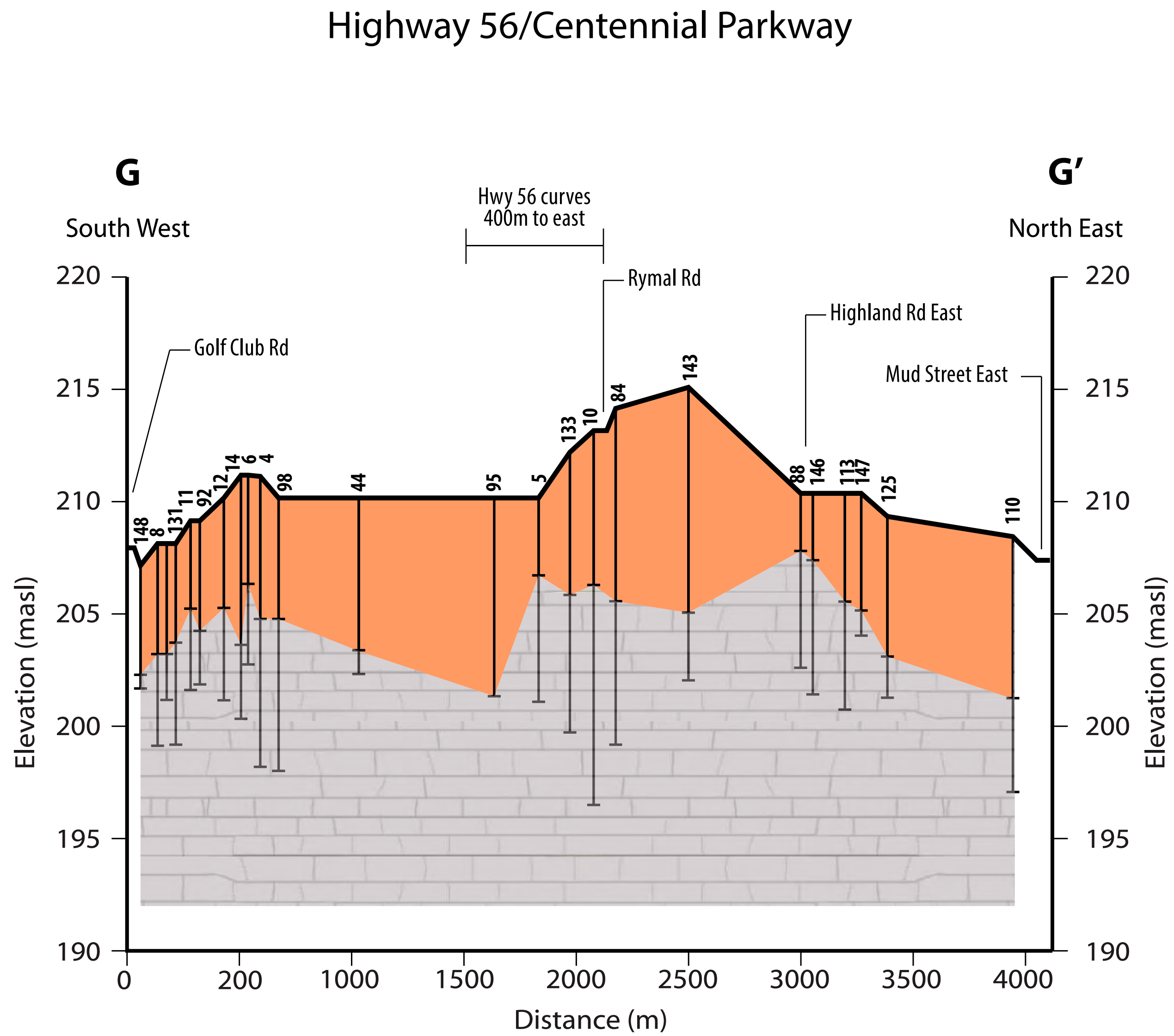


Elfrida Subwatershed Study

Legend

- Clay Overburden
- Dolostone Bedrock
- 55 Well Number and Location

Figure 3.8

Geologic Cross-section G - G'

Hamilton

Aquafor Beech Limited

3.1.2 Karst Hydrogeology

The Eramosa Member of the Lockport Formation is known to be karstic north of the western section of the study area within the Davis Creek and Hannon Creek subwatershed areas, especially where the Eramosa Escarpment is exposed at, or near, surface. This area, which is outside of the Elfrida study area to the northwest, has been extensively mapped for the presence of sinkholes and emergent springs (Buck et al., 2003, Terra-Dynamics, 2008).

A sinkhole is present in the northwest corner of the Elfrida study area within the Hannon Creek subwatershed. It is located in the eastern ditch of Trinity Church Road near the electrical transmission lines, as illustrated in **Figure 3.9**. This sinkhole was subject to a groundwater dye tracing study on March 28, 2016. Approximately 20 grams of Rhodamine WT dye was injected into the sinkhole at 12:00 hours (12 noon) on March 28, 2016 at a flow rate of approximately 0.4 Litres/second. The dye discharged approximately 650 m away at Spring 1 from approximately 3:40 to 6:15 hours after dye injection (**Figure 3.10**). The peak dye detection occurred 4:06 hours after injection indicating a dye travel time of approximately 160 m/hr. Spring 1 was flowing at approximately 5 Litres/second. A YSI 600 OMS data logger equipped with a Rhodamine WT fluorometer was used to detect the rhodamine WT at Spring 1. This sinkhole and spring were originally mapped by Terra-Dynamics (2001).

Figure 3.9: Location of Sinkhole

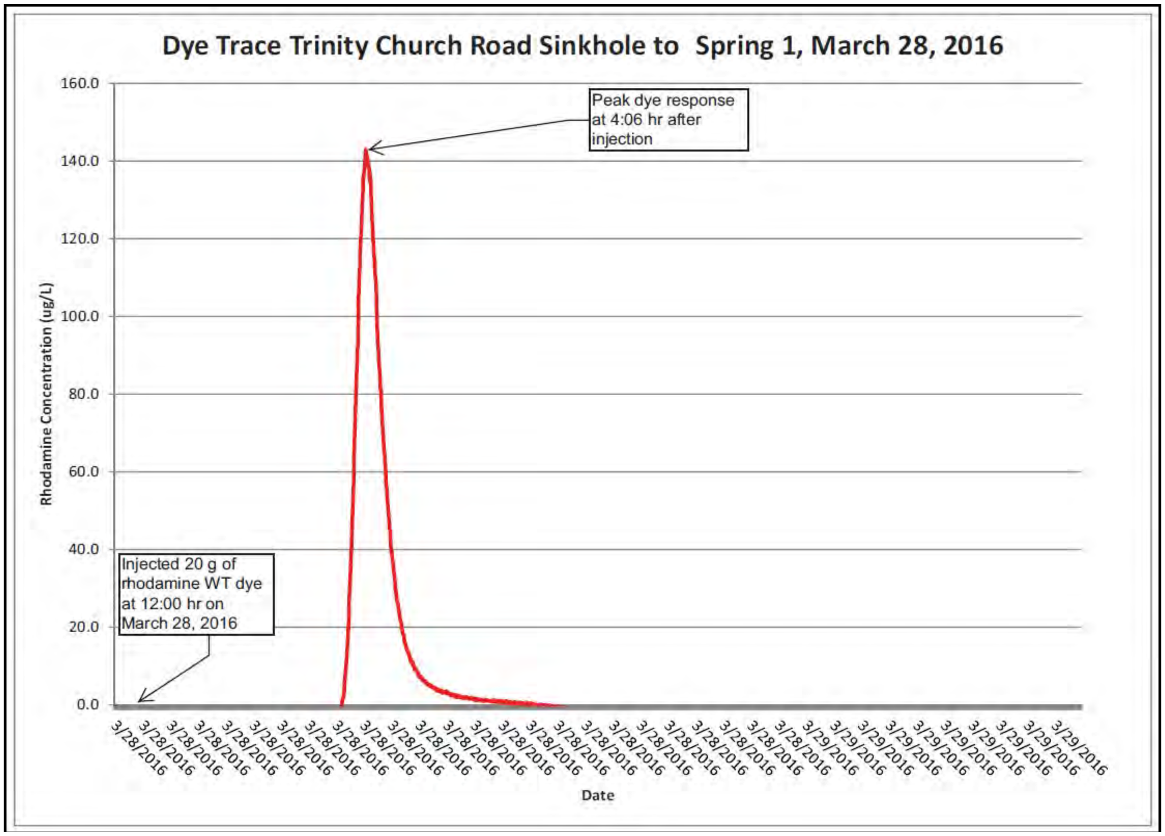
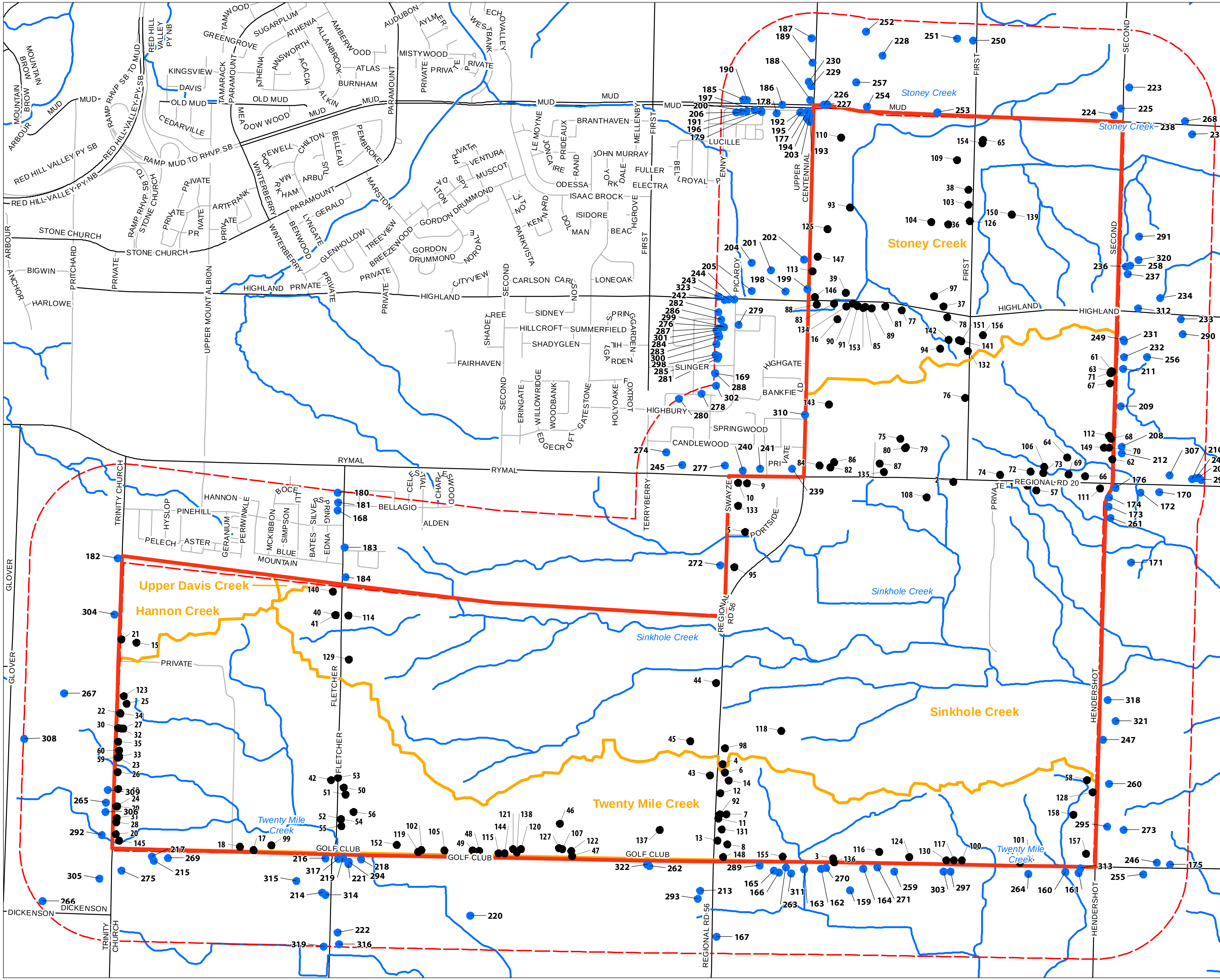


Figure 3.10: Results of Sinkhole Dye Trace

3.1.3 Water Well Records

Water well information for the province of Ontario is managed by the Ministry of the Environment and Climate Change (MOECC). The MOECC requires that a well record is completed by a licensed water well contractor and submitted to the MOECC when a new well is constructed in the province of Ontario. Information from these well records is stored and managed in the Water Well Information System (WWIS), which contains information pertaining to well construction, lithology, static and pumped water levels, water-bearing zones, and water use. Well records also contain well location information such as UTM coordinates, and municipal address information such as lot, concession and township.

Well records for the Elfrida Subwatershed Study Area were obtained from the MOECC WWIS on-line database. A total of 158 water well records were found within the Elfrida Subwatershed Study Area as of June 16, 2016. As of February 16, 2018 an additional 165 water well records were found within the 500 m Elfrida Subwatershed Study Area limit, bringing the total number of water well records found within the study area to 323. Water well locations within the Elfrida Subwatershed Study Area and within the 500 m Study Area limit are shown in **Figure 3.11**, and information from the MOECC database is compiled in **Appendix A**. Based on a review of the information contained in the well records, 321 of the 323 wells located within the study area are completed in the bedrock and 2 well are completed in the overburden. The well records also indicate that 285 of 323 wells located within the study area were constructed for domestic water use, and that the water quality is predominantly fresh. Other water uses found in the well records include commercial, irrigation, livestock and industrial.



Elfrida Subwatershed Study

Legend

- Study Area
- Study Area Limit
- Subwatershed Boundary
- Watercourse
- Well Locations Within Study Area
- Well Locations Within Study Area Limit

Figure 3.11

Well Locations (MOECC Well Records)

Date: May 2016
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

3.1.4 Permitted Water Takings

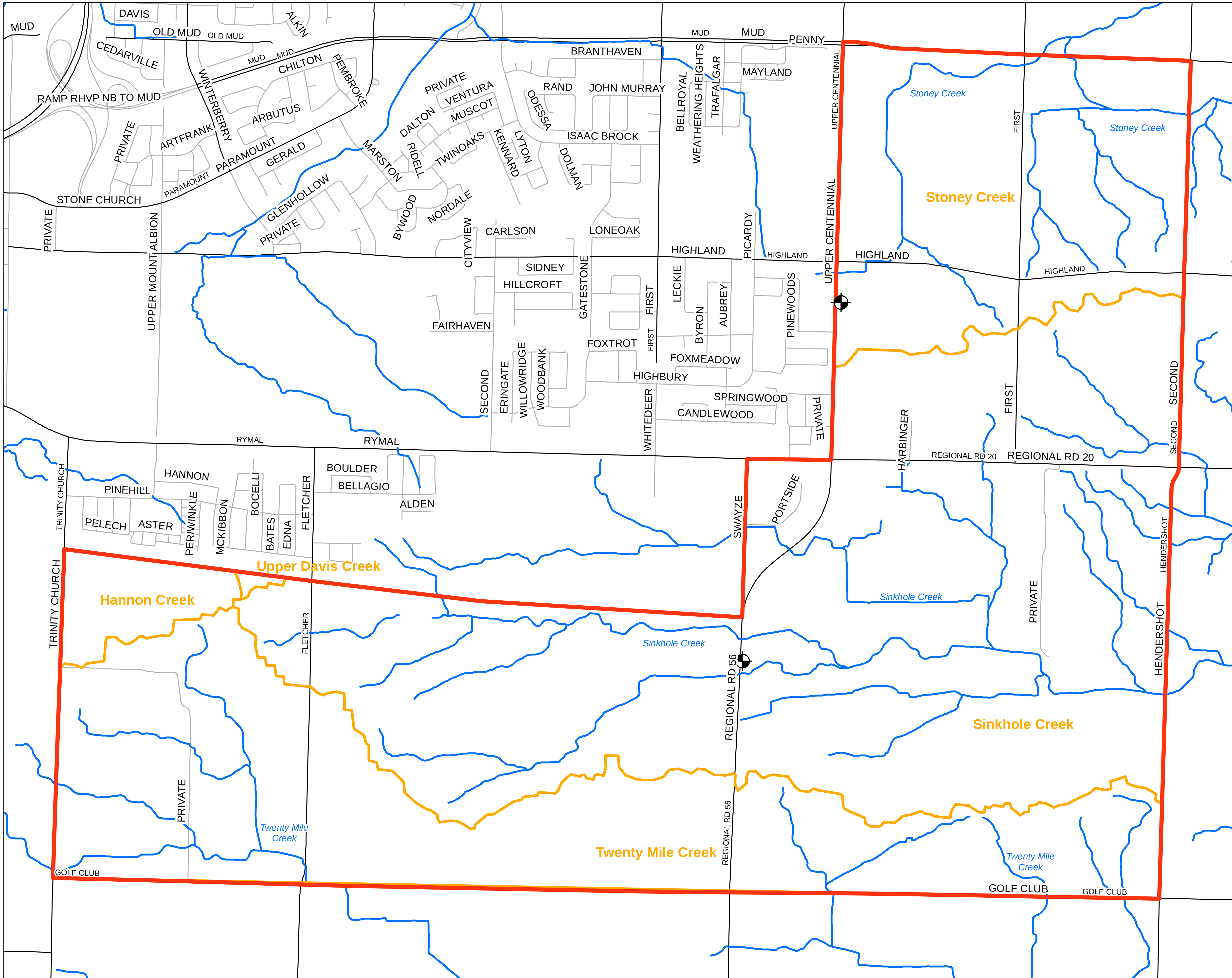
Water use in excess of 50,000 Litres/day requires a Permit to Take Water (PTTW) from the MOECC. Water takings requiring a permit could be from surface water sources or from groundwater sources. Permitted water takings located within the Elfrida Subwatershed Study Area were obtained from the MOECC PTTW database on August 16, 2016.

There are currently two permitted water takings in the study area located along Centennial Parkway and Highway 56 (see **Figure 3.12**). Both of the permitted water takings are covered by a single PTTW issued to the City of Hamilton for the withdrawal of groundwater for construction dewatering purposes. Details are provided in **Table 3.1** below:

Table 3.1: Permitted Water Takings

Permit Number	Permit Holder	Specific Purpose	Maximum Permitted Withdrawal (Litres per Day)	Source Type
8186-9RGL2N	City of Hamilton	Construction Dewatering	3,000,000	Groundwater

Elfrida Subwatershed Study



Legend

- Groundwater or Surface Water Takings
- Study Area
- Subwatershed Boundary
- Watercourse

Figure 3.12

Areas of Groundwater or Surface Water Takings as Permitted by the MOECC

Date: May 2016
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

3.1.5 Areas of Significant Groundwater Recharge

Areas of significant groundwater recharge in the Elfrida Subwatershed Study Area are shown in **Figure 3.13**. The areas shown in **Figure 3.13** were mapped based on the information provided in the Hamilton Source Protection Assessment Report (2015) and the Niagara Peninsula Source Protection Assessment Report (2013). The Assessment Reports contain Significant Groundwater Recharge Area (SGRA) mapping for the Hamilton Region and Niagara Peninsula Source Protection Areas and includes all of the lands in the Elfrida Subwatershed Study Area. SGRAs in these source protection areas were delineated by identifying areas where groundwater is recharged by a factor of 1.15 or greater of the average recharge rate for the source protection area, per the technical methodology recommended by the MOECC and Ministry of Natural Resources and Forestry (MNRF) (NPSPA, 2013). SGRA mapping also takes into account site-specific factors affecting recharge rates, such as topography, land cover, and soil texture (NPSPA, 2013).

Recharge rates in the Niagara Peninsula Source Protection Area (NPSPA) area are quite low at only 46 mm/year since overburden in Niagara consists predominantly of fine-textured clay and silt. Consequently, a recharge rate of 53 mm/year (i.e. 15% higher than the average recharge rate for the NPSPA) or higher is defined as significant in the context of average recharge rates for the NPSPA. Recharge rates in the Hamilton Region Source Protection Area (HRSPA) vary significantly due to changes in geology above and below the Niagara Escarpment. The prevalence of sandier soils and fractured dolostone above the escarpment results in higher recharge rates in these areas (Halton-Hamilton Source Protection Region, 2015). As a result, a recharge rate of 239 mm/year (i.e. 15% higher than the average recharge rate for the HRSPA) or higher is defined as significant in the context of average recharge rates for the HRSPA in areas above the Niagara Escarpment (Halton-Hamilton Source Protection Region, 2015).

As shown in **Figure 3.13**, SGRAs account for approximately 20% of the Elfrida Subwatershed Study Area. Average recharge rates for individual surface water catchment areas in the NPSPA were determined as part of the Niagara Peninsula Source Protection Area Water Availability Study for the Twenty Mile Creek Watershed Plan Area (Aqua Resource and NPCA, 2009). Average recharge rates for these surface water catchment areas in the Elfrida Subwatershed Study Area are similar to the average recharge rate for the NPSPA, ranging from 45 to 51 mm/year (Aqua Resource and NPCA, 2009). Average recharge rates for individual surface water catchment areas in the HRSPA were determined by Earthfx in 2010 (Earthfx Incorporated, 2010). Average recharge rates for the HRSPA surface water catchment areas within the Elfrida Subwatershed Study Area range from 123 to 164 mm/year (Earthfx Incorporated, 2010). Average recharge rates for the surface water catchments in the study area are summarized below in **Table 3.2**.

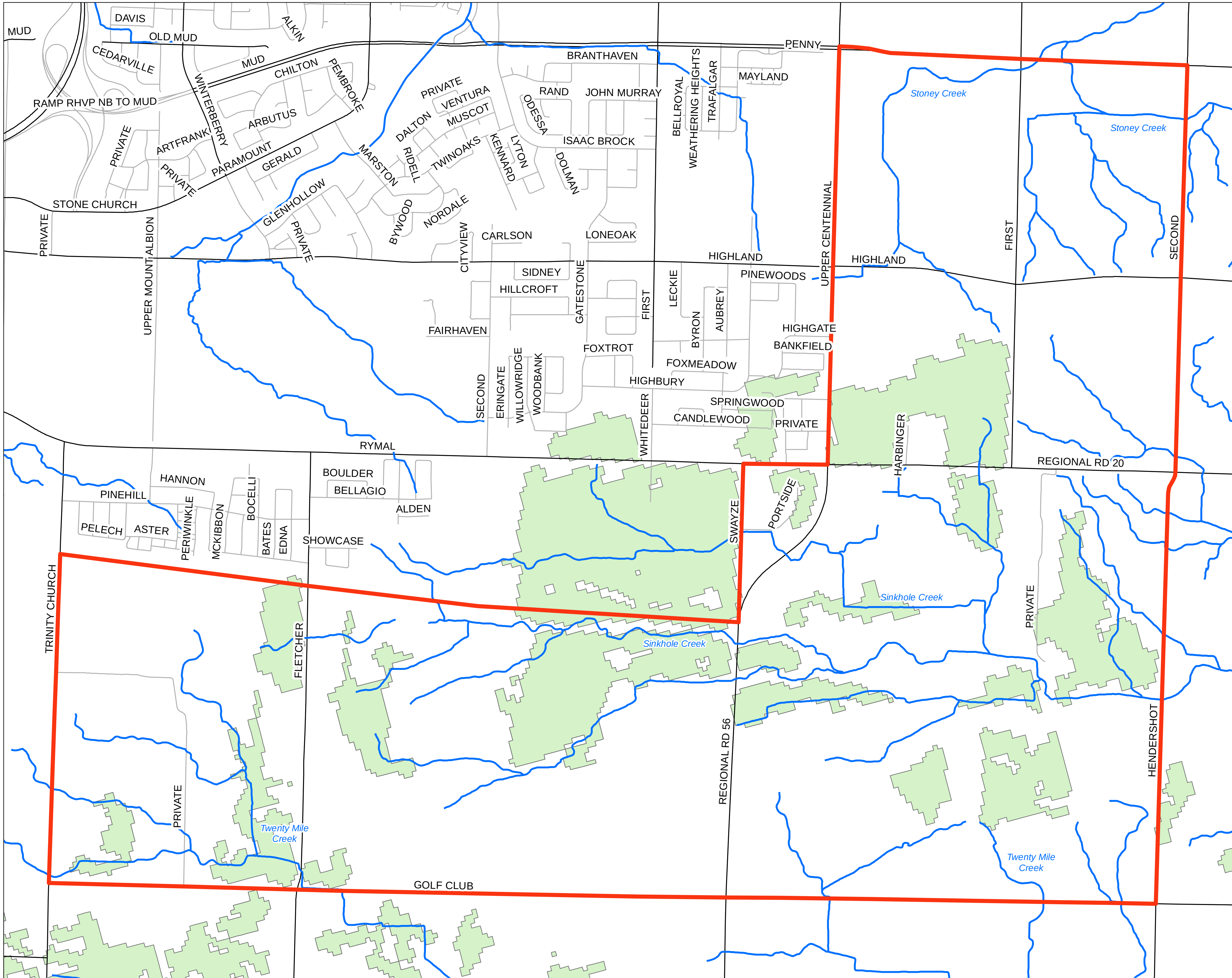
Groundwater recharge volumes under existing conditions were estimated for each sub-watershed in the Elfrida Subwatershed Study Area using the area of each sub-watershed within the study area boundary and the average recharge rates provided in **Table 3.2**. Under existing conditions, the average recharge volumes for the surface water catchments in the study area range from approximately 2,190 to 360,800 m^3/year (see **Table 3.2**).

Table 3.2: Existing condition groundwater recharge rates and recharge volumes for each sub-watershed in the Elfrida

Subwatershed Study Area

Sub-watershed	Sub-watershed Area (m^2)	Recharge (mm/year)	Recharge (m/y)	Recharge Volume (m^3/year)
Hannon Creek	310,000	123	0.123	38,130
Upper Davis Creek	15,000	146	0.146	2,190
Stoney Creek	2,200,000	164	0.164	360,800
Twenty Mile Creek*	3,400,000	47.5	0.0475	161,500
Sinkhole Creek**	6,310,000	48.5	0.0485	306,035

*the recharge rate for the Twenty Mile Creek watershed within the study area ranges from 45 to 50 mm/year therefore a mean recharge rate of 47.5 mm/year was used to calculate the recharge volume
**the recharge rate for the Sinkhole Creek watershed within the study area ranges from 46 to 51 mm/year therefore a mean recharge rate of 48.5 mm/year was used to calculate the recharge volume



Elfrida Subwatershed Study

Legend

- Areas of Significant Groundwater Recharge
- Study Area
- Watercourse

Figure 3.13

Areas of Significant Groundwater Recharge

Date: May 2016
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

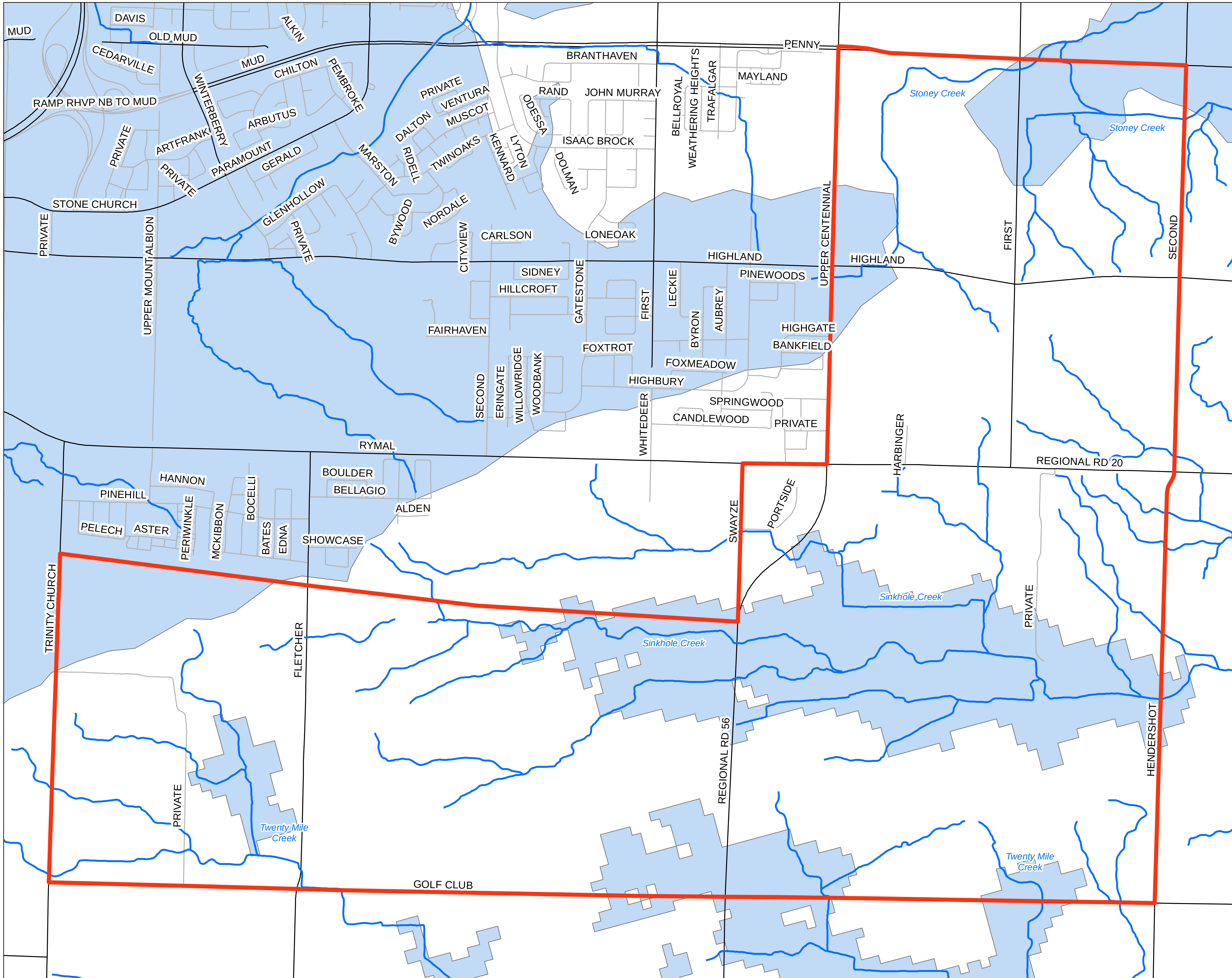
Aquafor Beech Limited

3.1.6 Areas Susceptible to Contamination

Areas susceptible to groundwater contamination in the Elfrida Subwatershed Study Area are shown in **Figure 3.14**. The areas shown on **Figure 3.14** were mapped based on the information provided in the Niagara Peninsula Source Protection Assessment Report (NPSP Area, 2013) and the Assessment Report for the Hamilton Region Source Protection Area (Halton-Hamilton Source Protection Region, 2015). The Assessment Reports contains Highly Vulnerable Aquifer (HVA) mapping for their respective watershed areas, which collectively encompass all of the lands in the Elfrida Subwatershed Study Area. HVAs in the Niagara Peninsula Source Protection Area were delineated by identifying areas where overburden thickness is 5 m or less based on information contained in the MOECC WWIS, oil and gas well records, and geotechnical borehole data (NPSP Area, 2013). HVAs in the Hamilton Region Source Protection Area were delineated based on the depth to the aquifer and to the water table, the properties of the overlying soil and/or rock, and the aquifer composition (Halton-Hamilton Source Protection Region, 2015). The MOECC WWIS and other borehole logs were used in the characterization of aquifers for the Hamilton Region Source Protection Area (2015).

As shown in the geologic cross-sections (**Figure 3.2** through **Figure 3.8**), the thickness of the clay overburden ranges from 2 to 3m on Highland Road East near Centennial Parkway to greater than 10 m along Highway 20 near 2nd Road East. This corresponds well to **Figure 3.14**, which shows the portion of Highland Road near Centennial Parkway mapped as an HVA area. As shown in **Figure 3.8**, clay overburden thickness ranges from 4 to 6m along Highway 56 near Golf Club Road, and near Sinkhole Creek just south of Rymal Road. As shown in **Figure 3.2**, clay overburden thickness is less than 5m along Golf Club Road just west of Hendershot Road. This corresponds well to **Figure 3.14**, which shows that these areas of thinner overburden are mapped as HVA areas. As shown in **Figure 3.14**, HVA areas account for approximately 20% of the Elfrida Subwatershed Study Area and are concentrated primarily along the tributaries of Sinkhole Creek, Twenty Mile Creek, and Stoney Creek.

Elfrida Subwatershed Study



Legend

- Study Area
- Watercourse
- Highly Vulnerable Aquifer

Figure 3.14

Areas Susceptible to Groundwater Contamination

Date: May 2016
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

3.1.7 Water Balance

To better characterize the existing infiltration rates for the study area, a basic water budget was prepared for the existing land use condition using monthly values for precipitation and temperature for the Hamilton Airport meteorological station (1981 – 2010 climate normals from Environment Canada). As shown in **Table 3.3**, on average, the area receives approximately 930 mm of precipitation per year.

Table 3.3: Thornthwaite Evapotranspiration Component

Month	Average Monthly Precipitation (mm)	Average Monthly Temperature (°C)	Evapotranspiration (ET) (mm)
January	64.0	-6.1	9.2
February	57.8	-5.0	10.5
March	68.4	-2.7	18.7
April	79.1	4.7	40.1
May	79.4	14.4	72.5
June	84.9	18.5	108.1
July	100.7	21.6	122.5
August	79.2	20.7	95.8
September	81.9	18.5	60.2
October	77.4	13.1	32.4
November	84.3	4.7	17.4
December	73.0	-1.6	10.9
TOTALS	**930.1**		**598.3**

Evapotranspiration (ET) was calculated according to the Thornthwaite and Mather Model (Thornthwaite and Mather, 1957) which uses an accounting procedure to analyze the allocation of water among various components of the hydrologic system. Inputs to the model are monthly temperature and precipitation. Outputs include monthly potential and actual evapotranspiration, and soil moisture storage. Using a water retention value of 250 mm (corresponding to moderately-rooted vegetation in a clay loam soil), the estimated annual evapotranspiration over the study area is approximately 598 mm (**Table 3.3**).

The evapotranspiration value was then used to estimate annual and monthly water surplus. The annual volume of surplus water was estimated at approximately 332 mm (**Table 3.4**) which was allocated between infiltration and runoff.

Table 3.4: Water Budget for Study Area

Water Budget Component	Source of Information	Value (mm/year)
Annual Precipitation (P)	Environment Canada climate normal for Vineland-Rittenhouse meteorological station	930
Actual Evapotranspiration (ET)	Thornthwaite model monthly calculation	598
Water Surplus	P – ET	332
Recharge	Average groundwater recharge per Aqua Resource and NPCA, 2009 (Haldimand Clay Plain)	48
Runoff	Water surplus – Recharge	284

As shown in **Table 3.4**, the estimated annual groundwater recharge for the clay soils over the majority of the study area is approximately 48 mm per year. The remaining 284 mm of surplus water occurs as overland runoff. These values are in reasonable agreement with the water balance estimates provided in the Updated Assessment Report for the Niagara Peninsula Source Protection Area (NPCA, October 2013).

3.1.8 Groundwater Monitoring

A series of fifteen (15) drive-point piezometers were installed throughout the study area (**Figure 3.16**). The piezometers were installed within stream beds and woodlot areas to investigate groundwater levels and determine if the streams were gaining water from groundwater discharge or losing water to the subsurface soils. Water levels in the piezometers were measured on four occasions (21 December 2015, 18 March 2016, 04 July 2016, and 28 October 2016).

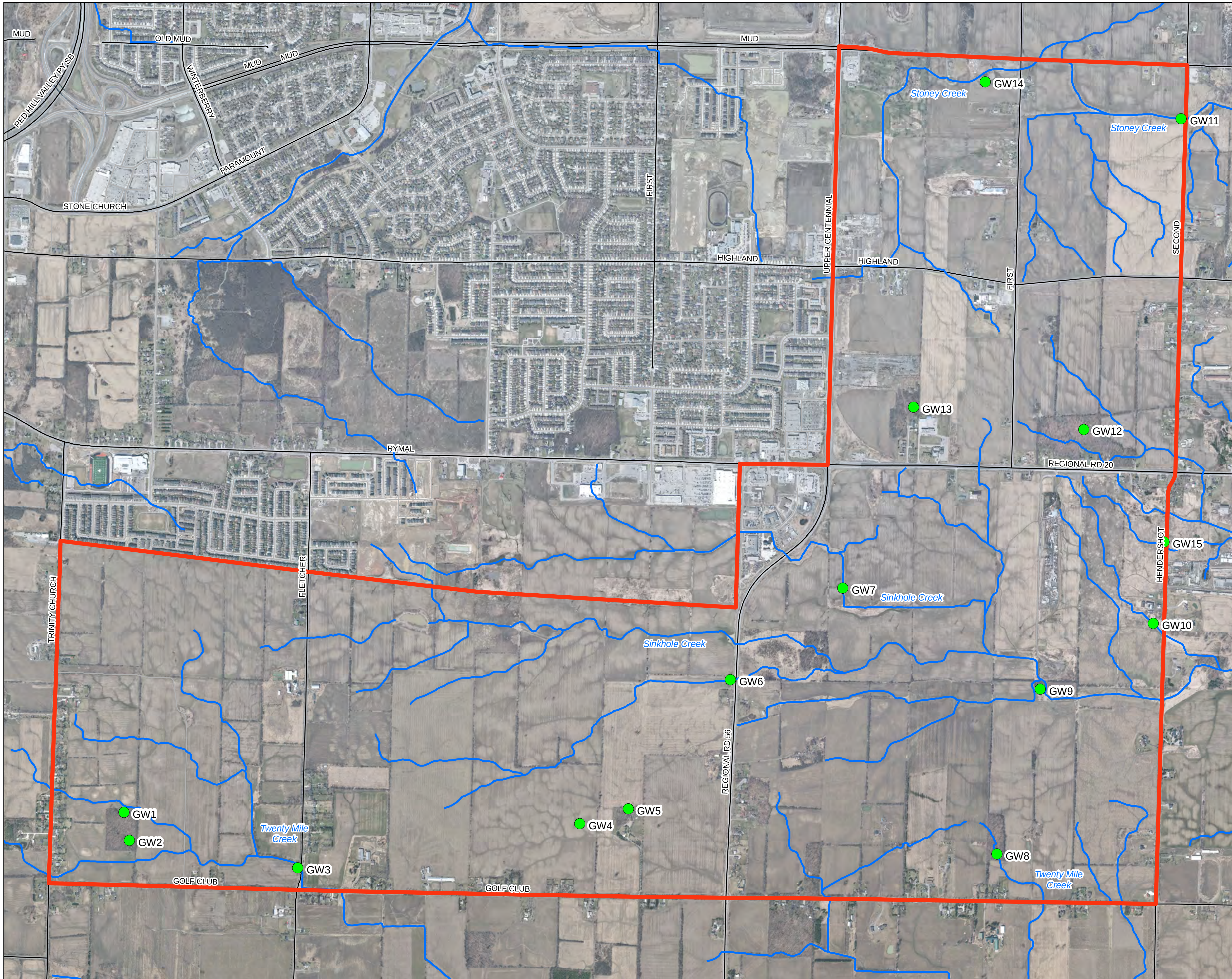
At most locations, piezometer readings indicate that the groundwater table is located below the stream bed or ground elevation and therefore does not supply any significant baseflow to the streams. This is supported by observations of intermittent flow. At monitoring sites GW3 (**Figure 3.15**), GW5, and GW8, the groundwater level was found to be located near or above the ground surface on select dates, indicating the potential for seasonal groundwater discharge at these locations in the Twenty Mile Creek watershed. Piezometer readings at these same locations indicated a groundwater level below the ground surface at other times of the year.

Figure 3.15: Groundwater bubbling up at GW3

3.1.9 Summary of Groundwater Limitations & Opportunities

Based on the above groundwater resources assessment, key items related to future development limitations and opportunities are summarized below:

- The geology of the Elfrida study area is relatively simple and is comprised of low permeability clay and silts overlying dolostone bedrock. Although the groundwater recharge potential for the Elfrida soils is quite low, future stormwater management planning should include measures to maintain the existing groundwater recharge rate of approximately 48mm per year. This will, in turn, help to minimize future increases in runoff rates.
- A karst sinkhole is present in the eastern ditch of Trinity Church Road in the Hannon Creek subwatershed. The sinkhole collects local drainage and conveys it to a downstream spring to the northwest. Future land use and stormwater management planning should protect this feature and the supply of surface runoff.



Elfrida Subwatershed Study

Legend

- Study Area
- Watercourse
- Groundwater Monitoring

Figure 3.16

Piezometer Monitoring Locations

Date: May 2016
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

3.2 Surface Water Resources

The surface water component of this study inventories the network of existing drainage channels through the study area. Further field analyses and modeling is completed to determine the environmental function of these drainage features and to establish any associated flooding and erosion hazards. The resulting environmental features and natural hazards are then used to identify limitations to future development, as well as restoration opportunities.

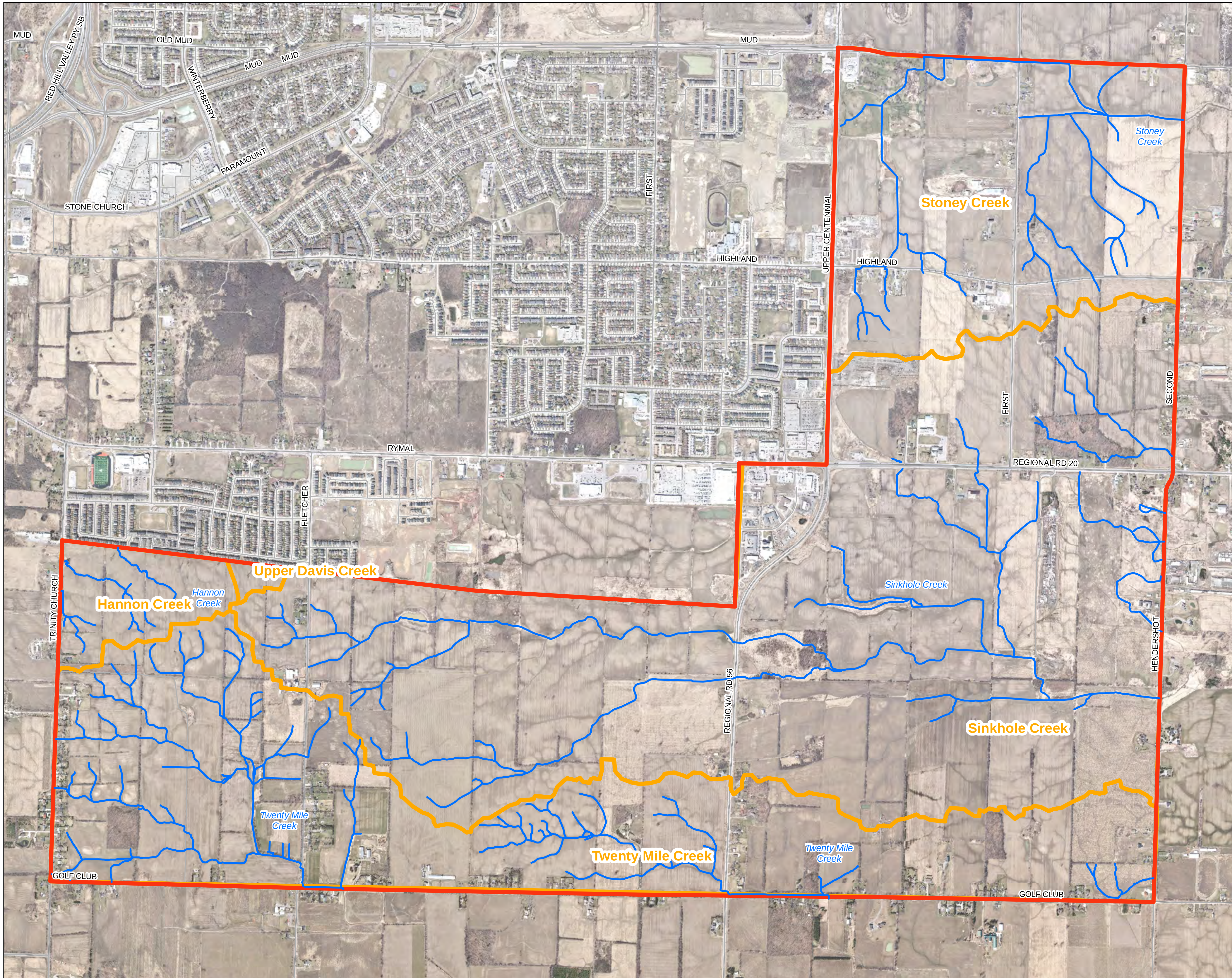
The drainage network is illustrated in **Figure 3.17**. As shown, the study area spans portions of five subwatersheds:

- Upper Davis Creek;
- Hannon Creek;
- Twenty Mile Creek;
- Sinkhole Creek; and
- Stoney Creek.

The Upper Davis, Hannon and Twenty Mile Creek subwatersheds originate within the Elfrida study area. The headwaters of Sinkhole Creek and Stoney Creek originate in the existing urbanizing lands to the west and drain into the Elfrida study area across Upper Centennial Parkway.

Limitations to future development related to surface water resources are defined in the subsequent report sections under the following topics:

- Headwater drainage features – defines management recommendations for the small headwater drainage channels throughout the study area;
- Fluvial geomorphologic resources – defines erosion hazard considerations for the streams as well as restoration opportunities; and
- Hydrology/hydraulics and flooding – defines the estimated flood flows, flood levels, and associated floodplain hazard lands.



Elfrida Subwatershed Study

Legend

- Study Area
- Subwatershed Boundary
- Watercourse

Figure 3.17

Surface Water Drainage Network

Date: February 2017
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

3.2.1 Headwater Drainage Feature Assessment

3.2.1.1 Introduction

Headwater drainage features (HDFs) have not traditionally been a part of most aquatic monitoring efforts. HDFs typically consist of shallow, seasonally ephemeral drainage features which provide primary and secondary inputs into more defined watercourses. HDFs vary in both form and function and may provide direct (both permanent and seasonal) habitat for fish. Examples of aquatic habitat types present in HDFs include refuge pools, seasonal spawning and nursery areas, and thermal refugia in areas of groundwater discharge. HDFs also provide indirect habitat by transport of detritus/invertebrates to downstream reaches. (OSAP, 2013) Further descriptions of HDF form and function is contained below in **Section 3.2.1.2**.

Examples of HDFs include small streams, springs, wetlands, swales, and ditches (natural or human- modified). These features are also important sources, conveyors, or sinks of sediment, nutrients, and flow. Some HDFs may function as important habitat for terrestrial and wetland species as breeding areas or corridors for travel.

3.2.1.2 Methodology

The Evaluation, Classification, and Management of Headwater Drainage Features Guidelines (TRCA & CVC 2014) was used to classify HDFs within the study area. These guidelines were developed to provide direction to practitioners for aquatic features that are not clearly covered by existing policy and legislation as being important eco-hydrological features (e.g. perennial streams and provincially significant wetlands) but may contribute to the overall health of a watershed. These guidelines attempt to evaluate, in a consistent way, the contribution of sediment, food and flow transport to downstream reaches, as well as the use of these features by biota. (TRCA & CVC 2014)

To distinguish HDFs from watercourses, the following definitions were utilized per the Ontario Stream Assessment Protocol (OSAP) and the TRCA & CVC document:

- HDFs are non-permanently flowing drainage features that may not have defined bed or banks; they are first-order and zero-order intermittent and ephemeral channels, swales and connected headwater wetlands, but do not include rills or furrows.
- Features within a valley are typically not considered HDFs.
- A HDF has a catchment of at least 2.5 ha in size.

In order to identify possible HDFs, a drainage network for the Elfrida study area was created using Arc Hydro in Esri's ArcMap 10.1. First, a Digital Elevation Model (DEM) was created from elevation contours provided by the City of Hamilton using the Topo to Raster tool in the 3D Analyst extension. The resulting DEM had a resolution of 10 m x 10 m. The DEM was then processed in Arc Hydro to correct potential processing problems. Flow direction and flow accumulation rasters were then created and the stream network was defined such that any streams with a catchment of 2.5 ha would be accounted for. After the stream network was defined, the streams were segmented and the catchments delineated. The final stream raster and catchment raster were converted to vector feature classes using the Spatial Analyst extension, and the stream order was then classified using the Spatial Analyst extension. Stream order classification is illustrated in **Figure 3.18**.

Stream order is a measure of the relative size of watercourses. The smallest, headwater tributaries are referred to as zero-order streams according to OSAP (yellow on **Figure 3.18)**. Zero-order streams do not have tributaries. Where two zero-order streams converge, they form a first-order stream (orange on **Figure 3.18**). Similarly, where two first-order streams converge, they form a second-order stream (green on **Figure 3.18**). If, for example, a zero-order stream converges with a first-order stream, the latter remains a first-order stream. It is not until one stream combines with another stream of the same order that the resulting stream increases by an order of magnitude. Field maps were prepared for Aquafor Beech biologists by overlaying the stream and catchment layers on aerial images.

HDF sampling locations were chosen based on road crossings where possible. However, due to the size of the study area, road crossings were not applicable to all HDFs. In these instances, a new sampling location was selected in a location where, per the TRCA & CVC Guidelines; vegetation, flow, or other habitat conditions change significantly and could result in a different stream classification.

A Standard Survey Type was applied, according to the recommendations in the Guidelines. This requires the use of the Ontario Stream Assessment Protocol (OSAP) to assess HDFs. The following modules were used:

- Section 4: Module 10 (Assessing Headwater Drainage Features); and
- Section 3: Module 1 (Fish Community Sampling Using Electrofishing Techniques.

Per the TRCA & CVC Guidelines, the OSAP Headwater module was completed three (3) times at each sampling location to assess the HDFs throughout the year:

<u>Site Visit #1:</u>

- Conducted from March-April, during the spring melt (frost-free conditions); and
- ArcHydro segments were confirmed in the field.

<u>Site Visit #2</u>:

- Conducted in April-May, when high melt flows have ceased;
- This visit ideally occurs before leaf-out, so that features can be easily observed; and
- Fish community sampling was conducted using the Ontario Stream Assessment Protocol (OSAP).

<u>Site Visit #3:</u>

- Conducted in July-August; and
- The purpose is to confirm hydrology, fish presence, and groundwater indicators.

Using TRCA & CVC Guidelines, the results of the HDF assessments were integrated with aquatic/terrestrial habitat observations, amphibian surveys, hydrology, and species at risk data. Due to the dynamic nature of these features, an extensive photo database was compiled to ensure proper classification of these watercourses (see **Appendix B**).

Once field surveys are complete, the HDFs are assessed in four (4) steps, based on criteria outlined in the Guidelines, to classify each HDF:

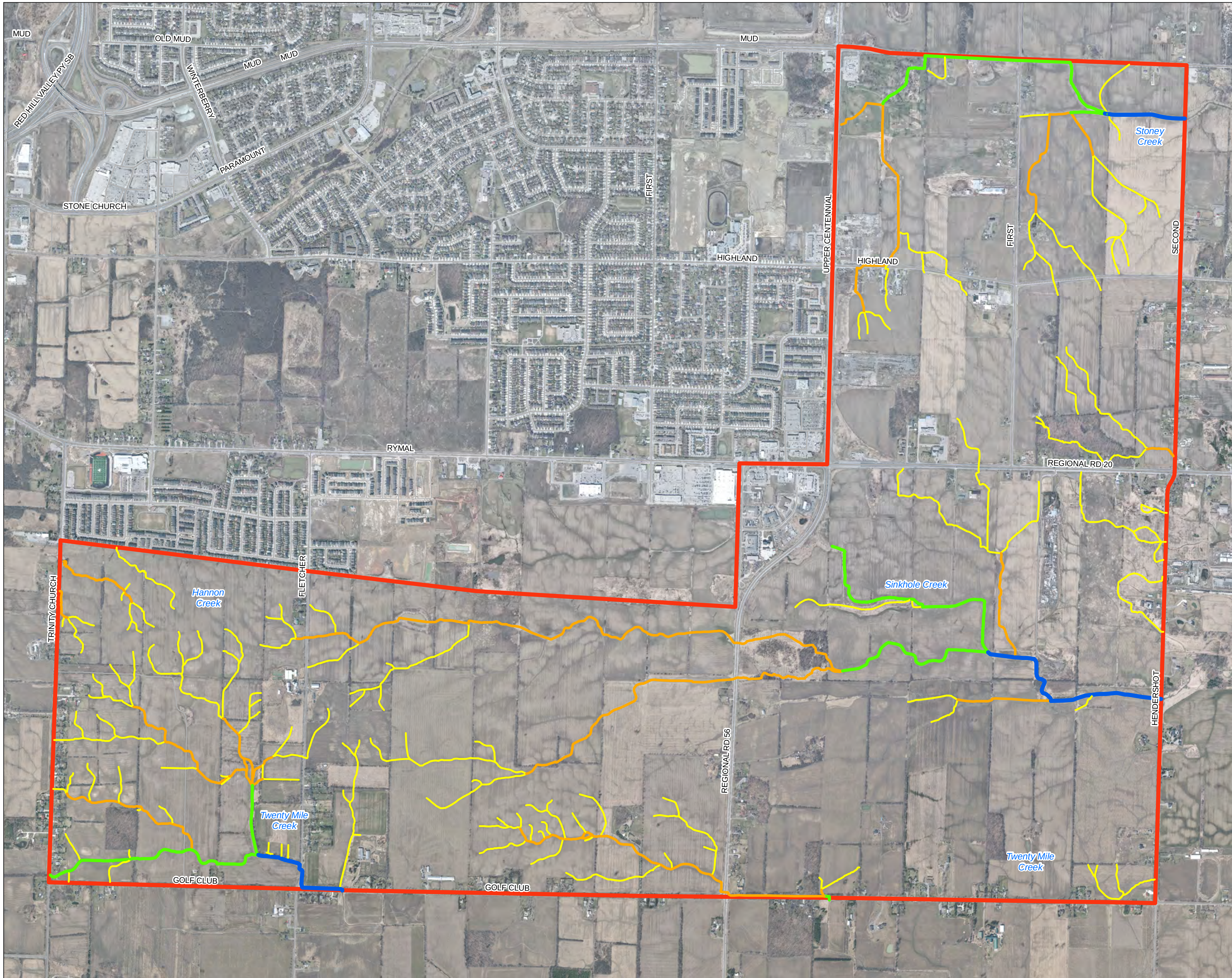
Step 1: Hydrology Classification: Flow conditions are classified into hydrology types

Step 2: Riparian Classification: The feature is classified with regard to riparian conditions

Step 3: Fish and Fish Habitat Classification: Fish and fish habitat is classified based on the presence of fish

Step 4: Terrestrial Habitat Classification: Features are classified based on the presence of breeding amphibians and wetlands

Finally, the results of Steps 1-4 are summarized and used in the Flow Chart within the TRCA & CVC Guidelines to assign a Management Recommendation (**Figure 3.19**).



Elfrida Subwatershed Study

Legend

Study Area

Stream Order

- 0
- 1
- 2
- 3

Figure 3.18

Stream Order Classification

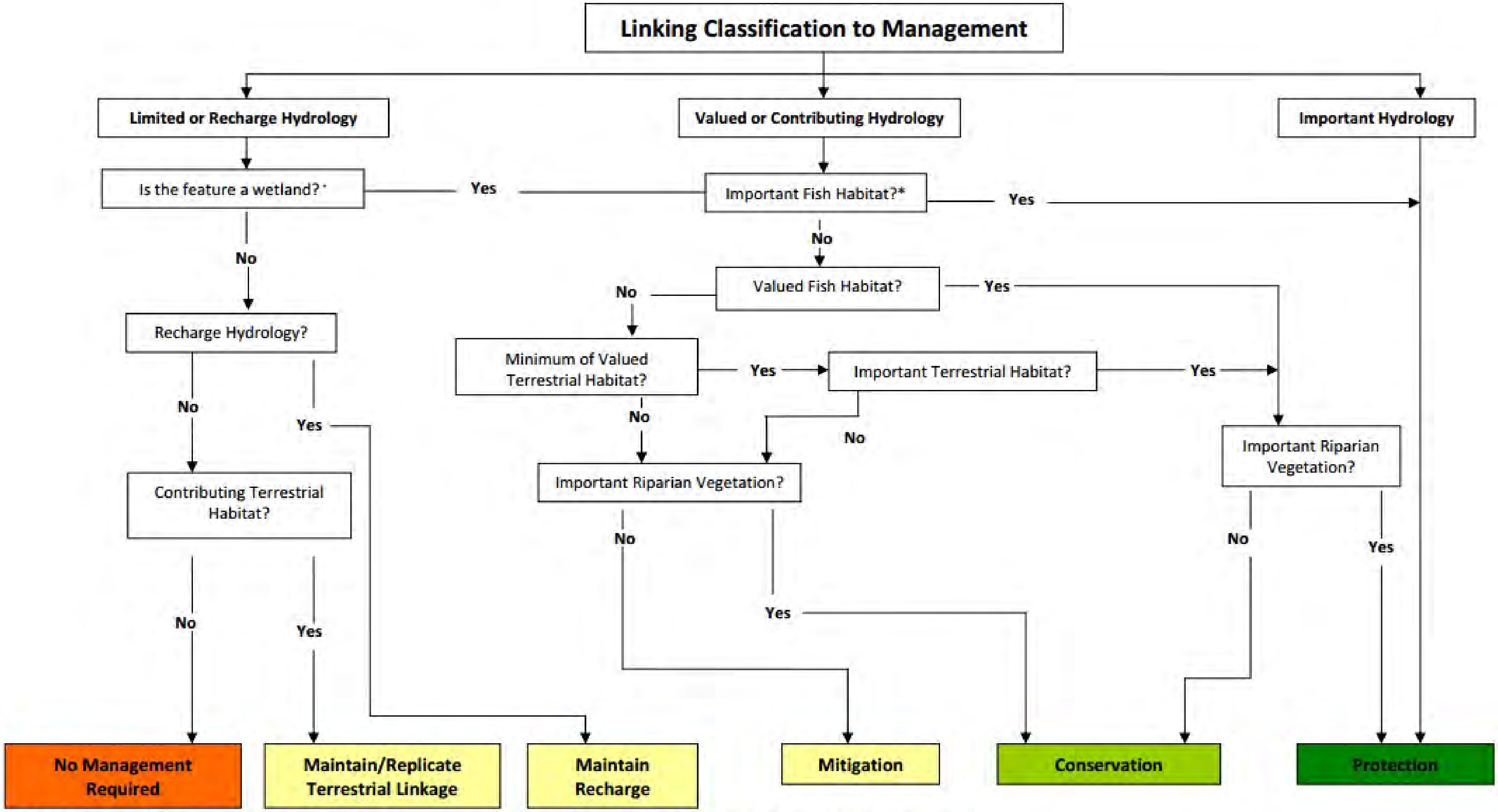
Date: February 2017
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited



*Other Conservation Authority policies or other legislation with respect to wetlands, watercourses and/or species at risk need to be assessed in the context of this key.
+Note that headwater wetlands are considered to be HDFs in the context of this guideline.

Figure 3.19: Headwater Drainage Feature Management Recommendations (CVC & TRCA 2014)

3.2.1.3 HDF Classifications and Management Recommendations

All OSAP field sheets and detailed criteria of the 4-Step Classification are located in **Appendix B**. Photographs of each HDF taken during the three site visits are also located in **Appendix B**.

Table 3.5 to **Table 3.8** below summarizes the results of the 4 Step Classification process for each subwatershed in the study area, as well as the assigned Management Recommendation. The Management Recommendations are based on the classification process outlined in **Figure 3.19**. According to the Guidelines, in the event that a lower level of protection is identified for a segment downstream of a segment with a higher level of protection, the more conservative approach shall be adopted for both segments and the downstream segment should be reclassified to match the upstream segment.

Table 3.5: HDF Classification: Stoney Creek

Drainage Feature Segment	STEP 1	STEP 2	STEP 3	STEP 4	Management Recommendation
	Hydrology	Riparian	Fish Habitat	Terrestrial Habitat	
ST1-H1 D/S	Valued or Contributing	Limited Functions	Contributing Functions	Limited Functions	**Mitigation**
ST2-H2 U/S ST2-H2 D/S ST2-H2 FEATURE 2	Valued or Contributing Valued or Contributing Valued or Contributing	Limited Functions Limited Functions Limited Functions	Contributing Functions Contributing Functions Contributing Functions	Limited Functions Limited Functions Limited Functions	**Mitigation** **Mitigation** **Mitigation**
ST1 H2B U/S ST1 H2B D/S	Valued or Contributing Valued or Contributing	Limited Functions Important Functions	Contributing Functions Contributing Functions	Limited Functions Limited Functions	**Mitigation** **Conservation**
ST1-H2C (U/S) ST1-H2C (D/S)	Limited or Recharge Valued or Contributing	Limited Functions Important Functions	Contributing Functions Contributing Functions	Limited Functions Important Functions	**No Management Required** **Conservation**
ST1-H2 (DS) (U/S)	Important	Important Functions	Valued Functions	Important Functions	**Protection**
ST1-H2 (US) (U/S) ST1-H2 (US) (D/S)	Valued or Contributing Important	Contributing Functions Important Functions	Contributing Functions Contributing Functions	Limited Functions Important Functions	**Conservation** **Protection**

Table 3.6: HDF Classification: Hannon Creek

Drainage Feature Segment	STEP 1	STEP 2	STEP 3	STEP 4	Management Recommendation
	Hydrology	Riparian	Fish Habitat	Terrestrial Habitat	
HC-H1 (U/S) HC-H1 (D/S)	Valued or Contributing Valued or Contributing	Limited Functions Valued Functions	Contributing Functions Contributing Functions	Limited Functions Limited Functions	**Mitigation** **Mitigation**
HC-H2A (U/S) HC-H2A (D/S) HC-H2A FEATURE 2	Valued or Contributing Valued or Contributing Valued or Contributing	Limited Functions Limited Functions Limited Functions	Contributing Functions Contributing Functions Contributing Functions	Limited Functions Limited Functions Limited Functions	**Mitigation** **Mitigation** **Mitigation**
HC-H2 (U/S) HC-H2 (D/S)	Valued or Contributing Valued or Contributing	Limited Functions Limited Functions	Contributing Functions Contributing Functions	Limited Functions Limited Functions	**Mitigation** **Mitigation**
HC-H2 (sink) (U/S)	Valued or Contributing	Important	Contributing Functions	Limited Functions	**Conservation**
HC-H3 (US) (U/S) HC-H3 (US) (D/S)	Limited or Recharge Valued or Contributing	Limited Functions Valued Functions	Contributing Functions Contributing Functions	Limited Functions Limited Functions	**Mitigation** **Mitigation**
HC-H3 (U/S)	Valued or Contributing	Valued Functions	Contributing Functions	Limited Functions	**Mitigation**

Table 3.7: HDF Classification: Twenty Mile Creek

Drainage Feature Segment	STEP 1 Hydrology	STEP 2 Riparian	STEP 3 Fish Habitat	STEP 4 Terrestrial Habitat	Management Recommendation
TM2-H4 (D/S)	Valued or Contributing	Limited Functions	Contributing Functions	Limited Functions	**Mitigation**
TM2-H2 (U/S)	Valued or Contributing	Important Functions	Contributing Functions	Valued Functions	**Protection**
TM2-H1E (U/S) TM2-H1E (D/S) TM2-H1E Feature 2	Valued or Contributing Valued or Contributing Limited or Recharge	Important Functions Limited Functions Limited Functions	Contributing Functions Contributing Functions Contributing Functions	Important Functions Limited Functions Limited Functions	**Protection** **Protection** **No Management Required**
TM2-H1B (U/S) TM2-H1B (D/S) TM2-H1B Feature 2	Valued or Contributing Valued or Contributing Valued or Contributing	Limited Functions Limited Functions Important Functions	Contributing Functions Contributing Functions Contributing Functions	Important Functions Important Functions Important Functions	**Protection** **Protection** **Protection**
TM1-H7C (U/S) TM1-H7C (D/S) TM1-H7C FEATURE 1	Valued or Contributing Valued or Contributing Limited or Recharge	Important Functions Limited Functions Limited Functions	Contributing Functions Contributing Functions Contributing Functions	Important Functions Limited Functions Limited Functions	**Protection** **Protection** **No Management Required**
TM1-H7 (U/S) TM1-H7 (D/S)	Valued or Contributing Valued or Contributing	Limited Functions Limited Functions	Contributing Functions Contributing Functions	Limited Functions Limited Functions	**Protection** **Protection**
TM1-H8 (U/S) TM1-H8 (D/S)	Valued or Contributing Valued or Contributing	Limited Functions Limited Functions	Contributing Functions Contributing Functions	Limited Functions Limited Functions	**No access** **Mitigation**
TM1-H6 (U/S) TM1-H6 (D/S) TM1-H6 FEATURE 2 TM1-H6 FEATURE 3	Valued or Contributing Valued or Contributing Valued or Contributing Valued or Contributing	Limited Functions Limited Functions Limited Functions Limited Functions	Contributing Functions Contributing Functions Contributing Functions Contributing Functions	Limited Functions Limited Functions Limited Functions Limited Functions	**Protection** **Protection** **Mitigation** **Mitigation**
TM1-H5 (U/S) TM1-H5 (D/S)	Limited or Recharge Valued or Contributing	Limited Functions Limited Functions	Contributing Functions Contributing Functions	Limited Functions Limited Functions	**No Management Required** **Mitigation**
TM1-H4 (U/S) TM1-H4 (D/S)	Valued or Contributing Valued or Contributing	Limited Functions Limited Functions	Contributing Functions Contributing Functions	Limited Functions Limited Functions	**Mitigation** **Mitigation**
TM1-H3 (U/S) TM1-H3 FEATURE 2 TM1-H3 FEATURE 3	Valued or Contributing Valued or Contributing Valued or Contributing	Limited Functions Limited Functions Limited Functions	Contributing Functions Contributing Functions Contributing Functions	Limited Functions Limited Functions Limited Functions	**Mitigation** **Mitigation** **Mitigation**
TM1-H2 (U/S)	Limited or Recharge	Limited Functions	Contributing Functions	Limited Functions	**No Management Required**

Drainage Feature Segment	STEP 1	STEP 2	STEP 3	STEP 4	Management Recommendation
	Hydrology	Riparian	Fish Habitat	Terrestrial Habitat	
TM1-H2 (D/S)	Limited or Recharge	Limited Functions	Contributing Functions	Limited Functions	**No Management Required**
TM1-H1 (U/S)	Valued or Contributing	Valued Functions	Contributing Functions	Limited Functions	**Mitigation**
TM3-H2A (U/S) TM3-H2A (D/S)	Valued or Contributing Valued or Contributing	Limited Functions Limited Functions	Contributing Functions Contributing Functions	Limited Functions Limited Functions	**Mitigation** **Mitigation**
TM3-H2A FEATURE 2 TM3-H2A FEATURE 3	Valued or Contributing Valued or Contributing	Limited Functions Limited Functions	Contributing Functions Contributing Functions	Limited Functions Limited Functions	**Mitigation** **Mitigation**
TM3-H3 (U/S) TM3-H3 (D/S) TM3-H3 FEATURE 2	Valued or Contributing Valued or Contributing Limited or Recharge	Limited Functions Limited Functions Limited Functions	Contributing Functions Contributing Functions Contributing Functions	Limited Functions Limited Functions Limited Functions	**Mitigation** **Mitigation** **No Management Required**
TM3- H1/H2 (U/S)	Valued or Contributing	Limited Functions	Contributing Functions	Limited Functions	**Mitigation**
TM4-H3-H5 (U/S)	Limited or Recharge	Limited Functions	Contributing Functions	Limited Functions	**No Management Required**

Table 3.8: HDF Classification: Sinkhole Creek

Drainage Feature Segment	STEP 1	STEP 2	STEP 3	STEP 4	Management Recommendation
	Hydrology	Riparian	Fish Habitat	Terrestrial Habitat	
SI3-H4 (U/S) SI3-H4 (D/S)	Valued or Contributing Valued or Contributing	Limited Functions Limited Functions	Contributing Functions Contributing Functions	Limited Functions Limited Functions	**Mitigation** **Mitigation**
SI3-H2 (U/S) SI3-H2 (D/S) SI3-H2 FEATURE 2	Limited or Recharge Limited or Recharge Limited or Recharge	Limited Functions Limited Functions Valued Functions	Contributing Functions Contributing Functions Contributing Functions	Limited Functions Limited Functions Limited Functions	**No Management Required** **No Management Required** **No Management Required**
SI3- H1A (U/S) SI3- H1A (D/S) SI3-H1A FEATURE 2	Limited or Recharge Valued or Contributing Valued or Contributing	Limited Functions Limited Functions Limited Functions	Contributing Functions Contributing Functions Contributing Functions	Limited Functions Limited Functions Limited Functions	**No Management Required** **Mitigation** **Mitigation**
SI3-H1 (U/S) SI3-H1 FEATURE 2	Valued or Contributing Valued or Contributing	Important Functions Important Functions	Contributing Functions Contributing Functions	Valued Functions Valued Functions	**Protection** **Protection**
SI4-H1 (U/S) SI4-H1 (D/S)	Valued or Contributing Valued or Contributing	Limited Functions Limited Functions	Contributing Functions Contributing Functions	Limited Functions Limited Functions	**Mitigation** **Mitigation**
SI4-H1 FEATURE 2	Valued or Contributing	Limited Functions	Contributing Functions	Limited Functions	**Mitigation**

Drainage Feature Segment	STEP 1	STEP 2	STEP 3	STEP 4	Management Recommendation
	Hydrology	Riparian	Fish Habitat	Terrestrial Habitat	
SI2-H1 (U/S)	Limited or Recharge	Limited Functions	Contributing Functions	Limited Functions	**No Management Required**
SI2-H1 (D/S)	Important	Important Functions	Contributing Functions	Important Functions	**Protection**
SI1-H3 (U/S)	Valued or Contributing	Contributing Functions	Contributing Functions	Limited Functions	**Mitigation**
SI1-H3 (D/S)	Valued or Contributing	Limited Functions	Contributing Functions	Limited Functions	**Mitigation**
SI1-H2 (U/S)	Limited or Recharge	Limited Functions	Contributing Functions	Limited Functions	**No Management Required**
SI1-H2 (D/S)	Valued or Contributing	Limited Functions	Contributing Functions	Limited Functions	**Mitigation**
S15-H1 (U/S)	Limited or Recharge	Limited Functions	Contributing Functions	Limited Functions	**No Management Required**
S15-H1 FEATURE 2	Limited or Recharge	Limited Functions	Contributing Functions	Limited Functions	**No Management Required**
S15-H1 FEATURE 3	Limited or Recharge	Limited Functions	Contributing Functions	Limited Functions	**No Management Required**
SI5-H2 (1) (U/S)	Limited or Recharge	Limited Functions	Contributing Functions	Limited Functions	**No Management Required**
SI5-H2 (1) (D/S)	Valued or Contributing	Contributing Functions	Contributing Functions	Limited Functions	**Mitigation**
SI5-H2 (2) (U/S)	Limited or Recharge	Limited Functions	Contributing Functions	Limited Functions	**No Management Required**
SI5-H2 (2) (D/S)	Valued or Contributing	Contributing Functions	Contributing Functions	Limited Functions	**Mitigation**
SI5-H2 (3) (U/S)	Valued or Contributing	Valued Functions	Contributing Functions	Limited Functions	**Mitigation**
SI6-H1 (US) (D/S)	Valued or Contributing	Limited Functions	Contributing Functions	Limited Functions	**Mitigation**
SI6-H1 (DS) (U/S)	Valued or Contributing	Valued Functions	Contributing Functions	Limited Functions	**Mitigation**
SI7-H1A (U/S)	Valued or Contributing	Important Functions	Valued Functions	Important Functions	**Protection**
SI7-H1A (D/S)	Valued or Contributing	Important Functions	Valued Functions	Important Functions	**Protection**
S17-H1C (U/S)	Limited or Recharge	Limited Functions	Contributing Functions	Limited Functions	**No Management Required**
S17-H1C (D/S)	Limited or Recharge	Limited Functions	Contributing Functions	Limited Functions	**No access**
SI7-H1 (U/S)	Valued or Contributing	Limited Functions	Contributing Functions	Limited Functions	**Protection**

3.2.1.4 Discussion of Results

Figure 3.20 displays the Management Recommendations for all HDFs in the study area. Definitions of Management Recommendations are listed in **Table 3.9**, below. As noted in the table, only one of three types of Mitigation HDF (i.e. Mitigation: Contributing Functions) is present in the study area.

HDFs on lands not accessed during this study will have to be assessed as part of a future study. It follows that HDFs downstream of HDFs not assessed as part of the SWS would need to be re-assessed, as upstream classifications affect downstream classifications.

Table 3.9: Definitions of Management Recommendations (TRCA & CVC, 2014)

HDF Management Recommendation	Definition
Protection (Important Functions)	• Protect and/or enhance the existing feature and its riparian zone corridor, and groundwater discharge or wetland in-situ; • Maintain hydroperiod; • Incorporate shallow groundwater and base flow protection techniques such as infiltration treatment; • Use natural channel design techniques or wetland design to restore and enhance existing habitat features, if necessary; realignment not generally permitted; and • Design and locate the stormwater management system (e.g. extended detention outfalls) are to be designed and located to avoid impacts (i.e. sediment, temperature) to the feature.
Conservation (Valued Functions)	• Maintain, relocate and/or enhance drainage feature and its riparian corridor; • If catchment drainage has been previously removed or will be removed due to diversion of stormwater flows, restore lost functions through enhanced lot level controls (i.e. restore original catchment using clean roof drainage), as feasible; • Maintain or replace on-site flows using mitigation measures and/or wetland creation, if necessary; • Maintain or replace external flows; • Use natural channel design techniques to maintain or enhance overall productivity of the reach; and • Drainage feature must connect to downstream.

HDF Management Recommendation	Definition
Mitigation (Contributing Functions)	• Replicate or enhance functions through enhanced lot level conveyance measures, such as well-vegetated swales (herbaceous, shrub and tree material) to mimic online wet vegetation pockets, or replicate through constructed wetland features connected to downstream; • Replicate on-site flow and outlet flow at the top end of the system to maintain feature functions with vegetated swales, bioswales, etc. If catchment drainage has been previously removed, due to diversion of stormwater flows, restore lost functions through enhanced lot level controls (i.e. restore original catchment using clean roof drainage); and • Replicate functions by lot level conveyance measures (e.g. vegetated swales) connected to the natural heritage system, as feasible and/or Low Impact Development (LID) stormwater options (refer to Conservation Authority Water Management Guidelines for details).
Mitigation (Recharge Functions) (note: HDF type not present in the study area)	• Maintain overall water balance by providing mitigation measures to infiltrate clean stormwater, unless the area qualifies as an Area of High Aquifer Vulnerability under the Oak Ridges Moraine Conservation Plan (ORMCP) or Significant Recharge Areas under the Source Water Protection Act. These areas will be subject to specific policies under their respective legislation. • Terrestrial features may need to be assessed separately through an Environmental Impact Study to determine whether there are other terrestrial functions associated with them.
Mitigation (Terrestrial Functions) (note: HDF type not present in the study area)	• Maintain the corridor between the other features through in-situ protection or if the other features require protection, replicate and enhance the corridor elsewhere • If the feature is wider than 20 m, it may need to be assessed separately through an Environmental Impact Study to determine whether there are other terrestrial functions associated with it.

HDF Management Recommendation	Definition
No Management Required (Limited Functions)	• The feature that was identified during desktop pre-screening has been field verified to confirm that no feature and/or functions associated with HDFs are present on the ground and/or there is no connection downstream. These features are generally characterized by lack of flow, evidence of cultivation, furrowing, the presence of a seasonal crop, and lack of natural vegetation. No management recommendations required.

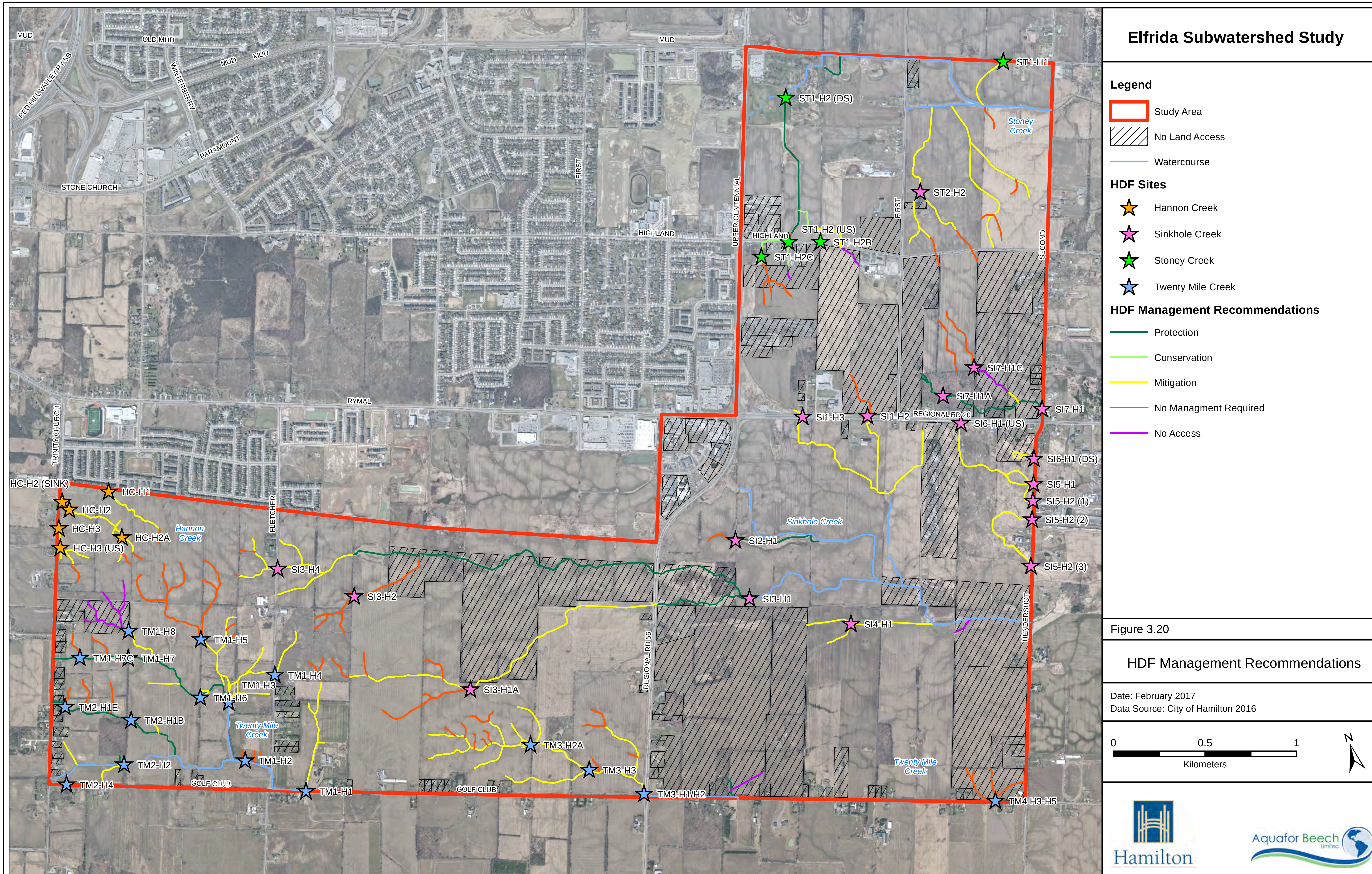


Figure 3.20

HDF Management Recommendations

Date: February 2017
Data Source: City of Hamilton 2016

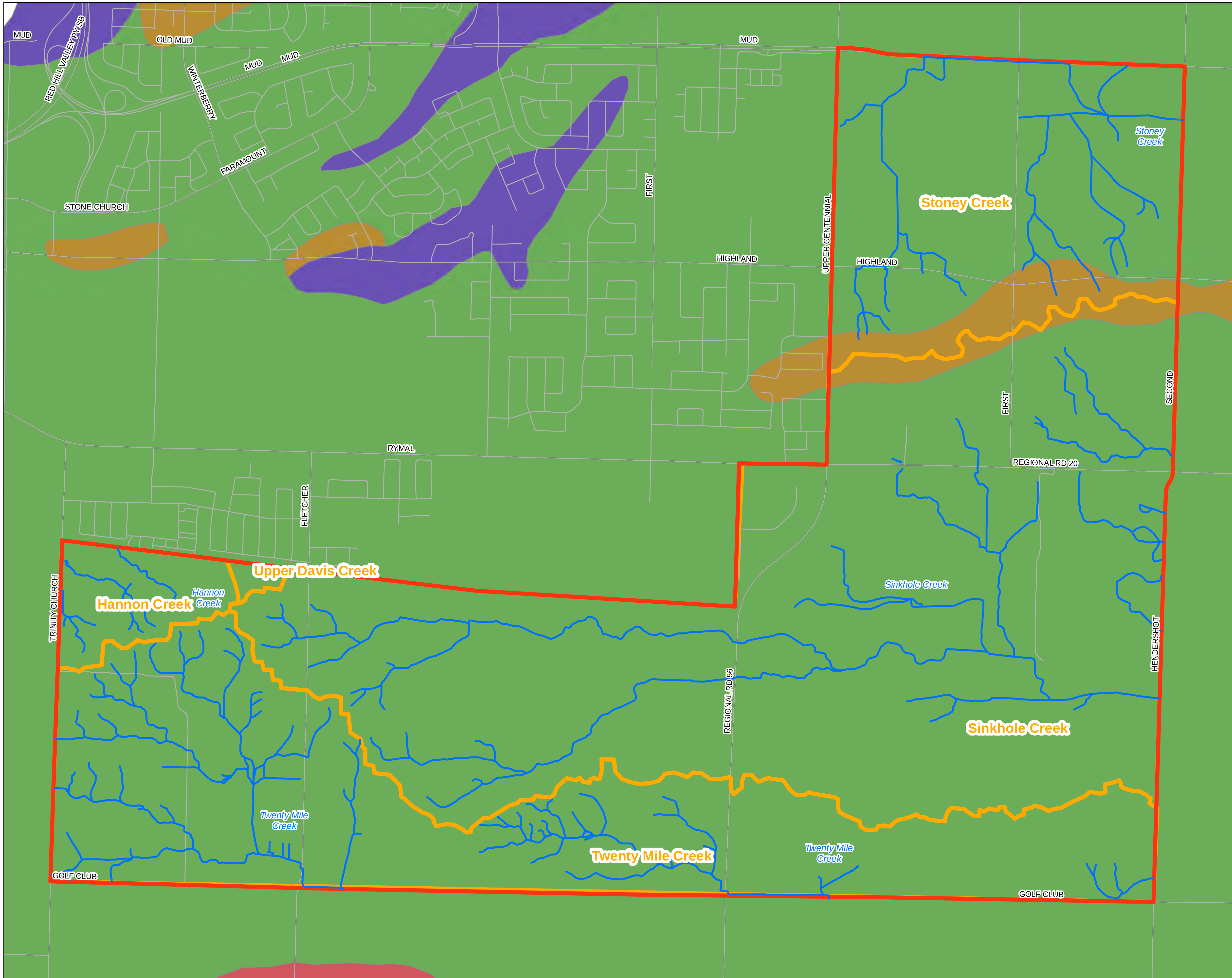
3.2.2 Fluvial Geomorphologic Resources

Fluvial geomorphological resources—the drainage network and channel landforms that make up the watershed—develop over the long-term as the integrated product of hydrological and biological stream processes interacting on the geological template of the landscape. As such, the characteristics of fluvial channels within the Elfrida study area are first considered with respect to the geological setting, and then the channels are described in terms of the historic changes and existing conditions. Field conditions in 2016 have been documented to provide recommendations for the geomorphic constraints/limitations to development, erosion potential, and restoration opportunities associated with existing and future land use developments.

3.2.2.1 Geologic Setting

As part of the more extensive Haldimand Clay Plain as named by Chapman and Putnam (1984), the study area geology is dominated by a fine-grained overburden covering karstic limestone bedrock (**Figure 3.21**). Situated 2–6 km south of the Niagara Escarpment, the topographic high-point of the Elfrida study area contributes surface drainage to five sub-watersheds. The three largest sub-watersheds drain to Twenty Mile Creek, Sinkhole Creek, and Stoney Creek. While the underlying limestone geology of the escarpment contributes to hydrological interactions between the surface water and underground karst features (e.g., sinkholes and springs), the overlying topography above the escarpment is of relatively low-relief. As such, drainage channels in the study area are typically low-energy with channels slopes in range of 0.001 to 0.003. The local topography is shaped by a relatively flat veneer of glacial silt and clay deposits 2 to 10 m thick (avg. 6–7 m; see Hydrogeology sections), with a gently sloping topographic ridge referred to as the Niagara Moraine dividing the Lake Ontario drainage flowing north (Upper Davis, Hannon, Stoney) from the Twenty Mile Creek drainage flowing south and east before draining to the lake (Twenty Mile, Sinkhole). The predominance of low-energy headwater drainage features within the study area limits the significance of fluvial geomorphologic resources within the study area due to ephemeral flow regimes (i.e., small drainage areas) and the dominance of vegetation within the channels and swales. Even the highest order channels (3rd order) are geomorphologically undeveloped due to historical modifications and the lack of perennial flow. Still, the hydrological and ecological resources of many of the drainage features are significant as described in other sections of the report.

Elfrida Subwatershed Study



Legend

- Study Area
- Subwatershed Boundary
- Watercourse
- Clayey Silt-Clay Till
- Dolostone (Limestone, Chert, And Shale)
- Glaciolacustrine Clay And Silt
- Glaciolacustrine Silt

Figure 3.21

Surficial Geology

Date: February 2017
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

3.2.2.2 Drainage Network and Landuse

The headwater drainage network has been highly modified within the study area including up to 2nd and 3rd order stream channels (**Figure 3.18**). The zero order and 1st order drainage features are typically agricultural swales and shallow ditches with perennially or seasonally vegetated boundaries. The 2nd and 3rd order drainage features are typically broad swales lined with marsh vegetation, becoming increasingly modified downstream as channelized ditches within agricultural fields and/or along roadsides. For example, the downstream reach of Sinkhole Creek can be considered a 3rd order stream within the study area (**Figure 3.18**), but the channel has been historically straightened as an agricultural ditch upstream of Hendershot Road. These modified headwater conditions, with predominantly ephemeral and intermittent flow regimes (**Section 3.2.1**), are important considerations in the assessment of fluvial geomorphic channel processes. Most notably, the channel forms are artificial and the channel boundaries are dominated by vegetation and fine alluvial material (silt, clay, and organics; or "silt loam"). While there are essentially no natural channels within the study area, these modified headwater conditions are common in southern Ontario due to historic and existing agricultural land use, particularly in the context of the low-relief topography and fine-grained surface materials (Phillips and Desloges, 2015).

3.2.2.3 Longitudinal Stream Profiles

As an important initial step in assessing fluvial geomorphologic resources, a desktop analysis of the longitudinal stream profiles and stream energy was completed based on available topographic mapping (contours, DEM) and stream power mapping methods outlined by Phillips and Desloges (2014). For each of the main tributaries in the study area, the longitudinal profiles presented in **Figure 3.22** demonstrate the relative patterns of stream energy (i.e., channel slope) within and downstream of the study area. In turn, **Figure 3.23** presents mapping of specific stream power (W/m^2) as an index of erosion potential. Specific stream power (ω) is calculated the product of discharge (*Q*) and slope (*s*) per unit width (*w*) of channel ($\omega = \gamma Qs/w$; where γ is the specific weight of water). For this desktop analysis, the stream power index is based on regional-based empirical equations for 2-year discharge and bankfull width as presented by Phillips and Desloges (2014) and provides a reasonable first-order approximation of erosion potential.

Given the low-energy headwater features and low-relief topography of Elfrida, typical values of stream power less than 10 W/m^2 are expected, with some local reaches of higher stream power downstream of the study area, but generally less than 20 W/m^2. Still, the patterns of slope and stream power presented in **Figure 3.22** and **Figure 3.23** provide a basis to identify pre- and post-development erosion monitoring priorities, particularly downstream of the study area. Specifically, the downstream reaches of higher stream power (and increasing stream power) represent channels with a higher potential for erosion and fluvial adjustments with post-development hydrological changes. It is important to note that glacial landforms and tributaries entering deeper stream valleys commonly show inflection points in the stream profile, and therefore steeper reaches (with higher erosion potential) need to be identified downstream of developments (Phillips and Desloges, 2014; e.g., see TM1 and SI profiles in **Figure 3.22**).

Preliminary recommendations for monitoring locations are presented in here in the Phase 1 report, and more detailed erosion monitoring recommendations will be considered further in

Phases 2 and 3 of the study.

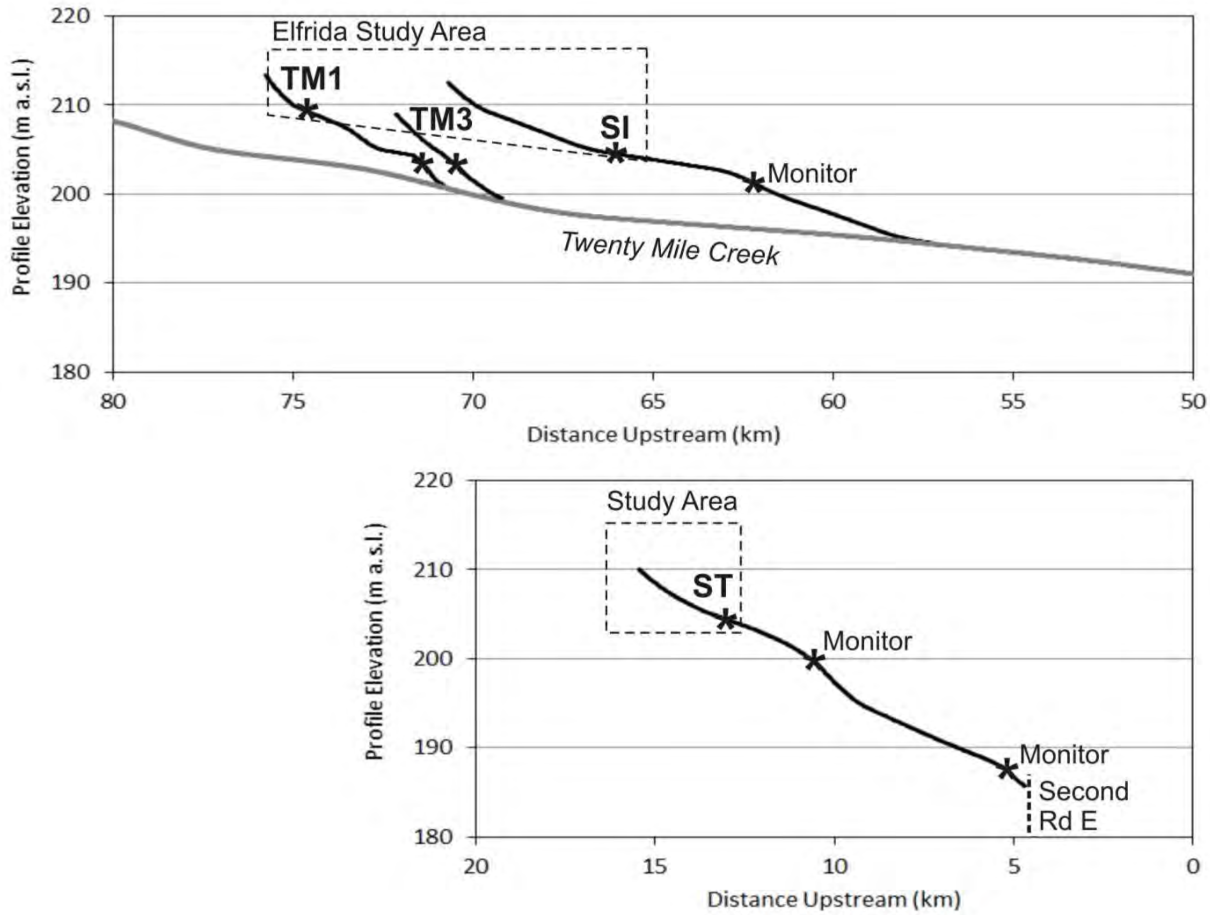


Figure 3.22: Longitudinal Stream Profiles

Longitudinal stream profiles of the Elfrida study area for each of the main tributaries: Twenty Mile Creek tributaries (TM1 and TM3); Sinkhole Creek (SI); and Stoney Creek (ST). Vertical exaggeration is about 250. Preliminary recommendations for post-development erosion monitoring locations (*) are presented based interpretation of stream profiles, stream power (**Figure 3.23**); and confirmed 2016 field conditions.

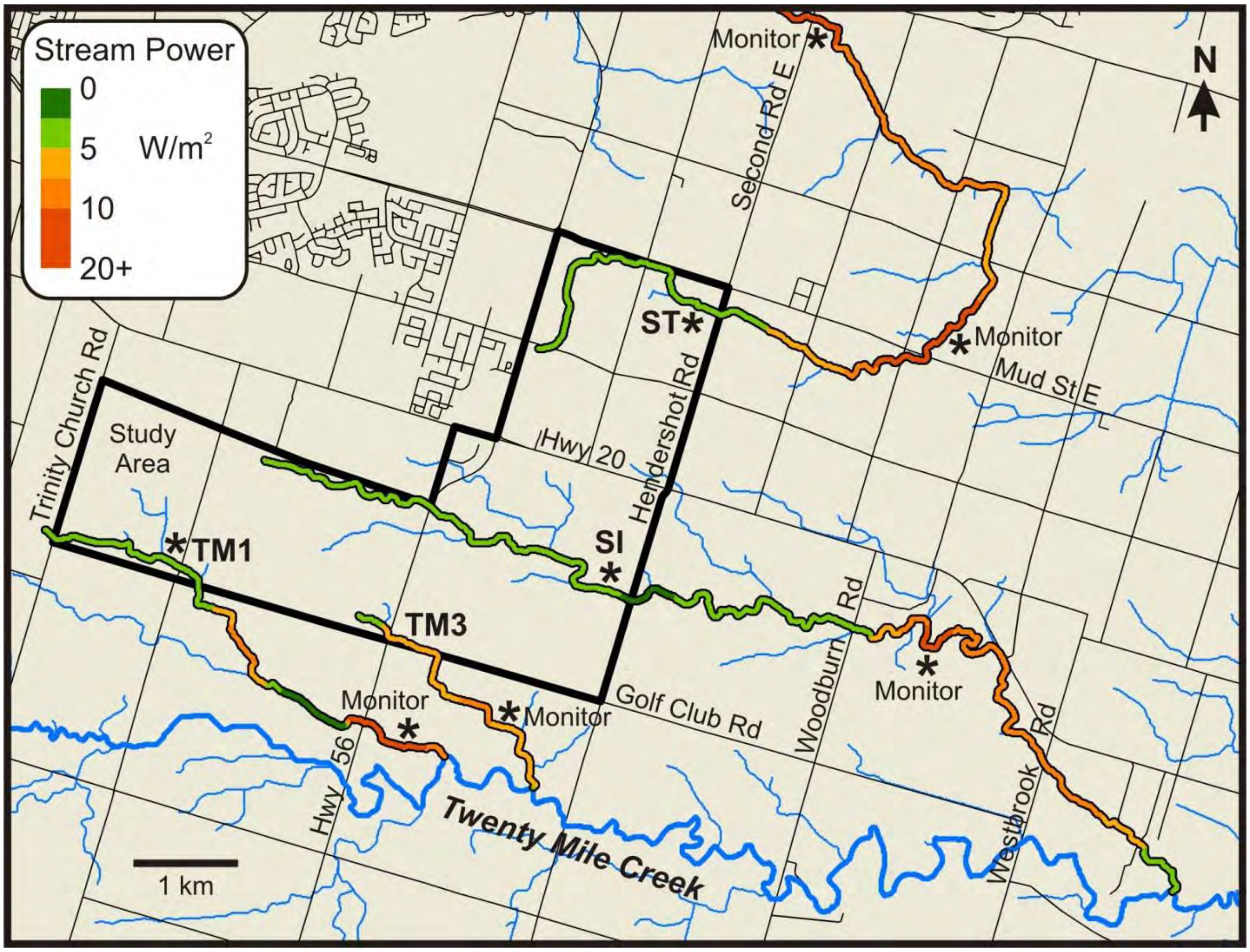


Figure 3.23: Stream Power Mapping

Specific stream power mapping (as per methods of Phillips and Desloges, 2014) of the Elfrida study area for each of the main tributaries: Twenty Mile Creek tributaries (TM1 and TM3); Sinkhole Creek (SI); and Stoney Creek (ST). Preliminary recommendations for post-development erosion monitoring locations (*) are presented based interpretation of stream profiles (**Figure 3.22**), stream power; and confirmed 2016 field conditions.

3.2.2.4 Reach Delineation and Field Characterization

Field reconnaissance in 2016 was completed to confirm existing channel conditions and delineate stream reaches for future watershed planning and watercourse management. In order to integrate the surface water components, the fluvial geomorphologic assessment was informed by the results of the HDF assessment described above in **Section 3.2.1**. The identification of HDFs within the study area was the basis upon which "watercourses" were defined for each drainage network (i.e., not HDFs). In addition to watercourses, the headwater drainage features classified for Conservation or Protection were also included as part of the fluvial geomorphic resource assessment and constraint/limitations mapping. Watercourse existing conditions are summarized in this section based on delineated stream reaches. HDF existing conditions are described in **Section 3.2.1**. Reach delineation is an approach whereby a watercourse is spatially grouped by channel characteristics and processes. Stream reaches are lengths of channel that display relative homogeneity with respect to the controlling and modifying influences of channel form. Reaches are typically defined by key factors, including hydrology, gradient, geology, valley setting, sinuosity, and riparian vegetation. Given the modified headwater channel conditions within the Elfrida study area, stream reaches are primarily dictated by the drainage network hydrology (i.e., tributary confluences) and the reach conditions are largely shaped by historical channel alterations and the adjacent land uses.

Stream reaches assessed for the Elfrida subwatershed study are presented in **Figure 3.24**. For each drainage network, the headwater drainage features (zero and 1st order) are predominantly agricultural swales and the downstream watercourses (2nd and 3rd order) include both swales and channelized ditches. The swales and ditches that make-up each drainage network in the study area contain significant amounts of "in-channel" vegetation, and as such fluvial processes are expected to be dominantly "vegetation-controlled." In other words, flow velocities, erosion processes, and geomorphic adjustments are strongly controlled by the type and condition of vegetation. The in-channel vegetation within the study area watercourses varies somewhat between long/short grasses, reeds, and cattails typical of riverine meadow and marsh lands in the region (note higher channel roughness values applied to hydraulic modeling, **Section 3.2.3**). The influence of the in-channel and riparian vegetation on fluvial processes is expected to vary seasonally with higher vegetation density and hydraulic roughness during the summer months and reduced roughness effects in the winter and spring as the vegetation may be "flattened" or locally removed by high flows and cold winter conditions. Specific comments for each of the main subwatershed stream reaches are provided below with referenced locations in **Figure 3.24** and photos below.

- **Twenty Mile Creek** – three main tributaries documented as TM1, TM2, and TM3. Agricultural fields and isolated woodlots include a patchwork of ephemeral swales and channelized ditches in the upper reaches of TM1-R1 and TM2-R1 (**Photo 1**). Lower reaches are more consistently channelized as agricultural ditches (TM1-R2) and roadside ditches (TM1-R3 and TM3-R1) flanked by narrow hedgerows of riparian trees and shrubs in some sections (**Photos 2**, **3**, and **4**).

- **Sinkhole Creek** – three main tributaries documented as SI1, SI2, and SI3. For the upper reaches, agricultural swales and ditches (**Photo 5**) vary between cultivated and perennial vegetation with the degree of agricultural activity and history of channel modification within individual property lots (SI1-R1, SI2-R1, SI3-H2). Broad topographic depressions within tributary reach SI2-R1 sustain a widened stream corridor of marsh and meadow vegetation in some sections (**Photo 6**). The lower reach of SI1-R2 (3rd order) is also highly modified as a straightened agricultural ditch, aligned upstream between local hedgerows and downstream across a broad agricultural field (**Photo 7**).

- **Stoney Creek** – two main tributaries documented as ST1 and ST2. Upper reaches of ST1-H2 are straightened agricultural channels with marsh and cattail vegetation (**Photo 8**). The middle reaches of tributary ST1 have been channelized within an old golf course (**Photo 9**, ST1-R1, including ponds and side channels,) and as a ditch along the south side of Mud Street East (ST1-R2) (**Photo 10**). Under existing conditions, there is also drainage from the west side of Upper Centennial Road (Hwy 20) that enters a ditch on east side of the highway and flows north and then east along Mud Street East to join the main branch of Stoney Creek (roadside ditch of ST1-R2). For future development, this ditch drainage should be reconnected through a restored natural corridor (**Photo 11**, see restoration opportunities). The lower reaches of Stoney Creek are channelized ditches within agricultural fields (ST1-R4) (**Photo 12**), with some sections locally flanked by narrow hedgerows of riparian trees and shrubs (ST1-R3).

The existing conditions for the headwater drainage features of **Upper Davis Creek** and Hannon Creek are documented in **Section 3.2.1**.

Photo 1: Agricultural swale Reach TM2-R1

Photo 2: Agricultural ditch Reach TM1-R2

Photo 3: Roadside ditch Reach TM1-R3

Photo 4: Roadside ditch Reach TM3-R1

Photo 5: Agricultural swale Reach SI3-H1B

Photo 6: Swale marsh Reach SI2-R1

Photo 7: Agricultural ditch SI1-R2

Photo 8: Swale marsh ST1-H2

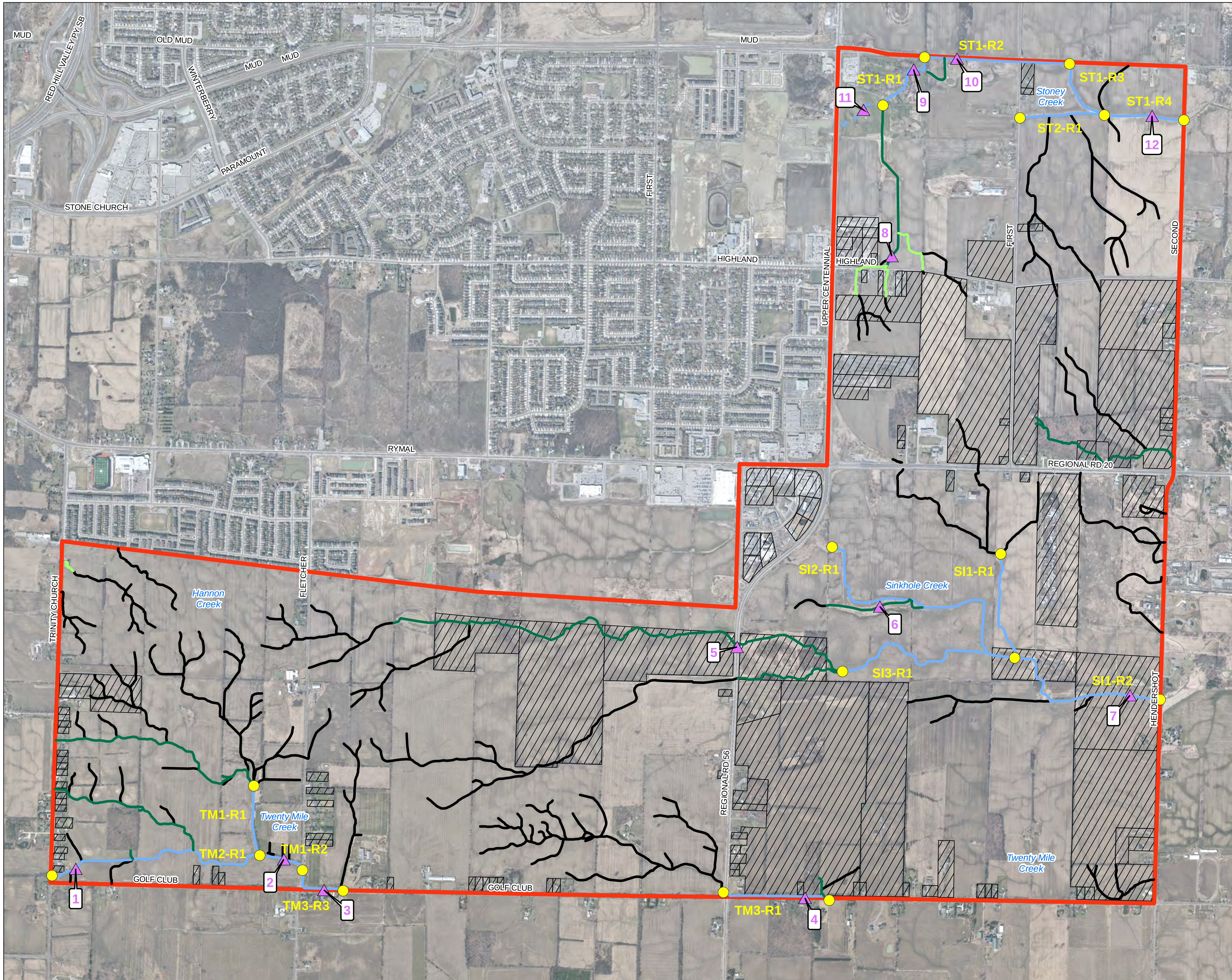
Photo 9: Golf course channel Reach ST1-R1

Photo 10: Roadside ditch Reach ST1-R2

Photo 11: Golf course channel, drainage connection restoration opportunity from Hwy 20 looking upstream to the west (right)

Photo 12: Agricultural ditch Reach ST1-R4

Elfrida Subwatershed Study



Legend

- Study Area
- No Land Access
- Watercourse
- Other HDFs

Sensitive HDFs

- Protection
- Conservation
- Reach Break
- Photograph Location (Number)

Figure: 3.24

Fluvial Geomorphic Reach Assessment

Date: February 2017
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

3.2.2.5 Geomorphic Limitations to Development

It is now recognized that sustainable long-term management strategies for watercourses should allow for natural fluvial processes to occur within an erodible corridor—a geomorphic hazard zone (Piégay *et al.,* 2005). Also proposed as 'Freedom Space', there are long-term ecological, economic, and social benefits to allowing rivers and streams enough space to adjust within a natural corridor (Biron *et al.,* 2014; Buffin-Bélanger *et al.,* 2015).

Geomorphic limitations for single-channel, perennial streams and rivers are typically evaluated as the corridor width of the "meander belt" plus a century-scale erosion allowance (TRCA, 2004), as well as stable slope allowances in confined valley settings. The degree to which a channel will meander—through fluvial processes of lateral migration and avulsion—depends upon the channel's hydrological flow regime and environment controls such as geology and vegetation. A meander belt can be a useful conceptual tool for planning around watercourses, but the concept has fundamental limitations for representing geomorphic erosion hazards around headwaters and low-order streams (e.g., 1st and 2nd order). In ephemeral and intermittent headwaters, natural fluvial processes are complicated by poorly defined channels and seasonally vegetated channel boundaries. While natural headwaters may wind back-and-forth to some degree, the processes of lateral channel movement are different from meandering processes in perennial streams and rivers. Still, headwater channels will naturally exhibit some degree of lateral expression within a geomorphically active corridor. For historically straightened channels, the ultimate lateral "migration" zone might be re-attained if given enough time to recover (i.e., natural channels are rarely straight).

Given the historic modifications and straightening of the headwater channels within the Elfrida study area, an empirical relationship was developed to evaluate corridor widths that will accommodate the natural geomorphic processes of each watercourse and significant headwater drainage feature. As the expected width of a meander belt does generally scale with stream size, drainage area (an index of discharge) provides a practical first-order empirical estimate for meander belt width (TRCA, 2004). Further, empirical relationships for larger perennial channels based on drainage area can provide a reasonable method for extrapolating meander belt widths to smaller headwater channels. To provide a local geographic dataset, empirical field data and meander belt widths were compiled for sites documented in the 1999 Twenty Mile Creek Geomorphology Study (Tinkler, 1999). The 1999 subwatershed study provides a fluvial geomorphic assessment of 31 field sites and includes estimates for the meander belt width. The drainage areas for these field sites range from 1 to 263 km^2.

For the current subwatershed study, the 1999 geomorphic data were evaluated to guide management decisions with respect to the geomorphic limitations within the Elfrida study area. Reassessment of the 1999 dataset included confirming and revising the meander belt width values and classifying each site as either a modified or a natural channel (i.e., in a relative sense) based on air photos and field observations. For this analysis, modified channels included channels and drainage features relocated and/or severely modified by historic and/or existing land uses. Compared to the 1999 dataset, meander belt values at some sites were increased where consideration of reach conditions upstream or downstream of site warranted a revised width (or possible report errors were found in some cases). Meander belt values were also decreased for some sites, again considering upstream and downstream conditions, as well as consideration of multiple nested scales of meandering—specifically large "paleo-meanders" often do not reflect modern-day hydrology and fluvial processes (Phillips and Robert 2007).

The results of the meander belt analysis are presented in **Figure 3.25**, providing empirical relationships for both the original 1999 dataset and the revised dataset for only the natural channels. As seen in **Figure 3.25** (right), a drainage area of 10 km^2 appears to be a reliable threshold between modified and natural channels, and this threshold is consistent with observations for southern Ontario presented by Phillips et al. (2010). Based on these results, the empirical relationship of $M_b = 30.2\ A_d^{0.333}$ is recommended to establish the geomorphic limitations within the Elfrida study area. Given the limitations of the meander belt concept applied to headwater features as discussed above and the City of Hamilton's policies for minimum watercourse buffers (**Section 3.3.9.1**), a consistent meander belt value of 30 m is recommended for all watercourse drainage areas less than 1 km^2 (and significant HDFs). The recommended geomorphic limitations for the Elfrida study area established by this analysis are mapped in **Figure 3.26**, with erosion corridor widths ***varying between 30 and 60 m*** (i.e., drainage areas of ~1 to 8 km^2). For mapping the meander belt of each reach in Figure 3.26, an additional 20% Factor of Safety allowance has been added to reflect analytical uncertainty (c.f., TRCA, 2004). Under future development conditions, these erodible corridors (i.e., meander belts) are to remain as low-lying floodplain areas adjacent to the watercourse and are not to include side-slopes associated with development regrading (i.e., side slopes do not count in the meander belt width).

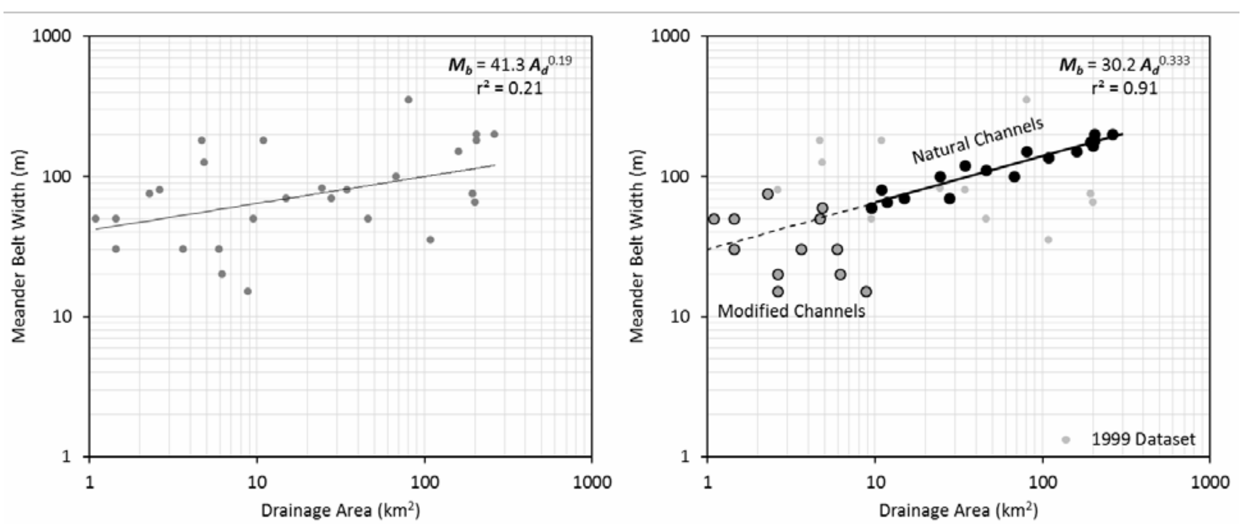
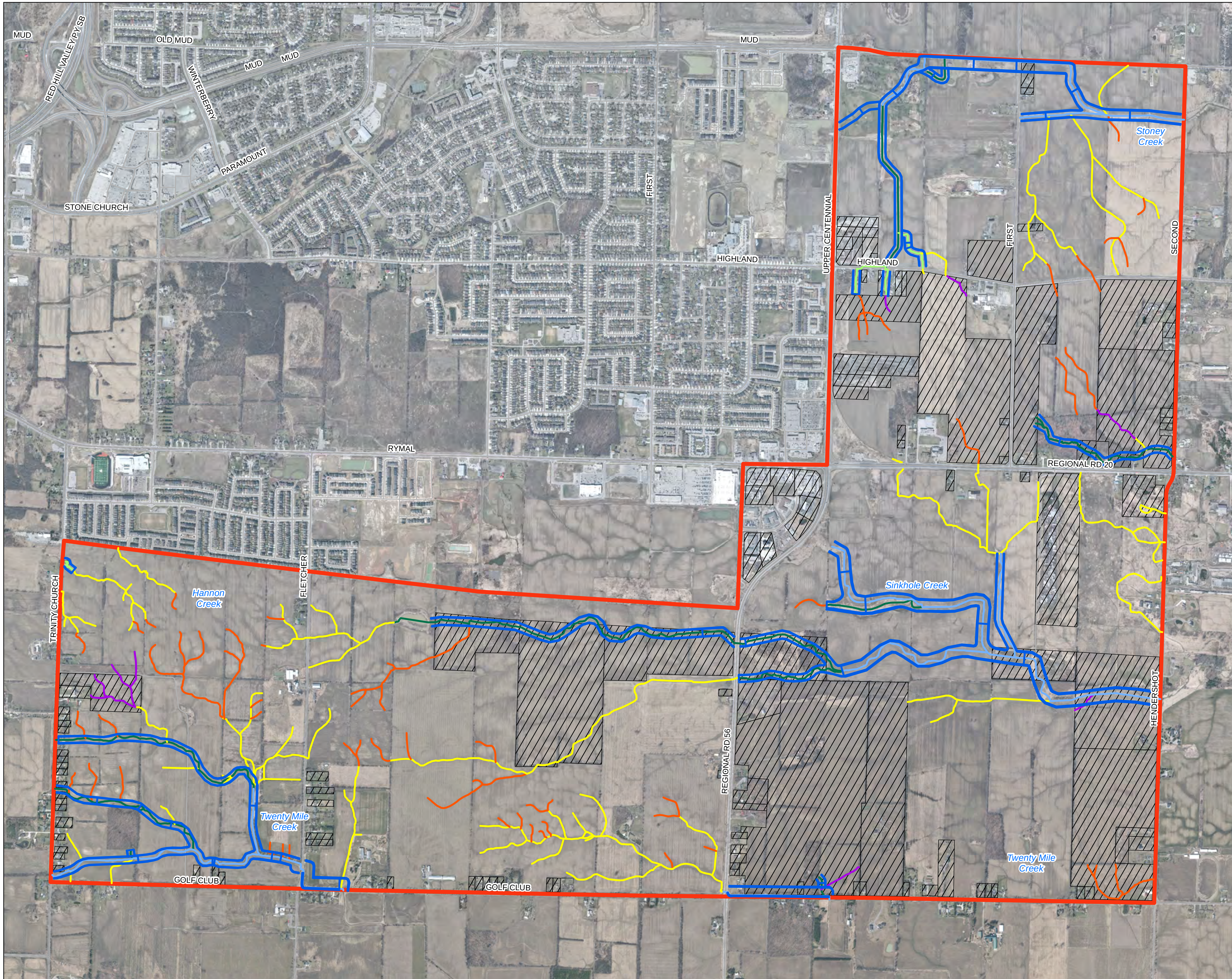


Figure 3.25: Meander Belt Analysis

Empirical relationships for watercourse meander belt width (M_b) based on drainage area index (A_d): (left) raw data from the 1999 geomorphology study (Tinkler, 1999); (right) revised data based on air photos, 2016 field observations, and review of meander belt estimates (natural and modified channels). Empirical meander belt equation $M_b = 30.2\ A_d^{0.333}$ is based on revised data for natural channels only (black circles). The dashed line is extrapolated down to A_d = 1 km^2 for modified headwater channels. A consistent meander belt value of 30 m is recommended for all drainage areas less than 1 km^2 (see discussion in text).



Elfrida Subwatershed Study

Legend

- Study Area
- No Land Access
- Watercourse
- Geomorphic Constraint (varies 33 to 66m)

HDF Management Recommendations

- Protection
- Conservation
- Mitigation
- No Managment Required
- No Access

Figure 3.26

Geomorphic Limitations

Date: November 2017
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

3.2.2.6 Assessment of Erosion Potential

Field assessments were completed in 2016 for the 3rd order tributary channels of Stoney, Sinkhole, and Twenty Mile creeks to characterize the basic geomorphological characteristics and to provide a basis to assess erosion potential in the drainage network. Respectively, the three main tributary reaches characterized were ST1-R4 (**Photo 12**), SI1-R2 (**Photo 7**), and TM1-R2 (**Photo 2**) as indicated in **Figure 3.24**. The key geometric field conditions for the channels within these reaches are outlined in **Table 3.10**. Due to the straightened and modified conditions of these channels as agricultural ditches, it is not surprising that the average channel dimensions tend to be relatively consistent with widths in the range of 2–3 m and depths in the range of 0.6–1.0 m. Channel slopes tend to be in the range of 1–2 m per kilometer (reach averages ~0.0015).

Table 3.10: Channel geometric field measurements[1] and characteristics for 3rd Order Reaches

Reach	Width (m)	Depth (m)	Area (m^2)	Est. Slope[2]	Bed	Banks
ST1-R4	2.5 ± 0.5	0.75 ± 0.1	1.9 ± 0.6	0.0014	Grass, reed, cattail Silt, clay, organics	Grass Cultivated fields
SI1-R2	2.5 ± 0.5	0.8 ± 0.2	2.0 ± 0.9	0.0010	Grass, reed, cattail Silt, clay, organics	Grass, herb Cultivated fields
TM1-R2	2.5 ± 0.5	0.9 ± 0.1	2.3 ± 0.7	0.0016	Grass, reed, cattail Silt, clay, organics	Grass, herb, trees Cultivated fields

[1]Values based on 3 rapid field measurements of channel dimensions
[2]Values estimated from topographic mapping data (DEM and contours)

As discussed in the above sections, the ephemeral headwater swales and modified channel conditions of the Elfrida study area are vegetation-dominated and geomorphologically undeveloped, and correspondingly no field evidence of excessive channel erosion was documented in 2016. Sedimentation (siltation), particularly in the vicinity of culverts, was observed to be the most significant sign of fluvial geomorphological adjustment within the study area. These observations are consistent with expectations for low-energy headwater channels with fine-grained surface geology, agricultural land uses, and undersized culverts (i.e., low-hydraulic capacity for snowmelt and seasonal flooding).

Established practices in tractive force analysis can be useful for evaluating erosion potential for some fluvial settings assuming idealized hydrological, hydraulic, and *gravel bed* conditions. Given the low erosion potential of the vegetation-dominated channels within the study area—and the complexity of predicting erosion thresholds in such conditions—there are significant technical limitations to using tractive force methods. In such cases, tabulated permissible velocities and/or shear stress provide a simplified estimate of erosion thresholds (e.g., Fischenich, 2001)—including for vegetated channel boundaries—but do not provide a robust scientific assessment of erosion potential.

One dimensional hydraulic calculations based on typical channel cross-sections for 3rd order stream reaches in the study area are presented in **Figure 3.27**. The typical bankfull channel geometrics used in the calculations include depths up to 1 m, widths up to 3 m, and average slopes of 0.0015. These results are first-order approximations for simplified thresholds that do not well represent fluvial erosion processes in fine-grained, vegetation-dominated channels.

As a simplified basis to evaluate erosion potential, both shear stress and velocity methods confirm that alluvial silt loam is easily transported (~2.5 N/m^2 and ~0.5 m/s thresholds respectively) and exposed sediments are likely transported under most storm and snowmelt events. Permissible values for vegetated-boundaries vary considerably over large ranges of shear stress and velocity (reflecting the complexity of the fluvial processes). The results in **Figure 3.27** suggest that typical values for channel shear stress and velocity do not generally exceed the permissible values (Fischenich, 2001), but may exceed the lowest permissible values for reeds (shear stress) and short grasses (velocity assuming low roughness values). The results are reasonable in the sense that they confirm that the channels and vegetation are generally stable, with a low probability of erosion under vegetated conditions, but exposed fine-grained silt loam materials can easily be transported during storm flow events. However, shear stress values are conservatively high given the seasonal influences on channel capacity with in-channel vegetation (i.e., reduced bankfull depths). The approximate bankfull discharge of these 3rd order stream channels (or ditches) from these calculations is in the range of 1 to 2 m^3/s based on channel depths of 0.6 to 1.0 m and roughness values of Manning's n = 0.030, 0.055, and 0.070. As a baseline average, bankfull discharge is approximately 1.5 m^3/s, and the probability of reed instability may start to increase above 0.9 m^3/s.

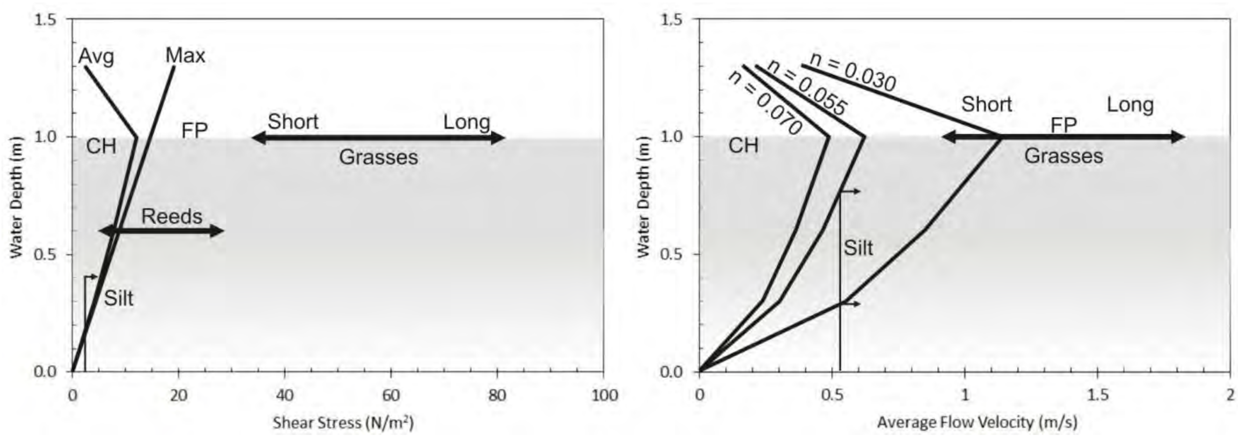


Figure 3.27: Simplified estimates of erosion thresholds for vegetation-dominated ditches

Simplified estimates of erosion thresholds for vegetation-dominated ditches in the Elfrida study area based on permissible shear stress (left) and velocity (right) from Fischenich (2001). One dimensional hydraulic calculations are based on typical channel depths up to 1 m (CH), channel widths up to 3 m, and average channel slopes of 0.0015 for the 3rd order stream reaches (FP = floodplain surface above 1 m). Hydraulic roughness for calculating average flow velocity (right) include both rough (n = 0.070), moderate (n = 0.055), and smooth (n = 0.030) values to reflect seasonal variations in vegetation conditions.

Because erosion thresholds are over-simplified for fine-grained, vegetation-dominated fluvial systems, tractive force methods do not provide a reliable method to evaluated erosion potential in

terms of a detail erosion exceedance analysis using continuous hydrologic and hydraulic modeling simulations (e.g., cumulative excess shear stress). As such, a generalized approach, consistent with the guidelines of the 2003 MOE Stormwater Management Planning and Design
Manual is recommended to set stormwater targets for instream erosion control for the Elfrida study area. However, it is recommended that pre-development and post-construction monitoring programs be established which include the 3rd order stream reaches within the study area, as well as reaches downstream of the study area (e.g., Howes and Phillips, 2016), particularly in areas with higher stream power and erosion potential (**Section 3.2.2.3**). The stormwater erosion control targets and more detailed erosion monitoring recommendations will be considered further in Phases 2 and 3 of the study.

3.2.2.7 Summary of Geomorphic Limitations and Restoration Opportunities

The fluvial geomorphologic resources of the study area have been assessed in terms of geologic setting; drainage network and land use; longitudinal stream profiles (stream power); reach delineation and field characterization; geomorphic limitations (to development); and erosion potential. The largely modified agricultural landscape, in the context of a low-relief and fine-grained surface geology, has led to the predominance of low-energy headwater drainage features within the study area. The ephemeral headwater swales and ditches of the Elfrida study area are vegetation-dominated and geomorphologically undeveloped, and as such:

- No locations within the study area (or immediately downstream) exhibited signs of excessive erosion in 2016, and therefore no existing erosion mitigation measures are required, but modified channels and particularly roadside ditches have been identified as important stream restoration opportunities within the study area. Localized issues of siltation may be addressed by increasing culvert sizes during future road upgrades.

The geomorphic limitations to development are recommended for watercourses and sensitive HDFs to accommodate natural fluvial processes within erodible corridor allowances (presented in **Figure 3.26**), with the intent of improving future stream functionality and habitat. The recommended widths for the geomorphic corridors are extrapolated from natural channel meander belt widths—based on data from the Twenty Mile Creek watershed—to the modified low-order tributaries of Elfrida (with drainage areas less than 10 km^2). To quantitatively assess erosion potential, field characterizations have included first-order approximations of erosion thresholds for the 3rd order stream reaches within the study area. The fine-grained, vegetation-dominated channel conditions are considered inappropriate for detailed tractive force analysis and continuous simulations of erosion threshold exceedance, and thus stormwater erosion control targets will consider more generalized approaches (e.g. 2003 MOE Stormwater Management Planning Manual).

Preliminary recommendations for future erosion monitoring locations—within and downstream of the study area—have been presented for further consideration based on 2016 field conditions and desktop analysis of stream profiles and stream power. In addition to allowing for the reestablishment of natural processes within defined geomorphic corridors, a number of specific restoration opportunities were identified by the fluvial geomorphologic assessment:

- **Watercourse reaches which currently act as roadside ditches:** There are opportunities to realign and restore the stream corridors away from the roads and to naturalize the stream channels. The geomorphically defined corridor widths would need to be re-established as low-lying floodplain areas adjacent to the watercourse, not to including side-slopes associated with development or road regrading (i.e., side slopes do not count in the meander belt width). These linear restoration opportunities are illustrated in **Figure 3.78**.
- **Stoney Creek tributary from Upper Centennial Road:** There is an opportunity to improve conveyance of flows from the west side of the road via a restored stream corridor with a better- defined drainage channel. These flows would be redirected from existing roadside ditches. See **Section 3.3.9.2** for further discussion.

Stream restoration approaches should consider a variety of "naturalized" channel design methods by a qualified stream restoration professional.

3.2.3 Hydrology / Hydraulics and Floodplain Hazards

The primary function of a floodplain is the conveyance of flood waters during extreme storm events and spring melts. It is dependent upon the shape of the channel and associated floodplain, the flow rate and the location of structures (buildings, roads, etc.). The Niagara Peninsula Conservation Authority (NPCA) and Hamilton Conservation Authority (HCA) regulate development applications within flood-susceptible areas such as the floodplains of watercourse systems. Future urban development is not permitted within the Regulatory Floodplain limits. Hydrologic, hydraulic modeling and associated floodline mapping was undertaken for this study to identify areas susceptible to flooding under Regulatory Flood conditions. For this study area, NPCA the Regulatory Flood using the 100-year storm event and HCA define the Regulatory Flood using the Regional storm event.

3.2.3.1 Hydrology

Hydrology is the science which deals with the interaction of water and land, and the processes by which precipitation is transformed into runoff to the receiving watercourses or infiltrated into the groundwater system. One of the most dramatic changes brought about by urbanization is the change in stream hydrology. For example, the replacement of vegetation and undisturbed terrain with impermeable surfaces (i.e. pavement, roof tops, graded surfaces and the provision of an underground storm drainage network) results in the greater interception of water that would naturally infiltrate into the ground and instead provides a direct and rapid transport of surface runoff to streams.

As a result, groundwater recharge diminishes, which in turn could potentially affect baseflows within streams which rely on groundwater discharge. A more rapid rate of stormwater runoff from rainfall events can result in an increase in the total volume, peak flow, and frequency of runoff occurrences. Uncontrolled, these hydrologic changes can result in increases in flooding, channel erosion, sediment transport, and pollutant loadings. These changes can also cause deterioration in natural channel morphology, fish and wildlife habitats, recreational opportunity and aesthetics.

It is important that the existing hydrologic characteristics of the study area and its watercourses be established. This information is critical in defining existing flood characteristics, defining

Regulatory floodplain limits, and providing key information on the selection and design of stormwater management facilities for future urban development lands.

3.2.3.2 Streamflow and Precipitation Monitoring

Streamflow and rainfall monitoring were undertaken through the spring and summer of 2016 in order to gather data in support of the setup and verification of hydrologic modeling for the study area streams. A precipitation gauge was installed at the Our Lady of Assumption Elementary School on Regional Road 20. Three water level gauges were also installed at the Elfrida study boundary on Stoney Creek (Site 1), Sinkhole Creek (Site 2) and Twenty Mile Creek (Site 3). Monitoring sites are illustrated in (**Figure 3.28**).

As part of the monitoring program, spot flow measurements were undertaken and correlated to the water level measurements at the stream gauge sites in an effort to develop rating curves for each location. Preliminary rating curves developed for each site are illustrated in **Figure 3.29**. These rating curves were used to translate the water level monitoring data into flow hydrographs over the monitoring period.

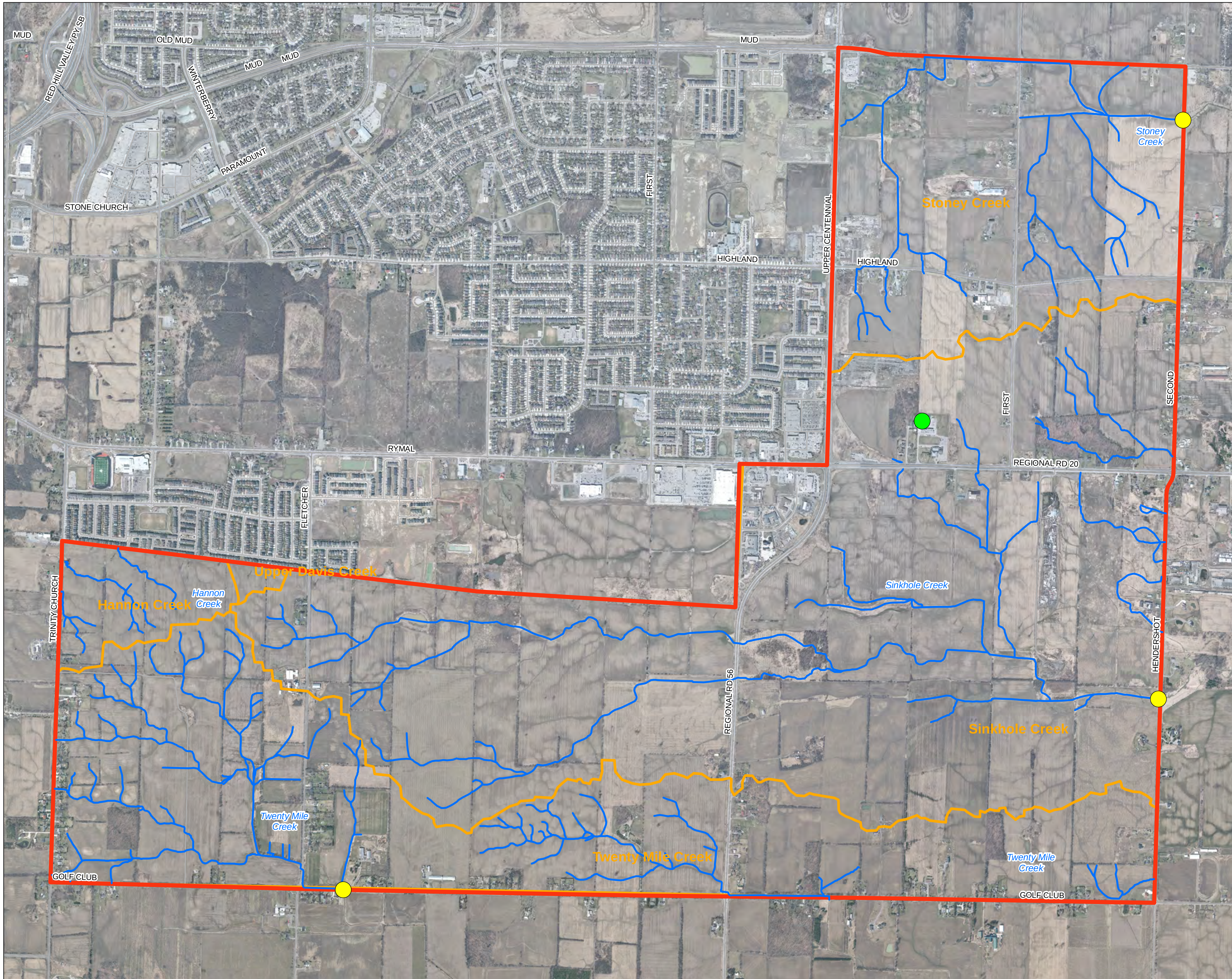
The resulting monitoring hydrographs and precipitation data were then reviewed further prior to attempting to use the data for model calibration. Examples are provided in **Figure 3.30** to **Figure 3.32**. As shown, inconsistencies in the monitoring results were observed:

- observed runoff events do not correlate well to precipitation events;
- hydrographs appear to have unrealistically long recession limbs, often exceeding several weeks; and
- based on the estimated rating curves and resulting hydrographs, the calculated runoff volumes are inconsistent over the study area. As shown in **Table 3.11**, runoff coefficients estimated from the monitoring results vary by a factor of up to 5 across the study area, despite very similar characteristics between the watersheds.

Table 3.11: Summary of Hydrologic Monitoring - Observed Rainfall vs. Runoff Volumes

Watercourse/ Gauge Site	Drainage Area (ha)	Observed Rainfall* (mm)	Observed Runoff Volume* (mm)	Estimated Runoff Coefficient
Stoney Creek (Gauge Site 1)	351	204	53	0.26
Sinkhole Creek (Gauge Site 2)	656	204	11	0.05
Twenty Mile Creek (Gauge Site 3)	251	204	29	0.14

* May-Sep 2016



Elfrida Subwatershed Study

Legend

Study Area

Subwatershed Boundary

Watercourse

Monitoring Sites

Rain Gauge

Stream Gauge

Figure 3.28

Rainfall and Streamflow Monitoring Sites

Date: February 2017

Data Source: City of Hamilton 2016

0 0.5 1

Kilometers

N

Hamilton

Aquafor Beech Limited

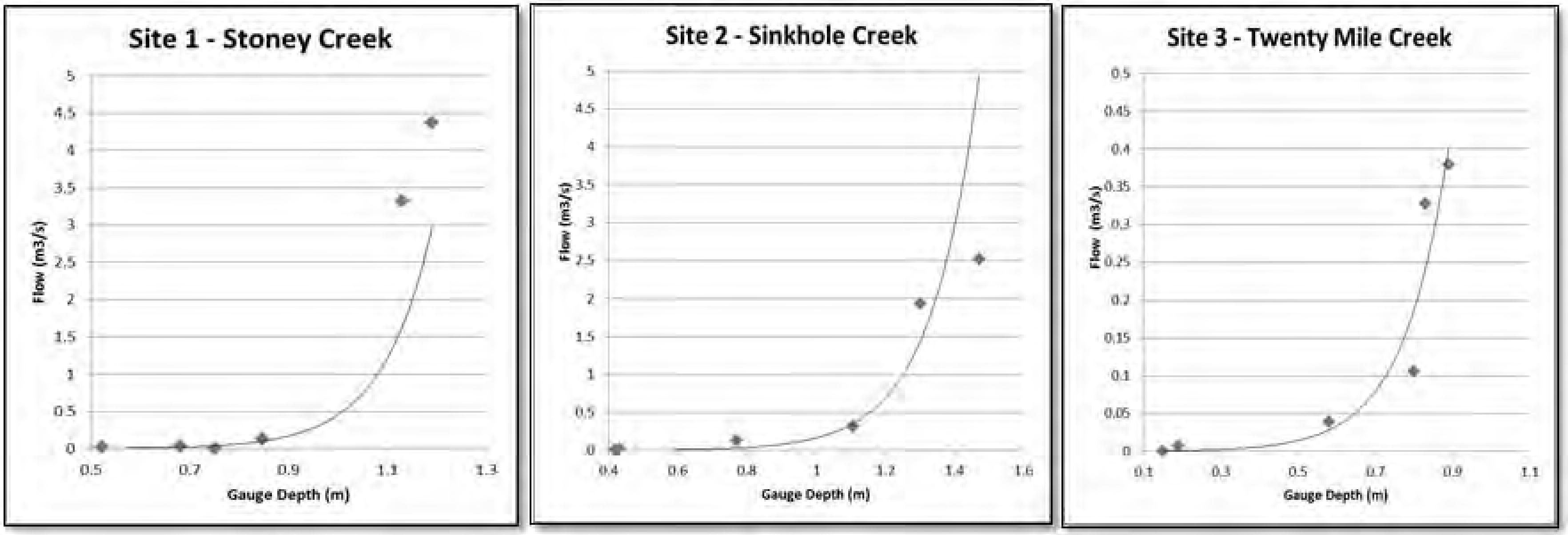


Figure 3.29: Stream Gauge Rating Curve Development

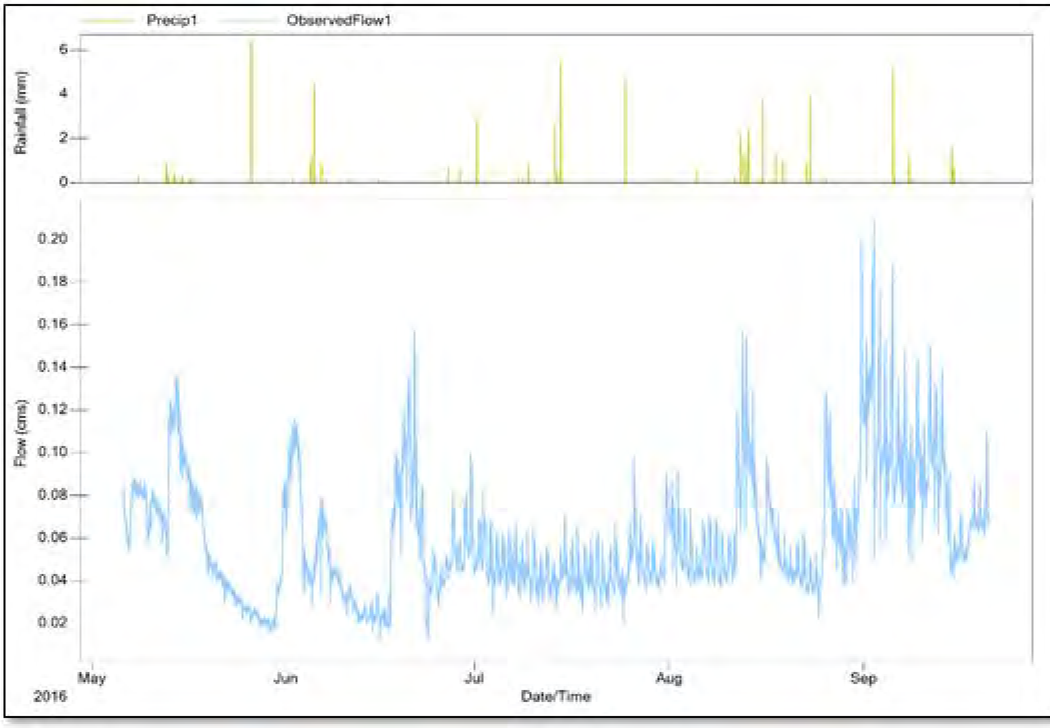


Figure 3.30: Observed Rainfall and Estimated Flow at Site 1 - Stoney Creek

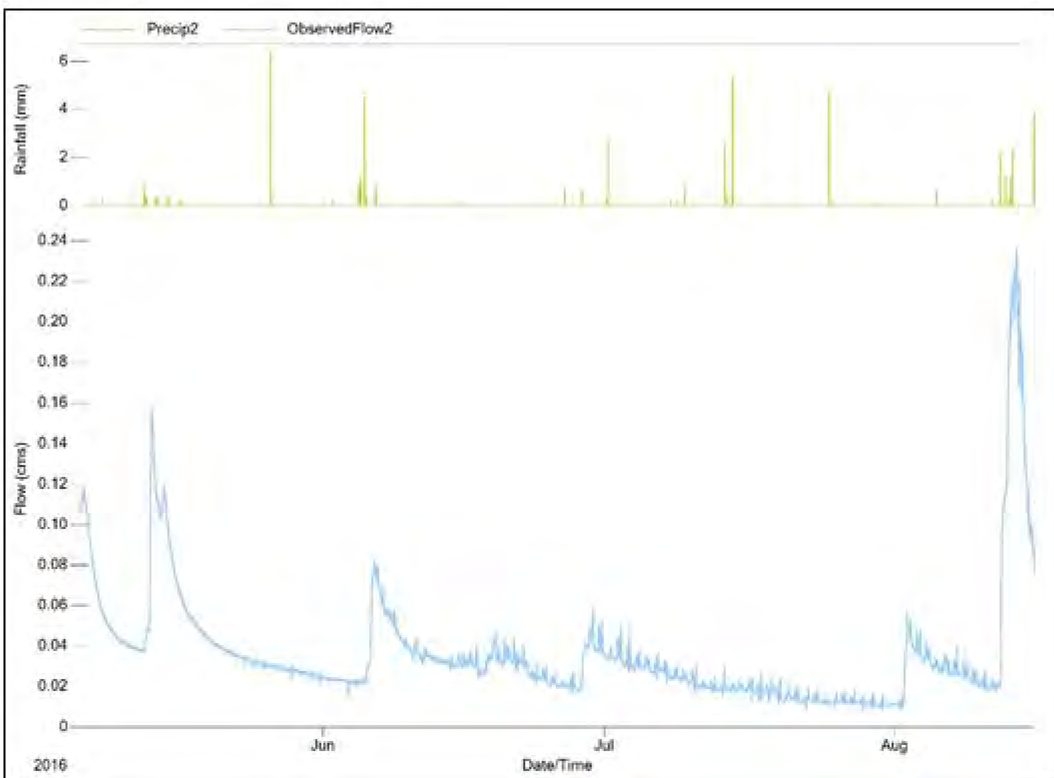


Figure 3.31: Observed Rainfall and Estimated Flow at Site 2 - Sinkhole Creek

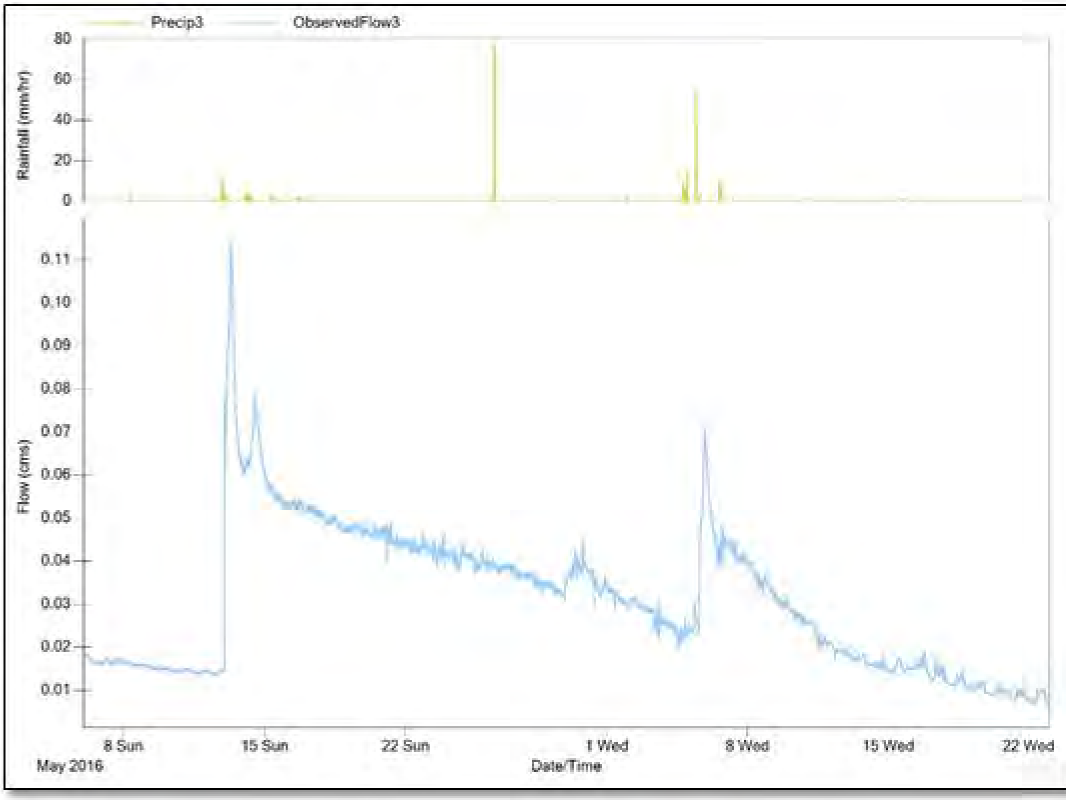


Figure 3.32: Observed Rainfall and Estimated Flow at Site 3 - Twelve Mile Creek

The inconsistencies in the observed hydrographs are believed to be attributed to a number of factors:

- the study area streams are small and intermittent headwater features, with little or no flow observed between precipitation events. The 2016 monitoring year was also very dry, with little precipitation;
- extremely slow- moving flows on these intermittent low-gradient streams make flow measurements problematic, resulting in difficulty defining the rating curves;
- flow conditions are heavily impacted by vegetation conditions which vary significantly from spring through the summer growing season and into fall (**Figure 3.33**). The low-gradient and vegetation resulted in backwater pools at the monitoring sites. Consequently, the water level readings at the gauges fluctuated not only with flow, but were also affected by backwater and evaporation during the dry inter-event periods.

Collectively, the above difficulties prevented a consistent and accurate estimate of the rating curves and consequentially, the runoff hydrographs. Due to these inconsistencies, the monitoring data was not carried forward at this time for use in the hydrologic modeling component of the study.

Stoney Creek (Site 1) – Spring

Stoney Creek (Site 1) – Summer

Sinkhole Creek (Site 2) – Spring

Sinkhole Creek (Site 2) – Summer

Twenty Mile Creek (Site 3) – Spring

Twenty Mile Creek (Site 3) – Summer

Figure 3.33: Variable Conditions at Stream Monitoring Sites

3.2.3.3 Model Selection and Setup

Flood flow estimates for the Elfrida study area streams were developed using the PCSWMM model 2017 Profession 2D, Version 5.1.012. As shown in **Figure 3.34**, drainage to Sinkhole Creek and Stoney Creek originate west of Upper Centennial Road, outside of the Elfrida study area. PCSWMM models for these external lands were incorporated from separate studies provided by the City of Hamilton for use in the overall Elfrida model:

- External area to Sinkhole Creek – "Swayze Lands" PCSWMM model (Nov 14, 2016)
- External area to Stoney Creek – "Felker Lands" PCSWMM model (May 30, 2016)
- External area to Sinkhole Creek – "Highgate Pond" – Report: Highgate Meadow Estates Plan of Subdivision Stormwater Pond Retrofit to Quality/Quantity Pond (March 3, 2009)

These external models include stormwater management facilities which serve the existing and proposed urban development over these external lands.

The remainder of the Elfrida study area was delineated according to the existing drainage network. In total, the overall model includes approximately 75 subcatchments in order to provide peak flow estimates at key locations, as illustrated in **Figure 3.34**. Soils and land use GIS shapefiles, aerial photographs, and a Digital Elevation Model (DEM) were obtained from the City of Hamilton. These items were used to derive the model parameters for the Elfrida catchments, including drainage areas, percent imperviousness, invert elevations, and channel cross-sections. The model was set up using the SCS curve number (CN) approach to estimate catchment runoff and infiltration losses. CN values were established using land uses from GIS and assigning a CN based on Table 2-2a from NRCS TR-55.

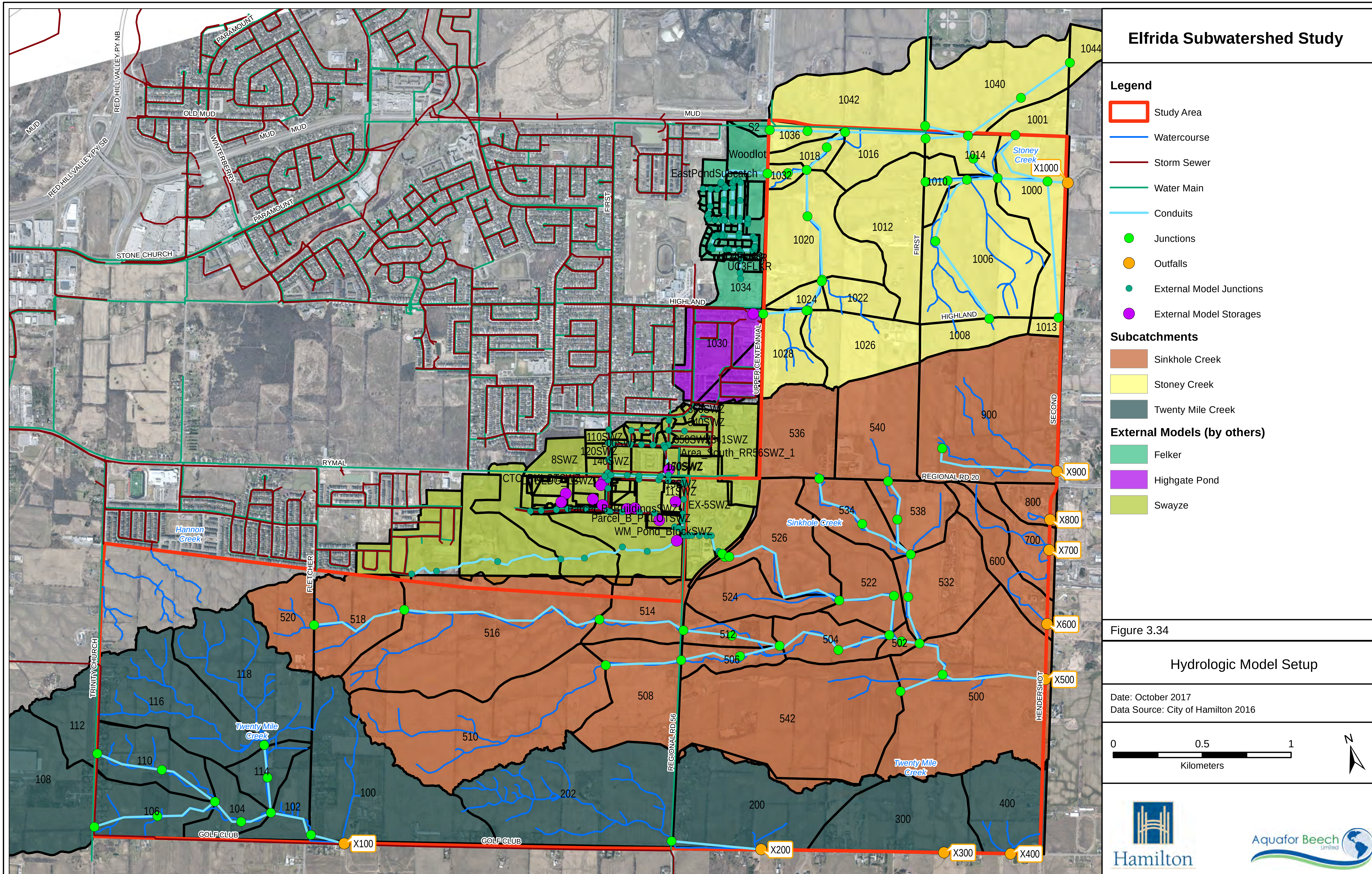
All values from the Felker and Swayze PC SWMM models have been left unchanged. For the Elfrida PC SWMM model, depression storage and Manning's values were assigned according to characteristics that were deemed appropriate for that watershed. The PC SWMM models use the following values:

Swayze:
Impervious Depression Storage: 2 mm
Pervious Depression Storage: 4.75 mm
Impervious Manning's n: 0.25
Pervious Manning's n: 0.015

Felker:
Impervious Depression Storage: 2 mm
Pervious Depression Storage: 4 mm
Impervious Manning's n: 0.1
Pervious Manning's n: 0.01

Elfrida:
Impervious Depression Storage: 2 mm
Pervious Depression Storage: 5 mm
Impervious Manning's n: 0.2
Pervious Manning's n: 0.013

A summary of subcatchment parameters used in the model is provided in **Appendix C**.


Elfrida Subwatershed Study
Legend
Study Area
Watercourse
Storm Sewer
Water Main
Conduits
Junctions
Outfalls
External Model Junctions
External Model Storages
Subcatchments
Sinkhole Creek
Stoney Creek
Twenty Mile Creek
External Models (by others)
Felker
Highgate Pond
Swayze
Figure 3.34
Hydrologic Model Setup
Date: October 2017
Data Source: City of Hamilton 2016
0
0.5
1
Kilometers
N
Hamilton
Aquafor Beech Limited
PARAMOUNT
RED HILL VALLEY PY NB
RED HILL VALLEY PY SB
OLD MUD
MUD
WINTERBERRY
STONE CHURCH
FIRST
HIGHLAND
UPPER CENTENNIAL
RYMAL
REGIONAL RD 20
SECOND
FLETCHER
TRINITY CHURCH
REGIONAL RD 56
GOLF CLUB
HENDERSHOT
Hannon Creek
Stoney Creek
Sinkhole Creek
Twenty Mile Creek
Woodlot
EastPondSubcatch
X100
X200
X300
X400
X500
X600
X700
X800
X900
X1000

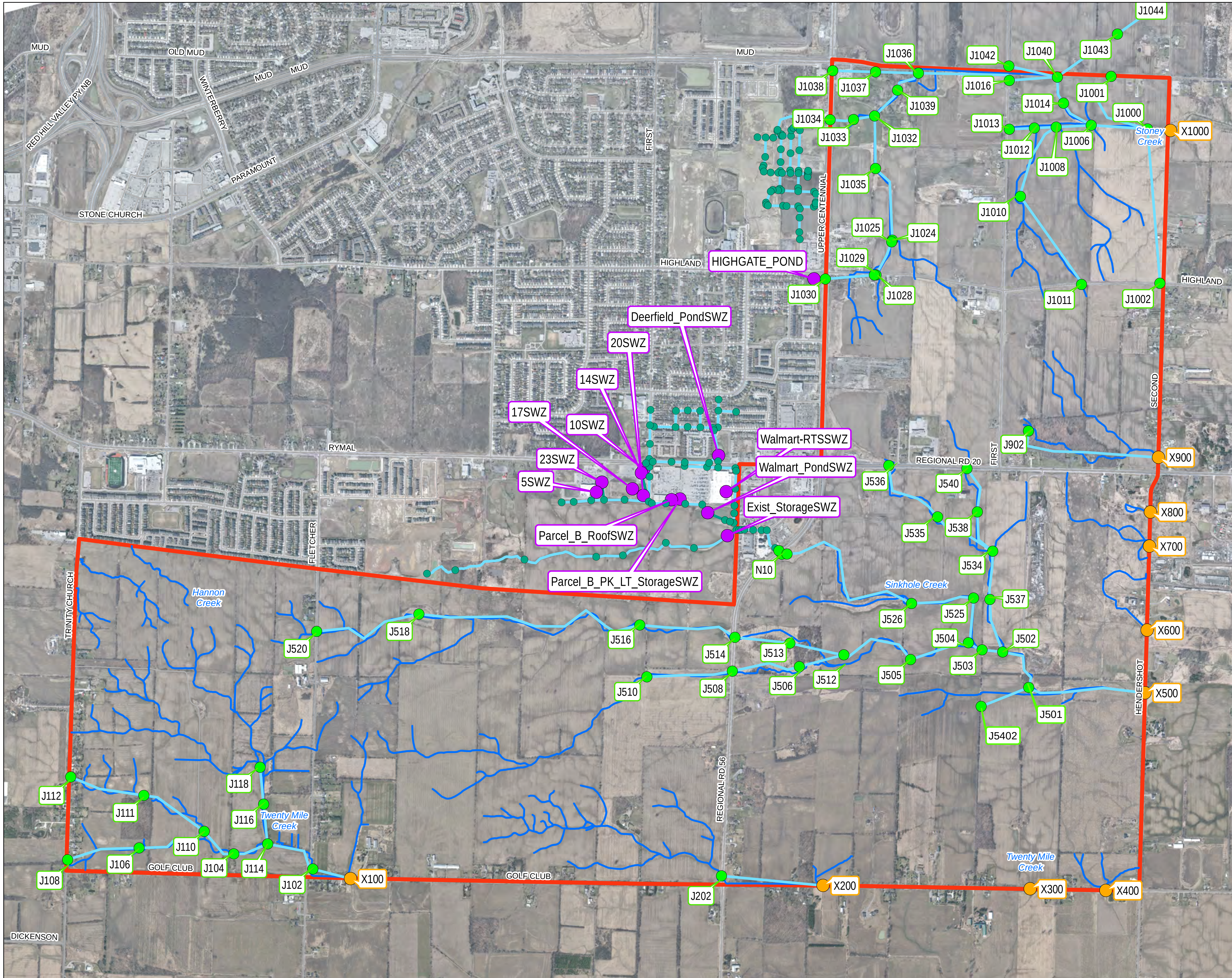
3.2.3.4 Flood Flow Estimates

The Elfrida hydrologic model was then applied to estimate flood flow rates for use in floodplain mapping at key locations throughout the study area watercourses. The Regulatory Flood event in the study area for floodplain management purposes is the 100-year flood flow for NPCA jurisdiction (i.e., Sinkhole Creek, Twenty Mile Creek and Hanon Creek) and the regional flood (i.e., Hurricane Hazel) for HCA jurisdiction (i.e., Stoney Creek).

A design storm approach was used to estimate the peak flows for the study area. With a design storm approach, a rainfall input (i.e. duration, return period depth, and temporal distribution) is selected and design flows are determined using specified antecedent moisture conditions and a computational technique such as a hydrologic model. It is assumed with this approach that peak flows which are generated are of approximately the same return period as the applied design storm.

The City of Hamilton document Criteria and Guidelines for Stormwater Infrastructure Design (September 2007) suggest design storm depths based on long-term data from the Mount Hope rainfall gauge station. Various design storm distributions and durations are available. For consistency, the 12-hour AES distribution was selected for application as it had been applied previously by NPCA to estimate flood flows as part of floodplain mapping for Sinkhole Creek (NPCA, April 2006). The 12-hour duration was selected over other shorter design storm options due to the slower runoff response and longer travel times of the primarily rural watersheds. Further, the larger runoff volumes associated with the longer duration storm are more appropriate for determining storage requirements for future stormwater management facilities. Design storm hyetographs are provided in **Appendix C**.

Table 3.12 summarizes the estimated flood flow rates at key locations throughout the Elfrida study area streams (**Figure 3.35**). As noted earlier, instead of attempting to use the inconsistent monitoring data to calibrate and validate the hydrologic model results, the estimated flood flows were instead compared carefully to results from past studies as well as other regional relationships in order to ensure that the model was producing reasonable results.



Elfrida Subwatershed Study

Legend

- Study Area
- Watercourse
- Conduits
- Junctions
- Outfalls
- External Model Storages
- External Model Junctions

Figure 3.35

Hydrologic Model
Location of Flood Flow Estimates

Date: February 2017
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

Table 3.12: Summary of Estimated Flood Flows

Flow Location (Model	Drainage Area (ha)	Flood Flow (m^3/s)						
		2-year	5-year	10-year	25-year	50-year	100-year	Regional
Stoney Creek								
X1000	350.9	1.36	3.17	2.43	6.14	7.52	9.21	28.97
J1000	350	1.37	3.20	4.55	6.20	7.58	9.31	29.21
J1001	7.3	0.04	0.08	0.12	0.16	0.20	0.24	0.75
J1002	1.9	0.01	0.03	0.04	0.05	0.06	0.07	0.23
J1006	314.7	1.22	2.84	4.03	5.48	6.68	8.22	25.80
J1008	85.8	0.40	0.88	1.24	1.74	2.15	2.64	8.11
J1010	53	0.25	0.54	0.75	1.07	1.32	1.62	5.03
J1011	9.3	0.06	0.12	0.17	0.23	0.28	0.34	1.06
J1012	32.8	0.16	0.35	0.49	0.69	0.84	1.03	3.13
J1013	27.1	0.12	0.28	0.39	0.54	0.67	0.83	2.56
J1014	229	0.85	1.99	2.83	3.87	4.67	5.75	18.02
J1016	155.3	0.71	1.61	2.29	3.14	3.81	4.56	12.89
J1024	68.2	0.44	0.82	1.13	1.55	1.87	2.29	5.87
J1025	64.5	0.44	0.77	1.06	1.45	1.75	2.14	5.50
J1028	56.9	0.43	0.69	0.94	1.29	1.57	1.90	4.77
J1029	36.2	0.42	0.61	0.74	0.96	1.15	1.37	2.79
J1030	23.2	0.41	0.59	0.72	0.89	1.02	1.17	1.52
J1032	133.1	0.61	1.37	1.97	2.74	3.28	3.91	10.88
J1033	33.8	0.13	0.37	0.55	0.74	0.83	0.93	2.49
J1034	31.4	0.11	0.34	0.49	0.67	0.75	0.84	2.22
J1035	99.3	0.50	1.03	1.45	2.02	2.47	2.99	8.51
J1036	143.9	0.66	1.50	2.14	2.95	3.56	4.24	11.88
J1037	5.7	0.04	0.07	0.10	0.14	0.17	0.20	0.58
J1038	1.3	0.01	0.02	0.03	0.04	0.05	0.05	0.16
J1039	138.2	0.63	1.43	2.05	2.84	3.40	4.07	11.35
J1040	221.4	0.83	1.93	2.75	3.77	4.57	5.60	17.66
J1042	27.6	0.05	0.15	0.22	0.34	0.41	0.53	2.18
J1043	38.4	0.10	0.25	0.37	0.55	0.67	0.86	3.25
J1044	6.2	0.03	0.06	0.09	0.13	0.16	0.19	0.61
Sinkhole Creek								
X500	656.15	1.85	4.57	6.68	9.47	11.83	14.99	45.23
J502	511.8	1.69	3.98	5.77	8.13	10.13	12.81	35.81
J503	407.6	1.33	3.11	4.51	6.32	7.87	9.95	35.68
J504	452.4	1.32	3.10	4.49	6.30	7.85	9.92	18.70
J505	244.9	0.49	1.31	2.01	2.89	3.69	4.78	7.11
J506	96.5	0.19	0.49	0.74	1.06	1.35	1.74	6.49
J508	89.1	0.16	0.43	0.65	0.93	1.18	1.53	4.01
J510	61.2	0.08	0.22	0.35	0.53	0.67	0.88	17.62
J512	231.2	0.44	1.21	1.87	2.68	3.43	4.45	10.61

Flow Location (Model	Drainage Area (ha)	Flood Flow (m^3/s)						
		2-year	5-year	10-year	25-year	50-year	100-year	Regional
J513	134.7	0.27	0.73	1.15	1.65	2.12	2.75	10.01
J514	126.1	0.24	0.67	1.06	1.51	1.95	2.53	8.68
J516	109.2	0.23	0.62	0.94	1.39	1.73	2.21	3.41
J518	36.9	0.12	0.30	0.44	0.63	0.79	0.99	1.34
J520	14	0.05	0.13	0.18	0.26	0.33	0.41	17.19
J525	207.5	0.87	1.83	2.53	3.48	4.26	5.20	15.52
J526	141.6	0.78	1.62	2.24	3.09	3.77	4.61	7.25
J534	78.7	0.29	0.69	0.99	1.40	1.76	2.19	3.44
J535	37.1	0.14	0.33	0.47	0.67	0.84	1.04	2.04
J536	22.4	0.07	0.17	0.25	0.37	0.46	0.58	9.59
J537	104.2	0.37	0.89	1.29	1.83	2.30	2.87	3.84
J538	41.6	0.16	0.37	0.52	0.75	0.93	1.15	2.40
J540	27.3	0.07	0.19	0.29	0.42	0.51	0.66	45.23
N10 (From	100.75	0.62	1.26	1.72	2.36	2.87	3.50	NA
X600	13.28	0.03	0.07	0.11	0.17	0.20	0.27	1.06
X700	11.87	0.04	0.09	0.13	0.19	0.24	0.30	1.08
X800	6.52	0.03	0.06	0.09	0.13	0.16	0.20	0.63
X900	61.68	0.14	0.37	0.56	0.80	1.02	1.32	5.11
J902	61.68	0.14	0.38	0.57	0.85	1.03	1.33	5.16
Twenty Mile Creek								
X100	250.6	0.62	1.62	2.43	3.56	4.48	5.70	21.08
J102	200.5	0.54	1.39	2.05	2.98	3.78	4.80	17.29
J104	107.5	0.54	0.82	1.19	1.71	2.17	2.74	9.60
J106	65.7	0.21	0.49	0.71	1.02	1.28	1.62	5.81
J108	48.6	0.16	0.36	0.53	0.76	0.96	1.21	4.30
J110	97.2	0.30	0.73	1.06	1.52	1.93	2.44	8.64
J111	31.5	0.10	0.25	0.37	0.53	0.66	0.83	2.89
J112	12.5	0.04	0.11	0.16	0.23	0.29	0.36	1.19
J114	190.4	0.52	1.32	1.95	2.80	3.56	4.51	16.42
J116	82.9	0.20	0.52	0.77	1.11	1.40	1.80	6.89
J118	74.1	0.16	0.43	0.66	0.98	1.18	1.53	6.05
X200	104.7	0.19	0.52	0.80	1.17	0.83	1.90	8.01
J202	59.7	0.11	0.29	0.45	0.68	0.83	1.07	4.52
X300	27.4	0.11	0.26	0.37	0.54	0.67	0.83	2.68
X400	22	0.07	0.17	0.25	0.37	0.46	0.58	2.02
Hannon Creek								
X2000	6.17	0.02	0.06	0.08	0.12	0.15	0.18	NA
X3000	10.83	0.03	0.08	0.12	0.17	0.21	0.27	NA
X4000	9.82	0.04	0.09	0.13	0.18	0.23	0.29	NA

In 1989, Marshall Macklin Monaghan developed watershed-scaled hydrologic modeling for all of the watersheds in the NPCA jurisdiction. These models were calibrated to observed streamflow gauge sites and then used to estimate peak flows at key locations throughout the NPCA watersheds. In 2006, NPCA also developed flow estimates for Sinkhole Creek using the HEC-HMS hydrologic model in support of floodplain mapping. **Table 3.13** compares peak flows from the 1989 and 2006 NPCA studies to those estimated by the Elfrida PC-SWMM model. As shown, the modeled flows for Sinkhole Creek are generally within the range of flows presented in the previous studies.

Table 3.13: Comparison of Hydrologic Model Results

Location	MMM 1989 Watershed Hydrology Study		NPCA 2006 Sinkhole Creek Floodplain Mapping Study		Aquafor 2016 Elfrida PCSWMM model	
	ID/Ref	100-yr Flow (m^3/s)	ID/Ref	100-yr Flow (m^3/s)	ID/Ref	100-yr Flow (m^3/s)
Sinkhole Creek – Swayze Tributary	102008	5.70	SiCk-6 (Tributary 1)	8.23	J525	5.25
Sinkhole Creek – Main Elfrida Tributary	102007	3.87	SiCk-7 (Main Upper)	6.21	J505	4.74
Sinkhole Creek - Confluence of Elfrida & Swayze Tribs	202007	9.52	J-Si6-/7	14.87	X500	14.94
Twenty Mile Creek at Golf Club Road	100065	2.16	n/a	n/a	X100	5.65

In addition to the above comparison to previous studies, the model results were also compared, on a flow per unit area basis, to typical ranges of values from gauged Ontario watersheds as reported in the TRCA Regional Headwater Hydrology Study (MacLaren Plansearch, 1991). **Figure 3.36** compares the results from the Elfrida PCSWMM model for various return periods to a range of typical unit discharges for a series of gauged Ontario watersheds.

As shown, the range of unit flows along Stoney Creek was found to be moderately higher than along Twenty Mile Creek and Sinkhole Creek. This is attributed to higher runoff clay soils as well as upstream urban development in the Stoney Creek portion of the study area. However, as shown, the ranges of peak flow estimates from the PC-SWMM model are generally within the range of reported flows from the 1991 TRCA study.

Based on the above comparisons, the peak flow estimates from the Elfrida PC-SWMM model were considered to be reasonable and representative for further hydraulic modeling and floodplain mapping analyses.

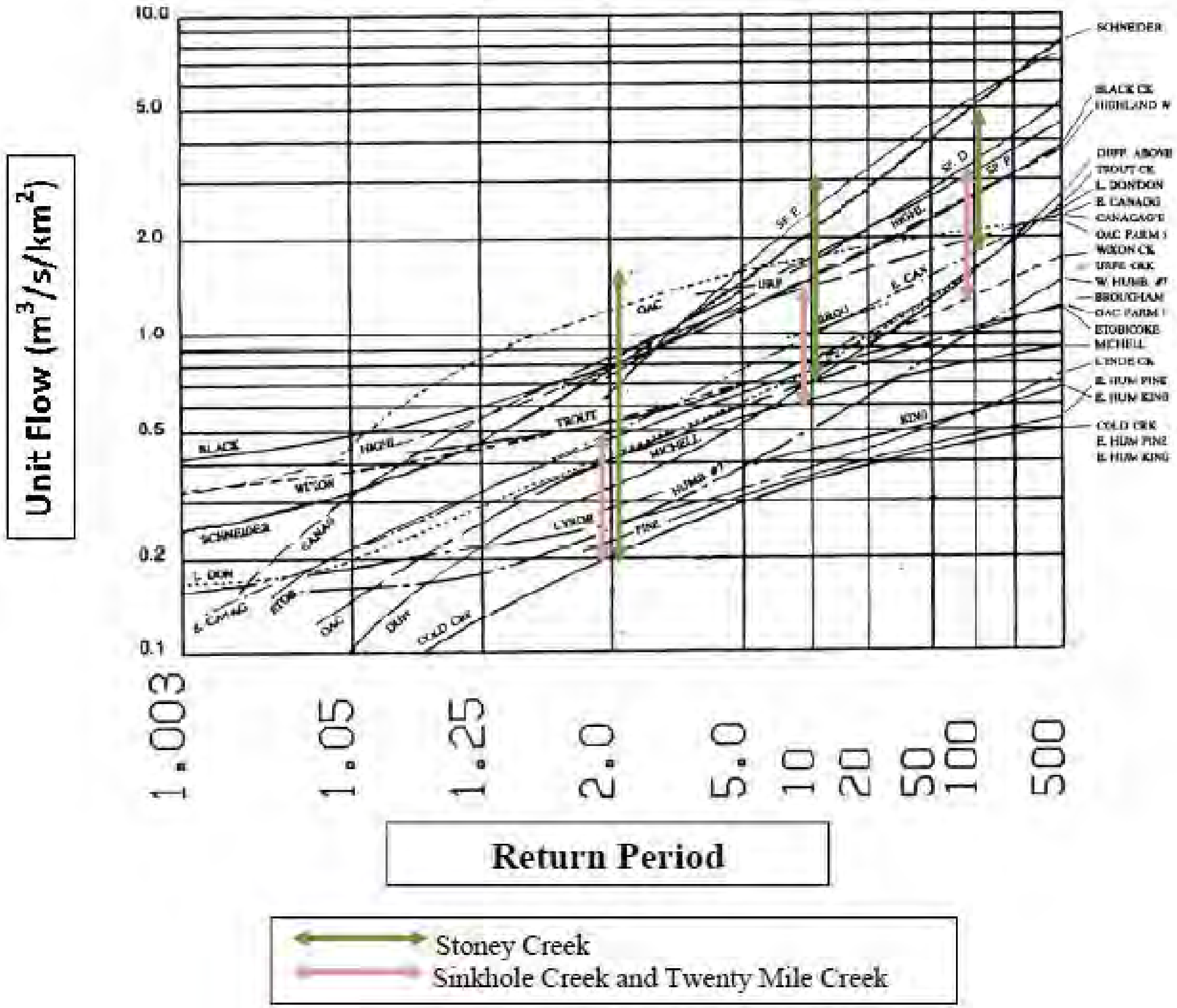


Figure 3.36: Comparison of Elfrida Model Results to other Ontario Unit Flow Rates*

* TRCA Regional Headwater Hydrology Study (1991)

3.2.3.5 Hydraulics and Floodplain Mapping

Hydraulic modeling and associated floodplain mapping were undertaken to define flood hazard lands along the major stream reaches within the Elfrida study area which will remain as open watercourses in the future urban landscape. This included stream reaches that were classified as either watercourses or headwater drainage features (HDFs) identified for "Protection" in Section **3.2.1.4** (**Figure 3.20**). It is understood that HDFs identified for "Conservation" will also be maintained as open watercourses, however floodplain mapping was not extended over these reaches as they may be re-aligned or modified within the future urban landscape.

Hydraulic Model Selection

Hydraulic analysis for the Elfrida Study area was undertaken using the GeoHEC-RAS hydraulic model. The HEC-RAS model engine was developed by the U.S. Army Corps of Engineers to compute water surface flood profiles using the standard step method and routines to analyze bridge and culvert road crossing structures.

Hydraulic Model Setup

In 2006 NPCA developed a HEC-RAS hydraulic model and floodplain mapping for Sinkhole Creek. Within the Elfrida study area, this model extended along the Main Elfrida branch of Sinkhole Creek from Hendershot Road to approximately 500m upstream of Regional Road 56, and along the north Tributary 1 (Swayze tributary) from the confluence with the Main Branch to Regional Road 56.

The reaches through the Elfrida Study area were updated and extended for this subwatershed study using City of Hamilton topographic information and the updated flood flow estimates developed above (**Table 3.12**). No previous hydraulic modeling or Regulatory floodplain mapping within the Elfrida study area was available for use in this study for Stoney Creek, Twenty Mile Creek, or Hannon Creek.

Hydraulic modeling for the Elfrida streams was setup using LiDAR data, which was used to develop a digital terrain model (DTM) and corresponding 0.25m interval contours.. This spatial data was used to define stream cross-section geometry for the subject stream reaches of Stoney Creek, Sinkhole Creek, and Twenty Mile Creek. Typical "low flow" channel locations and bathymetry were also coded into the model based on field measurements undertaken during the HDF and geomorphic stream assessments. It is noted that in some locations the topographic low points along the cross-sections, as defined by the DEM-derived contours, did not align with the stream centrelines observed through the field investigations. This is attributed to the very flat topography of the area that includes off-line depressions, together with the possibility that some of the smaller HDF channels may be re-aligned seasonally through agricultural ditching practices.

Topographic surveys were completed to collect hydraulic data required to simulate road crossing structures along the subject streams. The data included culvert material, shape, opening dimensions, and invert/obvert elevations relative to the road profile. An inventory of the culvert structures and survey data is provided in **Appendix D**.

For each of the three major stream systems, the hydraulic model was extended several hundred meters downstream of the study area in order to ensure that the model had sufficient tailwater information to accurately estimate flood elevations at the study area boundary.

Both channel roughness and overbank roughness coefficients were set to 0.070 to reflect the shallow flow and vegetation-dominated channels observed through the area. Standard roughness coefficients for corrugated steel and concrete were used for culvert structures.

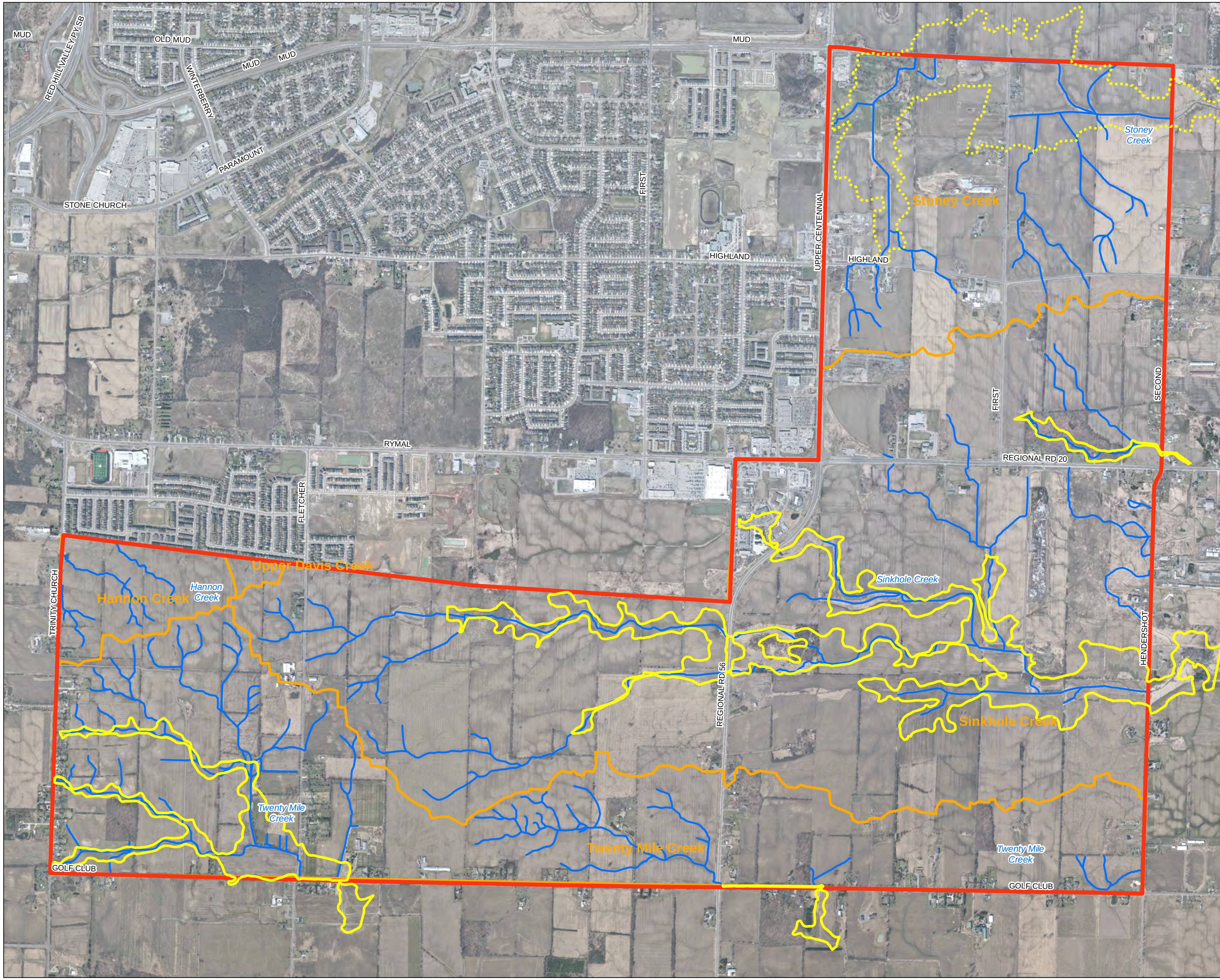
Flood flow estimates for the 2-year through 100-year design storm events, as determined from the PC-SWMM hydrologic model, were applied over the appropriate Elfrida stream reaches in the GeoHEC-RAS model. Model details, including flood profile plots, output tables, and floodline maps are provided in **Appendix D**.

Model results for the 100-year storm were then plotted on topographic mapping generated from the DEM over the study area. The resulting floodplain hazard lands are illustrated in **Figure 3.37**. As shown, the floodplains are relatively wide in several locations. This is consistent with the wide shallow flooding observed during the spring (**Figure 3.38**) and is attributed to the very flat topography and lack of valley formations through the study area.

As shown in **Figure 3.37**, there is a potential spill of floodwaters from the upper reaches of Stoney Creek eastward. The topography of the area is very flat without any valley slope to contain the flooding. This would potentially allow floodwaters to spill eastward via shallow overland flow. Based on the topography of the central portion of the site, any spilled floodwaters would be expected to re-join the main branch of Stoney Creek upstream of First Road East.

Spilling of floodwaters is also predicted between parallel tributaries of Sinkhole Creek in some locations. As shown in **Figure 3.37**, the floodplain forms a small "island" along the hydro right-of-way between two Sinkhole Creek tributaries near the central portion of the study area. Similar floodplain characteristics were presented in NPCA's 2006 floodplain mapping study for Sinkhole Creek.

Elfrida Subwatershed Study



Legend

- Study Area
- Subwatershed Boundary
- Watercourse

Regulatory Floodlines

- Regional Flood
- 100 Year Flood

Figure 3.37

Floodplain Hazard Lines

Date: January 2018
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

Stoney Creek at Second Road – spring 2016

Sinkhole Creek at Hendershot Road – spring 2016

Figure 3.38: Observed Flooding in Spring 2016

3.2.4 Water Quality

Water quality, including the pollutant levels found in surface runoff, can impact both human and ecological well-being. Agricultural and urban land use can impact the landscape, vegetation, and ecological functions within a watershed, which in turn can contribute to increases in the levels of pollutants in the receiving watercourses. There are a variety of pollutants as well as other physical, chemical and biological characteristics used to measure water quality. Some of the most common categories include:

- Solids (e.g., suspended solids, volatile solids, turbidity);
- Nutrients (e.g. phosphorus, nitrogen) ;
- Bacteria (e.g., coliforms);
- Metals (e.g., copper, zinc);
- Temperature;
- Chlorides; and
- Dissolved oxygen.

Provided below is an overview of these water quality parameters, their importance and influence in terms of aquatic and ecosystem health, and the potential impacts of urban development.

Solids and Turbidity

Suspended solids concentrations and turbidity both indicate the amount of solids suspended in the water, whether mineral (soil particles) or organic (algae). High concentrations of particulate matter can cause increased sedimentation and siltation in a stream, which in turn can degrade/impact important habitat areas for fish and other aquatic life. Elevated levels of suspended solids can also negatively affect water quality by absorbing light, thereby warming the water. Warm water holds less dissolved oxygen than cool water. The suspended particles also provide attachment places for other pollutants, such as metals and bacteria. High suspended solids or turbidity readings thus can be used as indicators of other potential pollutants.

Land use is probably the greatest factor influencing changes in TSS or turbidity in streams. Agricultural and urban land use results in an increase in disturbed areas, a decrease in vegetation, and an increase in the rate of runoff. These all cause increases in erosion, particulate matter, and nutrients, which promote increased algal growth. For example, loss of vegetation due to urbanization exposes more soil to erosion, allowing more runoff to form, and simultaneously reduces the watershed's ability to filter runoff before it reaches the stream.

Nutrients

Instream nutrients are essential for growth. The additional algae and other plant growth supported by nutrients may be beneficial up to a point, but may easily become a nuisance or negatively impact aquatic species/habitat. The main nutrients of concern are phosphorus and nitrogen.

Nutrient loading can result in increased algae growth. Excessive growths of attached algae can cause low dissolved oxygen (DO), unsightly conditions, odors, and poor habitat conditions for aquatic organisms.

Pollution from urban development can impact instream nutrient concentrations in a number of ways. Municipal and industrial discharges usually contain nutrients, and overland flow from developed watersheds contains nutrients from lawn and garden fertilizers as well as the additional organic debris, which is washed from urban surfaces. Increased runoff from urban surfaces may result in increased rates of erosion, which can also be a significant source of nutrients to receiving streams, as nutrients are also naturally present in many soils in Ontario. Agricultural areas also contribute to nutrient increases through poor manure and fertilizing practices and increased erosion from plowed surfaces.

Pathogens (Bacteria)

Fecal coliform bacteria are microscopic organisms that live in the intestines of warm-blooded animals, as well as in the waste material, or feces, excreted from the intestinal tract. When fecal coliform bacteria are present in high numbers in a water sample, it means that the water has received fecal matter from one source or another. Although not necessarily agents of disease, fecal coliform bacteria may indicate the presence of disease-carrying organisms, which live in the same environment as the fecal coliform bacteria.

Bacteria levels do not necessarily decrease as a watershed develops from rural to urban. Instead, urbanization usually generates new sources of bacteria. Farm animal manure and septic systems are replaced by domestic pets and leaking sanitary sewers.

Metals

Urban transportation systems are a primary source of metals in stormwater runoff to urban streams and groundwater. All cars, even the cleanest vehicles, shed small amounts of metals, fluids, and other pollutants. Cadmium, copper, cobalt, iron, nickel, lead and zinc are deposited into the environment by vehicle exhaust, brake linings, and tire and engine wear. They accumulate on road surfaces and are then washed into storm drains with the next rainfall.

Galvanized metal rooftops, gutters and downspouts, and moss killer are also a source of zinc in stormwater. Some copper comes from architectural uses and treated wood, and a primary source is brake pads. The erosion of soils can also be a significant natural source of metals within stormwater runoff.

The effects of a number of metals are reviewed below:

- Lead, which is often used as an indicator for other toxic pollutants in stormwater, can be harmful or deadly for human and aquatic life.
- Zinc, although not harmful to humans at concentrations normally found in stormwater, can be deadly for aquatic life.
- Cadmium can bioaccumulate in an ecosystem. Soil microorganisms are especially sensitive to it, and it is harmful to human health.
- Chromium damages fish gills and causes birth defects in animals. It is also dangerous to human health.
- Mercury is a neurotoxin that bioaccumulates.
- Low levels of copper inhibit the olfactory systems of salmonid fish, decreasing their

ability to hide in response to warning signals
- Some metals bind to soils and organic matter and are transported in sediment, while other metals dissolve in water. Rainwater is slightly acidic, which increases its ability to dissolve heavy metals and compounds the health and environmental effects of stormwater runoff from urban areas.

Temperature

Water temperature is important because it governs the kinds of aquatic life that can live in a stream. Fish, insects, zooplankton, phytoplankton, and other aquatic species all have a preferred temperature range. If temperatures get too far above or below this preferred range, the number of individual species decreases until finally there are none.

We usually think of thermal pollution in terms of heated municipal and industrial discharges. However, the process of watershed development also can affect temperatures in nearby streams. Streambank vegetation is lost when land is cleared, thereby exposing the stream to increased warming by sunlight. A less obvious impact is that runoff water may be warmer, especially during the summer months when it flows over hot asphalt or concrete.

Chlorides

Chloride is a conservative pollutant, in that it is not degraded or removed from water by any natural process. High levels of chlorides can inhibit plant growth and impair reproduction. They also reduce the diversity of fish and other aquatic organisms in streams. Chloride is a general surrogate for development pressures, from road salting and septic systems.

Dissolved Oxygen (DO)

Like terrestrial animals, fish and other aquatic organisms need oxygen to live. As water moves past their gills (or other breathing apparatus), microscopic bubbles of oxygen gas in the water, called dissolved oxygen (DO), are transferred from the water to their blood. In addition to being required by aquatic organisms for respiration, oxygen also is used for decomposition of organic matter and other biological and chemical processes.

Stormwater runoff delivers oxygen-demanding substances to streams. When a watershed becomes developed, greater quantities of pollutants are released and the total volume of runoff increases. Most conventional pollutants (sediments, nutrients, organic matter) require oxygen for decomposition or for chemical reactions. Consequently, instream DO concentrations often decrease in a developed or developing watershed.

3.2.4.1 Water Quality Monitoring

NPCA and HCA conduct surface water quality monitoring programs at various locations within their respective watersheds. Chemical, biological and BioMap analyses are used to evaluate the water quality and the general health of watercourses.

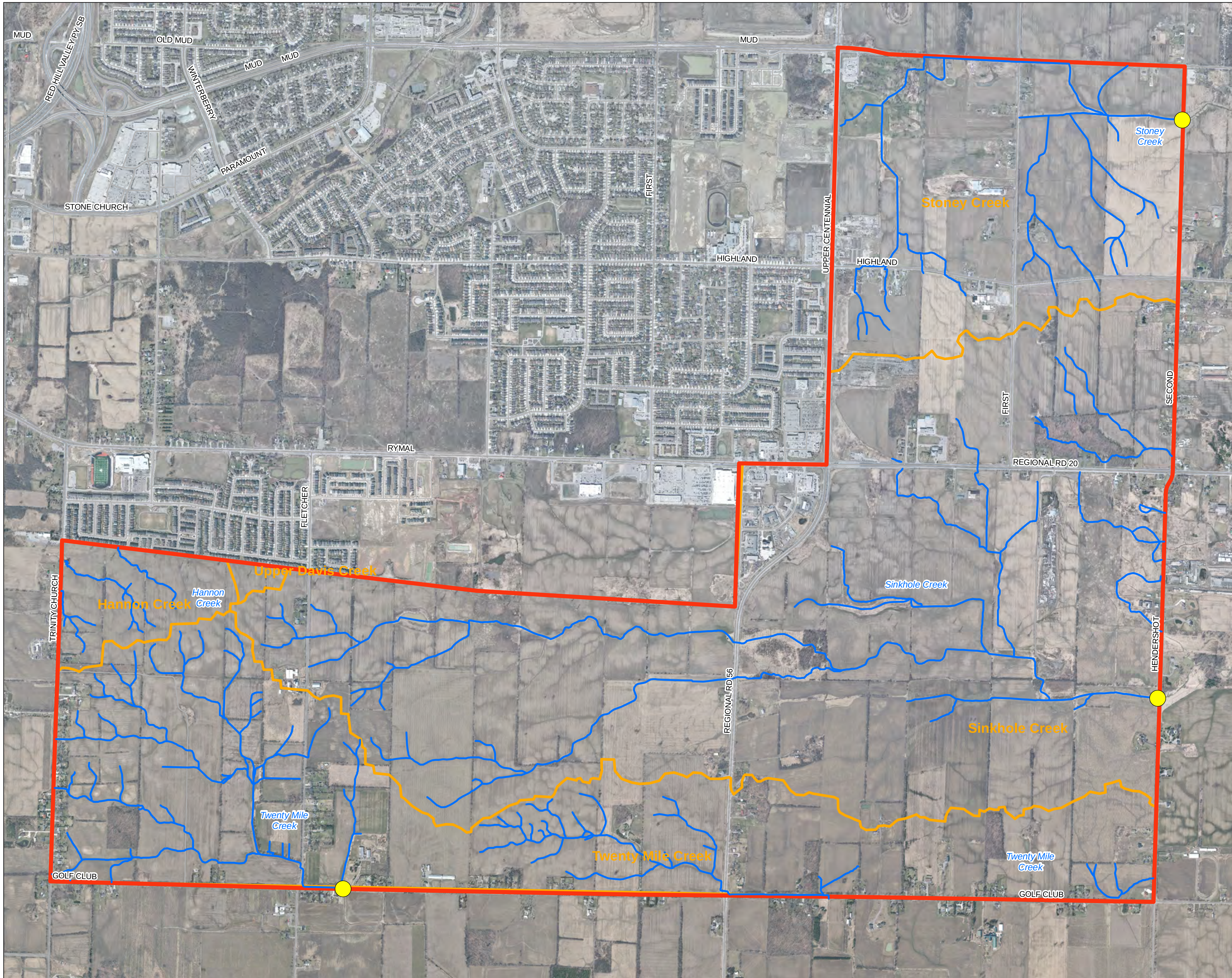
There are no monitoring sites located within the Elfrida study area itself, however, there are a number of water quality sampling sites located on Twenty Mile Creek downstream of the study area that are regularly tested as part of the NPCA Water Quality Monitoring Program. At these sites, concentrations of chloride, copper, *E.coli*, lead, nitrate, phosphorus, TSS, and zinc have been found to frequently exceed provincial guidelines. Elevated concentrations of total phosphorus are of particular concern, and levels have been found to be increasing over time.

As part of the Elfrida Subwatershed Study, additional water quality sampling was completed within the study area streams. Grab samples were taken from Twenty Mile Creek, Sinkhole Creek and Stoney Creek at the boundary of the study area (**Figure 3.39**). A representative dry weather sample and three wet weather samples were collected on the following dates at each of the sampling locations:

- 11 August 2015 - dry weather
- 20 August 2015 – wet weather
- 29 September 2015 – wet weather
- 29 October 2015 – wet weather

Laboratory analysis for key pollutants at each of the sites is presented in **Table 3.14**: Water Quality Sampling - Stoney Creek (Stoney Creek), **Table 3.15**: Water Quality Sampling - Sinkhole Creek (Sinkhole Creek), and **Table 3.16**: Water Quality Sampling - Twenty Mile Creek (Twenty Mile Creek). Further detailed laboratory results are provided in **Appendix E**. As shown, phosphorus and chloride concentrations consistently exceed water quality guidelines, often by a significant margin. Elevated levels of *E.coli*, TSS, and some metals were also observed in the study area streams. These results are consistent with the findings for sampling sites located downstream on Twenty Mile Creek as reported in the NPCA water quality monitoring program (NPCA, May 2014).

Elfrida Subwatershed Study



Legend

- Study Area
- Subwatershed Boundary
- Watercourse

Monitoring Sites

- Water Quality

Figure 3.39

Water Quality
Monitoring Sites

Date: February 2017
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

Table 3.14: Water Quality Sampling - Stoney Creek

Water Quality Parameter	Objective Concentration	unit	Reference*	Sampled Concentration**			
				11-Aug-15	20-Aug-15	29-Sep-15	29-Oct-15
				dry weather	wet weather	wet weather	wet weather
TSS	25	mg/L	BC MOE (2001)	<10	43	11	48
E.coli	100	count/100mL	PWQO (1994)	1,000	2,400	52	4,000
Total Phosphorus	30	µg/L	PWQO (1994)	70	260	248	380
Chloride	120	mg/L	CWQG (2011)	498	310	192	171
Copper	5	µg/L	PWQO (1994)	5.3	4.0	3.1	7.0
Lead	5	µg/L	PWQO (1994)	1.7	<0.5	1.2	6.5
Zinc	20	µg/L	PWQO (1994)	24.0	9.6	11.2	34.1

* PWQO - Provincial Water Quality Objectives, CWQG - Canadian Water Quality Guidelines, BC MOE - British Columbia Ministry of the Environment
** values in red exceed objective concentrations

Table 3.15: Water Quality Sampling - Sinkhole Creek

Water Quality Parameter	Objective Concentration	unit	Reference*	Sampled Concentration**			
				11-Aug-15	20-Aug-15	29-Sep-15	29-Oct-15
				dry weather	wet weather	wet weather	wet weather
TSS	25	mg/L	BC MOE (2001)	19	39	10.5	11
E.coli	100	count/100mL	PWQO (1994)	140	1,100	ND	60
Total Phosphorus	30	µg/L	PWQO (1994)	110	210	66	80
Chloride	120	mg/L	CWQG (2011)	705	722	475	142
Copper	5	µg/L	PWQO (1994)	1.7	2.2	3.7	3.9
Lead	5	µg/L	PWQO (1994)	<0.5	0.8	<0.5	1.0
Zinc	20	µg/L	PWQO (1994)	<5.0	11.9	<5.0	8.6

* PWQO - Provincial Water Quality Objectives, CWQG - Canadian Water Quality Guidelines, BC MOE - British Columbia Ministry of the Environment
** values in red exceed objective concentrations

Table 3.16: Water Quality Sampling - Twenty Mile Creek

Water Quality Parameter	Objective Concentration	unit	Reference*	Sampled Concentration**			
				11-Aug-15	20-Aug-15	29-Sep-15	29-Oct-15
				dry weather	wet weather	wet weather	wet weather
TSS	25	mg/L	BC MOE (2001)	13	53	10.5	33
E.coli	100	count/100mL	PWQO (1994)	1,200	5,500	6	17,000
Total Phosphorus	30	µg/L	PWQO (1994)	240	550	121	130
Chloride	120	mg/L	CWQG (2011)	340	282	448	141
Copper	5	µg/L	PWQO (1994)	2.3	7.1	1.8	3.9
Lead	5	µg/L	PWQO (1994)	0.8	1.5	0.5	2.3
Zinc	20	µg/L	PWQO (1994)	6.3	13.6	5.9	17.4

* PWQO - Provincial Water Quality Objectives, CWQG - Canadian Water Quality Guidelines, BC MOE - British Columbia Ministry of the Environment

** values in red exceed objective concentrations

3.3 Ecological Resources and Natural Heritage System

Natural heritage features within the Elfrida Subwatershed study area were characterized using a combination of primary and secondary information sources. The results of this baseline assessment were used to characterize the Natural Heritage System (NHS), as described in **Section 0**.

Aquafor Beech Limited obtained background information on the study area from the City of Hamilton, Hamilton Conservation Authority, Niagara Peninsula Conservation Authority, and the Guelph district Ministry of Natural Resources and Forestry (MNRF). Sources of background information reviewed by Aquafor Beech Limited in the preparation of the NHS include the following:

- City of Hamilton Rural Official Plan (City of Hamilton 2012);
- Guelph District MNRF management biologist (M. Martin);
- Natural Heritage Information Centre (NHIC) database records and mapping of significant species and natural areas;
- Hamilton Natural Areas Inventory (NAI) Project, 3rd Edition (Schwetz 2014); and
- Species accounts and checklists within the 3rd Edition of the Hamilton NAI (Schwetz 2014), including:
    - The Herpetofauna of Hamilton, Ontario (Zammit 2014);
    - The Fishes of Hamilton, Ontario (Coker 2014);
    - The Vascular Plants of Hamilton, Ontario (Goodban 2014);
    - The Vegetation Communities of Hamilton, Ontario (Goodban 2014);
    - The Butterflies of Hamilton, Ontario (Van Ryswyk 2014);
    - The Mammals of Hamilton, Ontario (Schwetz 2014); and
    - The Breeding Birds of Hamilton, Ontario (Smith 2014).

3.3.1 Fieldwork Supporting the Characterization of the Subwatershed

In addition to the use of the background resources listed above, existing conditions in the subwatershed study area were characterized through field investigations.

Table 3.17 details the survey types and associated methodologies and dates for all natural heritage field investigations completed in 2015 and 2016. Further information regarding conditions at the time of each survey are contained within the associated subsections. The locations of all wildlife survey stations are contained in **Appendix F**. Botanical surveys occurred in lands subject to vegetation community classification surveys, the maps for which are contained within **Appendix G**.

A figure illustrating the status of land access permissions is contained within **Appendix H**. Features on lands not accessed during this study were evaluated from adjacent lands, if possible, and through air photo interpretation and background review. As discussed in **Section 5**, lands not accessed as part of this study will need to be assessed at a subsequent planning stage.

Table 3.17: Summary of Ecological Field Surveys

Survey Type (Report Section)	Methodology	Date(s)
Breeding Bird Surveys (**Section 3.3.2.1**)	Breeding birds were surveyed in accordance with the guidelines in the Atlas of the Breeding Birds of Ontario (Cadman et al., 2007).	June 9, June 16 and June 23, 2016.
Reptile Surveys (**Section 3.3.2.2**)	Snakes: active hand searches were completed in accordance with the Guelph district MNRF's Milksnake Survey protocol (2013). Turtles: basking surveys were conducted from the shoreline of open water habitats (i.e.	October 22, 2015; April 21, May 10, June 17, and October 12, 2016
Amphibian Calling Surveys (**Section 3.3.2.3**)	Amphibian calling surveys were conducted at the study site in accordance with the methodology of the Marsh Monitoring Program (BSC, 2003).	April 26, May 25, and June 29, 2016
Salamander Surveys (**Section 3.3.2.4**)	Vernal pools were surveyed using the methods of the Sampling Protocol for Determining the Presence of Jefferson Salamanders in Ontario (JSRC, 2013).	March 14 & 15, 17 &18, 22 & 23, 29 & 30,31 & April 1 2016.
Vegetation Community Classification (**Section 3.3.2.5**)	Vegetation community surveys were completed in accordance with the Ecological Land Classification system for Southern Ontario (Lee et al., 1998).	Sept. 3, October 22 &23, Nov. 3, 2015; May 5, 11 & 12, June 16, 17, 29 & 30, August 5, 11, 16, 29 & 30, September 3, 15, 20 & 21, and October 12 2016.
Botanical Inventories (**Section 3.3.2.6**)	On lands also subject to vegetation community classification, or where surveys could be completed from adjacent lands (i.e. Natural Heritage Area Si5), a three- season botanical inventory was conducted using an area search methodology.	Sept. 3; October 22, 23, & 27; Nov. 3 2015. May 5, 11, & 12; June 16, 17, 29, & 30; August 5, 11, 16, 29 & 30; Sept. 3, 15, 20 & 21 2016
Wetland Evaluations (**Section 3.3.2.7**)	Unevaluated wetlands ≥ 0.5 ha were evaluated in accordance with the Ontario Wetland Evaluation System, Southern Manual, 3rd Edition (MNR, 1993 with subsequent updates).	June 17, August 29 &30, Sept. 15, 20 & 21 2016
Hedgerows (**Section 3.3.2.8**)	N/A	Work was completed by WSP in 2017.
Incidental Wildlife (**Section 3.3.2.9**)	Incidental observations of wildlife were recorded during all other field surveys.	Incidental wildlife observations were recorded during all field surveys; dates as above.

Survey Type (Report Section)	Methodology	Date(s)
Aquatic Communities (**Section 3.3.3.1**)	Watercourses were sampled using a backpack electrofisher, following the Ontario Stream Assessment Protocol (Stanfield, 2013).	May 24, 27 & 30 2016
Benthic Invertebrates (**Section 3.3.3.3**)	Benthic macroinvertebrates were collected using the traveling kick-and-sweep method in accordance with the Ontario Stream Assessment Protocol (Stanfield, 2013).	May 24, 27 & 30 2016

3.3.2 Terrestrial Resources

The following subsections detail the terrestrial natural heritage features present within and adjacent to the study area.

To allow for easy reference to terrestrial natural heritage features throughout this report, Aquafor Beech Limited has classified patches of terrestrial natural heritage features into *Natural Heritage Areas* (NHAs) in accordance with the subwatershed in which they are located (i.e. “Si” denotes an NHA in Sinkhole Creek, “St” denotes an NHA in Stoney Creek, etc.). The number assigned to each NHA is arbitrary and does not indicate significance. The minimum patch size for a NHA is 0.5 ha. A total of eleven (11) NHAs were identified within the study area. They are named as follows:

- Sinkhole 1 (Si1)
- Sinkhole 2 (Si2)
- Sinkhole 4 (Si4)
- Sinkhole 5 (Si5)
- Sinkhole 6 (Si6)
- Sinkhole 7 (Si7)
- Stoney 1 (St1)
- Twenty Mile 1 (Tw1)
- Twenty Mile 2 (Tw2)
- Twenty Mile 3 (Tw3)
- Twenty Mile 4 (Tw4)

An additional six (6) NHAs were identified on lands adjacent to the study area:

- Sinkhole 3 (Si3)
- Sinkhole 8 (Si8)
- Stoney 2 (St2)
- Stoney 3 (St3)
- Stoney 4 (St4)
- Twenty Mile 5 (Tw5)

All seventeen (17) NHAs are illustrated below in **Figure 3.40.** Of these, Aquafor Beech Limited was granted land access to all NHAs within the study area except for Si5, Tw2, and Tw3. Where possible, surveys were conducted from lands adjacent to these three NHAs (i.e. NHA Si5). NHAs outside of the study area were not surveyed and are classified using available background information. The Hamilton Natural Areas Inventory (NAI) (Schwetz et al., 2014) and Niagara NAI (Lindbald, 2010) surveys did not cover lands within or adjacent (i.e. within 120 m) to the study area.

Elfrida Subwatershed Study

Legend

- Study Area
- Natural Heritage Areas
- Watercourse

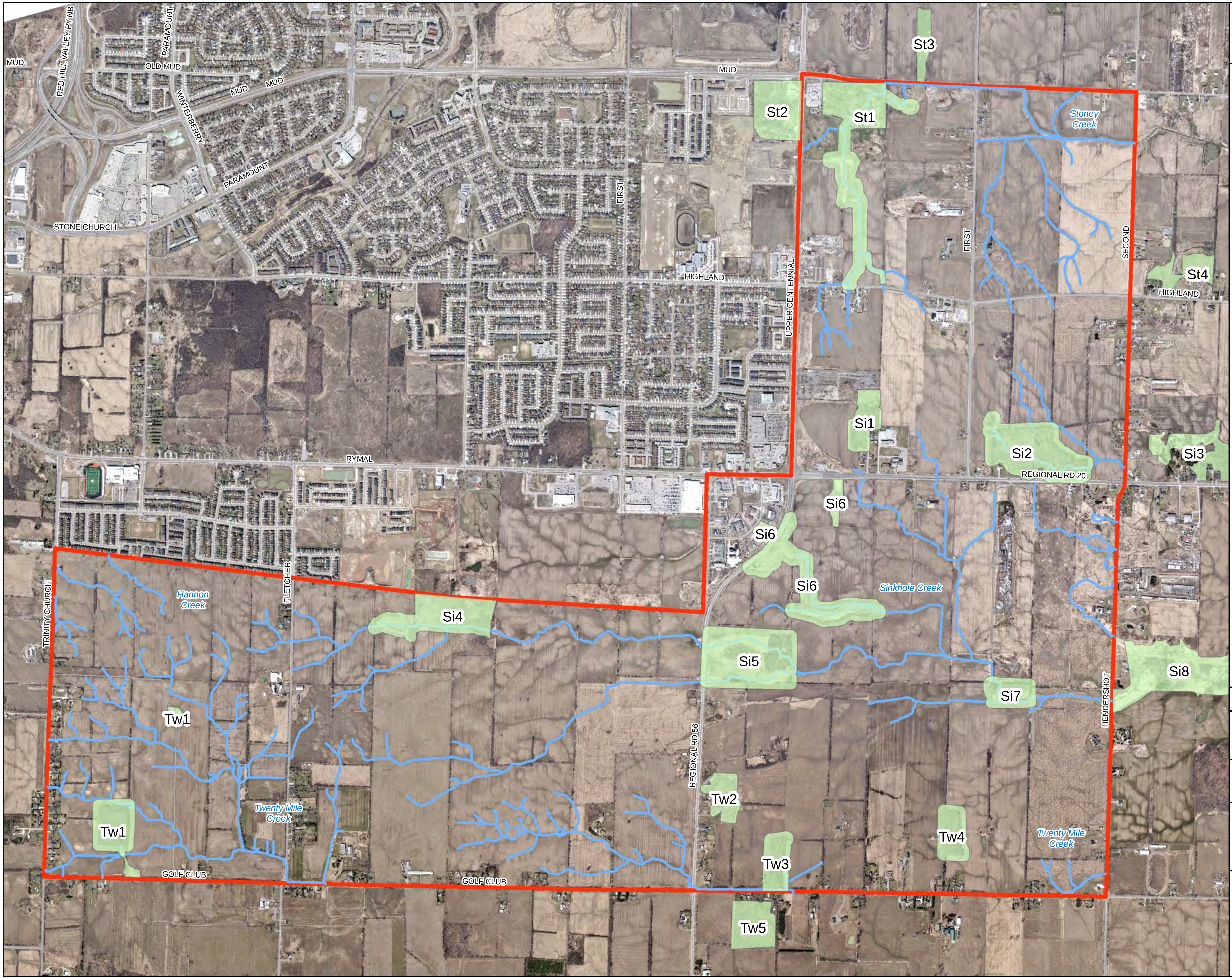


Figure 3.40

Natural Heritage Areas

Date: February 2017
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

3.3.2.1 Breeding Bird Surveys

As detailed above, breeding bird point count surveys followed the Ontario Breeding Bird Atlas protocol (Cadman et al., 2007); surveys were completed during appropriate weather conditions, and started approximately a half an hour before sunrise and were completed by midday. Two visits within the first survey period were completed; the surveyor needed two days' time to visit sites within the study area which could prove suitable for point count surveys (June 9th & 16th). The surveyor was then able to visit all relevant survey sites in one day during the second survey period (June 23rd). A total of 33 bird species were recorded during breeding bird field surveys. Of the species observed, 32 exhibited signs of breeding; such as males singing, agitated behavior or defending nests, and the presence of fledged young. A comprehensive bird species list, including field observations, is included in **Table 3.18**, below.

The most abundant species observed during breeding bird surveys included American tree swallow (*Spizella arborea*), common grackle (*Quiscalus quiscula*) and red-winged blackbird (*Agelaius phoeniceus*). Only one species is considered to be Uncommon in the Hamilton Area: a single singing male vesper sparrow (*Pooecetes gramineus*) was identified during the breeding bird field surveys in the area of First Road East and Highland Road East, west of Survey Point #4. This species favours short grass habitat within well-drained fields.

One species-at-risk, Eastern wood-pewee (*Contopus virens*), was recorded at Survey Point #8 (NHA St1) during breeding bird surveys and again in the same location during other natural heritage investigations. Accordingly, its breeding status is listed as 'probable'. Eastern wood-pewee is Threatened nationally and is listed as Special Concern in Ontario. Discussion relating to this and other species-at-risk can be found in **Section 3.3.4**. Vesper sparrow, an uncommon species, was recorded singing in the agricultural field between Survey Points 1 and 4.

Table 3.18: Breeding Bird Survey Results

Species		Status									Highest Breeding Evidence[9]	Breeding Status[9]	Highest Abundance	Point Count Locations*
Common Name	Scientific Name	G RANK[1]	S RANK[2]	COSEWIC[3]	COSSARO[4]	SARA Status[5]	Hamilton Region Significance[6]	Area Sensitive[7]	Habitat Use[8]	NHIC Tracked				
American Crow	*Corvus brachyrhnchos*	G5	S5B						E	N	S/H	POSS	5	1, 2, 5, 9
American Goldfinch	*Spinus tristis*	G5	S5B						E	N	S/H	POSS	6	1, 2, 3, 7, 8, 9
American Robin	*Turdus migratorius*	G5	S5B						E	N	S/H	POSS	7	1, 2, 3, 4, 6, 9
Baltimore Oriole	*Icterus galbula*	G5	S5B						I/E	N	S/H	POSS	1	3
Black-capped Chickadee	*Poecile atricapillus*	G5	S5B						I/E	N	S/H	POSS	1	2
Blue Jay	*Cyanocitta cristata*	G5	S5B						I/E	N	S/H	POSS	1	2
Brown-headed Cowbird	*Molothurs ater*	G5	S5B						E	N	S/H	POSS	1	4
Cedar Waxwing	*Bombycilla cedrorum*	G5	S5B						E	N	S/H	POSS	2	1, 7
Chipping Sparrow	*Spizella passerina*	G5	S5B						E	N	S/H	POSS	3	2, 3, 4
Common Grackle	*Quiscalus quiscula*	G5	S5B						E	N	S/H	POSS	9	3, 7, 8
Common Yellowthroat	*Geothlypis trichas*	G5	S5B						I/E	N	S/H	POSS	2	3, 4
Eastern Wood-Pewee	*Contopus virens*	G5	S5B	THR	SC				I/E	N	S/H	PROB	1	8
European Starling	*Sturnus vulgaris*	G5	SE						E	N	S/H	POSS	4	1, 3
Gray Catbird	*Dumetella carolinensis*	G5	S5B						E	N	S/H	POSS	2	1, 2
House Sparrow	*Passer domesticus*	G5	SE						E	N	NY	CONF	6	1, 3, 6, 8
House Wren	*Troglodytes aedon*	G5	S5B						I/E	N	S/H	POSS	2	1, 3
Killdeer	*Charadrius vociferus*	G5	S5B						E	N	A	PROB	2	3, 8
Mourning Dove	*Zenaida macroura*	G5	S5B						E	N	S/H	POSS	3	6, 8, 9
Northern Cardinal	*Cardinalis cardinalis*	G5	S5B						I/E	N	S/H	POSS	4	2, 4, 5, 7
Northern Flicker	*Colaptes auratus*	G5	S5B						I/E	N	S/H	POSS	1	2
Red-eyed Vireo	*Vireo olivaceus*	G5	S5B						I/E	N	S/H	POSS	1	8
Red-tailed Hawk	*Buteo jamaicensis*	G5	S5B	NAR					I/E	N	FY	CONF	3	3
Red-winged Blackbird	*Agelaius phoneniceus*	G5	S5B						E	N	S/H	POSS	8	1, 2, 3, 4, 5, 7, 8
Ring-billed Gull	*Larus delawarensis*	G5	S5B						M/F	N	X	OBS	4	4, 8
Savannah Sparrow	*Passerculus sandwichensis*	G5	S5B						E	N	S/H	POSS	2	3, 8
Song Sparrow	*Melospiza melodia*	G5	S5B						E	N	S/H	POSS	4	1, 4, 5, 7
Spotted Sandpiper	*Actitis macularius*	G5	S5B						M/F	N	S/H	POSS	1	8
Tree Swallow	*Tachycineta bicolor*	G5	S5B						M/F	N	NY	CONF	21	2, 3, 8
Vesper Sparrow	*Pooecetes gramineus*	G5	S5B				Uncommon		E	N	S/H	POSS	1	4
Warbling Vireo	*Vireo gilvus*	G5	S5B						I/E	N	S/H	POSS	1	8
Wild Turkey	*Meleagris gallopavo*	G5	S5B						I/E	N	S/H	POSS	1	2
Willow Flycatcher	*Empidonax traillii*	G5	S5B						M/F	N	S/H	POSS	3	2, 5, 8
Yellow Warbler	*Dendroica petechia*	G5	S5B						E	N	S/H	POSS	4	1, 2, 8

***Point count locations (PCL) that correspond to Natural Heritage Areas (NHAs) are as follows: PCL 1=NHA Si1, PCL 2=NHA Si2, PCL 3 = NHA Tw4, PCL 5=NHA Tw1, PCL 8=NHA St1, PCL 9=NHA Si5.**

Glossary of Terms and References:

[1]**G-Rank (global)**
Global ranks are assigned by a consensus of the network of Conservation Data Centres (CDCs), scientific experts, and the Nature Conservancy to designate a rarity rank based on the range-wide status of a species, subspecies, or variety.
G1 Extremely rare - usually 5 or fewer occurrences in the overall range or very few remaining individuals; or because of some factor(s) making it especially vulnerable to extinction.
G2 Very rare - usually between 5 and 20 occurrences in the overall range or with many individuals in fewer occurrences; or because of some factor(s) making it vulnerable to extinction.
G3 Rare to uncommon - usually between 20 and 100 occurrences; may have fewer occurrences, but with a large number of individuals in some populations; may be susceptible to large-scale disturbances.
G4 Common - usually more than 100 occurrences; usually not susceptible to immediate threats.
G5 Very common - demonstrably secure under present conditions.

[2]**S-Ranks (provincial)**
Provincial (or Subnational) ranks are used by the Natural Heritage Information Centre (NHIC) to set protection priorities for rare species and natural communities. These ranks are not legal designations. Provincial ranks are assigned in a manner similar to that described for global ranks but consider only those factors within the political boundaries of Ontario.
S1 Critically Imperiled - Critically imperiled in the nation or state/province because of extreme rarity (often 5 or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the state/province.
S2 Imperiled - Imperiled in the nation or state/province because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the nation or state/province.
S3 Vulnerable - Vulnerable in the nation or state/province due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation.
S4 Apparently Secure - Uncommon but not rare; some cause for long-term concern due to declines or other factors.
S5 Secure - Common, widespread, and abundant in the nation or state/province.
S#S# Range Rank - A numeric range rank (e.g., S2S3) is used to indicate any range of uncertainty about the status of the species or community. Ranges cannot skip more than one rank (e.g., SU is used rather than S1S4).
SAN Non-breeding accidental.
SE Exotic - not believed to be a native component of Ontario's fauna.
SZN Non-breeding migrants/vagrants.
SZB Breeding migrants/vagrants.

[3]**COSEWIC (Committee on the Status of Endangered Wildlife in Canada)**
(federal status from COSEWIC May 2011)
EXT Extinct - A species that no longer exists.
EXP Extirpated - A species no longer existing in the wild in Canada but occurring elsewhere.
END Endangered - A species facing imminent extirpation or extinction.
THR Threatened - A species likely to become endangered if limiting factors are not reversed.
SC Special Concern (formerly vulnerable) - A species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
NAR Not At Risk - A species that has been evaluated and found to be not at risk of extinction given the current circumstances.
DD Data Deficient (formerly Indeterminate) - Available information is insufficient to resolve a species' eligibility for assessment or to permit an assessment of the species' risk of extinction.

[4]**OMNR (Ontario Ministry of Natural Resources)**
(provincial status from MNR June 8 2011)
The provincial review process is implemented by the MNR's Committee on the Status of Species at Risk in Ontario (COSSARO).
EXT Extinct - A species that no longer exists anywhere.
EXP Extirpated - A species that no longer exists in the wild in Ontario but still occurs elsewhere.
END Endangered - A species facing imminent extinction or extirpation in Ontario which is a candidate for regulation under Ontario's Endangered Species Act (ESA) (END-R designations are no longer relevant as species are covered under new ESA April 2009)
THR Threatened - A species that is at risk of becoming endangered in Ontario if limiting factors are not reversed.
SC Special Concern (formerly Vulnerable) - A species with characteristics that make it sensitive to human activities or natural events.
NAR Not at Risk - A species that has been evaluated and found to be not at risk.
DD Data Deficient (formerly Indeterminate) - A species for which there is insufficient information for a provincial status recommendation.

[5]**SARA (Species at Risk Act) Status and Schedule**
The Act establishes Schedule 1, as the official list of wildlife species at risk. It classifies those species as being either Extirpated, Endangered, Threatened, or a Special Concern. Once listed, the measures to protect and recover a listed wildlife species are implemented. http://www.sararegistry.gc.ca/sar/listing/listing_e.cfm
EXT Extinct - A wildlife species that no longer exists.
EXP Extirpated - A wildlife species that no longer exists in the wild in Canada but exists elsewhere in the wild.
END Endangered - A wildlife species that is facing imminent extirpation or extinction.
THR Threatened - A wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction.
SC Special Concern - A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Schedule 1: is the official list of species that are classified as extirpated, endangered, threatened, and of special concern.
Schedule 2: species listed in Schedule 2 are species that had been designated as endangered or threatened and have yet to be re-assessed by COSEWIC using revised criteria. Once these species have been re-assessed, they may be considered for

inclusion in Schedule 1.
Schedule 3: species listed in Schedule 3 are species that had been designated as special concern and have yet to be re-assessed by COSEWIC using revised criteria. Once these species have been re-assessed, they may be considered for inclusion in Schedule 1.
The Act establishes Schedule 1 as the official list of wildlife species at risk. However, please note that while Schedule 1 lists species that are extirpated, endangered, threatened and of special concern, the prohibitions do not apply to species of special concern. Species that were designated at risk by COSEWIC prior to October 1999 (Schedule 2 & 3) must be reassessed using revised criteria before they can be considered for addition to Schedule 1 of SARA. After they have been assessed, the Governor in Council may on the recommendation of the Minister, decide on whether or not they should be added to the List of Wildlife Species at Risk.

Government of Canada. Species at Risk Public Registry. Website: [http://www.sararegistry.gc.ca/default_e.cfm]
Glossary: http://www.sararegistry.gc.ca/about/glossary/default_e.cfm#e
Species Index A-Z: http://www.sararegistry.gc.ca/sar/index/default_e.cfm
Species Listing by Schedule: http://www.sararegistry.gc.ca/sar/listing/default_e.cfm

6 **Regional Status- Hamilton Region**
From : Hamilton Natural Areas Inventory (Schwetz, 2014)
A = Abundant, >1000 pair
C = Common, 201-1000 pair
U = Uncommon, 21-200 pair
R= Rare, 1-20 pair
EL = Extralimital, Breeding well outside the recognized breeding range with no evidence that it represents a general expansion of the breeding range and with no expectation that it will reoccur.
I = Interruptive, A species that has adapted to breeding where suitable and sufficient food supply is available. This may include locations outside their normal breeding range.
E = Extirpated, No longer breeding in Hamilton.

7 **MNR Significant Wildlife Habitat Technical Guide Area Sensitive Species**
Area Sensitivity is defined as species requiring large areas of suitable habitat in order to sustain population numbers.
From: Ministry of Natural Resources. 2000. Significant Wildlife Habitat Technical Guide – Appendix G. Fish and Wildlife Branch, Wildlife Section. Science Development and Transfer Branch, Southcentral Science Section. 151pp. + appendices.

8 **Habitat Use**
I=interior species, I/E=interior edge species, E=edge species (Freemark and Collins, 1989); M/F=Marsh/Fen, S/B=Treed Swamp/Bog.

9 **Ontario Breeding Bird Atlas - Breeding Evidence Codes**
OBSERVED
X Species observed in its breeding season (no breeding evidence).
POSSIBLE
H Species observed in its breeding season in suitable nesting habitat.
S Singing male(s) present, or breeding calls heard, in suitable nesting habitat in breeding season.
PROBABLE
P Pair observed in suitable nesting habitat in nesting season.
T Permanent territory presumed through registration of territorial behavior (song, etc.) on at least two days, a week or more apart, at the same place.
D Courtship or display, including interaction between a male and a female or two males, including courtship feeding or copulation.
V Visiting probable nest site
A Agitated behavior or anxiety calls of an adult.
B Brood Patch on adult female or cloacal protuberance on adult male.
N Nest-building or excavation of nest hole.
CONFIRMED
DD Distraction display or injury feigning.
NU Used nest or egg shells found (occupied or laid within the period of the survey).
FY Recently fledged young (nidicolous species) or downy young (nidifugous species), including incapable of sustained flight.
AE Adult leaving or entering nest
FS Adult carrying fecal sac.

3.3.2.2 Reptile Surveys

As outlined above, surveys were conducted for snakes and turtles. Snake active hand search survey routes and turtle basking survey locations are illustrated in **Appendix F**.

Figure 3.41: Eastern gartersnake observed along the eastern edge of NHA Si5

One (1) reptile species was observed during reptile surveys (**Figure 3.41**). Eastern gartersnake (*Thamnophis sirtalis sirtalis*) is common and widespread in Ontario, with global and subnational ranks of G5 and S5, respectively; and is not considered at-risk at a national or provincial level. This species was found along reptile survey routes 5 (NHA Si5), 10 (NHA Si2), and 11 (NHA Si1); with the highest abundance of observations being made along the eastern edge of reptile survey route 5 in October 2015.

Potential snake habitat was located along reptile survey route 6, within a pile of rubble, gravel, and soil on a property that previously contained a century farmstead. For further information on this area, see section on "*Reptile Hibernaculum*" and **Figure I1** in **Appendix I**.

Despite numerous attempts, turtles were not observed within the study area. Potentially suitable foraging and basking habitat are located within NHA St1, which is primarily comprised of a former golf course having a network of permanent online ponds with soft- substrate bottoms (**Figure 3.42**). Potentially suitable nesting sites within the study area consist of road sides; no evidence of turtle nesting was observed.

Figure 3.42: Turtle Survey Station 3 - One of Several Permanent Ponds in NHA St1

3.3.2.3 Anuran Calling Surveys

Aquafor Beech Limited selected 34 monitoring locations for anuran call surveys (station #16 was removed from the monitoring program due to land accessibility challenges). Monitoring was conducted using the methods of the Marsh Monitoring Protocol (MMP) (Environment Canada, 2003). Three calling surveys were undertaken at all stations. Date selection and methodology followed the MMP.

Night time air temperatures did not exceed 5˚C for the first visit, 10˚C for the second visit, or 17˚C for the third visit, while survey dates were separated by at least 15 days. Surveys were conducted on still nights, typically during or immediately after rain. Parameters recorded during each survey include date, time, air temperature, wind speed, the degree of cloud cover, and level of precipitation.

At each call survey station, the intensity and number of calling amphibians were measured and recorded using call level and abundance codes, as outlined in the MMP. Codes are as follows:

Level 1: Calls are not simultaneous and calling individuals can be counted;
Level 2: Some calls are simultaneous but individual calls are distinguishable; and
Level 3: Calls are continuous and overlapping, individuals cannot be distinguished.

A total of 34 anuran (i.e. frogs and toads) calling survey stations were surveyed in 2016. A total of six (6) species were recorded during surveys, with the most commonly encountered species being western chorus frog (*Pseudacris triseriata*, Carolinian population). The site conditions and results of the anuran calling surveys are contained in **Table 3.19** and **Table 3.20**, respectively. An annotated species list of amphibians recorded during calling surveys is contained within **Table 3.21**. Anuran survey locations are illustrated in **Appendix F**.

Table 3.19: Conditions During Anuran Calling Surveys

Survey Station	Date (2016)	Time (24hr)	Beaufort Wind Scale	Cloud Cover (10ths)	Air Temp (°C)	Precip.
1	April 27	22:46	1	3	5.5	None
	May 25	23:20	1	4	22	Damp
	June 29	22:10	2	0	17	None
2	April 27	23:27	1	3	6	None
	May 25	23:35	1	4	22	Damp
	June 29	21:51	1	0	18	None
3	April 27	22:58	1	3	6	None
	May 25	23:32	1	5	20	None
	June 29	22:00	2	0	18	None
4	April 27	22:51	1	3	6	None
	May 25	23:29	1	4	22	Damp
	June 29	22:15	2	0	17	None
5	April 27	22:46	1	3	6	None
	May 25	23:03	1	4	23	Damp

Survey Station	Date (2016)	Time (24hr)	Beaufort Wind Scale	Cloud Cover (10^{ths})	Air Temp (°C)	Precip.
	June 29	22:22	2	0	17	None
6	April 27	22:41	1	3	5.5	None
	May 25	23:48	1	4	22	Damp
	June 29	22:30	2	0	17	None
7	April 27	23:16	1	4	5.5	None
	May 25	00:02	1	4	22	None
	June 29	22:37	2	0	17	None
8	April 27	23:22	2	4	5.5	None
	May 25	00:10	1	4	22	Damp
	June 29	22:45	1	0	18	None
9	April 27	23:29	2	4	6	None
	May 25	00:17	1	4	22	Damp
	June 29	22:53	1	0	18	None
10	April 27	22:26	2	3	6	None
	May 25	22:45	1	3	23	Damp
	June 29	23:29	1	0	18	None
11	April 27	22:50	1	2	6	None
	May 25	23:14	1	3	22	Damp
	June 29	23:00	1	0	18	None
12	April 27	22:33	2	4	5.5	None
	May 25	23:20	1	3	24	None
	June 29	23:07	1	0	18	None
13	April 27	23:07	1	3	5.5	None
	May 25	23:55	1	4	22	Damp
	June 29	23:15	1	0	17	None
14	April 27	23:11	1	3	5.5	None
	May 25	23:58	1	4	22	Damp
	June 29	23:20	1	1	16.5	None
15	April 27	23:18	1	3	5	None
	May 25	22:25	1	3	21	Damp
	June 29	23:10	1	0	18	None
17	April 27	23:49	1	5	5	None
	May 25	00:04	1	3.5	18	Damp
	June 29	01:04	1	0	18	None
18	April 27	23:45	1	5	5	None
	May 25	00:00	1	3.5	18	Damp
	June 29	01:00	1	0	18	None
19	April 27	23:40	1	5	5	None
	May 25	23:56	1	3.5	19	Damp
	June 29	00:56	1	0	18	None
20	April 27	23:41	1	5	5	None
	May 25	23:52	1	3.5	19	Damp
	June 29	00:52	1	0	18	None
21	April 27	23:36	1	5	5	None

Survey Station	Date (2016)	Time (24hr)	Beaufort Wind Scale	Cloud Cover (10ths)	Air Temp (°C)	Precip.
	May 25	23:48	1	3.5	18	Damp
	June 29	00:48	1	0	18	None
22	April 27	23:32	1	5	5	None
	May 25	23:43	1	3.5	18	Damp
	June 29	00:39	1	0	18	None
23	April 27	23:26	1	5	5	None
	May 25	21:49	1	3	24	None
	June 29	20:26	1	0	18	None
24	April 27	23:20	1	5	5	None
	May 25	21:56	1	3	26	None
	June 29	22:23	1	0	18	None
25	April 27	22:03	1	5	6	None
	May 25	22:12	0	3.5	26	None
	June 29	00:44	1	0	18	None
26	April 27	23:18	1	5	5	None
	May 25	23:29	1	3.5	18	Damp
	June 29	00:28	1	0	18	None
27	April 27	23:22	1	5	5	None
	May 25	23:33	1	3.5	18	Damp
	June 29	00:31	1	0	18	None
28	April 27	23:13	1	5	5	None
	May 25	23:38	1	3.5	18	Damp
	June 29	00:35	1	0	18	None
29	April 27	23:08	1	5	5	None
	May 25	23:23	1	3.5	18	Damp
	June 29	00:24	1	0	18	None
30	April 27	23:03	1	5	5	None
	May 25	23:19	1	3.5	18	Damp
	June 29	00:00	1	0	18	None
31	April 27	22:58	1	5	5	None
	May 25	23:14	1	3.5	19	Damp
	June 29	23:55	1	0	18	None
32	April 27	22:53	1	5	5	None
	May 25	23:10	1	3.5	19	Damp
	June 29	23:49	1	0	18	None
33	April 27	22:49	1	5	5	None
	May 25	23:06	1	3.5	20	Damp
	June 29	23:45	1	0	18	None
34	April 27	21:05	1	5	7	None
	May 25	21:30	0	3.5	26	None
	June 29	21:08	3	0	18	None
35	April 27	22:39	1	5	7	None
	May 25	21:23	0	3	26	None
	June 29	22:00	3	0	18	None

Table 3.20: Anuran Calling Survey Results

Survey Station	Date	Species Detected	Call Code	Number of Anurans Calling
1	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	No amphibians calling	N/A	N/A
2	April 27, 2016	Chorus Frog	1	2
	May 25, 2016	Spring Peeper	1	3
	June 29, 2016	No amphibians calling	N/A	N/A
3	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	No amphibians calling	N/A	N/A
4	April 27, 2016	Unable to survey – no access	N/A	N/A
	May 25, 2016	Northern Leopard Frog	1	1
	June 29, 2016	No amphibians calling	N/A	N/A
5	April 27, 2016	Chorus Frog	1	3
	May 25, 2016	Northern Leopard Frog	1	1
	June 29, 2016	No amphibians calling	N/A	N/A
6	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	No amphibians calling	N/A	N/A
7	April 27, 2016	Chorus Frog	2	2
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	No amphibians calling	N/A	N/A
8	April 27, 2016	Chorus Frog	2	2
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	American Toad	1	1
9	April 27, 2016	Unable to survey - Construction	N/A	N/A
	May 25, 2016	Green Frog	1	1
	June 29, 2016	No amphibians calling	N/A	N/A
10	April 27, 2016	Spring Peeper	2	3
	April 27, 2016	Chorus Frog	3	Full Chorus
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	Gray Treefrog	1	1
11	April 27, 2016	Chorus Frog	1	2
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	No amphibians calling	N/A	N/A
12	April 27, 2016	Unable to survey - Construction	N/A	N/A
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	No amphibians calling	N/A	N/A
13	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	No amphibians calling	N/A	N/A

Survey Station	Date	Species Detected	Call Code	Number of Anurans Calling
14	April 27, 2016	Spring Peeper	1	1
	May 25, 2016	Spring Peeper	1	2
	June 29, 2016	No amphibians calling	N/A	N/A
15	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	Spring Peeper	1	1
	June 29, 2016	No amphibians calling	N/A	N/A
17	April 27, 2016	Northern Leopard Frog	1	1
	April 27, 2016	Chorus Frog	3	Full Chorus
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	No amphibians calling	N/A	N/A
18	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	No amphibians calling	N/A	N/A
19	April 27, 2016	Chorus Frog	3	Full Chorus
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	No amphibians calling	N/A	N/A
20	April 27, 2016	Chorus Frog	1	1
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	No amphibians calling	N/A	N/A
21	April 27, 2016	Spring Peeper	1	1
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	Green Frog	1	2
22	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	No amphibians calling	N/A	N/A
23	April 27, 2016	Chorus Frog	2	3
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	Green Frog	1	2
24	April 27, 2016	Chorus Frog	1	3
	May 25, 2016	Spring Peeper	1	1
	June 29, 2016	No amphibians calling	N/A	N/A
25	April 27, 2016	Spring Peeper	1	1
	April 27, 2016	Chorus Frog	1	2
	May 25, 2016	Green Frog	1	1
	May 25, 2016	Spring Peeper	1	1
	June 29, 2016	Green Frog	1	1
26	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	Green Frog	1	3
	June 29, 2016	No amphibians calling	N/A	N/A
27	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	Spring Peeper	1	1
	June 29, 2016	No amphibians calling	N/A	N/A
28	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	Green Frog	1	3

Survey Station	Date	Species Detected	Call Code	Number of Anurans Calling
	June 29, 2016	No amphibians calling	N/A	N/A
29	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	Green Frog	1	2
30	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	American Toad	1	1
	June 29, 2016	No amphibians calling	N/A	N/A
31	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	Green Frog	1	4
32	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	No amphibians calling	N/A	N/A
3	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	No amphibians calling	N/A	N/A
34	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	Green Frog	1	4
35	April 27, 2016	No amphibians calling	N/A	N/A
	May 25, 2016	No amphibians calling	N/A	N/A
	June 29, 2016	Green Frog	2	5

Table 3.21: Anurans Recorded During Calling Surveys

Species		COSEWIC	COSSARO	G Rank	S Rank	Hamilton Status	Survey Station(s)
Scientific name	Common name						
Anaxyrus americanus	American toad	-	-	G5	S5	Abundant	8 & 30.
Pseudacris triseriata (Carolinian Pop.)	Chorus Frog	NAR	NAR	G5	S4	Common	2, 5, 7, 8, 10, 11, 17, 19, 20, 23, 24, & 25.
Lithobates clamitans	Green Frog	-	-	G5	S5	Abundant	9, 21, 25, 26, 28, 29, 31, 34 & 35.
Hyla versicolor	Grey Treefrog	-	-	G5	S5	Abundant	10.
Lithobates pipiens	Northern Leopard Frog	NAR	NAR	G5	S5	Abundant	4, 5, & 17.
Pseudacris crucifer	Spring Peeper	-	-	G5	S5	Abundant	2, 10, 14, 15, 21, 24, 25 & 27.

On the first night of amphibian surveys, the most abundant species recorded was chorus frog. Full choruses were heard at sites 10, 17, and 19. Individual chorus frog calls could be heard at survey stations 2, 5, 7, 8, 11, 20, 21, 23, 24 and 25. Chorus frogs were heard at 13 stations, spring peepers (*Pseudacris crucifer*) were heard individually at four (4) stations, and northern leopard frogs (*Lithobates pipiens*) were only heard at station 17. Three (3) of the survey sites (9%) could not be monitored due to construction barriers that made surveying unsafe, or access to the site was not available on April 27, 2016. Seventeen (17) of the survey stations had no amphibian calls (50%), including all sites along Mud St E (sites 29-35) and Highland Rd E (sites 26-28). In total, three (3) species of frogs were recorded during the first night of amphibian surveys from fourteen (14) stations, representing 41% of the survey stations.

The second night of amphibian surveys occurred on May 25, 2016. This was the warmest night during amphibian surveys, with temperatures ranging from 18°C to 26°C throughout the time of the survey. Four (4) species were recorded: Green frog (*Lithobates clamitans*), northern leopard frog, spring peeper, and American toad (*Anaxyrus americanus*). Nine (9) spring peepers and green frogs were recorded, at six (6) and five (5) stations respectively. Two (2) northern leopard frogs were recorded at as many numbers of sites, and one (1) American toad was recorded at site 30. In total, amphibian calls were recorded at twelve (12) sites, representing 35% of the survey sites. Twenty-two (22) sites had no amphibians calling (65%).

During the final night of amphibian surveys on June 29, 2016, three species were recorded throughout the study area: Green frog, gray treefrog (*Hyla versicolor*), and American toad. Green frogs were the most abundant, with a total of 20 individual having been heard at seven (7) stations. There was one (1) individual gray treefrog and American toad heard at separate stations.

Twenty-five (25) stations representing 74% of survey stations had no amphibian observations, therefore nine (9) stations had amphibian observations, representing 26% of survey stations.

In summary, six (6) species of frogs and toads were recorded in the Elfrida subwatershed during field surveys in the spring of 2016. None of the species are endangered, threatened, S1-S3 ranked, or rare in the City of Hamilton. All species are common in the City of Hamilton. **Table 3.22** illustrates the breakdown of sites to the number of species recorded:

Table 3.22: Anuran Diversity

	Number of Species Recorded					Total
	0	1	2	3	4	
Number of sites	9	16	7	1	1	**34**
Percent (%)	**26**	**47**	**21**	**3**	**3**	**100**

As detailed above in **Table 3.22**, most survey sites had a least one (1) species recorded.

It is worthwhile noting that 2016 was an exceptionally dry year and also one of the hottest on record. Spring, in particular, came earlier than what is typical and was drier than usual due to a low snow pack and low amounts of precipitation. For these reasons, it is likely that the diversity and amount of amphibians recorded in the study area are underestimated.

3.3.2.4 Salamander Surveys

To assess the potential presence of Jefferson Salamander (*Ambystoma jeffersonianum*) and other ambystomatid salamanders, Aquafor Beech Limited completed salamander surveys (i.e. trapping) at seven suitable breeding sites (primarily vernal pools) within the study area (**Figure 3.43**). The survey methodology used was developed in consultation with the MNRF and follows that of the Guelph district MNRF office's 2013 *Sampling Protocol for Determining the Presence of Jefferson Salamanders (Ambystoma jeffersonianum*) *in Ontario*.

In accordance with MNR requirements, Aquafor Beech Limited requested a Wildlife Scientific Collector's Authorization to complete salamander surveys; Authorization #1082456 was issued on March 18, 2016. Salamander surveys were also authorized under Wildlife Animal Care Committee Protocol Number 16-360 and Permit GU-B-003-16 issued under Section 17(2)(b) of the Endangered Species Act (2007).

Surveys were conducted over five nights during the first spring rains in March and April of 2016.

Table 3.23 provides the dates and times of all salamander surveys. Depending on the size of the pond, between two and three square mesh traps were set in the evening at each site. Aquafor Beech Limited staff ensured that a portion of each trap remained above the waterline, and traps were well-marked with the surveyor's contact information. Traps were checked the following morning and no trap was left in the water for more than 12 hours. Surveyed ponds were given a number from 1-5. Station #2 was removed from the field program after the second round of surveys due to insufficient water depths.

Salamanders were not caught during surveys (**Table 3.24**). Potentially suitable habitat for this taxa is present at Stations 1 (NHA Tw1), 4 (NHA Si1), and 6 (NHA Si2). Stations 2 (NHA Tw1) and 3 (NHA Si1) did not contain sufficient water, and Station 5 (NHA Si2) contained fish. Therefore, these three Stations likely would not support successful salamander breeding.

Table 3.23: Conditions During Salamander Surveys

Station No.	Survey No.	Type	Date	Air Temp. (°C)	Sky Code	Wind Scale	Water Temp. (°C)	Water pH
1	1	Set	03/14/16	14	2	1	10	6
		Check	03/15/16	10	4	1	10	-
	2	Set	03/17/16	10	9	4	9	7
		Check	03/18/16	3.5	2	2	4	6
	3	Set	03/22/16	5	2	1	*	*
		Check	03/23/16	3	5	2	4	6.5
	4	Set	03/24/16	5	0	1	5	7
		Check	03/30/16	2	0	1	1.5	6
	5	Set	03/31/16	4	6	4	10.5	7
		Check	04/01/16	10	1	1	8	7
2 (Removed from program after 2nd survey)	1	Set	03/14/16	11	2	1	10	6
		Check	03/15/16	11	4	1	9	-
	2	Set	03/17/16	10	9	4	11	7
		Check	03/18/16	7	2	2	-	-
	3	Set	03/22/16	5	2	1	7	6
		Check	03/23/16	3	5	2	*	*
	4	Set	03/24/16	5	0	1	*	*
		Check	03/30/16	-	-	-	*	*
3	1	Set	03/14/16	11	2	3	-	-
		Check	03/15/16	11	4	1	9	-
	2	Set	03/17/16	10	9	4	9	6.5
		Check	03/18/16	6	2	2	5.5	6
	3	Set	03/22/16	5	2	1	*	*
		Check	03/23/16	3	5	2	*	*
	4	Set	03/24/16	5	0	1	6	6
		Check	03/30/16	6	1	1	3.5	6
	5	Set	03/31/16	4	6	4	10	7
		Check	04/01/16	10	1	1	9	7
4	1	Set	03/14/16	11	2	2	-	-
		Check	03/15/16	12	4	1	9	-
	2	Set	03/17/16	10	9	4	10	7
		Check	03/18/16	8	2	2	8	7
	3	Set	03/22/16	5	2	1	7	7
		Check	03/23/16	3	5	2	5	7
	4	Set	03/24/16	5	0	1	8	6

Station No.	Survey No.	Type	Date	Air Temp. (°C)	Sky Code	Wind Scale	Water Temp. (°C)	Water pH
		Check	03/30/16	6	1	1	5	6
	5	Set	03/31/16	4	6	4	11	7
		Check	04/01/16	10	1	1	10	6
5	1	Set	03/14/16	11	2	2	9	6
		Check	03/15/16	11	4	1	7	-
	2	Set	03/17/16	10	9	4	9	6.5
		Check	03/18/16	7	2	2	5	7
	3	Set	03/22/16	3	5	2	7	6
		Check	03/23/16	3	5	1	4	7
	4	Set	03/24/16	5	0	1	6	6
		Check	03/30/16	5	0	1	11	7
	5	Set	03/31/16	4	6	4	10	6
		Check	04/01/16	10	1	1	9	7
6	1	Set	03/14/16	11	2	2	12	6
		Check	03/15/16	11	4	1	10	-
	2	Set	03/17/16	10	9	4	14	6
		Check	03/18/16	6	2	2	5	6
	3	Set	03/22/16	3	5	2	7	6
		Check	03/23/16	3	5	2	4	6
	4	Set	03/24/16	5	0	1	7.5	7
		Check	03/30/16	5	0	1	3	6
	5	Set	03/31/16	4	6	4	12	7
		Check	04/01/16	10	1	1	9.5	6

Figure 3.43: Salamander Survey Stations 1,3, 4, 5, and 6

Table 3.24: Salamander Survey Results

Station No.	Survey No.	Results
1	1	-
	2	-
	3	-
	4	-
	5	Chorus Frog adult (1), Snail (1)
2	1	Insufficient water depth.
	2	Insufficient water depth.
	3	Not surveyed. Insufficient water depth.
	4	Not surveyed. Insufficient water depth.
3	1	-
	2	-
	3	Not surveyed. Insufficient water depth.
	4	Water Beetle (1)
	5	-
4	1	-
	2	-
	3	Water Beetle (2)
	4	-
	5	Northern Leopard Frog (2), Water Beetle (1), Water Boatman (1)
5	1	-
	2	Green Frog tadpole (2), Fathead Minnow (3)
	3	Fathead Minnow (5), Green Frog tadpole (1), Central Mudminnow (2)
	4	Central Mudminnow (2), Green Frog Tadpoles (6)
	5	Central Mudminnow (1), Green Frog tadpole (9), Isopod (3), Terrestrial worm (1), Fathead Minnow (7), Megaloptera (1)
6	1	-
	2	Giant Water Beetle (4), Diving Beetle (1), Juv. Water Beetle (1)
	3	-
	4	Water Beetle (1)
	5	Water Beetle (1), Megaloptera (1)

3.3.2.5 Vegetation Community Classification

In 2015 and 2016, Aquafor Beech Limited conducted vegetation community assessments within lands where access was permitted. Survey dates are provided above in **Table 3.17**. Vegetation communities were assessed according to the methodology of Lee et. al (1998). A total of twenty-four (24) vegetation community polygons representing eighteen (18) community types were recorded within the Elfrida subwatershed study area (**Table 3.25**). In cases where the community codes in the 1998 ELC manual fell short of describing vegetation communities, as is often the case with culturally influenced communities, the vegetation community codes within the 2012 version of the ELC manual was used. Vegetation community mapping, descriptions, and field sheets are contained within **Appendix G**.

One (1) vegetation community recorded within the study area is considered rare at a global and provincial level. A remnant Bur Oak Mineral Deciduous Swamp is located within the northeast portion of NHA St1. This vegetation community also contains a locally rare oak species (see **Section 3.3.2.6**, below). All other vegetation communities recorded within the study area are considered common and secure on both a global and provincial level.

Table 3.25: Summary of Vegetation Communities

Natural Heritage Area (NHA)	ELC Polygon	Vegetation Community		Rank	
		ELC Code	Name	Global	Provincial
St1	1	CUS1	Mineral Cultural Savannah	N/A	N/A
	2	WODM5*	Fresh-Moist Deciduous Woodland	N/A	N/A
	3	SWD1-2	Bur Oak Mineral Deciduous Swamp	G2G3Q	S3
	4	SAF1-3 [MAM2]	Duckweed Floating-leaved Shallow Aquatic [complex: Mineral Meadow Marsh]	G5Q	S5
	5	MAM2	Mineral Meadow Marsh	N/A	N/A
	6	SAM1-4	Pondweed Mixed Shallow Aquatic	G5Q	S5
	7	CUM1-1	Dry-Moist Old Field Meadow	N/A	N/A
	8	MAS2-1	Cattail Mineral Shallow Marsh	G5	S5
Si1	1	FOD4-1 (MAM2)	Dry-Fresh Beech Deciduous Forest (inclusion: Mineral Meadow Marsh)	G4G5	S4S5
	2	CUT1	Mineral Cultural Thicket	N/A	N/A
	3	CUM1-1 [MAM2] (MAS2)	Dry-Moist Old Field Meadow [Complex: Mineral Meadow Marsh] (Inclusion: Mineral Shallow Marsh)	N/A	N/A
Si2	1	SWD3-1 [FOD4-1]	Red Maple Mineral Deciduous Swamp [Complex: Dry- Fresh Beech Deciduous Forest]	G4? [G4G5]	S5 [S4S5]
	2	SWT2 (MAM2-2)	Mineral Thicket Swamp (Inclusion: Reed Canary Grass Meadow Marsh	N/A	N/A
	3	FOD4-1	Dry-Fresh Beech Deciduous Forest	G4G5	G4G5
Si5	0	CUM1-1	Dry-Moist Mineral Cultural Meadow	N/A	N/A
	1	CUM1-1 (MAM2)	Dry-Moist Mineral Cultural Meadow (Inclusion: Mineral Meadow Marsh)	N/A	N/A
	2	MAS2-1 [MAM2]	Cattail Mineral Shallow Marsh [Complex: Mineral Meadow Marsh]	G5	S5
Si7	1	SWD2-2	Green Ash Mineral Deciduous Swamp	G?	S5
	2	CUM1-1	Dry-Moist Old Field Meadow	N/A	N/A
	3	MAS2	Mineral Shallow Marsh	N/A	N/A
Tw1	1	SWT2-5	Red-osier Mineral Thicket Swamp	G5	S5

Natural Heritage Area (NHA)	ELC Polygon	Vegetation Community		Rank	
		ELC Code	Name	Global	Provincial
	2	FOD4-1 [FOD9-2]	Dry-Fresh Beech Deciduous Forest [Complex: Fresh-Moist Oak-Maple Deciduous Forest]	G4G5 [G?]	S4S5 [S5]
	3	CUM1-1 (MAM2)	Dry-Moist Old Field Meadow (Inclusion: Mineral Meadow Marsh)	N/A	N/A
	4	CUM1-1	Dry-Moist Old Field Meadow	N/A	N/A
Tw4	1	FOD5-2 (SWD1/SWD3-3)	Dry-Fresh Sugar Maple- Beech Deciduous Forest (Inclusion: Oak Mineral Deciduous Swamp/Swamp Maple Mineral Deciduous Swamp)	G5? (/G4?)	S5 (/S5)

*2012 ELC code was used to describe this vegetation community.

3.3.2.6 Botanical Inventories

A total of 232 species of vascular plants were catalogued during three-season botanical inventories, vegetation community classification surveys, and wetland evaluations within the study area. 210 species were identified to the species level. Of those species inventoried, 179 (77.2%) are native to Ontario and 53 (22.8%) are introduced species. The majority of species inventoried have a high range of habitat tolerances, as evidenced by the high proportion of species with a low coefficient of conservatism (CC) values. Species with narrow habitat tolerances (i.e., with CC values ≥7), of which 17 were recorded, were found primarily within NHAs Si2 and Tw1.

None of the species recorded during surveys are of global, national, or provincial significance. Four (4) species recorded are considered rare in Hamilton according to the Hamilton NAI (Schwetz 2014):

- Low serviceberry (*Amelanchier spicata*), recorded in NHA Tw1;
- Fireberry hawthorn (*Crataegus chrysocarpa*), recorded in NHA Si1;
- Smooth Solomon's seal (*Polygonatum biflorum*), recorded in NHA Si2;
- Schuett's oak (*Quercus bicolor* x *macrocarpa*), located in NHA Tw4; and,
- Tapegrass (*Vallisneria americana*), located in NHS St1.

In addition, a locally rare species, spearscale (*Atriplex patula*), was recorded within NHA Tw1. An annotated list of flora recorded within the study area is contained within **Appendix G**.

3.3.2.7 Wetland Evaluations

Wetlands are highly valuable features on the landscape that provide habitat for wildlife, stormwater attenuation, groundwater recharge, as well as educational and recreational value for humans. The Ontario Ministry of Natural Resources and Forestry is responsible for the evaluation of wetlands in Ontario. Wetlands in the subwatershed study area are regulated by the Niagara Region Conservation Authority under Ontario Regulation 155/06 (Sinkhole Creek and Twenty Mile Creek) or the Hamilton Conservation Authority under Ontario Regulation 161/06 (Hannon Creek and Stoney Creek). The Ontario Wetland Evaluation System (OWES), defines wetlands as:

> Lands that are seasonally or permanently flooded by shallow water as well as lands where the water table is close to the surface; in either case, the presence of abundant water has caused the formation of hydric soils and has favoured the dominance of either hydrophytic or water-tolerant plants. (MNR, 1994)

Wetland complexes are defined as wetlands in the same subwatershed that are within 750 meters of each other and may have similar or complementary biological, social, and/or hydrological functions (MNR, 1994).

According to OWES, wetland evaluations are considered 'open files'; wetland evaluation data is reflective of the site conditions at the time of the evaluation and wetland data can be added to the wetland data record at any time. As such, the wetland d information contained in this study may be subsequently updated as new information becomes available and/or if relevant agencies deem it necessary.

The Ontario Wetland Evaluation System (OWES) provides a standard system of wetland evaluation where results can be reviewed and shared between relevant agencies such as the MNR and Conservation Authorities. OWES divides wetland values into four components: Biological, Social, Hydrological, and Special Features. These four components are further subdivided into subcomponents, attributes, and sub-attributes. Relevant wetland information is ascribed points according to predefined numerical values in the OWES manual. Thus, relevant wetland information is evaluated and scored on a numerical basis, allowing for a final relative score for each of the major components and for a final total score. The maximum number of points a wetland can receive in any one of the four main components is 250, and an individual wetland can score up to 1000 points. An evaluated wetland is considered to be a Provincially Significant Wetland (PSW) if:

1. The wetland achieves a score of 200 points in either the Biological component or the Special Features component, or
2. The wetland achieves a total score of 600 points or more.

The MNRF sets minimum size criteria for wetlands and wetland complexes to be evaluated under OWES. In general, wetlands or wetland complexes smaller than 2 ha in total are not evaluated (MNR, 1994). However, in recognition of the relative rarity of wetlands on the Southern Ontario landscape and the value of smaller wetlands to local wildlife and hydrology, wetlands below the minimum size criteria can be evaluated granted that a rationale is provided by the wetland evaluator or a governing agency (MNR, 1994).

Multiple wetlands are present throughout the study area. Some of these, i.e. the Sinkhole Creek Wetland Complex (NHAs Si7, in part, and Si8) and the Lower Twenty Mile Creek Provincially Significant Wetland (NHAs Si2 and Si3), have already been evaluated. Of those not already evaluated, or those that were partially evaluated (i.e. NHA Si6), Aquafor Beech Limited completed wetland evaluations for wetlands greater or equal to 0.5 ha in size according to the methodology of the Ontario Wetland Evaluation System for Southern Ontario (MNR, 1994). The results of the assessments are summarized in **Table 3.26**, below. Wetland data records are contained in **Appendix L. None of the wetlands evaluated by Aquafor Beech Limited within the Elfrida Subwatershed study area are considered provincially significant.** As such, these evaluated wetlands are considered Locally Significant under the City of Hamilton's OP; wetlands are regulated by the applicable Conservation Authority and are protected under the City of Hamilton's OP.

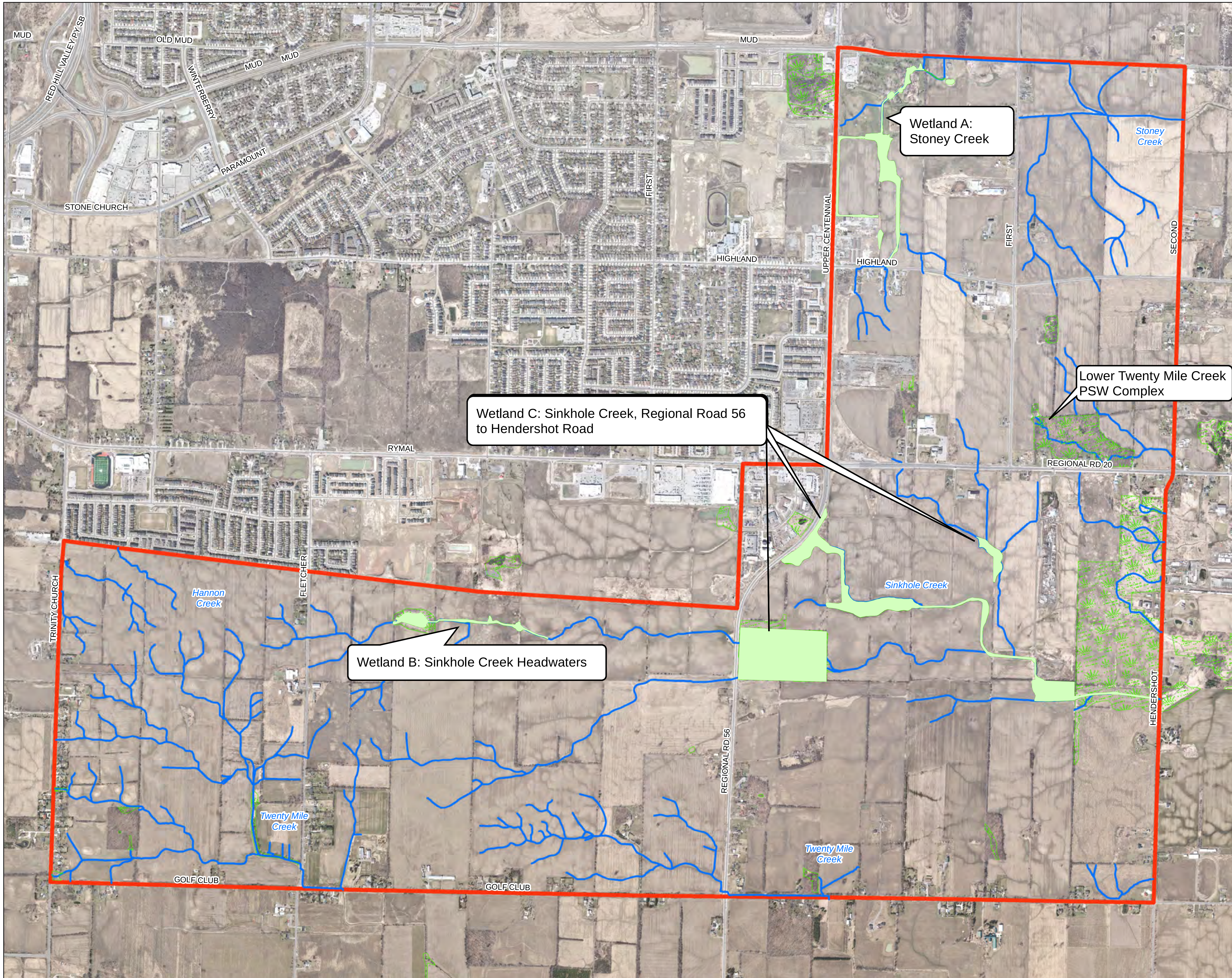
It is important to note that significant portions of the Sinkhole Creek Provincially Significant Wetland (e.g. lands adjacent to Hendershot Road) were converted into agriculture in 2016 (**Figure 3.44**). The revised boundaries of this feature are included in the NHS and associated development limitations mapping within this report.

Figure 3.44: Lands North of the Sinkhole Creek Crossing of Hendershot Road (centre & right), and at the Hendershot Road Crossing (left) have been converted to Agriculture

Wetlands evaluated as part of this study are illustrated in **Figure 3.45.**

Table 3.26: Wetland Evaluation Results

Wetland	Wetland Evaluation Components and Scoring				
	Biological	Social	Hydrologic	Special Features	Total Score
Wetland A (Stoney Creek)	121	52	196	161	***530***
Wetland B (Sinkhole Creek Headwaters)	107	63	189	131	***490***
Wetland C (Sinkhole Creek, RR56 to Hendershot Rd.)	101	66	184	143	***494***



Elfrida Subwatershed Study

Legend

- Study Area
- Watercourse
- Wetlands Evaluated as Part of this Study
- Other Wetlands

Note: Previously unevaluated wetlands >0.5 ha were subject to evaluation as part of this study.

Figure 3.45

Wetlands Evaluated as Part of this Study

Date: October 2017
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

3.3.2.8 Hedgerows

Hedgerows are rows of woody vegetation that separate one piece of (most often agricultural) land from another. These features were often intentionally planted as windbreaks, sound barriers, property markers, etc. or may have grown along fence or property lines that were left unmanaged. Less often, hedgerows are remnants of woodlands that have been cleared. Owing to the open surroundings, some trees within hedgerows have grown to have wide-spreading canopies. As such, specimen trees are often found in hedgerows. In addition, while typically not intended to provide habitat for wildlife, hedgerows can provide food and shelter for wildlife and can function as a corridor between isolated patches of habitat. In general, hedgerow continuity and width are positively correlated with ecologic function. The presence of other habitat features, such as cover objects (e.g. rock piles, boulders, large woody debris) and water, add to a hedgerow's function as direct habitat and as a corridor.

The Elfrida Secondary Plan is being developed concurrent with the Subwatershed Study. Hedgerows subject to an assessment completed in support of the Secondary Plan (WSP, 2018) are illustrated on **Figure 3.47**. As detailed in **Table 3.27**, below, management recommendations were ascribed to each hedgerow based upon an assessment of spatial, aesthetic, and biophysical characteristics. **Please note that the assessment presented below is in draft form; the final Secondary Plan should be consulted for final hedgerow assessment results.**

Hedgerows recommended for retention or enhancement due to their current or potential natural heritage value have, following discussions with the City of Hamilton, been included as linkages within the SWS. These hedgerows include HR5, HR6, and HR13 (pictured in **Figure 3.46**). Hedgerows that have been deemed Feature Areas to be considered for integration based on provision of wildlife habitat (i.e. HR30) have been included in the linkage mapping. Such Feature Area hedgerows are recommended to be retained if possible (e.g. if adjacent land uses such as parklands allow) and, in subsequent Subwatershed Study mapping, are differentiated from linkages that are required to be included in the NHS.

Figure 3.46: Southern end of Hedgerow 13 (photo taken facing south west)

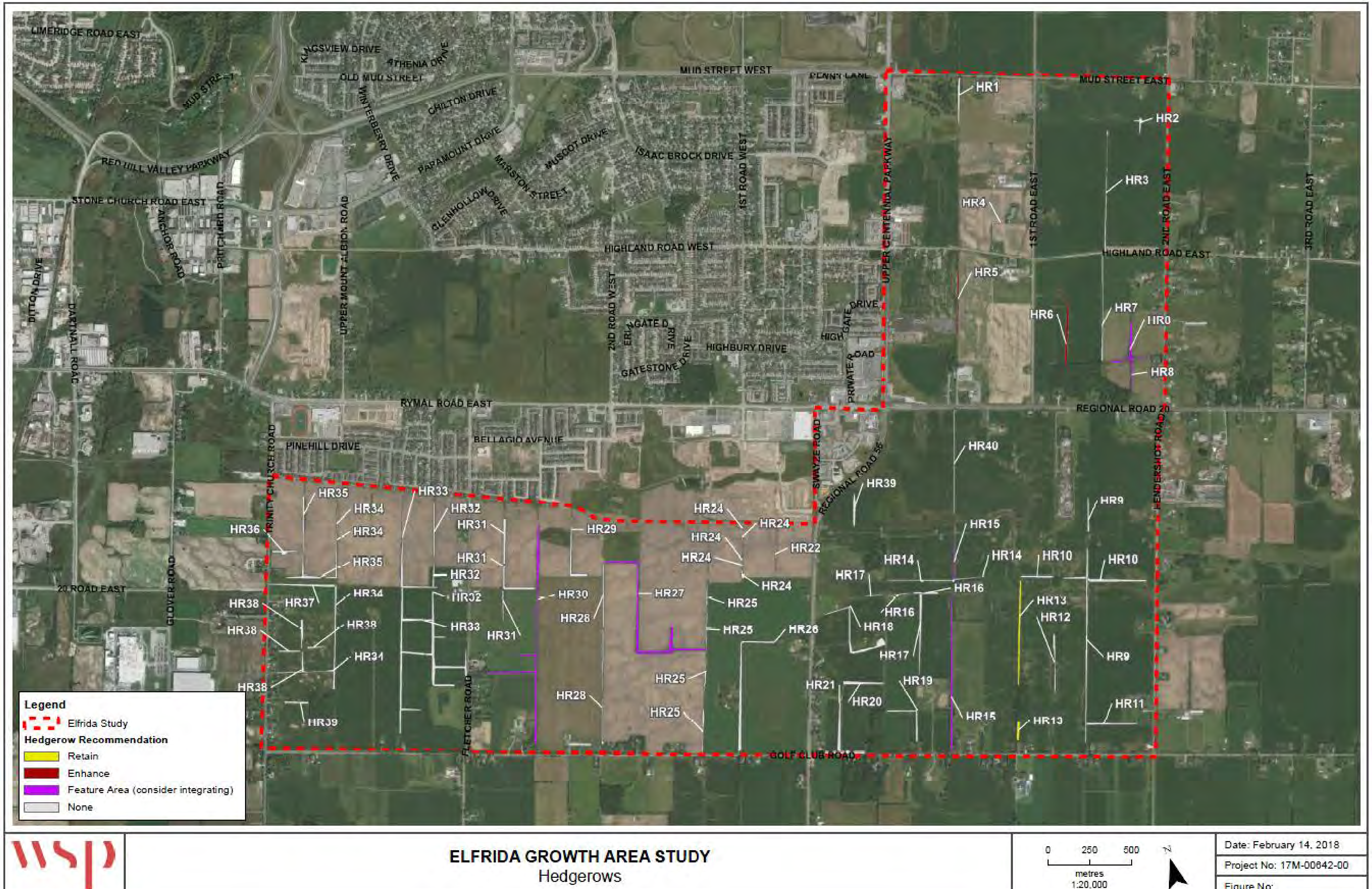


Figure 3.47: Hedgerows assessment completed as part of the Secondary Plan (WSP, 2018)

Table 3.27: Hedgerow Assessment (draft, completed by WSP)

Hedgerow	Dimensions & Continuity	Connectivity/Linkage Potential	Habitat Potential	Vegetative Quality	Aesthetic	Species Ranking	Existence of Specimen Trees	Recommendation
HR1	Low. Within the study area, the hedgerow is narrow, has sparse cover and is discontinuous. North of the study area, the hedgerow shows better continuity.	Moderate. Immediately adjacent to an NHS feature (confirmed SWH), but does not provide connection between NHS features. Has opportunity to connect to Greenbelt NHS north of the study area.	Moderate. Immediately adjacent to NHS feature.	Low. Large number of Ash trees present. Dead Ash and Ash showing dieback are prominent.	Low. Dead Ash and Ash with dieback. Limited other species present.	Low: Mostly Ash, considered low quality because of susceptibility to Emerald Ash Borer. No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	**None.** This hedgerow is not recommended for retention. It does not add significant function or value to the adjacent features and within the study area has limited connectivity. Potential connectivity to the Greenbelt NHS can be achieved without retaining this hedgerow due to the presence of the adjacent NHS feature.
HR2	Low. Small tree grouping, not a continuous hedgerow.	Low. Tree grouping is located along Stoney Creek, but does not connect any NHS features.	Low. Dead / Dying semi-mature to mature ash trees provide little cover for habitat.	Low. Tree grouping appears to primarily consist of dead and dying Ash trees.	Low. Dead and dying Ash.	Low: Mostly Ash, considered low quality because of susceptibility to Emerald Ash Borer.	Low: No specimen trees present	**None.** A portion of this feature may be retained within the buffer to the watercourse. The remainder is not recommended for retention or incorporation.
HR3	Low. Narrow (~4m wide) and discontinuous. Southern portion of hedgerow has shrubs or low quality trees.	Low. Through its connection to HR7 across Highland Road E, this hedgerow provides a long, narrow connection to the NHS. Without habitat nodes, this connection does not provide significant ecological function. Large ~300m gap north of Stoney Creek limits potential connectivity to the north.	Low. Discontinuous shrub and small tree species do not provide significant habitat potential.	Low. Vegetation generally in good health, but of low general quality based on high percentage of shrub / invasive species	Low. No large specimen trees and too narrow to provide significant aesthetic value for retention.	Low. No moderate or high quality species present.	Low: No specimen trees present	**None.** Does not provide direct connectivity between NHS features. Minor connection via HR8 to one NHS feature, but a large ~300m gap to the north does not provide substantial north-south connection beyond the study area. No significant quality, aesthetic, species or specimens present
HR4	Low. The hedgerow is continuous with presence of consistent canopy (trees and shrubs), but narrow (~6m wide). Tree cover is not continuous.	None. This hedgerow appears to have been established for property demarcation and does not connect to any NHS features in a north-south or east-west direction.	Unknown: No access granted for close visual inspection.	Low. Discontinuous tree canopy; no evidence of significant specimen trees. Tree health is variable. Presence of non-native shrubs.	Low. No large specimen trees and shrubs without significant aesthetic value for retention.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	**None.** This is a small, narrow hedgerow that does not provide ecological connectivity or significant aesthetic value to warrant retention.
HR5	Moderate. This hedgerow has a relatively continuous canopy; with larger specimen trees to the south end. It is of narrow to moderate width ranging from ~4m to ~8m.	Moderate. Opportunity to connect NHS features through feature enhancement. Existing connection to SWH (candidate), woodland and wetland to the south and opportunity to connect to features to the north via a *Conservation* HDF.	Moderate. Large semi-mature to mature trees, as well as connection potential provide habitat opportunities.	Moderate. Northern portion has lower vegetative quality with a higher shrub:tree ratio. Southern portion appear to have good vegetative quality / tree health.	Moderate. Some good specimen trees towards south, good canopy and structure. Some enhancement would benefit.	Moderate: Mixture of low ranking (Willow) and high ranking (oak, hickory) species. Overall number of trees is low.	Moderate: One Shagbark Hickory meets criteria for specimen trees.	**Enhance.** Natural Heritage - Secondary. There is some opportunity to develop a north-south corridor that builds upon the hedgerow in this location to connect otherwise relatively isolated NHS features.
HR6	Low. This hedgerow has gaps in the canopy and ranges in width from ~4m to ~8m.	Moderate. This hedgerow connects an otherwise isolated NHS feature (woodland) to a large woodland & wetland feature at its south end. There is no broader connection to the NHS.	Moderate: Semi-mature high ranking tree species offers some habitat potential.	Low. Discontinuous tree canopy.. Tree health is variable.	Low. Limited aesthetic value for retention.	Moderate: Mixture of low ranking (Pear), medium ranking (basswood) and high ranking (oak, hickory) species.	Moderate: Two Shagbark Hickory meet criteria for specimen trees.	**Enhance.** Natural Heritage - Secondary. This hedgerow provides an opportunity to connect two NHS features that are otherwise isolated. Opportunity to strengthen and integrate this connection into land development plans would be beneficial.

Hedgerow	Dimensions & Continuity	Connectivity/Linkage Potential	Habitat Potential	Vegetative Quality	Aesthetic	Species Ranking	Existence of Specimen Trees	Recommendation
HR7	Moderate. Small gaps in the canopy exist and much of the hedgerow appears to be shrubs. The hedgerow is of moderate width ranging between ~6m and ~10m.	Low. Through its connection to HR3 across Highland Road E, this hedgerow provides a long, narrow connection to the NHS. Without habitat nodes, this connection does not provide significant ecological function.	Moderate: Semi-mature high ranking tree species offers some habitat potential.	Moderate. Primarily young-aged trees; some older specimen trees present near south end (Shagbark Hickory). North portion has lower quality vegetation.	Low. Few semi-mature trees at south end have some added aesthetic value, but overall low.	Moderate: Majority of trees present are Apple species. Some high ranking species present (Sugar Maple, Oak, Hickory)	Low: No specimen trees present	**None.** There is not sufficient form or function to recommend for retention.
HR8	Moderate. Portions of the hedgerow are wide (>10m) through the north/south portion of the hedgerow, with good canopy cover. Other portions become sparse and narrow.	None. This hedgerow does not connect NHS features.	Moderate: Semi-mature high ranking tree species offers some habitat potential.	High. The central portion of this hedgerow has high quality vegetation. Good specimen trees in good health. Other portions are of moderate quality.	High. Good tree structure, wide hedgerow provides good aesthetic value to the landscape.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	**Feature Area (consider integrating).** Vegetative Quality and Aesthetic. Opportunity to incorporate all or portions of this feature should be explored. Land area within the hedgerow and adjacent to the NHS may provide an opportunity for park space or other compatible land use that could integrate this feature.
HR9	Low. Narrow to moderate width (~4m-6m) through most of its length; hedgerow is discontinuous with numerous open patches.	Low. Central portion of hedgerow is along the edge of a wetland NHS feature and it crosses the hydro line linkage; however it does not provide connection to any other NHS features and connectivity between the wetland and the hydro linkage can be provided via the watercourse and its associated buffer / set-back.	Moderate: Semi-mature high ranking tree species offers some habitat potential.	Low to Moderate. The northern portion is of low quality. Some trees with good structure are present through the central portion (hickory, oak). Numerous Ash in decline were noted throughout its length.	Low. Ash present throughout in various states of decline. Removal of these trees would be required and remaining specimen trees have relatively low density.	Low: high number of dead/dying Ash reduce ranking despite existence of intermittent high ranking species (hickory, oak)	Moderate: One Burr Oak meets criteria for specimen trees.	**None.** Although there are specimen trees present, there is not sufficient form or function to recommend for retention.
HR10	Low. Narrow width (~4m) through its length. Sparse trees with discontinuous canopy.	Moderate. An east-west connection could be established by connecting this HR10 to HR14, connecting three NHS features. However, east-west connectivity can be achieved along the watercourse and hydro corridor linkage through this area; as such, this hedgerow does not add significant additional value as a stand-alone connection within the NHS.	Low: high numbers of dead/dying Ash trees reduces utility as habitat.	Low: predominantly dead/dying ash.	Low: predominantly dead/dying ash.	Low: Majority of trees are dead / dying Ash. Limited numbers of Black Walnut, and intermittent oak/hickory.	Low: No specimen trees present	**None.** This hedgerow in combination with HR14 could be enhanced to provide an east-west connection to NHS features; however presence of a watercourse (Sinkhole Creek), which runs east-west between these features with its associated buffer will effectively provide a connection. Presence of the east-west linkage associated with the hydro corridor provides another landscape-level movement opportunity.
HR11	Low. Narrow (<4m), continuous hedgerow with and patchy canopy cover.	None. This east-west oriented hedgerow connects to HR9, but does not provide direct connection between NHS features within or beyond the study area.	Low: limited canopy cover and low ranking species offers little habitat potential.	Low. Appears to be predominantly shrubs, including invasive and non-native species.	Low. No large trees.	Unknown: No access granted for close visual inspection.	Low: No specimen trees present	**None.** Low vegetation quality and no ecological connection provided. Not recommended for retention.
HR12	Moderate to High. The southern portion of the hedgerow is narrow; the northern portion is ~10-15m in width. The hedgerow is continuous, but sparse at its south end.	None. The hedgerow extends northerly from a Candidate SWH NHS feature and does not provide connectivity to other features.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	**None.** Potential mature trees may be of value, but retention of the hedgerow through integration in design is not required.

Hedgerow	Dimensions & Continuity	Connectivity/Linkage Potential	Habitat Potential	Vegetative Quality	Aesthetic	Species Ranking	Existence of Specimen Trees	Recommendation
HR13	Low to Moderate. North of the woodlot, the hedgerow is discontinuous and narrow. South of the woodlot, the hedgerow is >10m with a good canopy structure.	Moderate. Hedgerow provides an opportunity to connect the NHS feature (woodland) to the linkage, watercourse and other features to the north. Connectivity however is limited by the length of the connection (~700m) and existing quality of the hedgerow. The Greenbelt NHS is at one of its closest points to the study area in this location; a 500m gap exists without an existing hedgerow.	Unknown: No access granted for close visual inspection.	High (south of woodlot). Good structure young to mid-aged vegetation provided an extension / peninsula to the woodlot. The portion north of the woodlot could not be determined as PTEs were not granted.	Moderate (south of woodlot). Young to mid-aged vegetation has good aesthetic as a group, no specimen trees noted from roadside. North of woodlot, aesthetic value is low.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	**Retain.** Natural Heritage - Primary Vegetative Quality and Aesthetic. Opportunity to incorporate all or portions of the hedgerow extending from the southern end of the woodlot. Opportunity to enhance the hedgerow as a north-south connection with opportunity for long-term connectivity to the Greenbelt NHS for landscape-level connectivity. This connection is poor at this time, however few connections exist to connect the Greenbelt NHS to the NHS within the Elfrida Area.
HR14	Low. Narrow width (~4m) through much of its length. Sparse trees with discontinuous canopy. Small tree groupings are present at intersections (existing or historical) with other hedgerows.	Moderate. An east-west connection could be established by connecting this hedgerow (HR14) to HR10, connecting three NHS features. However, east-west connectivity can be achieved along the watercourse and hydro corridor linkage through this area; as such, this hedgerow does not add significant additional value as a stand-alone connection within the NHS.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	**None.** This hedgerow in combination with HR10 could be enhanced to provide an east-west connection to NHS features; however presence of a watercourse (Sinkhole Creek), which runs east-west between these features with its associated buffer will effectively provide a connection. Presence of the east-west linkage associated with the hydro corridor provides another landscape-level movement opportunity.
HR15	Low to Moderate. Through the northern portion, the hedgerow is discontinuous and narrow. The southern portion is wider with good structure.	Low. Does not directly connect NHS features within Elfrida and length of hedgerow to connect to Greenbelt NHS is prohibitive without nodes / stopover areas.	High. Mature high ranking species exist. Specimen trees provide large continuous canopy for potential habitat.	Moderate (south end). Good quality Sugar Maple and Oak present in the south with young successional development evident.	Moderate (south end). Young, semi mature and mature vegetation has good aesthetic near the south with some specimen trees present.	High: Numerous oak and shagbark hickory present.	High: More than five trees meet criteria for specimen trees.	**Feature Area (Consider Integrating).** Vegetative Quality and Aesthetic. Opportunities to retain all, or portions of the hedgerow including individual specimen trees can be considered through site-level planning, as appropriate.
HR16	Low. Discontinuous with several breaks >30m. Most eastern section has moderate width.	None. Does not connect NHS features.	Moderate: Semi-mature trees offer some potential for stand-alone habitat.	Low: limited structural quality to semi mature trees.	Low: understorey dominated by invasive shrubs.	Low: Majority of trees are Osage Orange with buckthorn understorey.	Low: No specimen trees present	**None.**
HR17	Moderate. Hedgerow is >10m at its northern limit and narrows to the south, becoming quite narrow (~6m).	None. Does not connect NHS features.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	**None.**
HR18	Moderate. Some portions are discontinuous with breaks in the canopy. South of the driveway, the hedgerow appears to have larger trees with a wider and more consistent canopy structure.	None. Does not connect to any NHS features within or outside the study area.	Unknown: No access granted for close visual inspection.	Good quality canopy trees appear to be present south of the driveway, but species and health could not be assessed.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	**None.** Opportunities to retain portions or individual semi mature trees can be considered through site-level planning, as appropriate.

Hedgerow	Dimensions & Continuity	Connectivity/Linkage Potential	Habitat Potential	Vegetative Quality	Aesthetic	Species Ranking	Existence of Specimen Trees	Recommendation
HR19	Low. The hedgerow is continuous with presence of consistent canopy (trees and shrubs), but narrow (~6m wide). Tree cover is not continuous.	Low. Hedgerow appears to have been established for property demarcation. It is connected to one NHS feature (woodland, wetland and SWH), but does not provide connectivity to other NHS features within or outside the study area.	Moderate: Semi-mature trees offer some potential for stand-alone habitat.	High (north-south section). Vegetation through this section is in good health with some good canopy trees. Low (east-west section) is less continuous and appears to have lower quality vegetation.	Moderate. The north-south section offers good aesthetic value.	High: Majority of trees are Burr Oak.	Low: No specimen trees present	**None.** Opportunities to retain portions or individual semi mature trees can be considered through site-level planning, as appropriate.
HR20	High. Hedgerow is wide (10-15m) and continuous.	Low. Hedgerow connects to a woodland that is part of the NHS system, it does not provide a direct connection to any other NHS features. A ~35m gap between the woodland and HR21 could provide an opportunity to connect to another woodland feature.	Moderate: Semi-mature trees offer some potential for stand-alone habitat.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	Unknown: No access granted for close visual inspection.	**None.** Opportunities to retain portions or individual semi mature trees can be considered through site-level planning, as appropriate.
HR21	Moderate. The portion of the hedgerow along the road is moderate to wide (~8m-15m) and has a fairly continuous tree canopy with some gaps where dead and dying trees are present. The north-south portion of this hedgerow has a discontinuous canopy as it moves north and is widest at its southern end.	Low. Hedgerow connects to a woodland that is part of the NHS system, it does not provide a direct connection to any other NHS features. As noted for HR20, a ~35m gap between the woodland and HR21 could be bridged to connect these two features, however strength of this connection is anticipated to be low.	Moderate: Semi-mature trees offer some potential for stand-alone habitat.	Moderate. Along Golf Club Road, some good structure trees were observed. Dead and dying Ash were also noted. The north-south portion of the hedgerow could not be assessed during roadside survey.	Moderate. Along Golf Club Road, some trees were observed that offer aesthetic value to the road ROW and adjacent development as a visual screen. The north-south portion of the hedgerow could not be assessed.	Moderate: Hedgerow is a mixture of Ash (Low ranking) and Sugar Maple (High ranking)	Low: No specimen trees present	**None.** Opportunities to retain portions or individual trees can be considered through site-level planning, as appropriate.
HR22	Low. Discontinuous and very narrow.	Low. Does not connect NHS features.	Low: Low potential based on species and connectivity.	Low. No significant specimen trees noted; narrow vegetation.	Low. Does not provided significant aesthetic value to justify retention.	Low: Only low ranking species present.	Low: No specimen trees present	**None.**
HR23	Low. Discontinuous and very narrow.	Low. Does not connect NHS features.	Low: Low potential based on species and connectivity.	Low. No significant specimen trees noted; narrow vegetation.	Low. Does not provided significant aesthetic value to justify retention.	Low: Only low ranking species present.	Low: No specimen trees present	**None.**
HR24	Low. Discontinuous and very narrow.	Low. Does not connect NHS features.	Low: Low potential based on species and connectivity.	Low. No significant specimen trees noted; narrow vegetation.	Low. Does not provided significant aesthetic value to justify retention.	Low: Only low ranking species present.	Low: No specimen trees present	**None.**
HR25	Low. Discontinuous and very narrow.	Low. Does not connect NHS features.	Moderate: Semi-mature trees offer some potential for stand-alone habitat.	Low. Low number of trees noted; narrow vegetation.	Low. Does not provided significant aesthetic value to justify retention.	Moderate: Mixture of low, medium and high ranking species present.	Moderate: One Burr Oak meets criteria for specimen trees.	**None.**
HR26	Low. Hedgerow consists of a row of planted and managed trees that line a property limit and driveway. Area between trees is manicured; no consistent canopy.	Low. South of the study area, a more natural hedgerow of moderate quality provides a connection to the Greenbelt NHS. No connectivity is provided along the hedgerow within the study area to NHS features.	Moderate: Semi-mature trees offer some potential for stand-alone habitat.	Moderate. Individual trees appear to be in good health.	Moderate. Some good specimen trees.	Moderate: Mixture of low, medium and high ranking species present.	Moderate: Two trees (Burr Oak, Red Oak) meet criteria for specimen trees.	**None.** Opportunities to retain portions or individual specimen trees can be considered through site-level planning, as appropriate.

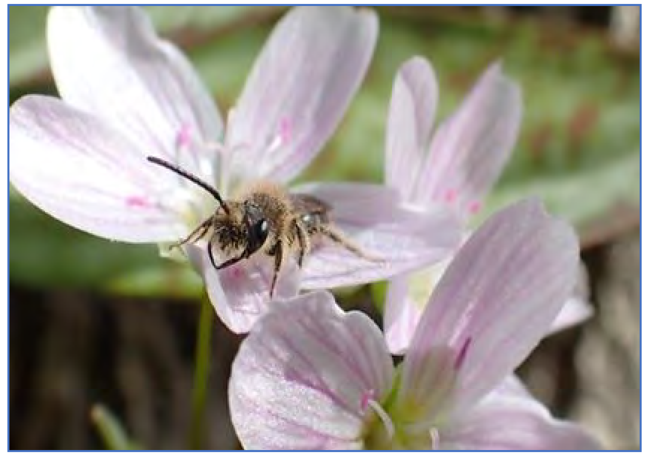
Hedgerow	Dimensions & Continuity	Connectivity/Linkage Potential	Habitat Potential	Vegetative Quality	Aesthetic	Species Ranking	Existence of Specimen Trees	Recommendation
HR27	Moderate. Portions of the hedgerow are wide (>10m) with particular focus on the southwest corner. Other portions thin to <5m. Hedgerow thins at northern limit. Continuous canopy through much of its length.	Low. Does not connect directly with any NHS features within or outside the study area.	Moderate: Semi-mature trees offer some potential for stand-alone habitat.	Moderate. Portions of the hedgerow show a good structure with variable age range. Dead / dying Ash and Elm were noted in some areas.	Moderate. Some good specimen trees. Southwest corner has good structure.	High: Majority of trees are high ranking (Oak), though numerous Dead / Dying Ash trees reduce ranking slightly.	High: More than five trees meet criteria for specimen trees. Numerous Oak over 1 metre in Diameter at Breast Height	**Feature Area (Consider Integrating)** Vegetative Quality and Aesthetic. Opportunities to retain all, or portions of the hedgerow including individual specimen trees can be considered through site-level planning, as appropriate.
HR28	Low. Hedgerow is discontinuous and narrow (<5m) throughout its length.	Low. Could provide connection to woodland south of study area to the hydro corridor linkage, however length (>1000m) and narrow width make this a poor quality connection between features.	Moderate: Semi-mature and mature trees offer some potential for stand-alone habitat.	Low. Shrubs with few trees.	Low. Few to no large specimen trees and discontinuous nature minimize aesthetic value for retention.	Low: Few medium ranked species present.	Low: No specimen trees present	**None.**
HR29	Low. Narrow to moderate width with some patches between trees / tree groupings.	Low. Adjacent to a NHS feature within the study area; hedgerow does not connect NHS features.	Low: Limited, sparse canopy cover offers little habitat potential.	Low: Poor structure and low species ranking make for low overall quality.	Low. Does not provided significant aesthetic value to justify retention.	Low: Predominantly low ranking species	Low: No specimen trees present	**None.**
HR30	Low. Long, with gaps >30m along its length. Hedgerow is narrow (<5m) for most of its length.	Low. Does not connect features within the study area. Opportunity to connect to Greenbelt NHS, however distance (>1000m) without stopover habitat / habitat node, limits feasibility and functionality.	Low: Intermittent nature of trees provides limited habitat potential.	High: Presence of large trees with good structure.	High. Presence of large specimen trees adds good aesthetic value.	High: Mixture of high ranking (oak, maple, hickory) and medium ranking species (black walnut).	Moderate: Four Burr Oak meet criteria for specimen trees.	**Feature Area (Consider Integrating)** Vegetative Quality and Aesthetic. If fits into land use plan, opportunities to add a habitat node could be explored through complimentary land uses. Opportunities to retain portions or individual specimen trees can be considered through site-level planning, as appropriate.
HR31	Moderate. Hedgerow is wide (>10m) and continuous at its northern limit, becoming narrow (<5m) and patchy at its southern limit.	Low. Does not connect NHS features within the study area or provide connectivity opportunities beyond the study area limits.	Moderate: presence of large specimen trees along western arm of hedgerow could provide some stand-alone habitat potential.	Moderate. Individual trees appear to be in good health.	Moderate. Intermittent semi-mature trees add landscape value.	High: Majority of trees are Shagbark Hickory (high ranking)	Low: No specimen trees present	**None.** Opportunities to retain portions or individual trees can be considered through site-level planning, as appropriate.
HR32	Moderate. Hedgerow is of variable width along its length ranging from narrow (<5m) to wide (>10m). It is discontinuous in some areas.	Low. Does not connect NHS features within the study area or provide connectivity opportunities beyond the study area limits.	Low: Presence of numerous dead / dying Ash reduces potential for lasting habitat.	Low: High numbers of dead / dying Ash.	Low: High numbers of dead / dying Ash.	Medium: High numbers of Ash offset slightly by presence of Basswood and Shagbark Hickory.	Low: No specimen trees present	**None.** Opportunities to retain portions or individual trees can be considered through site-level planning, as appropriate.
HR33	Moderate. Hedgerow is of variable width along its length ranging from narrow (<5m) to wide (>10m). It is discontinuous in some areas.	Low. Does not connect NHS features within the study area or provide connectivity opportunities beyond the study area limits. Several small east-west hedgerows connect HR33 to HR32, however they do not provide connectivity to other NHS features.	Moderate: Semi-mature and specimen trees offer some potential for standalone habitat.	Moderate. Individual trees appear to be in good health.	Moderate. Intermittent semi-mature trees add landscape value.	Moderate: Majority of trees are Basswood, Black Walnut, Oak and Hickory.	High: More than five trees meet the criteria for specimen trees.	**None.** Opportunities to retain portions or individual specimen trees can be considered through site-level planning, as appropriate.
HR34	Low. Hedgerow is narrow (<5m) to moderately	Low. Does not connect NHS features within the study area or provide connectivity	Moderate: Semi-mature trees offer some	Moderate. Individual trees appear to be in good health.	Moderate. Intermittent semi-mature trees add landscape value.	Moderate: Majority of trees are Basswood, with	Low: No specimen trees present	**None.**

Hedgerow	Dimensions & Continuity	Connectivity/Linkage Potential	Habitat Potential	Vegetative Quality	Aesthetic	Species Ranking	Existence of Specimen Trees	Recommendation
	narrow (<10m) with gaps and discontinuous patches.	opportunities beyond the study area limits.	potential for standalone habitat.			interspersed Oak, Hickory, Maple and Walnut.		
HR35	Low. Hedgerow is narrow (<5m) to moderately narrow (<10m) with gaps and discontinuous patches.	Low. Does not connect NHS features within the study area or provide connectivity opportunities beyond the study area limits.	Moderate: Semi-mature and specimen trees offer some potential for standalone habitat.	Moderate. Individual trees appear to be in good health.	Low: Limited aesthetic value based on limited number of trees in hedgerow	Moderate: High numbers of Oak and Hickory (high ranking) offset by numerous Basswood (medium) and Ash (Low).	Moderate: Two trees (English Oak, Shagbark Hickory) meet criteria for specimen trees.	**None.** Opportunities to retain portions or individual specimen trees can be considered through site-level planning, as appropriate.
HR36	Low. Small and discontinuous canopy. Hedgerow is narrow,.	Low. Does not connect NHS features within the study area or provide connectivity opportunities beyond the study area limits.	Low: Limited connectivity and small quantity of trees reduces potential.	Moderate: Good structure and semi-mature size.	Moderate: Good aesthetic value based on species ranking and landscape appeal.	High: Majority of trees are Shagbark Hickory (high ranking)	Low: No specimen trees present	**None.**
HR37	Low - Moderate. Narrow to moderate width (<5m - <10m). Some discontinuity in the canopy.	Low. Does not connect NHS features within the study area or provide connectivity opportunities beyond the study area limits.	Low: Limited total number of trees.	Low. Limited number of trees with good structure and health.	Low. Does not provide significant aesthetic value to justify retention.	Moderate: Majority of trees are Black Walnut (medium ranking)	Moderate: One White Oak meets criteria for specimen tree.	**None.**
HR38	Low. Hedgerow includes a number of north-south and east-west sections. Most are patchy and discontinuous.	Low. Does not connect NHS features within the study area or provide connectivity opportunities beyond the study area limits.	Low: Limited total number of trees.	Low. Limited number of trees with good structure and health.	Low. Does not provide significant aesthetic value to justify retention.	Moderate: Majority of trees are Basswood (medium ranking)	Low: No specimen trees present	**None.**
HR39	Low. Although wide (>10m), this hedgerow has a discontinuous canopy with few trees.	Low. Does not connect NHS features. A 50m gap at the north end of the hedgerow exists between a wetland and the hedgerow; the hedgerow connects to hydro linkage feature to its south. This connectivity is already provided by the wetland along the watercourse (Sinkhole Creek) to the west.	Low: Mostly invasive and no-invasive shrubs.	Low. Shrubs with few trees. Many invasive species.	Low. Few canopy trees, scrubby quality with evidence of disturbance.	Low: Comprised of shrubs and fruit trees.	Low: No specimen trees present	**None.**
HR40	Low. Highly discontinuous with large gaps between shrub groupings. No canopy trees noted during roadside survey.	Low. Hedgerow does not provide significant cover or connectivity for plants or wildlife. Does not directly connect NHS features.	Low: Mostly invasive and no-invasive shrubs.	Low. Shrubs with few trees. Many invasive species.	Low. Few to no large specimen trees and discontinuous nature minimize aesthetic value for retention.	Low: Comprised of shrubs and fruit trees, with interspersed Shagbark Hickory.	Low: No specimen trees present	**None.**

3.3.2.9 Incidental Wildlife Observations

Incidental wildlife observations recorded during field surveys include the following:

- Botanical surveys;
- Vegetation community surveys;
- Wetland evaluations; and
- Targeted wildlife surveys.



A total of thirty (30) wildlife species were recorded incidentally within the study area; including five (5) amphibians, one (1) reptile, thirteen (13) birds, eight (8) mammals, one (1) odonate, and one (1) lepidopteran. A consolidated list of incidental wildlife observations is found below in **Table 3.28**.

Of the species recorded incidentally, one (1) is considered a species-at-risk and one (1) is considered uncommon in Hamilton.

- Eastern wood-pewee (Special Concern) was observed within ELC polygons 1 and 2 within NHA St1. This species was also recorded in the same location during breeding bird surveys. Further information regarding this species and its presence within the study area is contained within **Section 3.3.4**.
- Red-bellied woodpecker (uncommon) was observed within ELC polygon 1 within NHAs Si1 and ELC polygon 1 within NHA Tw4. According to the Hamilton NAI (Schwetz, 2014), this species is widespread in Hamilton, typically stays within woodlands, and is “currently undergoing a rapid and remarkable expansion in Ontario both in range and in population”. The NAI further indicates that the species “might better be described as common”.

Table 3.28: Incidental Wildlife Observations

Species		Status					Natural Heritage Area (NHA)							
Scientific Name	**Common Name**	**COSEWIC**	**COSSARO**	**G-Rank**	**S-Rank**	**Hamilton**	**Si1**	**Si2**	**Si5**	**Si6**	**Si7**	**St1**	**Tw1**	**Tw4**
Birds														
Contopus virens	Eastern Wood-Pewee	SC	SC	G5	SNA			X				X		
Branta canadensis	Canada Goose	-	-	G5	S5								X	
Melanerpes carolinus	Red-bellied Woodpecker	-	-	G5	S4	Uncommon		X						X
Quiscalus quiscula	Common Grackle	-	-	G5	S5B			X				X		X
Picoides pubescens	Downy Woodpecker	-	-	G5	S5			X					X	X
Buteo jamaicensis	Red-tailed Hawk	-	-	G5	S5B			X		X		X		X
Bombycilla cedrorum	Cedar Waxwing	-	-	G5	S5			X						
Meleagris gallopavo	Wild Turkey	-	-	G5	S4			X						X
Cyanocitta cristata	Blue Jay	-	-	G5	S5			X					X	
Turdus migratorius	American Robin	-	-	G5	S5B			X					X	
Corvus brachyrhynchos	American Crow	-	-	G5	S5B							X		
N/A	Sparrow species	-	-	-	-							X		
Carduelis tristis	American Goldfinch	-	-	G5	S5B		X			X			X	
Mammals														
Procyon lotor	Raccoon	-	-	G5	S5			X	X			X		X
Odocoileus virginianus	White-tailed Deer	-	-	G5	S5			X				X		X
Sciurus carolinensis	Eastern Gray Squirrel	-	-	G5	S5			X						X
N/A	Bat species	-	-	-	-							X		
Mephitis mephitis	Striped Skunk	-	-	G5	S5								X	
Vulpes vulpes	Red Fox	-	-	G5	S5								X	
Sylvilagus floridanus	Eastern Cottontail	-	-	G5	S5		X							
Canis latrans	Coyote	-	-	G5	S5		X					X		X
Fish														
Cyprinus carpio	Common Carp	-	-	G5	SNA							X		
Herpetofauna														
Lithobates clamitans	Green Frog	-	-	G5	S5			X				X		
Thamnophis sirtalis sirtalis	Eastern Gartersnake	-	-	G5T5	S5			X	X					
Anaxyrus americanus	American Toad	-	-	G5	S5			X	X			X		
Lithobates palustris	Pickerel Frog	-	-	G5	S4								X	
Pseudacris triseriata, pop. 2	Western Chorus Frog (Carolinian population)	-	-	G5TNR	S4								X	
Lithobates pipiens	Northern Leopard Frog	-	-	G5	S5					X		X	X	
Odonates and Lepidopterans														
Sympetrum vicinum	Autumn Meadowhawk	-	-	G5	S5							X	X	
Danaus plexippus	Monarch	SC	SC	G4	SN2,S4B			X					X	

3.3.3 Aquatic Resources

3.3.3.1 Aquatic Habitat

The following section describes the aquatic habitat of Hannon Creek, Twenty Mile Creek, Sinkhole Creek, and Stoney Creek, within the Elfrida subwatershed study area. Field assessments were conducted by Aquafor Beech Limited biologists.

Methodology

The drought conditions experienced in 2016 prevented Aquafor Beech biologists from conducting specific aquatic habitat assessments (such as OSAP Section 4: Module 2) as the watercourses had a large section of dried up channels early in the field season. However, Aquafor Beech biologists conducted HDF field assessments, electrofishing, and benthic surveys throughout the 2016 field season in accordance with the Ontario Stream Assessment Protocols (OSAP); at which time general aquatic habitat observations were made including information on substrate, composition, in-stream cover, stream shading, and vegetation.

A detailed discussion of HDF assessments can be found in **Section 3.2.1**, with HDFs illustrated in **Figure 3.20**. Aquatic sampling sites are illustrated in **Figure 3.51**, below.

Results

Hannon Creek

Only the uppermost portions of the headwaters for Hannon Creek are present within the study area. These ephemeral streams dry up soon after the freshet and convey water at other times of the year during rain events.

Twenty Mile Creek

Fish sampling site TM03 (see **Figure 3.51**) is located near the southwest corner of the study area, close to Golf Club Road and Trinity Church Road. The straightened channel passes through agricultural fields both upstream and downstream of the site, with cropland as the only riparian vegetation. Some emergent and submergent vegetation were observed in the channel with localized areas of attached algae. The substrate consists of clay and silt with some gravel and cobbles. Some undercut banks at the upstream end of the site provided opportunities for cover, while instream vegetation and some cobbles provided cover further downstream. There were no mature trees or scrubland to provide shade to the stream. A wetland (marsh) drains into the channel upstream of the site. Bankfull width is 2.5 m.

Further downstream from TM03 is TM02, a site located just upstream of Fletcher Road. This site consists of cropland (corn) up to the left bank, with scrubland on the right bank to 10 m, then cropland (hay). Some shade is provided to the stream by mature trees along the right bank. Instream vegetation consists of abundant floating algae and some filamentous algae, as well as emergent and submergent plants. Stream cover is provided by instream vegetation, woody debris, and some cobbles. The substrate is dominated by silt, with clay and some cobbles. An agriculture tile drains into the creek downstream of the sampling site. Bankfull width is 6.2 m.

After TM02, the western branch of Twenty Mile Creek crosses Fletcher Road and runs parallel to Golf Club Road, then crosses Golf Club Road southwards and exits the study area. TM01 is located just upstream of the crossing at Golf Club Road, near the area where a swale drains into the channel. Some canopy cover is provided by mature trees on the right bank. Meadow was the dominant vegetation type on the left bank before the road. Instream vegetation is dominated by emergent plants with some submergents. Attached algae is also present at the site. The substrate consisted mainly of silt with some clay. Deep sediment lined the channel at this location. Instream cover was provided vegetation. Bankfull width is 6.5 m.

Twenty Mile Creek crosses Regional Road 20 at Golf Club Road and runs parallel to Golf Club before crossing the road and exiting the study area. Bankfull width is 2.2 m with a bankfull depth of 300 mm. Water persisted in this area during HDF field visits. Submergent vegetation dominated in stream and some overhanging cover was provided by mature trees. The substrate was silt with some clay.

<u>Sinkhole Creek</u>

At HDF site SI3-H4 on Fletcher Road, Sinkhole Creek is surrounded by cropland with no overhanging vegetation to provide cover. The stream is intermittent here and is plowed over during the planting season, visible only as a depression. Bankfull width is 0.5 m and bankfull depth is 110 mm. SI3-H4 was representative of many upstream reaches of Sinkhole Creek.


Figure 3.48: Giant Floater Mussel Found Near HDF Site S13-H1

East of Regional Road 56, HDF site SI3-H1 is found at the confluence just downstream of the woodland. While upstream of the site there are mature trees providing good overhanging cover for the stream, within the site, there are no mature trees to provide shade. Riparian vegetation consists of cropland on both banks. No instream vegetation was present on the first HDF visit, while crops were in the channel on the second visit. The stream had dried up by the second HDF visit on May 20, 2016.

However, despite the HDF drying up, the shell of a Giant Floater mussel (*Pyganodon grandis*, **Figure 3.48**) was observed on the bank of the HDF at the woodland boundary by Aquafor Beech staff. The mussel may have been moved there by a predator from the online pond just upstream. Its presence suggests that suitable habitat exists in the area for fish as mussels cannot exist without using fish as a host to complete their life cycle. Bankfull width is 1.2 m and bankfull depth is 150 mm.

Downstream of HDF sites SI3-H1 and SI2-H1, Sinkhole Creek is a defined watercourse, with a permanent channel, surrounded by wetland vegetation. The channel did dry up during the summer (other than a puddle by the culvert at Hendershot Rd) but that may be due to the extremely dry conditions. Instream vegetation consists of both submergent and emergent plants, with some woody debris and detritus. Shade is provided to the creek by tall grasses (e.g. Phragmites), and cattails. The substrate consists of silt and clay.

Stoney Creek

From the crossing at Highland Road, just east of Upper Centennial, Stoney Creek passes through a wetland dominated by Phragmites with cattails. At HDF site ST1-H2(DS), the creek has a bankfull width of 1.9 m and a bankfull depth of 300 mm. The channel had been straightened and has a sediment depth of 8 cm. Shade is provided to the creek by the tall, dense phragmites and the odd mature tree. Beyond the wetland, riparian vegetation consists of meadow on either side of the bank. Downstream of ST1-H2(DS) the watercourse transitions into the old golf course, where the straightened channel passes through four online ponds, with riparian vegetation ranging from meadow, to wetland, to forest. Throughout the golf course, some shade is provided to the creek from overhanging trees. The substrate through the golf course is largely clay with silt. Instream vegetation consists of emergents and submergents.

Stoney Creek exits east from the former golf course and then bends north before running eastward parallel to Mud Street, past First Street, before turning to the south. Fish sampling site STO2 is located approximately 125 m south of Mud Street. Riparian vegetation consists of cropland on both banks and extending back 100 m. The substrate is silt with clay. Instream cover is provided by submergent vegetation, some woody debris, and detritus. Some canopy cover from mature trees provides shade to the creek. Bankfull width is 5.5 m.

Fish sampling site ST01 is located at the downstream end of Stoney Creek, at Second Street, at the eastern edge of the study area. Surrounded by cropland on both sides, the immediate riparian area has some cattails, Phragmites, and grass. Within the channel, submergent vegetation dominated, with some emergents and some woody debris. The substrate is dominated by silt with some sand. Deep sediment within the channel extended the length of the site. There are no mature trees in the riparian area and no shade cover for the creek. Bankfull width is 6.2 m.

Figure 3.49: Looking Upstream From The Golf Course At ST1-H2(DS)

Figure 3.50: Looking Downstream Towards The First Pond In The Golf Course

Conclusions

Within the study area, Hannon Creek has a limited function as aquatic habitat. The three tributaries exiting the study area terminate in a stormwater sewer, a karst sinkhole, and a culvert emptying into a wetland. These streams dried up almost immediately after the freshet.

Twenty Mile Creek consists largely of defined channels and areas of overland flow, with water remaining in some areas for the majority of the year. Aquatic habitat quality here tends to be low, with little diversity in available instream habitat and limited cover provided by riparian vegetation.

With online ponds, and watercourses that pass through forested areas and wetland complexes, Sinkhole Creek provides a range of aquatic habitat. However, much of the upstream HDF areas dried up early and the channels were plowed over during planting season. The most downstream section at the eastern edge of the study area has a well-defined channel with tall grasses and wetland plants providing shade. Though the downstream end of the watercourse did dry up in 2016, it was likely due to the drought and thus it is difficult to determine if this watercourse is permanent or intermittent. The presence of the observed mussel suggests suitable fish habitat is present.

Stoney Creek provides higher quality habitat than elsewhere within the study area. Water is present throughout the year in the wetland upstream of the former golf course, and within the former golf course through the ponds and channel. The wetland provides average quality habitat with good instream cover and shade provided by the emergent wetland vegetation. Downstream of the wetland, the ponds provide areas for fish to retreat to if the channel dries up. The flow was observed within the former golf course throughout the year, as well as in the channel that originates at First Road. Although Stoney Creek was dry at the downstream end of the study area (a possible anomaly due to the drought in 2016), it appears to hold water upstream throughout the year, providing habitat for fish and benthic macroinvertebrates year round.

3.3.3.2 Fisheries Surveys

Fish sampling was conducted within the Sinkhole Creek, Stoney Creek, and Twenty Mile Creek subwatersheds. The Hannon Creek subwatershed was unsuitable for fish community sampling as only ephemeral HDFs were located within the subwatershed.

Methodology

Fish communities within the Stoney Creek and Twenty Mile Creek subwatersheds were surveyed in accordance with the OSAP fish community sampling procedures (Section 3: Module 1). Surveys were conducted using a Halltech HT2000 Backpack Electrofisher and involved a standard single pass sampling technique with 1 netter. The electrofisher was set to a frequency of 80 Hz with an output voltage dependant on the conductivity at each site. To standardize sampling effort, each site extended for a length of 40 m.

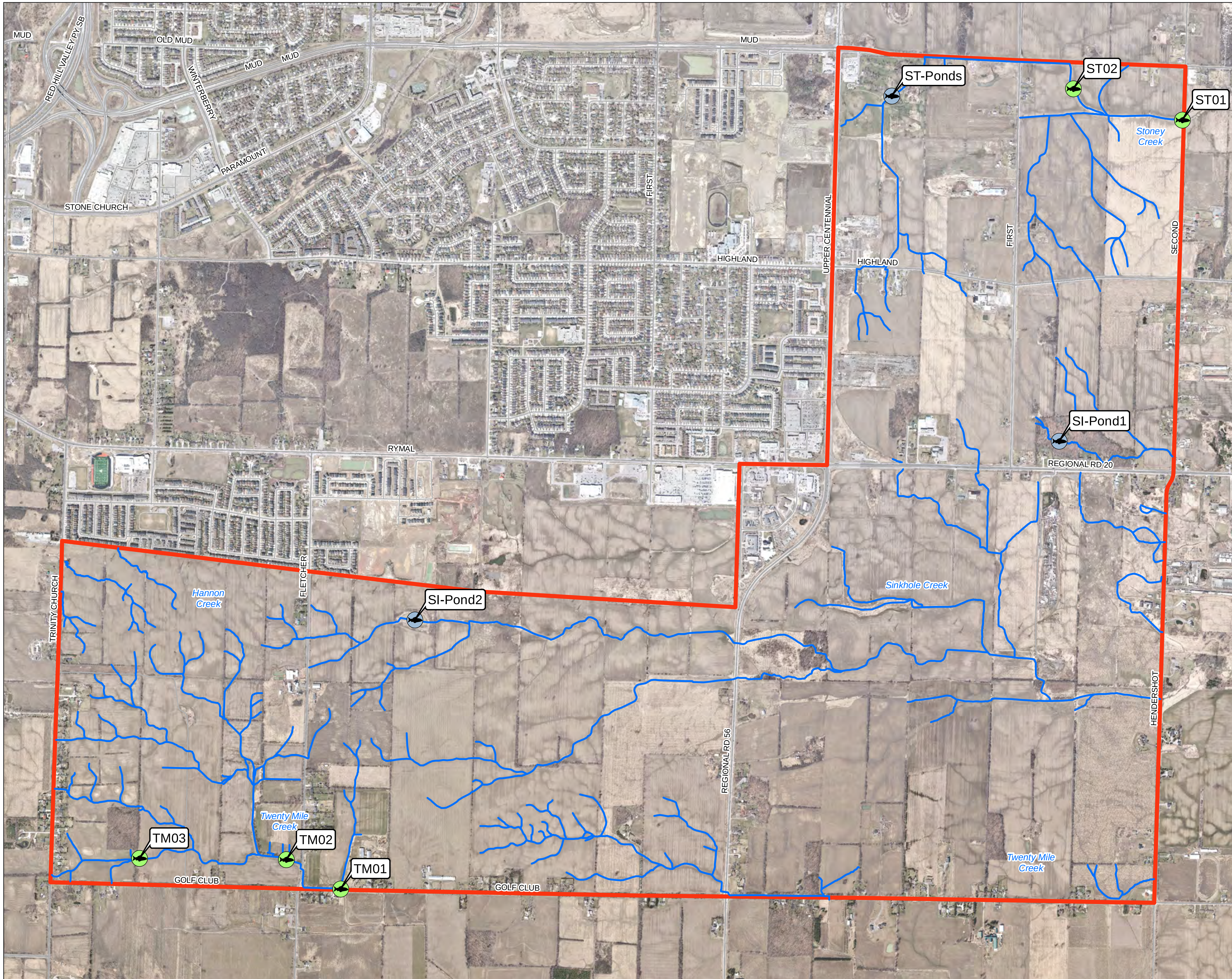
Minnow traps were used to sample fish communities in online ponds within the study area. Multiple traps were placed around the perimeter of the pond, at varying distances from the shoreline. Each trap was anchored and left in place for 24 hours. At the end of the 24 hours, Aquafor Beech staff removed the traps and recorded the amount and type(s) of fish contained within them.

Results

Fish community surveys were completed at a total of eight (8) sites, as shown in **Figure 3.51**. Three sites were sampled on Stoney Creek (ST01, ST02, ST-Ponds – the former golf course ponds), along with three sites on Twenty Mile Creek (TM01, TM02, and TM03), and two sites on Sinkhole Creek (ST-Pond1 and ST-Pond2). A summary of the species found at each site is provided in **Table 3.28**.

A total number of six species representing five genera were recorded in Stoney Creek, Twenty Mile Creek, and Sinkhole Creek. Three fish at ST01 (*Lepomis sp.*) and six fish at SI-Pond1 (*Lepomis sp.*) could not be identified down to the species level. The six species sampled were evenly split between warmwater and coolwater species, while tolerance levels were also evenly split between tolerant and intermediates species. Fathead minnow (*Pimephales promelas*), a tolerant warmwater species, was the most widely distributed being found in six of the eight sites, followed by central mudminnow (*Umbra limi*), a tolerant coolwater species, in five of the eight sites. Creek chub (*Semotilus atromaculatus*) and green sunfish (*Lepomis cyanellus*) were each recorded at only one site. With five species recorded, SI-Pond1 was the most diverse site, followed by ST01. The majority of sites (six of eight) had only one or two species recorded during sampling. All species collected are considered common to abundant within Hamilton and are widespread in Ontario. Photographs of sampling sites can be seen in **Figure 3.52** through **Figure 3.56**.

Elfrida Subwatershed Study



Legend

Study Area

Watercourse

Aquatic Sampling Sites

Fish & Benthic Macroinvertebrates

Fish

Figure 3.51

Aquatic Sampling Sites

Date: January 17, 2017
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

Table 3.29: Fish Community Survey Results

Scientific Name	Species	Tolerance	Thermal Regime	Stoney Creek			Twenty Mile Creek			Sinkhole Creek	
				ST01	ST02	ST-Ponds	TM01	TM02	TM03	SI-Pond1	SI-Pond2
Umbra limi	Central Mudminnow	Tolerant	Coolwater	7			2	1		2	4
Pimephales promelas	Fathead Minnow	Tolerant	Warmwater	8	1			17	4	14	14
Semotilus	Creek Chub	Intermediate	Coolwater							1	
Culaea inconstans	Brook Stickleback	Intermediate	Coolwater	9	2					1	
Lepomis cyanellus	Green Sunfish	Tolerant	Warmwater			22					
Lepomis sp.	Lepomis sp.	Intermediate	Warmwater	3						6	

Date:	24-May-16	24-May-16	28-Sep-16	27-May-16	27-May-16	30-May-16	28-Sep-16	15-Mar-16
Electrofish seconds:	781	450	N/A	396	748	321	N/A	N/A
Length of site (m):	40	40	N/A	40	40	40	N/A	N/A
Air Temperature (°C):	22	29	N/A	28	30	25	N/A	N/A
Water Temperature (°C):	16.8	21.5	N/A	21	25	22	N/A	N/A
Total individuals:	27	3	22	2	18	4	24	18
Total Species Richness	4	2	1	1	2	1	5	2
Fish/100 electrofishing seconds	3.5	0.7	N/A	0.5	2.4	1.2	N/A	N/A

Figure 3.52: Fish Sampling Site TM03 Looking Upstream In March

Figure 3.53: Fish Sampling Site TM01 Looking Upstream in May

Figure 3.54: Fish Sampling Site SI-Pond2

Figure 3.55: Fish Sampling Site SI-Pond1

Figure 3.56: Fathead Minnow Captured At SI-Pond2

Conclusions

The reduced species diversity found in Twenty Mile Creek suggests that this reach provides lower quality habitat than that found in the other two subwatersheds sampled. Both fish species sampled in Twenty Mile Creek (Central Mudminnow and Fathead Minnow) are tolerant of disturbance and are often associated with slow/still waters (Scott and Crossman, 1973). A juvenile Fathead Minnow caught at TM03 suggests the possibility of this area being used as nursery habitat. This creek was also the only one without online ponds or large wetland complexes, features that may impact water quality but also provide potentially valuable refuge for fish when the streams dry up.

Increased species richness at the downstream end of Stoney Creek suggests better fish habitat than areas upstream with reduced species richness. Though two of the species captured are classified as coolwater species (Central Mudminnow (**Figure 3.56**) and Brook Stickleback), they are often found in areas that dry up quickly, have stormwater inputs, and are heavily influenced by humans (Schwetz, 2014). However, Brook Stickleback are also found in cool, clear, densely vegetated waters, suggesting the habitat may be of higher quality in these areas. While yielding a decreased species richness compared to that recorded at the downstream sampling site, the upstream portion of Stoney Creek has several online ponds and a large wetland complex (i.e. NHA Si2) that provide refugia for fish if the streams dry up. The presence of Fathead Minnows less than 45 mm in total length (some fish captured were 35 mm and 38 mm) indicates that juvenile fish may be using the area as a nursery. Overall, Stoney Creek provides low to medium quality habitat for fish.

Online ponds were the only areas available for sampling along Sinkhole Creek in 2016. Sampling in a non-drought year would provide more insight into the fish community that uses the upper portions of this creek. However, the two ponds sampled were at the upstream reaches of the watershed and show that suitable habitat exists within those reaches to maintain a fish population. The diversity noted in SI-Pond1 was somewhat surprising given its location, with five (5) species captured and the majority of them being coolwater species. These species are common and do not have the specific habitat requirements of more sensitive species. Sampled reaches of Sinkhole Creek provide low quality habitat.

3.3.3.3 Benthic Macroinvertebrates

Benthic macroinvertebrates are commonly used to assess water quality, health, and integrity of aquatic ecosystems. They are suitable for study for many reasons, including:

a) Benthic invertebrates are highly sensitive to environmental changes which make them excellent indicators of water quality;
b) Benthic invertebrates are abundant in nearly all watercourses, living on or in the substrate;
c) Benthic invertebrates can be easily and inexpensively collected and easily quantified;
d) Benthic invertebrates are easily identified; and
e) They have restricted mobility and specific habitat preferences, and therefore cannot simply move away from environmental stresses occurring at a site. (Griffiths, 1999)

Aquafor Beech Limited staff identified suitable sampling locations while conducting the HDF assessments (**Section 3.2.1**). Due to the ephemeral nature of watercourses in headwaters areas, many streams were dry soon after the freshet. As well, most of Southern Ontario experienced drought conditions for much of the year, with less than 17 mm of total precipitation being recorded near the study area for the month of May (EC, 2016), when benthic macroinvertebrate sampling normally occurs. As a result, watercourses in both the Hannon Creek subwatershed and the Sinkhole Creek subwatershed had dried up prior to sampling. Samples were collected from three sites in the Twenty Mile Creek subwatershed (TM01, TM02, and TM03), and two sites in the Stoney Creek subwatershed (ST01 and ST02). See **Figure 3.51** for sampling locations.

Methodology

Sites were set up using Section 1: Modules 1-3 (Site Identification and Site Features) of the OSAP. Sampling was conducted in accordance with OSAP, using the transect traveling kick and sweep method (Section 2: Module 3). This method involves walking from one bank to the other for three minutes while kicking the stream bed and holding a 500 µm D-net downstream to collect dislodged organisms. After three minutes the organisms are emptied from the net, placed in a jar and preserved in the field using isopropyl alcohol. This collection is completed at three sampling locations within a sampling reach (riffle-pool-riffle).

Samples were subsampled using the teaspoon method until at least 100 specimens were found. Specimens from each sample were identified to Family level. The raw data and OSAP field sheets are presented in **Appendix J**.

To analyze samples, water quality can be assessed using multiple indices, or metrics, which are easy to calculate. Multiple indices could relate to specific impacts, making it necessary to use many metrics to detect impacts (TRCA, 2000).

In addition to species richness (e.g., the total number of taxa) and composition metrics (e.g., % Diptera), macroinvertebrates can also be classified according to:

- functional feeding groups (e.g., % Collector-Filterers, % Scrapers, % Shredders)
- habit/behavior characteristics (e.g., % Clingers)

Functional feeding groups provide an indication of food web relationships. Habitat and behavior characteristics indicate the functionality of the organism (e.g., the way it moves or searches for food) (Barbour et al, 1999).

The samples collected as part of this study were analyzed and compared qualitatively using a multimetric approach to summarize the condition of the watercourse, using the following indices:

Taxa Richness: Indicates diversity of taxa. The number of taxa increases with habitat quality and water quality.

% EPT: Percent composition of Ephemeroptera, Plecoptera and Trichoptera (EPT). Reflects the composition of the benthic community within Families that are considered to be sensitive to water quality.

% Oligochaeta: Percent composition by aquatic worms (tolerant organisms).

% Diptera: The percent composition by larvae of true flies.

% Chironomidae: The percent composition by larval midges.

% Collector-filterer: The percent composition by detrivores (feed on decomposing fine particulate organic matter) which filter feed or are suspension feeders.

% Collector-Gatherer: The percent composition by detrivores which gather food or are deposit feeders.

% Predator: The percent composition of organisms that feed on living animal tissue (not including parasitic organisms) by engulfing or piercing (Merritt et al, 2008).

% Scraper: The percent composition by organisms that feed on periphyton by grazing and scraping mineral and organic surfaces (Merritt et al, 2008).

% Shredder: The percent composition by organisms that feed on living vascular aquatic plant tissue by chewing, detrivores that feed on decomposing vascular plant tissue (coarse particulate organic matter) by chewing, and/or organisms that feed on wood by gouging and excavating (Merritt et al, 2008).

% Clinger: The percent composition by organisms having fixed retreats or adaptations for attachment to surfaces in flowing water (Barbour et al, 1999).

Shannon's Diversity Index:

Shannon's Diversity Index is calculated using the following formula:

$$H' = -\sum(p_i)(Lnp_i)$$

Where p_i is the proportion of individuals in the "ith" taxon of the community. H' increases as the number and distribution of taxa (diversity) in a sample increases.

Hilsenhoff's Family Biotic Index:

The Hilsenhoff's Family Biotic Index (FBI) uses the pollution tolerances of organisms to determine the level of stream impairment. Each organism is assigned a tolerance value of 0 to 10, with a value of 0 indicating that the organism has a very low tolerance to pollution and a value of 10 indicating that the organism has a very high tolerance to pollution. The index is calculated using the following formula:

$$FBI = \sum(x_i)(t_i) / n$$

Where x_i is the number of organisms in the i^{th} taxon, t_i is the tolerance value of the i^{th} taxon, and n is the total number of organisms in the sample.

Interpretation of the FBI Value is as follows:

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very Good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probably
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly Poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very Poor	Severe organic pollution likely

Results

The following are the results of the habitat assessment, benthic invertebrate community, and associated metrics. **Table 3.30** provides a summary of the aquatic habitat conditions of the five (5) sites sampled, including the sampling date, water temperature, dissolved oxygen, pH, conductivity, average wetted width, average wetted depth, average hydraulic head, average bankfull width, channel substrate, and descriptions or instream and riparian habitats.

Table 3.30: Benthic Invertebrate Habitat Summary

Site	Date Sampled	Water Temp. (°C)	Dissolved Oxygen (%Sat)	pH	Conductivity (µS/cm)	Average Wetted Width (m)	Average Depth (mm)	Average Hydraulic Head (mm)	Average Bankfull Width (m)	Substrate	Instream Habitat	Riparian Habitat	Other Site Features
TM01	May 27, 2016	21.0	81.6	8.1	2304	0.83	203	0	6.5	Silt and some clay	Emergent vegetation abundant, while submergent vegetation was present throughout the site. Detritus is present in some areas. Attached algae was observed. There is limited canopy cover from overhanging trees.	Meadow on left bank to 10 m, no vegetation to 30 m (Golf Course Road), and lawn beyond. Right bank is scrubland to 10 m and cropland beyond.	Agriculture adjacent to and upstream of the site is a possible source of contamination or nutrients. Road runoff both upstream and adjacent to the site provides another possible source of contamination. The channel has been straightened and contains deep sediment. The stream is intermittent at this site.
TM02	May 27, 2016	25.0	83.0	8.2	1862	2.00	510	0	6.2	Silt and clay	Submergent and emergent vegetation were present throughout the site. Floating algae is abundant, and filamentous algae is also present. Some cover was provided by overhanging trees on the right bank. Woody debris and some cobbles are in located in the channel.	Left bank riparian vegetation consists of cropland. Scrubland dominates on right bank to 10 m, then cropland beyond.	Cropland both upstream and adjacent to the site provides a possible source of contamination or nutrients. The channel has been straightened. Minor log jams were observed within the site.
TM03	May 30, 2016	22.0	76.0	8.5	1010	1.10	113	1	2.5	Clay and silt	Limited instream vegetation consists of emergent and submergent vegetation. Attached algae is present in the runs. Localized areas with undercut banks provide some cover, while there was no canopy cover provided by overhanging trees.	Cropland on both banks to 100 m.	The straightened channel is both adjacent to, and downstream of, agriculture which is a potential source of contamination or nutrients.
ST01	May 24, 2016	16.8	88.2	8.5	2316	3.33	167	0	6.2	Silt and sand	Dominated by abundant submergent vegetation. Some woody debris and detritus in channel. Deep sediment. No trees to provide overhanging cover.	Cropland on both banks to 100 m.	Straightened channel. Agriculture upstream and adjacent to the site is a possible source of contamination or nutrients. Stream is intermittent.
ST02	May 24, 2016	21.5	81.2	8.1	2612	3.07	157	0	5.5	Silt and some clay	Submergent vegetation is abundant throughout the site. Woody debris and some detritus are present. Some undercut banks provide cover, while overhanging trees provide some canopy cover.	Cropland on both banks to 100 m.	Road runoff upstream provides a possible source of contamination. Agriculture upstream and adjacent to the site provides a possible source of nutrients or contamination. Straightened channel. Stream is intermittent.

Benthic Invertebrate Community

The metrics calculated for the organisms collected at each site are summarized in **Table 3.31**, below; detailed information about each sampling site follows. Given that it is difficult to determine specific thresholds for the number, or percentage, of organisms for each metric that should be found in an unimpaired stream sample, sampled sites were compared to each other.

There are known differences in the way the indices respond to human disturbance/habitat degradation (Jones, 2007). For Taxa Richness, % EPT, % Scraper, % Shredder, % Clinger, % Omnivore and the Shannon Index, a larger value implies a healthy biological community and low values imply reduced health (Jones, 2007; Barbour et al, 2009). For % Oligochaeta, % Chironomidae, % Isopoda and FBI, a lower value implies a healthier community (Jones, 2007; Barbour et al, 2009). However, there is no "target value" since there are no reference sites in this study. We can only determine which sites have higher or lower values.

In the case of % Collector-Filterer, % Collector-Gatherer, % Predator and % Diptera, critical values lie at both extremes (Jones, 2007; Barbour et al, 2009). Therefore, these metrics were not used as an indication of better water quality between sites. However, they are useful to note habitat differences and changes in habitat quality over time, which suggests a change in water quality.

Table 3.31: Benthic Invertebrate Monitoring Results

	TM01	TM02	TM03	ST01	ST02
Total Number of Organisms	322	316	201	320	321
Taxa Richness	7	5	4	7	6
% Oligochaeta	23.29	13.92	0.00	6.56	10.28
% Diptera	59.94	78.80	87.56	88.13	83.49
% Chironomidae	59.94	78.80	87.56	86.56	83.49
% Isopoda	0.00	5.06	1.99	3.44	4.05
% EPT	0.01	0.00	0.00	0.00	0.01
% Collector-Filterer	0.00	0.00	0.00	0.00	0.00
% Collector-Gatherer	87.58	97.78	97.01	97.19	98.44
% Predator	60.56	79.43	90.55	87.81	83.49
% Scraper	12.42	1.58	0.00	1.88	2.18
% Shredder	0.00	0.00	0.00	0.31	0.00
% Clinger	0.62	0.00	2.99	0.31	0.62
Shannon-Weiner Diversity	0.49	0.31	0.21	0.25	0.27
FBI	7.21	6.71	5.71	6.37	6.50

Indicates best water quality

Indicates second best water quality

Indicates worst water quality

Twenty-Mile Creek

TM01

Analytical results indicate that site TM01 scored the best in six of the community metrics calculated. This site showcased the highest diversity with the best value for taxa richness (7) and for the Shannon-Weiner Diversity Index (0.49). Additionally, it had the best score for % Chironomidae at 59.94%, substantially fewer Chironomidae than in the other sites, and the best score for % Isopoda. However, TM01 had the worst score for % Oligochaeta, a very pollution tolerant taxa. Having the best score for % Scraper indicates the presence of algae for organisms to feed on. TM01 also had the best score for % EPT and the second-best score for % Clinger. The site ranked worst in the FBI with a score of 7.21, indicating poor water quality with very substantial organic pollution likely, though TM02 also ranked within that range.

TM02

TM02 was the only site to not score at the top of any metrics. It scored worst for % Isopoda, % Clinger, % EPT, and % Shredder. It had the second-best score for % Chironomidae, though they still accounted for a significant portion of the sample from the site. With the second-best score for the Shannon-Weiner Diversity Index, this site had higher diversity than others. The high percentage of Gatherer-Collectors indicates the presence of decomposing fine organic matter, which supports the field observation of instream vegetation.

TM03

The analysis shows that site TM03 ranks poorest in measures of diversity with the lowest number of taxa (4) and the lowest score (0.21) for the Shannon-Weiner Diversity Index. The site also ranked lowest in % Chironomidae, % EPT, % Scraper, and %Shredder. As a result of the high number of Chironomids, the main functional feeding group was Collector-Gatherers (97.01%).

Figure 3.57: An Example Of A Megaloptera Found In Elfrida Study Area

The lack of scrapers and shredders is indicative of the minimal instream vegetation and algae noted within the site. Due to the presence of Megaloptera: Corydalidae (**Figure 3.57**), TM03 ranked highest for % Clinger, a specialized habit whereby organisms have adaptations to allow them to attach to surfaces stream riffles, suggesting riffle habitat is present within this site.

Despite its low rank in many categories, TM03 had the best score for FBI at 5.71, which indicates that fairly substantial pollution is likely. Site TM03 ranked best for % Oligochaeta with none of the pollution tolerant organisms being sampled at this site.

Stoney Creek

ST01

Site ST01 ranked highest in taxa richness along with TM01, with a score of 7. Although this site had the second best FBI score, the value ranks the water quality as fairly poor (substantial organic pollution likely). Organisms from specialized feeding and habit group were sampled in ST01, with the site having the best score for % Shredders due to the presence of Tipulidae. Pollution tolerant Chironomidae accounted for a large portion of the site, but ST01 did score second best for % Oligochaeta, with only 6.56% of the sample being made up of these pollution tolerant organisms. The high percentage of Collector-Gatherers within the site (97.19%) indicates the presence of decomposing fine particulate organic matter.

ST02

The presence of two Ephemeroptera (Baetidae) had site ST02 tied for best score in % EPT, though the value was small at 0.01%. Baetidae is moderately tolerant of pollution. The majority of the organisms sampled here are considered to be pollution tolerant. With the second-best score for taxa richness, ST02 contains slightly more diversity than some of the other sites. A score of 6.5 on the FBI ranks the water quality as Fairly Poor with substantial pollution likely. This site ranked second best for % Scraper, indicating the presence of algae as a food source.

Conclusions

Overall, the benthic invertebrate sites in Twenty Mile Creek and Stoney Creek indicate generally poor water quality. The majority of the organisms sampled in these creeks are pollution tolerant and are expected to be found in highly disturbed areas. However, the presence of Ephemeroptera, even a moderately tolerant family, indicates the potential for improved habitat in restored areas.

Aquatic habitat at site TM03 was substantially different than that at TM02 and TM01. TM03 had limited instream vegetation, less cover, and a clay bottom compared to a silt bottom with deep sediment. The limited instream vegetation and overhead cover reduce the amount of food available to organisms in the stream, possibly leading to the reduced diversity noted at the site. The availability of food increases by TM02.

Stoney Creek had similar aquatic habitat at each site, as evidenced by the similarity in their metrics. Each site ranked worst in only one metric and in general, tended to be of higher water quality overall than the Twenty Mile Creek sites.

Site TM01 had the best water quality rank in six metrics, compared to TM03 with the best water quality rank in three metrics. TM03 had the worst water quality rank in six metrics, compared to TM02 which ranked worst in four metrics. Twenty Mile Creek showed more variety in results than the sites in Stoney Creek, where the sites had similar results to each other.

Measures of biodiversity can be influenced by factors outside of water quality, while the time of sampling and also the drought conditions experienced in 2016 can also impact results. For a better understanding of water quality using benthic invertebrates as indicators, sampling would need to be conducted each spring over a period of years to allow comparison between sites and over time. Establishing a reference site for the study area would also be beneficial for future monitoring.

3.3.3.4 Fish Barriers and Online Ponds

Fish barriers and online ponds can have impacts on the thermal regime of watercourses and the ability of fish to migrate through the study area. Online ponds can impact a stream by increasing the temperatures downstream of the pond while decreasing the dissolved oxygen within the stream (Maxted et al. 2010). Ponds fed by headwater streams, such as those within the study area, are generally cooler than those found further downstream in the system (Ebel & Lowe 2013). Knowing where these features occur can help inform management decisions in regards to watercourses.

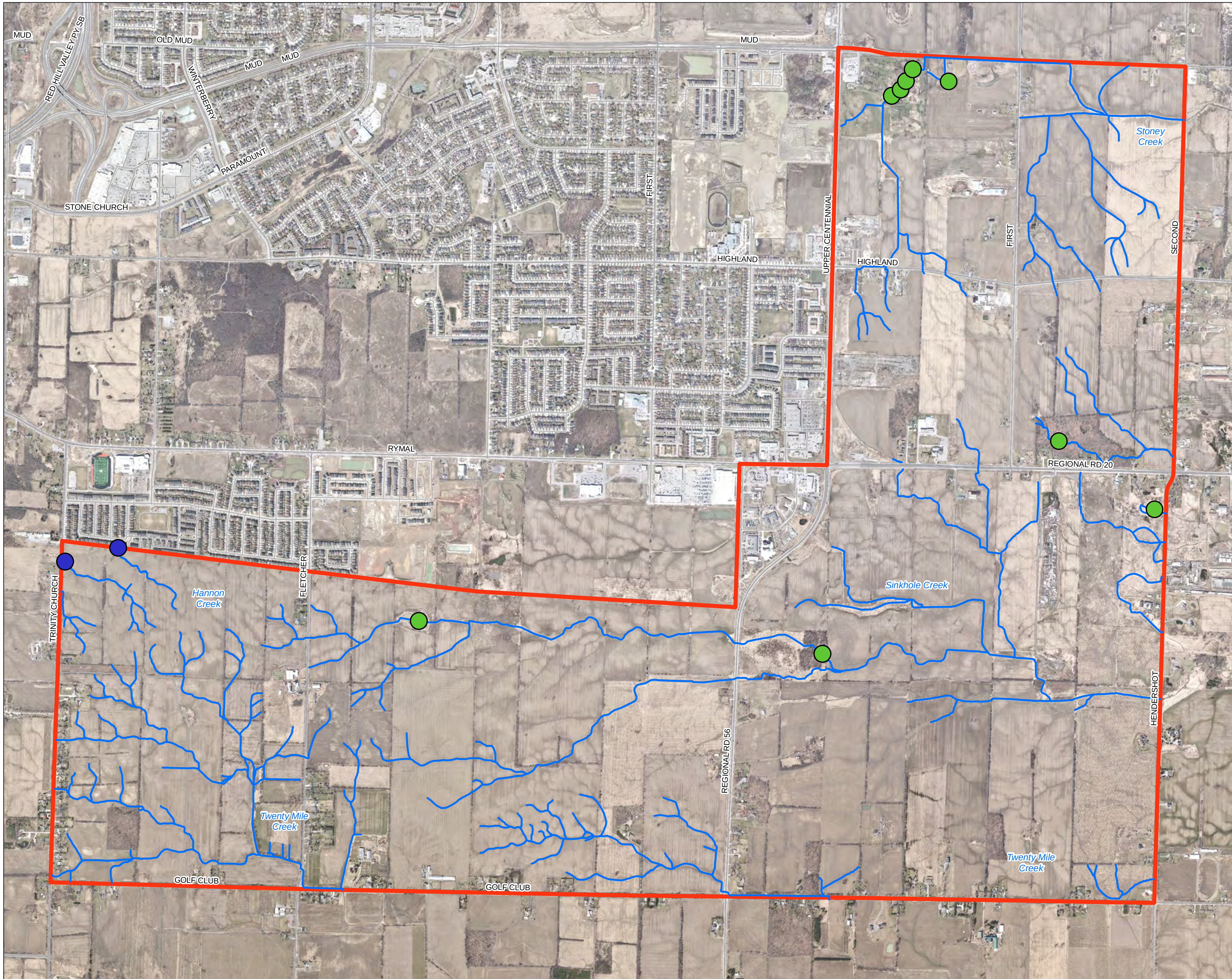
Methodology
An inventory of fish barriers and online ponds was compiled based on observations made during field work and through an analysis of aerial photographs of the study area.

Results
A list of fish barriers and online ponds occurring within the study area is presented in **Table 3.32** Their locations are shown in **Figure 3.58**.

Table 3.32: Fish Barriers and Online Ponds

Subwatershed	Type	Location	Description
Hannon Creek	Fish Barrier	Northwest corner of the study area in the thicket at Trinity Church Road. *17T 595766 m E, 4781285 m N*	HDF drains into a karst sinkhole within the thicket. No possibility for fish to move into this reach from downstream. Although this feature dries up quickly, the possibility would exist for fish to move into this area from downstream during the freshet, if not for the sinkhole.
	Fish Barrier	Past first hedgerow east of Trinity Church Road, along the hydro corridor. *17T 596031 m E, 4781281 m N*	HDF drains into a storm sewer and exits the study area. Storm sewer acts as a barrier to fish passage.
Sinkhole Creek	Online Pond	Second hedgerow east of Fletcher Road, adjacent to the hydro corridor. *17T 597363 m E, 4780563 m N*	This pond exists at the uppermost portion of the subwatershed and is connected to an HDF. Classified as a wetland, this pond provides habitat for fish for at least part of the year (five species of fish were captured here during sampling).
	Online Pond	Woodland near northeast corner of the Regional Road 20 and Second Road intersection. *17 T 600548 m E, 4780598 m N*	Connected to an HDF, this pond maintained water throughout the year, even after the HDF dried up. This pond is known to provide fish habitat with two species of fish being captured here.
	Online Pond	First stream crossing on Hendershot Road, south of Regional Road 20, on west side of road. *17 T 600912 m E, 4780157 m N*	No land access was permitted here but the connected HDF was assessed from the road. No water flowed from the pond outlet by April.
	Online Pond	Woodland east of Regional Road 56, south of the hydro corridor. *17 T 599186 m E, 4779924 m N*	This online pond was observed through aerial photos. Passing through a woodland, it is connected to an HDF.
Stoney Creek	Online Pond	Pond 1 (from east) in golf course at Upper Centennial Parkway and Mud Street. *17 T 600201 m E, 4782417 m N*	The most upstream pond within the golf course, it is also the largest. This pond has some shade provided to it by mature trees, but much of the surface is open, allowing for heating from the sun. Fish were captured in this pond. The outlet appears to maintain flow throughout the year. As with the remainder of the ponds in the golf course, this is classified as a wetland.

Subwatershed	Type	Location	Description
	Online Pond	Pond 2 (from east) in golf course at Upper Centennial Parkway and Mud Street *17 T 600253 m E, 4782432 m N*	Online pond downstream of Pond 1, also fairly open canopy.
	Online Pond	Pond 3 (from east) in golf course at Upper Centennial Parkway and Mud Street *17 T 600288 m E, 4782467 m N*	Online pond downstream of Pond 2, a little more protected by tall vegetation and overhanging canopy. Fish were captured in this pond during 2016 sampling.
	Online Pond	Pond 4 (from east) in golf course at Upper Centennial Parkway and Mud Street *17 T 600334 m E, 4782514 m N*	Most downstream pond within the golf course. Overhanging vegetation provides some shade to the pond but it is still largely open. Fish were captured during 2016 sampling.
	Online Pond	First property east of the golf course on the south side of Mud Street. *17 T 600495 m E, 4782408 m N*	A very shallow pond full of submergent vegetation, this pond outlets to an HDF during high flow conditions.
Twenty Mile Creek	No fish barriers or online ponds observed within the study area.		



Elfrida Subwatershed Study

Legend

- Study Area
- Watercourse
- Fish Barrier
- Online Pond

Figure 3.58

Fish Barriers & Online Ponds

Date: January 17, 2017
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

Conclusions
Minimal fish barriers were observed within the study area. The barriers in Hannon Creek are unlikely to cause problems due to the ephemeral nature of the HDFs in this area. No other fish barriers were observed.

Online ponds were noted in Sinkhole Creek (four ponds) and Stoney Creek (five ponds). The ponds in Sinkhole Creek are distributed throughout the subwatershed. In Stoney Creek, four of the ponds are in close proximity to the former golf course (i.e. the north section of NHA St1), with the fifth one just east of the golf course. With the exception of one pond that is adjacent to a treed swamp, these ponds generally lack overhanging vegetation, leaving the pond open to heating from solar radiation and may be responsible for raising temperatures downstream. Further monitoring would be required to assess thermal impacts of the online ponds on the streams. However, due to the intermittent nature of some of the streams connected to these ponds, the ponds are providing year-round habitat for fish within the subwatersheds when streams dry up.

3.3.3.5 Stream Characterization

Identifying the thermal regime of a watercourse is a standard method of classifying streams. The thermal regime can indicate the sensitivity of a stream, the quality of aquatic habitat available, and the type of aquatic species that may be found in the area. Understanding the thermal regime can inform decisions made in regards to restoration.

In order to classify the watercourses within the study, the thermal regime was calculated using standardized methods. However, to get a more comprehensive characterization of a stream's existing conditions, more than thermal regime must be considered. Therefore, a summary of stream characteristics is provided in this section, giving an overall view of each stream.

Methodology
A method developed by Stoneman and Jones (1996) and revised by Chu (2009) was utilized to classify sites into coldwater, coolwater, or warmwater habitats based on their maximum air and water temperatures during the summer months. The methodology uses single measurements of daily maximum air temperature (>24.5 °C) and water temperatures between 16:00 hrs and 18:00 hrs, between July 1 and August 31 plotted on a nomograph to approximate the thermal classification of each site (Chu, 2009). This method was applied to Stoney Creek, Sinkhole Creek, and Twenty Mile Creek using the continuous temperature data recorded at the three flow monitoring stations. Hannon Creek was not included as only HDFs were present within the study area.

The summary of stream characteristics uses the results of the HDF assessments and the aquatic resource assessments to characterize each stream.

Results

Thermal regimes for Stoney Creek, Sinkhole Creek, and Twenty Mile Creek are shown in the nomograph in **Figure 3.59**. Using the Stoneman and Jones (1996) method of classifying thermal regime, Twenty Mile Creek is Warm to Coolwater, while Stoney Creek and Sinkhole Creek are Coolwater. Results are illustrated in **Figure 3.60**.

The results of the comprehensive stream characterization are summarized in **Table 3.33**.

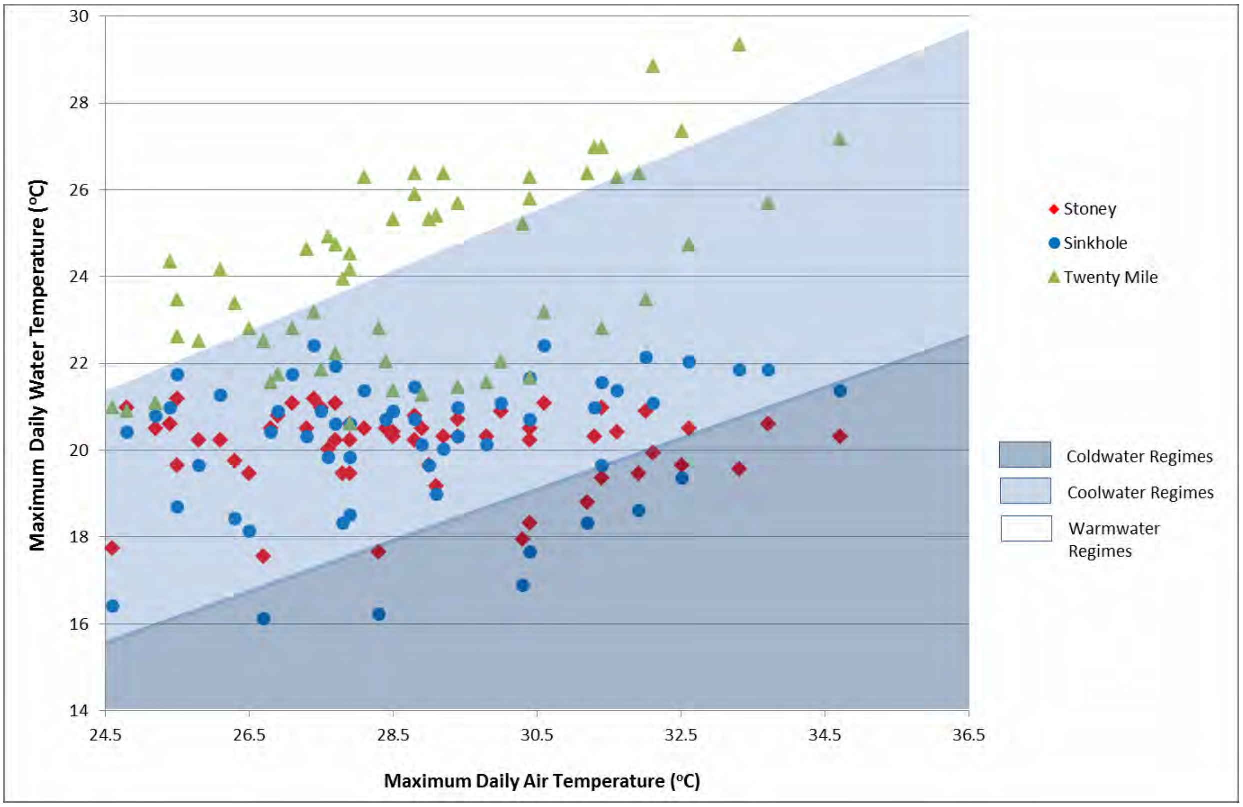
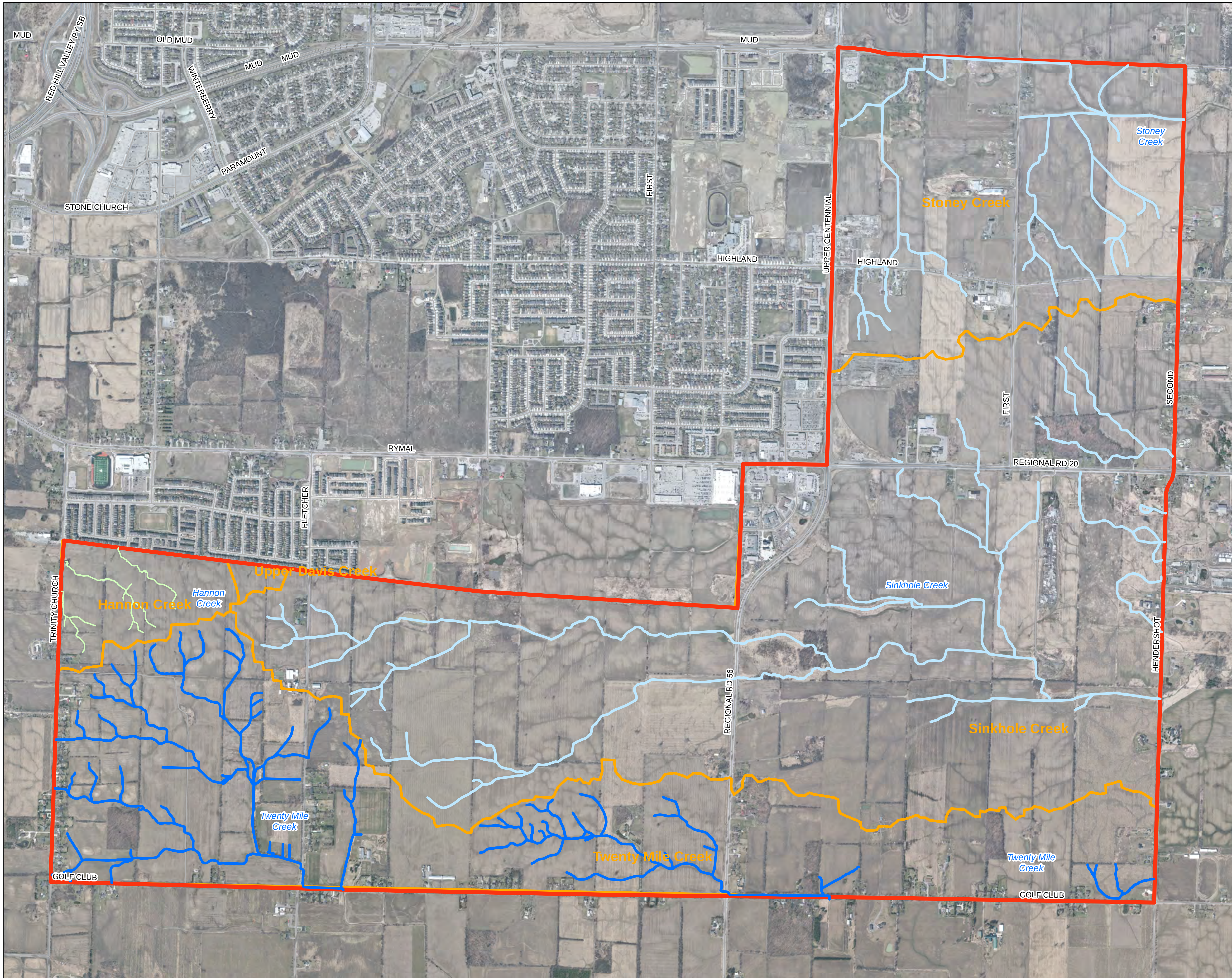


Figure 3.59: Nomograph Showing Thermal Regimes of Stoney, Sinkhole, and Twenty Mile Creeks



Elfrida Subwatershed Study

Legend

Study Area

Subwatershed Boundary

Thermal Regime

Coolwater

Warm-Coolwater

Not Applicable

Figure 3.60

Thermal Regime

Date: February 2017
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

Table 3.33: Stream Characteristics

Subwatershed	HDF Assessment	Aquatic Habitat Assessment	Fisheries Surveys	Benthic Macroinvertebrates	Fish Barriers/Online Ponds	Thermal Regime	Flow Regime
Hannon Creek	Streams were assessed as Mitigation or No Management Required.	Limited aquatic habitat due to ephemeral nature of streams.	N/A	N/A	Two barriers (karst sinkhole and stormwater pipe). Not major obstacles due to ephemeral nature of streams.	N/A	Intermittent
Twenty Mile Creek	Some HDFs upstream of Fletcher Road were classified as Protection and will have their features and riparian corridors protected and/or enhanced. Many stretches assessed as Mitigation or No Management Required.	Downstream sections have deeper silty sediment with some clay, dense instream vegetation, and minimal overhanging cover. Upstream sections have less sediment, the substrate consists of clay and some silt, little instream vegetation, and no overhanging cover. More diversity in form upstream (some riffles and pools) versus downstream (long runs with the odd pool).	Coolwater and warmwater species were sampled from three sites. Low species diversity. Juvenile fish captured	Majority of organisms are pollution tolerant. Water quality ranked from Fair to Poor on the Hilsenhoff FBI. Metrics varied between the sites.	N/A	Warm to Coolwater	Permanent*
Sinkhole Creek	Large sections of Protection HDFs feeding into the watercourse. Remainder of HDFs are ranked as Mitigation or No Management Required.	Tall grasses and wetland vegetation provide shade and cover for the stream. Some woody debris and detritus. Sediment was silt and clay. Few pools or riffles, large runs.	Coolwater and warmwater species were sampled from the online ponds. More diversity than Twenty Mile Creek.	N/A	Two online ponds that were sampled and yielded fish, showing these ponds are providing fish habitat. The HDFs running though these ponds dried up through the year. Two additional online ponds are within the subwatershed.	Coolwater	Permanent*
Stoney Creek	Protection and Conservation HDFs upstream of the golf course, Mitigation and No Management Required elsewhere.	Good amount of instream vegetation, deep sediment, silt substrate with some clay, some woody debris for cover, minimal overhanging vegetation to shade the stream. Long runs, few pools and riffles.	Coolwater and warmwater species were sampled from three sites. Diversity increased further downstream. Juvenile fish were captured.	Pollution tolerant organisms. FBI ranked water quality as Fairly Poor.	Five online ponds within the golf course and just downstream of it. Fish were captured in the golf course ponds which remained wet throughout the year, providing fish habitat.	Coolwater	Permanent*

* The City of Hamilton OP (2014) defines permanent streams as those that would have permanent flow in an average year. Although large sections of the streams dried up in 2016, it was likely a result of the drought and in an average year these streams probably maintain permanent flow.

Conclusions

Though large sections of the watercourses in all subwatershed dried up in 2016, pools remained under the culverts where flow monitoring loggers were installed. It is possible that shading from the culverts and inputs from roadside ditches may bias the calculation of the thermal regimes, thus it is recommended that further monitoring is conducted in the future to confirm thermal regime.

3.3.4 Species-at-Risk and Other Species of Conservation Concern

For the purpose of this Study, *species-at-risk* are defined as species listed as Endangered, Threatened, or of Special Concern by the Committee on the Status of Species at Risk in Ontario (COSSARO). *Species of Conservation Concern* are defined as species listed as Endangered, Threatened, or of Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC); species with Global ranks of G1 – G3; species with Subnational/Provincial ranks of S1-S3; and species considered rare within the City of Hamilton according to the Hamilton Natural Areas Inventory (Schwetz, 2014).

Aquafor Beech Limited consulted a number of primary and secondary information sources to assess the presence of species-at-risk and species of conservation concern within the study area. To assess the potential for the occurrence of species-at-risk in the study area, Aquafor Beech Limited solicited natural heritage information from the Guelph District MNRF as well as the MNRF's NHIC Make-a-Map online database. Correspondence with the MNRF is contained within **Appendix K**.

The MNRF indicated that there are previous records of spoon-leaved moss, black bullhead, grass pickerel, and bobolink within and/or adjacent to the study area. In addition to the aforementioned SAR records, MNRF also provided a list of sixty (60) SAR known to occur within Hamilton (also contained within **Appendix K**). Data collected from the Natural Heritage Information Centre (NHIC) through the MNRF's online Make-a-Map database provided twenty (20) additional records of provincially rare species previously recorded within the vicinity of the study area; seven (7) of these species are considered extirpated from Ontario.

A detailed assessment of SAR and their potential to occur within the study area is contained within **Appendix K**. Species included in the screening exercise were populated from the list of SAR provided by the MNRF and NHIC data from the MNRF Make-a-Map query results. A total of sixty-four (64) species-at-risk and other species of conservation concern have previously been recorded within or adjacent to the Elfrida Subwatershed study area. Extirpated and historical records from the NHIC database were excluded from the list unless there was a reasonable possibility that these species could occur within the study area. Using this aggregated list of SAR, Aquafor Beech Ltd. cross-referenced the habitat needs of each species with the habitat conditions present within the subject property and adjacent lands.

3.3.4.1 Screening Exercise Results

A total of five (5) species-at-risk and four (4) species of conservation concern occur or could potentially occur within the study area. These species and their habitats identified within the Elfrida subwatershed study area are detailed below.

Eastern Wood-pewee – present, confirmed
Status: Special Concern (COSEWIC & COSSARO)
The Eastern wood-pewee occurs throughout Southern Ontario, breeding most often in deciduous woods, and sometimes in more open habitats, with a preference for open habitats (such as open water, roadways, and clearings) adjacent to nesting sites (Peck and James, 1987). The MNRF (2000) further describes the habitat of Eastern wood-pewee as an open, deciduous, mixed or coniferous forest; predominated by oak with little understory; forest clearings, edges; farm woodlots, and parks. In general, the size of forest fragments does not appear to be an important factor in habitat selection, though adjacent land uses (i.e. residential housing) are known to negatively impact the species (COSEWIC 2013). "More than most other eastern flycatcher species, the Eastern Wood-pewee uses dead branches as hunting perches, which may be an additional habitat need" (COSEWIC 2013).

The presence of Eastern wood-pewee in the Elfrida Subwatershed study area was assessed by Aquafor Beech Limited biologists. The bird was found in the wooded areas of NHA St1: once during breeding bird surveys and incidentally during wetland evaluations (**Figure 3.61**).

Figure 3.61: Eastern wood-pewee Observed in a Bur Oak Tree in NHA St1

Monarch – present, confirmed

Status: Endangered (COSEWIC), Special Concern (COSSARO)

Since 2006, the status of the Monarch butterfly has changed significantly. COSEWIC has recently published a proposed species-at-risk management plan for the Monarch in Canada. Monarch populations have declined dramatically over the past 15-20 years. Most recently (2013-2014 overwintering period), the Monarch population in Eastern Canada occupied only 0.67 ha of overwintering habitat, compared with a 1994-2014 average of 6.39 ha.

Figure 3.62: Monarch Larvae (i.e. Caterpillar)

The primary threats facing Monarchs in Eastern Canada include the degradation and loss of overwintering habitat in Mexico, the widespread use of pesticides and herbicides throughout their breeding grounds, climate change, severe weather events, succession and/or conversion of breeding and nectaring habitat, and the impacts of bark beetles on overwintering habitat (Environment Canada, 2014).

Potential marginal nectaring habitat exists along woodland edges and hedgerows where wildflowers exist, and uncultivated lands within the hydro corridor (e.g. NHA Si4, in part). Large patches of the species' host plant, milkweed (*Asclepias* spp.), were not found within the study area. This species was observed in NHAs Si2 (**Figure 3.62**) and Tw1.

Butternut – potentially present

Status: Endangered (COSEWIC & COSSARO)

Butternut is a short-lived (<75 years) mast-bearing tree in the walnut family (Juglandaceae). It is frequently found along moist streambanks and within riparian areas, although it will also occur on well-drained sites underlain by limestone (Poisson and Ursic, 2013). As butternut is intolerant of shade it does not comprise a large component of mature forests. In Canada, this species is restricted to southern Ontario and Quebec where the soils are calcareous and is absent on the granites of the Canadian Shield.

Like American chestnut and eastern flowering dogwood, the primary threat to butternut is an introduced exotic fungal pathogen, *Sirococcus clavigignenti-juglandacearum* ("butternut canker"). Infection generally occurs through wounds, broken branches or leaf scars, causing twig dieback and eventual tree mortality. The most obvious sign of infection is a black, oozing canker on the stem or twigs. Potential habitat for butternut occurs throughout the subwatershed study area. The Butternut Recovery Strategy (Environment Canada, 2010) states the following:

> Butternut can tolerate a large range of soil types. It typically grows best in rich, moist, well-drained loams often found along stream banks but can also be found on well-drained gravelly sites, especially of limestone origin. Butternut is intolerant of shade and competition, requiring sunlight from above to survive but it has the ability to maintain itself as a minor component of forests in later successional stages. As a result, the species is typically scattered throughout a stand and occasionally, groups of butternuts can be found along forest roads, forest edges or anywhere sunlight is adequate to support regeneration through seed.

Suitable habitat for this species was present throughout much of the subwatershed study area; however, there were no documented occurrences within areas surveyed. Surveys completed by Aquafor Beech Limited did not cover all potentially suitable butternut habitats; individual Butternut could be present in NHAs Si5, Tw2, & Tw3; hedgerows; on residential properties; etc. Accordingly, additional surveys for Butternut at subsequent planning stages are recommended.

Eastern Flowering Dogwood – potentially present
Status: Endangered (COSEWIC & COSSARO)
Eastern flowering dogwood (**Figure 3.63**) is a showy understory species in the dogwood family (*Cornaceae*). Its distribution in Ontario is restricted to the southwest (i.e. Carolinian Zone). It exists in a variety of mid-aged to mature forests, including open dry-mesic hickory woodlands, mesic maple-beech deciduous forest and mixed forest (Bickerton and Thompson-Black, 2010); and can also occur within hedgerows. It prefers coarser soils, in particular, acidic sandy-loams.


Figure 3.63: Eastern flowering dogwood

Infection by an exotic fungus known as *Discula destructiva* ("dogwood anthracnose") is the primary threat to this species. It tends to be most severe in shaded, moist areas, and it spreads primarily in cool, wet seasons. After infection, tan spots surrounded by a purple ring develop in the lower leaves. The infection then spreads further into the crown and may produce cankers along the stem.

Eastern flowering dogwood was not recorded in any of the NHAs surveyed as part of this study. However, not all potentially suitable habitats (e.g. hedgerows; NHAs Si5, Tw2, & Tw3) within the study area have been surveyed.

Myotis bats – potentially present
Status: Endangered (COSEWIC & COSSARO)
According to COSEWIC, "Habitat for bats is composed of 1) hibernacula for overwinter survival and 2) summering areas with suitable foraging areas within commuting range to structures used for roosting or maternity colonies. The habitat requirements of temperate-region bats vary by season. Maternity sites (trees, rock crevices, buildings, bat houses) and hibernacula (cave, mine, or building used for hibernation) are the main limiting habitat features for the three species within their range." (2013)

Suitable hibernation sites (i.e. mines and caves) are not present within the study area; however, one karst sinkhole is present near Trinity Church Road. It is not known if bats are using the karst as habitat.

Potentially suitable maternity roosting habitat is present within NHAs St1, St2, St3, St4, Si1, Si2, Si3, Si5, Si8, Tw1, Tw2, Tw3, Tw4, and Tw5. While targeted surveys for bats and bat maternity roosting habitat were not completed as part of this study, bats (species unknown) were observed foraging over ponds and in open areas between trees in NHA St1 and within the forest in Si2 during amphibian calling surveys. While all three bat SAR are known to forage in canopy gaps within forests, little brown Myotis is noted for its tendency to forage over still water (COSEWIC 2013). Cavity trees and snags are especially prevalent in NHA Si2. Cavity trees were not observed in NHA Si7. NHAs Si3, Si5, Si8, St2, St3, St4, Tw2, Tw3, and Tw5; all of which could contain potentially suitable maternity roost and foraging habitat; were not included in field surveys due to lack of land access permissions. As such, further study is required to assess these areas' potential suitability as habitat for bats.

Woodland Vole – potentially present
Status: Special Concern (COSEWIC & COSSARO)
In Ontario, the woodland vole is restricted to the Carolinian zone. While found in most forest types, especially those with well-developed duff and humus layers, they are most common in mesic mixed or dry deciduous forests; though they may also use marginal habitats adjacent to forests (COSEWIC 2010[2]). Soil moisture and type is important in habitat selection, as species prefer dry friable soils which make burrowing easy (COSEWIC 2010[2]).

Mammal surveys were not conducted as part of this Study. As such, the presence of this small mammal has not been fully assessed. Potentially suitable habitat for this species within and adjacent to the study area includes NHAs St2, Si1, Si2, Si4, Si5, Tw1, Tw3, Tw4, and Tw5. As all of these potentially suitable habitats will be protected as part of the Natural Heritage System, future surveys for woodland vole is unnecessary.

Eastern Milksnake – potentially present
Status: Special Concern (COSEWIC)

The eastern milksnake (**Figure 3.64**) is a harmless snake that occurs throughout southern Ontario. The species uses a wide range of habitats, including suburban parks and gardens, hayfields, pastures, old fields, meadows, and deciduous, coniferous and mixed forests. In rural areas, the species is found in and around sheds, barns, abandoned buildings and anthropogenic debris (Harding 1997, COSEWIC 2002). Little is known about the movement patterns of Eastern milksnakes in Canada, but their activity range is estimated to encompass approximately 20 ha and it is assumed that individuals migrate to and from hibernation sites (COSEWIC 2002).


Figure 3.64: Eastern milksnake (Adult)

The presence of Eastern milksnake in the Elfrida subwatershed has been assessed by an Aquafor Beech biologist. Eastern milksnake was not found during targeted surveys, though due the species' secretive nature (COSEWIC, 2002) Aquafor Beech Limited staff cannot say with certainty that Eastern milksnake is not within the study area.

Accordingly, additional surveys of suitable habitat at subsequent planning stages to determine whether the species is extant are recommended. The presence of snake hibernacula was not confirmed during surveys, though a potential candidate site was located in a rubble pile on an old homestead property east of NHA Tw4 (see **Appendix I** for details).

3.3.5 Significant Wildlife Habitat

Aquafor Beech Limited used the MNRF's *Significant Wildlife Habitat Criteria Schedules for Ecoregion 7E* (Jan 2015) as a guiding document in determining the presence of significant wildlife habitat within the study area. The corresponding analysis and assessment are detailed in **Appendix I**. The subsections below detail confirmed and candidate Significant Wildlife Habitat (SWH) types identified through this study. SWH is illustrated at the end of this section in **Figure 3.68**.

3.3.5.1 Specialized Habitat for Wildlife: Seeps and Springs

One type of SWH confirmed within the study area includes groundwater seepage areas within NHA Si2.

Figure 3.65: Potential Seepage/Headwater Area (circled in red)

In addition, a wooded area approximately 350 m north of Si2 is located at the headwaters of a tributary/HDF to Sinkhole Creek (**Figure 3.65**). This area, which is surrounded by agricultural fields, was not visited during field surveys due to lack of land access permissions. It is evident from air photos that the area is seasonally wet, and spring peeper was recorded calling from this area on May 25th, 2016. Accordingly, it is possible that this is an area of groundwater seepage and therefore it should be considered candidate SWH subject to confirmation through further study.

3.3.5.2 Specialized Habitat for Wildlife: Amphibian Breeding Habitat (woodlands)

Other SWH consists of woodland amphibian breeding habitat. Breeding amphibians were recorded in wooded NHAs St1, Si1, Si2, Si5, Tw1 and Tw2. However, (likely) due to the very dry conditions in 2016, there was insufficient evidence to confirm the presence of SWH. Due to the presence of suitable breeding habitat in the above-listed NHAs, in the opinion of Aquafor Beech Limited, these NHAs could potentially be confirmed SWH and should be considered candidate SWH until proven otherwise (during a suitable monitoring year). The following NHAs, which were not surveyed, potentially contain amphibian woodland breeding habitat: St2, St4, Si3, and Si8. In addition, one spring peeper (call level code 1) was recorded in the wooded area approx. 350 m north of Si2 (see **Figure 3.65**, above, for location). Given that 2016 was an exceptionally dry year, it is possible that amphibian calling results at this location would be different (i.e. more substantial) during regular or wetter years. Accordingly, subject to further study this area should be considered candidate SWH.

3.3.5.3 Specialized Habitat for Wildlife: Amphibian Breeding Habitat (wetlands)

Amphibian wetland breeding habitat recorded in small wetlands that are within or in close proximity to other natural heritage features and thus plausibly contribute to amphibian diversity with the greater Elfrida NHS are listed below. The corresponding locations of the observations are listed in brackets.

- Survey station 8 (isolated pond on rural property)
- Survey station 9 (NHA Si6)
- Survey station 17 (note: part of large PSW complex)
- Survey station 19 (isolated ponds on residential properties east of the study area)
- Survey station 21 (isolated wetland on residential property)

Due to the very dry conditions in 2016, there likely was insufficient evidence to confirm the presence of SWH. Due to the presence of suitable breeding habitat in the above- listed areas, in the opinion of Aquafor Beech Limited these areas could potentially be confirmed SWH and should be considered candidate SWH until proven otherwise (during a suitable monitoring year). It should be noted that amphibian observations were made at survey station 5, which correspond with a natural area north of Si4, however at the time of writing the lands have draft plan approval and thus are not eligible for further designations under the Planning Act (Summit Park-Swayze Lands 25T-201309; UHOPA-15-020; ZAC-13-059).

3.3.5.4 Seasonal Concentrations of Animals: Bat Hibernacula and Snake Hibernacula

The status of hibernacula for snakes and bats is currently unknown; NHA Si5 and a gravel/rubble pile east of Tw4 (**Figure E1, Appendix I**) may contain a hibernaculum for snakes, and the karst sinkhole near Trinity Church Road may function as a hibernation site for bats. Further study is required to confirm or refute wildlife's use of these areas/features.

3.3.5.5 Seasonal Concentrations of Animals: Bat Maternity Colonies

Figure 3.66: Beech snag with cavity, NHA Si2

Furthermore, several forested blocks have the potential to function as candidate bat maternity roosts.

Potentially suitable bat maternity colony habitat is present within NHAs St1, St2 (this NHA contains many cavity trees and snags, **Figure 3.66**), St3, St4, Si1, Si2, Si3, Si5, Si8, Tw1, Tw2, Tw3, Tw4, and Tw5. Bats were observed foraging in NHAs St1 and Si2 during amphibian calling surveys. Cavity trees and snags are prevalent in NHA Si2, as were mature shagbark hickory (*Carya ovata*) trees; cavity trees were not observed in NHA Si7. Furthermore, NHAs Si3, Si5, Si8, St2, St3, St4, Tw2, Tw3, and Tw5 were not included in field surveys due to lack of land access permissions. As bat surveys were not completed as part of this study, it is recommended that surveys be completed a subsequent planning stage.

3.3.5.6 Rare Vegetation Communities: Other Rare Vegetation Communities

One (1) provincially and globally rare vegetation community type was identified within the study area during vegetation community assessments (**Section 3.3.2.5**). This remnant Bur Oak Mineral Deciduous Swamp community is located within NHA St1 (ELC polygon 3). This community contains clay soils and has scattered low spots that hold water seasonally. This community has been significantly influenced by human activity; exotic species are commonplace, portions of the community have been cleared, and a channelized watercourse, which connects a series of permanent ponds built as part of a now-defunct golf course, runs through the swamp (**Figure 3.67**).

Figure 3.67: Bur Oak Mineral Deciduous Swamp in NHA St1

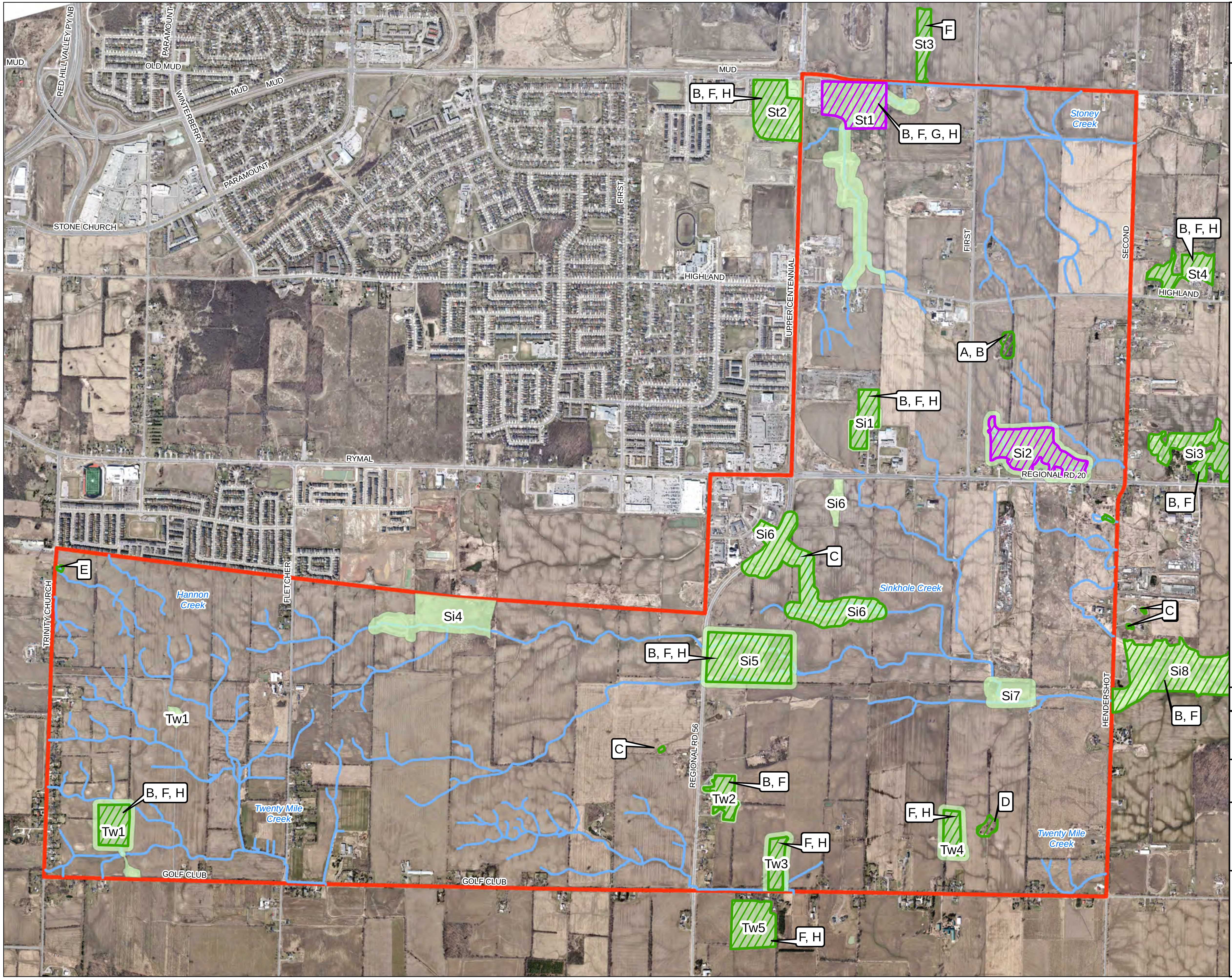
3.3.5.7 Habitats of Species of Conservation Concern: Special Concern and Rare Wildlife Species

As detailed above in (**Section 3.3.4**) Special Concern species observed during field studies include Eastern wood-pewee (NHA St1) and monarch (NHAs Si2 and Tw1). The confirmed habitat of Eastern wood-pewee consists of the northern section of NHA St1 (i.e. ELC polygons 1-4). Habitat protection considerations for monarch are not warranted, as no significant swaths of milkweed were identified within the study area and the species status is primarily caused by loss of overwintering habitat in Mexico.

Potential habitat for woodland vole (Special Concern) and Eastern milksnake (Special Concern) has been identified within the study area. Potentially suitable habitat for woodland vole is present within NHAs St2, Si1, Si2, Si4, Si5, Tw1, Tw3, Tw4, and Tw5. While it is not known if this species is present within the study area; as all of these potentially suitable habitats will be protected as part of the Natural Heritage System, future surveys for woodland vole is unnecessary.

Lastly, potentially suitable habitat for Eastern milksnake is present in natural, semi-natural, agricultural, and farmstead properties within and adjacent to the study area. This species was not found during targeted surveys, though due to the species' secretive nature (COSEWIC, 2002) Aquafor Beech Limited cannot say with certainty that the species is not within the study area. Further studies, especially but not limited to investigations of the former farmstead property northeast of NHA Tw4, are recommended at subsequent planning stages.

Elfrida Subwatershed Study



Legend

- Study Area
- Watercourse
- Natural Heritage Areas

Significant Wildlife Habitat

- Candidate
- Confirmed

Significant Wildlife Habitat Types

Specialized Habitat for Wildlife
A: Seeps and Springs
B: Amphibian Breeding Habitat (Woodlands)
C: Amphibian Breeding Habitat (Wetlands)

Seasonal Concentrations of Animals
D: Snake Hibernacula
E: Bat Hibernacula
F: Bat Maternity Colonies

Rare Vegetation Communities
G: Other Rare Vegetation Communities

Habitats of Species of Conservation Concern
H: Special Concern and Rare Wildlife Species

Figure 3.68

Significant Wildlife Habitat

Date: January 26, 2017
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

3.3.6 Environmentally Sensitive Areas

In accordance with the definition provided in the City of Hamilton's Rural OP (2016), Environmentally Sensitive Areas (ESAs) are locally significant areas that meet any one of the following criteria:

a) The area is a good representative of a biotic community characteristic of the natural landscapes of the City and not adequately represented in existing protected areas or the area is a good representative of pre-settlement biotic community;

b) There are biotic communities that are rare in the City, Province, or Canada;

c) The area is a large natural area (20 hectares or more in size); it may be sufficiently large to provide habitat for species requiring large habitat areas;

d) There is habitat for species considered significant in the City, Province, or Canada;

e) The site fulfills a significant hydrological function (groundwater recharge or discharge, ground or surface water quality, or flood attenuation);

f) The site contains a significant earth science feature (distinctive and unusual landform);

g) There is a high diversity of native species or biotic communities;

h) The area provides *essential* habitat for the continuation of species; for example, significant areas of species concentrations, areas *essential* for certain stage of the life cycle, source areas for species;

i) There are significant seasonal concentrations of wildlife;

j) The area acts as a link between natural areas or functions as a corridor for wildlife;

k) The area is in good natural condition, with few non-native species, particularly invasive non-natives; or

l) The area contains significant *fish habitat*.

At the request of the City of Hamilton, an analysis of potential ESAs within the study area has been completed. Details are contained in **Table 3.34**, below. The analysis is subject to limitations of site access and may need to be updated at a future planning stage. NHAs not subject to field studies have been indicated as such in the table below (orange font), and due to the lack of information, their ESA status is currently unconfirmed. ESA criteria correspond with those listed above. Criteria marked with an upper-case "X" are those which have been confirmed through this study. In cases where ESA criteria have the potential to occur, ESA criteria are indicated with a lower-case "x".

Table 3.34: Analysis of Environmentally Significant Areas

Natural Heritage Area	ESA Criteria												Meets criteria for designation as an ESA?
	a)	b)	c)	d)	e)	f)	g)	h)	i)	j)	k)	l)	
St1		X		X				X	x			X	Confirmed
St2									x				Unconfirmed
St3									x				Unconfirmed
St4									x				Unconfirmed
Tw1	X							X	x		X	X	Confirmed
Tw2				x					x				Unconfirmed
Tw3				x					x				Unconfirmed
Tw4	X			x					x		X		Confirmed
Tw5				x					x				Unconfirmed
Si1				x				X	x				Confirmed
Si2	X			X	X		X	X	x		X		Confirmed
Si3									x				Unconfirmed
Si4										X		X	Confirmed
Si5				x					x	X		x	Confirmed
Si6										X		X	Confirmed
Si7										X		X	Confirmed
Si8									x	X			Confirmed

3.3.7 Designated Natural Areas

According to the MNRF, natural areas records within the general area include the following:

- Twenty Mile Creek Meander Belt (Regional Life Science ANSI);
- Eramosa Karst (Provincial Earth Science ANSI);
- Sinkhole Wetland Complex (evaluated wetland, other); and
- Lower Twenty Mile Creek Wetland Complex (Evaluated, provincially significant).

All but the first listed natural area are at least partially within the boundaries of the study area.

3.3.8 Elfrida Natural Heritage System

The following subsections outline the NHS policy framework as well as the NHS identification and development undertaken for the Elfrida Subwatersheds Study Area.

Provincial Context

The 2014 Provincial Policy Statement (PPS), promulgated under the Planning Act, directs municipal land-use planning activities related to matters of provincial interest. Section 2.1.2 of the Provincial Policy Statement (PPS) states that:

> *the diversity and connectivity of natural features in an area, and the long-term ecological function and biodiversity of natural heritage systems, should be maintained, restored or, where possible, improved, recognizing linkages between and among natural heritage features and areas, surface water features and ground water features (Ministry of Municipal Affairs and Housing, 2014).*

The PPS supports not only the protection of individual natural heritage features (woodlands, wetlands, valleylands, wildlife habitat, etc.) but also the linkages that connect them into a broader Natural Heritage System (NHS). The NHS approach is effective because it acknowledges that natural heritage features have strong functional ties to one another, and this functionality may be compromised when such features become isolated within a predominately agricultural or urban matrix. Accordingly, a key objective of the Elfrida Subwatershed Study is to provide a framework to guide the development of lands so that their ecological processes, functions and significant natural features are protected, maintained and enhanced (City of Hamilton, 2014).

The Province of Ontario provides technical guidance to implement the natural heritage policies of the PPS through the Natural Heritage Reference Manual (NHRM). The first iteration of the NHRM, issued by the Ministry of Natural Resources and Forestry (MNRF) in 1999, recognizes the development of a natural heritage system as a comprehensive approach to defining and protecting natural heritage features and areas. The most recent edition of the NHRM, issued in 2010, places greater emphasis on planning for natural heritage systems and providing connectivity among natural heritage features and areas (MNRF 2010). The NHRM itself is an advisory document outlining what planning authorities (e.g. municipalities, conservation authorities) should consider when reviewing development proposals for impacts on natural heritage features.

The PPS defines a Natural Heritage System as:

> *a system made up of natural heritage features and areas, and linkages intended to provide connectivity (at the regional and 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 and areas with the potential to be restored to a natural state, areas that support hydrologic functions, and working landscapes that enable ecological functions to continue* (Ministry of Municipal Affairs and Housing, 2014).

The NHS approach is a useful method for the protection of natural heritage features and areas because it reinforces an understanding that the elements of the system have strong ecological ties to each other, as well as to other physical features and areas in the overall landscape. The NHS approach also addresses a number of important land use planning concerns, including biodiversity decline, landscape fragmentation and the maintenance of ecosystem health. The NHRM describes these planning concerns in greater detail and outlines the potential benefits of a NHS (MNR 2010).

The study area is outside of lands subject to the Niagara Escarpment Plan and the Greenbelt Plan.

Local Context

The Elfrida Subwatershed study area contains a number of Natural Heritage Features, including:

- Woodlands*;
- Wetlands*;
- Earth Science Areas of Natural and Scientific Interest (Eramosa Karst);
- Forests*;
- Thickets;
- Meadows;
- Fish Habitat, Watercourses, and Headwater Drainage Features; and
- Significant Wildlife Habitat.

Together, the above mentioned Natural Heritage Features complement one another in the context of the greater NHS.

*Note: The City of Hamilton considers woodlands and forests, as defined by Lee et al. (1998), as "woodlands". It is worth noting that treed swamps are considered both woodlands and wetlands according to the City of Hamilton.

The City of Hamilton employs a nested approach to natural heritage system planning: the NHS is comprised of Core Areas and Linkages, as illustrated below in **Figure 3.69**. The City of Hamilton (2014) defines Core Areas as *Key Natural Heritage Features*, *Key Hydrologic Features*, and *Local Natural Areas*. Definitions for these Features and Linkages are detailed below.

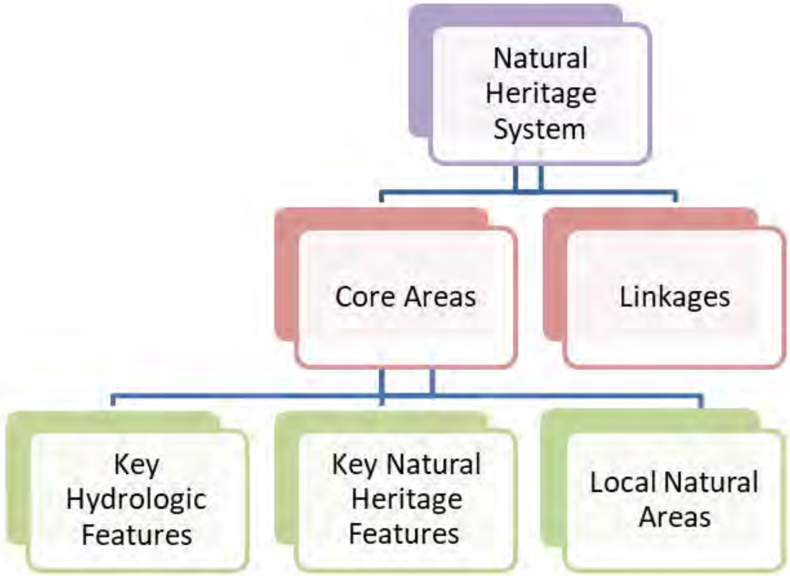


Figure 3.69: The City of Hamilton's Approach to Natural Heritage Planning

Applicable Definitions

During the preparation of its Rural Official Plan (completed in 2012), the City of Hamilton identified the components of a municipal Natural Heritage System (NHS) consisting of Core Areas and Linkages. In developing the NHS, Aquafor Beech Limited relied on applicable definitions from the City of Hamilton's Rural Official Plan, as follows:

The City of Hamilton (2014) defines **Key Natural Heritage Features** as:

- Significant habitat of endangered, threatened, and special concern species;
- Fish habitat;
- Wetlands;
- Life Science Areas of Natural and Scientific Interest (ANSIs);
- Significant valleylands;
- Significant woodlands;
- Significant wildlife habitat;
- Sand barrens, savannahs, and tallgrass prairies; and
- Alvars.

The City of Hamilton (2014) defines **Key Hydrologic Features** as:

- Permanent and intermittent streams;
- Lakes (and their littoral zones);
- Seepage areas and springs; and
- Wetlands.

The City of Hamilton (2014) defines **Local Natural Areas** as:

- Environmentally Significant Areas as identified by the City of Hamilton;
- Unevaluated wetlands; and
- Earth Science Areas of Natural and Scientific Interest.

The City of Hamilton (2014) defines **Linkages** as landscape areas that connect natural areas. Linkages *may* include the following:

- Woodland linkages (e.g. small woodlands); and
- Other natural vegetation types (e.g. meadows, old field, thickets).

Table 3.35 provides a further description of the City of Hamilton's definitions of *woodland linkages* and *other natural vegetation types*:

Table 3.35: City of Hamilton definitions of woodland linkages and other natural vegetation types

Term	Definition
Woodland linkage	Any natural or planted wooded area of any size or composition that either connects or lies within 100 m of a Core Area.
Other natural vegetation types	Any meadow, thicket, or old field that connects Core Areas or is situated within 100 m of a Core Area.

A more thorough definition of Linkages, as provided by the City of Hamilton (2014), is as follows:

> Linkages are ... landscape areas that connect natural areas. Linkages are also important natural features, either in their own right or through restoration activities. They are avenues along which plants and animals can propagate, genetic interchange can occur, populations can move in response to environmental changes and life cycle requirements, and species can be replenished from other natural areas. Conserving linkages also protects and enhances Core Areas.

It is noted that once the Elfrida SWS study area is brought into the Urban Areas, the City of Hamilton's Urban Official Plan would then apply.

3.3.9 Natural Heritage System Methodology

Aquafor Beech Limited used a systems approach to identify an NHS for the Elfrida Subwatershed study area. The systems approach identifies a NHS that includes core areas while ensuring that smaller, less significant natural areas or degraded lands between these areas are maintained or restored to provide a connected system of natural areas (City of Hamilton 2014). Briefly, the approach used by Aquafor Beech Limited involved the following steps:

(1) A preliminary NHS for the study area and adjacent lands was identified based on Core Areas as mapped by the City of Hamilton (2014).
(2) Data from existing information sources and supplemental fieldwork was used to characterize the existing conditions of the study area. Outside of the study area, natural heritage features were classified based on air photo interpretation and mapping provided by the City of Hamilton.

The Elfrida NHS builds upon the pre-existing NHS identified by the City of Hamilton. The NHS includes the pre-existing NHS (with applicable refinements based on field observations) and the following three (3) features:

(1) Core Areas and Linkages as defined by the City of Hamilton (2014);
(2) Vegetation protection zones consistent with the minimum requirements of the City of Hamilton (City of Hamilton 2014) and, where applicable, per the recommendations of this study; and
(3) Opportunities to enhance the attributes of Core Areas and Linkages.

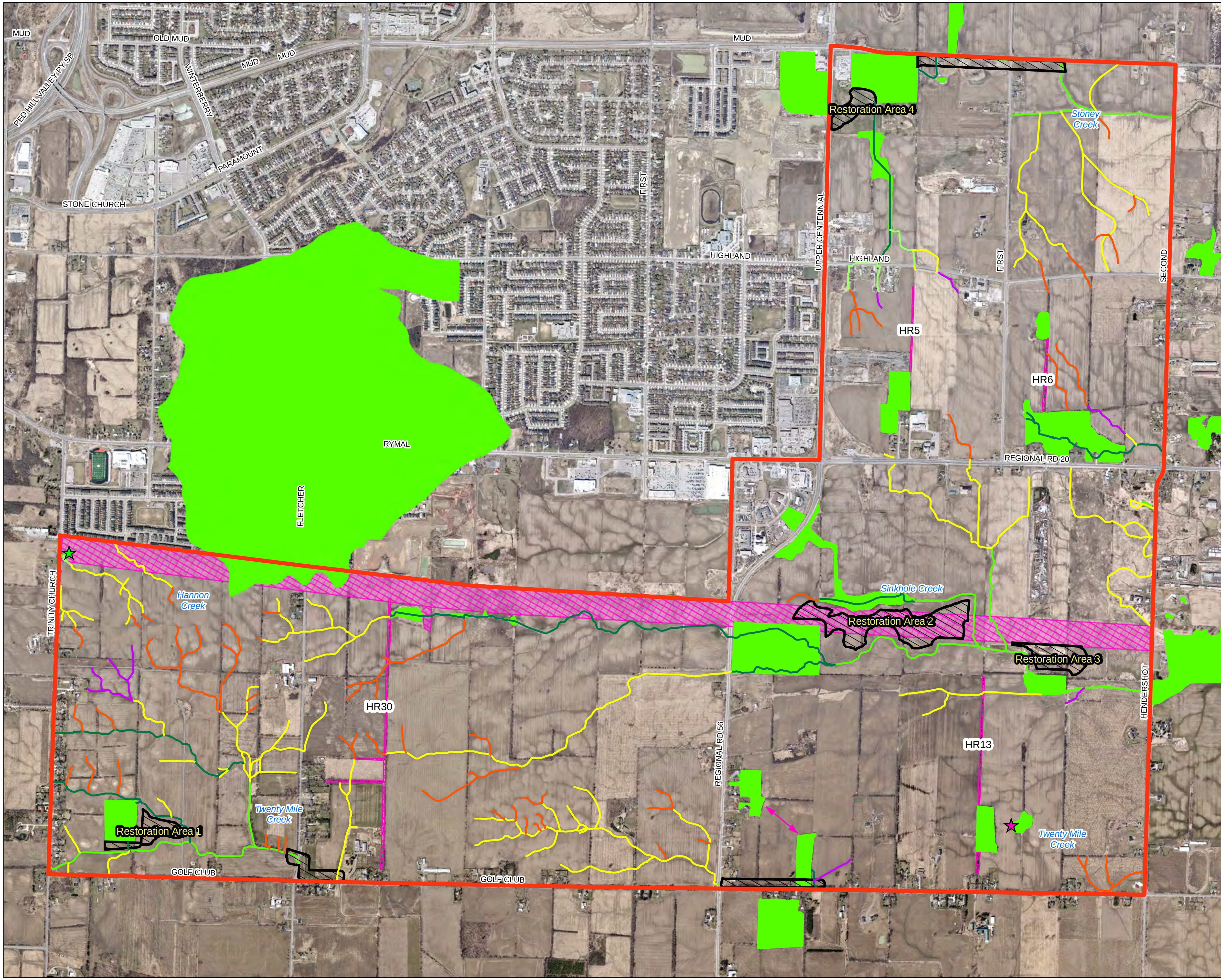
The following table (**Table 3.36**) details the results of the assessment of Core Areas and Linkages within and adjacent to the Elfrida Subwatershed study area. Core Areas and Linkages are illustrated in **Figure 3.70**. Vegetation Protection Zones (VPZs) and enhancement areas within the study area are discussed below in **Section 3.3.9.1**.

The NHS for the Elfrida Subwatershed study area, which includes Core Areas, Linkages, applicable VPZs, and areas recommended for restoration and enhancement; is illustrated at the end of this section in **Figure 3.78.**

Table 3.36: Summary of Natural Heritage Features within the Elfrida Natural Heritage System

Natural Heritage Designations			Discussion
Core Areas	Key Natural Heritage Features	**Significant Habitat of Endangered, Threatened, and Special Concern Species**	Habitat for Special Concern species has been confirmed in NHA St1, ELC polygons 1 and 2. This area has been included as part of the NHS. Potential habitats for species-at-risk, as detailed in **Appendix F**, is contained within natural heritage features having other overlapping natural heritage designations (e.g. significant woodlands) and are therefore included within the NHS.
		Fish Habitat	Within the study area, fish habitat consists of watercourses as shown on **Figure 3.78**; as well as ponds within NHA St1, the headwater wetland/pond in NHA Si4, and a pond within the woodland in NHA Si5. These ponds have overlapping natural heritage designations (e.g. wetlands) and are included within the NHS.
		Wetlands	Wetlands within the study area include those mapped by the City of Hamilton and those identified through vegetation community surveys completed by Aquafor Beech Limited. A total of thirteen (13) wetland communities or inclusions were identified through vegetation community surveys. Of these, three (3) were evaluated according to OWES and include wetlands within NHAs St1, Si4, and Si6. As detailed in **Section 3.3.2.7**, a significant portion of the Sinkhole Creek Wetland Complex was put into agriculture in 2016; the wetland boundaries shown in the NHS mapping reflects this change to the wetland boundary. See also *Local Natural Areas: Unevaluated Wetlands*, below, for further context.
		Life Science ANSIs	Life Science ANSIs are not present within the study area.
		Significant Valleylands	The topography of the study area is quite flat; Significant Valleylands are not present within the study area boundary.
		Significant Woodlands	Significant woodlands, as identified by the City of Hamilton (2014), include NHAs Si2, the wooded (east) portion of Si5, Tw1, Tw3, and Tw4. Outside of the study area, significant woodlands identified by the City of Hamilton (2014) include NHAs Si3, Si4, wooded portions of Si8, and Tw5. Following investigations by Aquafor Beech Ltd., wooded communities with NHA St1 (ELC polygons 2 and 3) were added to the suite of Significant Woodlands based on the area's proximity to a watercourse and wetlands as well as its provision of habitat for a Special Concern species (i.e. Eastern wood-pewee).
		Significant Wildlife Habitat	As detailed in **Section 3.3.5** and **Appendix E**, confirmed and candidate SWH has been identified throughout the study area and adjacent lands. Confirmed SWH consists of the north portion of NHA St1 and all of NHA Si2.
		Sand barrens, savannah, and tallgrass prairies	Sand barrens, savannah, and tallgrass prairies were not recorded within the study area.
		Alvars	Alvars are not present within the study area.
	Key Hydrologic Features	**Permanent and Intermittent streams**	Permanent and intermittent watercourses are primarily considered under *Key Natural Heritage Features: Fish Habitat*, above. Additional features within the study area which qualify as intermittent streams include HDFs classified as Protection, Conservation, or Mitigation. HDFs that were not visited as part of the study due to lack of access permissions are shown in the Core Areas and Linkages map (**Figure 3.70**) for reference only; the status of these HDFs will be determined through future study.
		Lakes (and their littoral zones)	Lakes are not present within the study area.
		Seepage areas and springs	Two seepage areas were confirmed within the study area: one in NHA Tw4 and another at Groundwater Monitoring Station #3. As the former is within a significant woodland and the latter within the floodplain and minimum Vegetation Protection Zone associated with Twenty Mile Creek, these features are included within the NHS. The presence of seepage areas on lands north of NHA Si2 (see **Figure 3.65**) will be confirmed through further study.
		Wetlands	See discussion under *Key Natural Heritage Features: Wetlands*, above.
	Local Natural Areas	**Environmentally Significant Areas**	The City of Hamilton has not identified any Environmentally Significant Areas within or adjacent to the study area. An analysis of each NHA`s candidacy for designation as an Environmentally Sensitive Area is contained in **Section 3.3.6**.
		Unevaluated wetlands	Unevaluated wetlands within the study area consist of small isolated agricultural ponds, a small wetland in NHA Tw1 (ELC Polygon 3) that is isolated from the woodland, and other small (<0.5 ha) wetlands within woodlands (e.g. treed swamps within Tw3 and Tw4). The latter is not considered further as they are protected under other natural heritage designations. Given the demonstrated limited ecological function of these ponds (e.g. habitat for amphibians) and the anticipated further limitations in a post-development scenario, isolated agricultural ponds were included in the NHS only when they were connected or adjacent to another natural heritage feature or if the pond had a demonstrable ecologic function. ELC Polygon 3 of NHA Tw1 is a small isolated wetland that appears to have developed following excavation; there is no inlet or outlet for this feature, and it does not support amphibians. Its hydrologic function could be replicated and enhanced through restoration efforts adjacent to the south side of the forest of Tw1 and Twenty Mile Creek channel.

Natural Heritage Designations			Discussion
		Earth Science ANSIs	A small portion of the Eramosa Karst Provincial Earth Science ANSI "feeder area" is within the study area boundary near the northern section of Fletcher Road. According to mapping received from the City of Hamilton, the ANSI is split into three sections: the "core" area and majority of the "feeder" area of the ANSI are outside of the study area and are within the Eramosa Karst Conservation Area. The largest portion is designated as the 'developed' portion of the ANSI and consists primarily of residential development lands. Within the study area, the portion of the ANSI that is outside of the hydro ROW or is under agriculture.
Linkages	**Woodland linkages**		Woodlands within the study area that qualify as linkages include: • A small woodland within NHA Si4 (the woodland is adjacent to a wetland and a watercourse and contributes to the linkage function of the riparian corridor); • NHA Tw2 (note: contains a wetland); • NHA Si1 (note: contains and is adjacent to multiple wetlands, and is within 50 m of an HDF); and • The small green ash swamp within NHA Si7 qualifies as a woodland linkage, though its designation as a wetland takes precedence.
	Other natural vegetation types		Within the study area, other natural vegetation types (i.e. meadow, thicket, or field) within 100 m of a Core Area include meadows within NHA Si4. This meadow is already within a linkage (i.e. the Hydro corridor) that was identified by the City of Hamilton prior to the commencement of this study. Furthermore, as detailed in **Section 3.3.2.8**, hedgerows identified as having ecological/linkage value have been included as linkages. A conceptual location for a future linkage, identified between NHAs Tw 2 and Tw3, has been included in the mapping. It is suggested that the linkage area be created/vegetated as part of development application(s).
	Streams and watercourses that connect core areas		Streams and watercourses that connect core areas within the study area are considered Core Areas; this designation supersedes their designation as a Linkage.



Elfrida Subwatershed Study

Legend

- Study Area
- Restoration Areas
- Karst Sinkhole

CORE AREAS

- Core Areas

LINKAGES

- Linkages
- Linkage: Conceptual Location
- Potential Future Snake Corridor

HEADWATER DRAINAGE FEATURES

- Protection
- Conservation
- Mitigation
- No Managment Required
- No Access

Figure 3.67

Core Areas, Linkages, & Restoration Areas

Date: May, 2018
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

3.3.9.1 Vegetation Protection Zones

Many species, including Chorus Frog (pictured above), rely on different habitat types throughout the year. VPZ recommendations resulting from detailed studies (i.e. an EIS) should be context-sensitive and address the habitat requirements of flora and fauna within the NHS.

Vegetation protection zones (VPZs), sometimes referred to as buffers, are required to aid in mitigating potential adverse environmental impacts to natural features and habitats resulting from development and/or site alteration. VPZs are vegetated physical separations between natural features and development areas intended to preserve the ecological integrity of natural features and their associated processes (MNR 2010). The VPZ is to be of sufficient width and design to protect the natural area and its ecological functions from the impacts of the proposed land use and site alteration occurring during and after construction, and where possible, restores or enhances the natural area and/or its ecological functions.

Minimum VPZ recommendations for Natural Heritage Features are discussed below in a general sense given the absence of final detailed land use plans for developable areas within the study area. Context is of paramount importance: it is recommended that the minimum VPZ widths outlined in this report be revisited as new information regarding the potential land use and updated information on the ecological function of natural heritage features becomes available. **Once VPZs are determined, they become part of the NHS**. VPZs are to be imposed only where new development and/or site alteration is to occur but will not affect lands which are within the study area but not being proposed for development and/or site alteration.

Within the Elfrida Subwatershed Study Area, preliminary minimum VPZ widths consistent with the requirements of the City of Hamilton's Rural Official Plan (**Table 3.37**) were included within the Elfrida NHS (**Figure 3.78**). Special consideration for the hydrologic requirements required to maintain wetland hydrology and ecologic function (e.g. amphibian breeding habitat) within NHA Si2 warrants the application of a minimum VPZ of 60 m along the northern edge of the feature along with special post-development considerations for the maintenance of sheet flow coming from adjacent lands (see below for further details). Aside from this one case, the minimum VPZs applied to natural heritage features are consistent with the minimum values listed in **Table 3.37.**

At this stage in the planning process the NHS, the elements of which are detailed in **Section 3.3.6**, are subject to the minimum VPZ requirements as defined by the City of Hamilton's Rural Official Plan and contained within this Subwatershed study. The widths of these preliminary minimum VPZs are to be reviewed at subsequent planning stages and may be augmented (i.e. increased or decreased) based on the recommendations of an approved study such as an Environmental Impact Statement (EIS) per Policies 2.4.10 to 2.4.14 of the City's Rural Official Plan (2012), or Urban OP (2017, effective 2013) as applicable. Per Section 2.4.14 of the City of Hamilton's Rural Official Plan:

Permitted uses in a VPZ shall be limited to low impact uses ... New development or site alteration areas shall be located outside of the vegetation protection zone. Private sewage disposal systems and new impervious surfaces associated with the development shall not be permitted within the vegetation protection zone.

Table 3.37: Minimum Vegetation Protections Zones applicable to natural heritage features within Rural Areas

Applicable Natural Heritage Features	Minimum Vegetation Protection Zone (VPZ) Requirements (per the City of Hamilton's Rural OP)
Permanent and Intermittent Streams	30 m VPZ on each side of the watercourse, measured from beyond the stable top of bank.
Fish Habitat	30 m VPZ on each side of the watercourse, measured from beyond either side of the top of bank or meander belt allowance.
Wetlands	30 m VPZ. Adjacent upland habitat that is required by wetland species for breeding, foraging, dispersal and other life processes must be taken into consideration.
Woodlands	15 m VPZ, measured from the drip line of trees at the woodland's edge.
Significant Woodlands	30 m VPZ, measured from the drip line of trees at the woodland's edge.
Significant Habitat of Threatened or Endangered Species and Significant Wildlife Habitat	The VPZ shall be determined through an EIS, dependent on the sensitivity of the feature.

As previously mentioned, urban expansion is proposed within the study area. Areas that are brought into the urban planning boundary will be subject to the provisions of the City of Hamilton's Urban Official Plan, including minimum vegetation protection zones requirements, as detailed below in **Table 3.38**.

Table 3.38: Minimum Vegetation Protections Zones applicable to natural heritage features within the Urban Boundary

Applicable Natural Heritage Features	Minimum Vegetation Protection Zone (VPZ) Requirements (per the City of Hamilton's Urban OP)
Coldwater Watercourse and Critical Habitat	30 m VPZ on each side of the watercourse, measured from the bankfull channel.
Warmwater Watercourse and Important and Marginal Habitat	15 m VPZ on each side of the watercourse, measured from the bankfull channel.
Provincially Significant Wetlands	30 m VPZ, measured from the boundary of the wetland, as approved by the Conservation Authority or Ministry of Natural Resources.
Unevaluated Wetlands	15 m VPZ, measured from the boundary of the wetland, as approved by the Conservation Authority or Ministry of Natural Resources, unless an Environmental Impact Statement recommends a more appropriate vegetation protection zone.
Woodlands	10 m VPZ, measured from the edge (drip line) of the woodland.
Significant Woodlands	15 m VPZ, measured from the edge (drip line) of the significant woodland.
Areas of Natural and Scientific Interest (ANSIs)	Life and Earth Science ANSIs require a 15 m VPZ.
Significant Habitat of Threatened or Endangered Species and Significant Wildlife Habitat	The minimum VPZ shall be determined through an EIS and will be dependent on the sensitivity of the feature.

Cases Where the Recommended Minimum VPZ Differs From the Minimum VPZ Widths Specified by the City of Hamilton's Official Plan:

The following paragraphs detail the ecological form and functions observed during field studies completed during this study which warrant VPZ widths greater than the minimums specified by the City of Hamilton.

NHA Si2 represents the largest forested area within the study area. Multiple natural heritage designations are applicable to this NHA, including:

- Lower Twenty Mile Creek Provincially Significant Wetland Complex;
- "Protection" HDF;
- Direct and indirect fish habitat;
- Significant Woodland;
- Environmentally Sensitive Area;
- Potential roosting and foraging habitat for SAR bat species;
- Significant Wildlife Habitat, consisting of the following types:
    - Seeps and springs (confirmed);
    - Amphibian breeding habitat (woodland) (confirmed);
    - Bat maternity colonies (candidate); and,
    - Habitat for Special Concern and rare wildlife species (confirmed).

There are eight (8) species of bat known to occur in Niagara and Hamilton. Of these, four (4) are considered at-risk. As mentioned in **Section 3.3.5**, actively foraging bats were incidentally observed in NHA Si2. In addition, many cavity trees, trees with loose bark, as well as large-diameter oak and maple trees which could provide roosting habitat for bats are present within the NHA (, **Figure 3.71**, and **Figure 3.72**). Bats were also observed foraging over standing water adjacent to the northern portion of the forest. Acoustic surveys and comprehensive surveys for potential roosting habitat were both outside of the scope of work for this study and as such were not completed. Such studies are recommended at a subsequent planning stage.

Figure 3.71: Shagbark hickory (*Carya ovata*) trees in NHA Si2

Figure 3.72: Select examples of typical large diametre trees and cavity trees within NHA Si2.

When considering habitat requirements for bats, it is important to consider roosting needs as well as foraging needs. Hibernation requirements are critically important; however, they will not be discussed because potentially suitable hibernation sites are not present in NHA Si2. Several recent studies have found that "the distances between bat and background and between food item and background have been identified as the most relevant ecological constraint which have shaped the foraging and echolocation behavior of bats" (Denzinger and Schnitzler, 2013 (quoted); Jacobs and Bastien, 2016). Based on this constraint, Denzinger and Schnitzler (2013) have categorized bat foraging habitat into three (3) types: open space, edge space, and narrow space. Open space foraging bats exploit aerial insect prey that are located far from background objects (e.g. trees, buildings, ground and water surfaces, etc.). Edge space foragers exploit aerial insect prey that are located close to background objects, with species in this guild commonly foraging for aerial insect prey above water. Lastly, bats foraging in narrow spaces exploit prey on or near background objects. The foraging and roosting habits of bats, as described by Thorne (2017), and foraging guild in accordance with the definitions provided by Denzinger and Schnitzler, are presented in **Table 3.39**, below.

Table 3.39: Foraging and roosting habits of bat species whose range includes the Hamilton and Niagara areas.

Species		Status				Foraging (F) and Roosting (R) Habitat Requirements	Foraging Guild
Common Name	Scientific Name	COSSARO	COSEWIC	S-Rank	Hamilton		
Big brown bat	*Eptesicus fuscus*	-	-	S5	Uncertain	F: open spaces and, less commonly, woodland edges, hedgerows, and over water. R: tree cavities, anthropogenic structures, and caves.	Open spaces
Eastern red bat	*Lasiurus borealis*	-	-	S4	Uncertain	F: open spaces close to cover such as woodlands & hedgerows. R: trees.	Open spaces
Eastern small-footed myotis	*Myotis leibii*	-	END	S2 S3	Uncertain	F: within woodlands and around water, eats aerial and terrestrial-bound insect prey. R: rocky escarpments and woodlands.	Edge & Narrow spaces
Hoary bat	*Lasiurus cinereus*	-	-	S4	Uncertain	F: open spaces. R: trees.	Open spaces
Little brown myotis	*Myotis lucifugus*	END	END	S4	Uncertain	F: often associated with water. R: anthropogenic structures, tree cavities, and caves.	Open, Edge, & Narrow spaces
Northern myotis	*Myotis septentrionalis*	END	END	S3	Uncertain; most commonly captured species during 2001-02 mammal inventory	F: forests. R: forests.	Narrow spaces
Silver-haired bat	*Lasionycteris noctivagans*	-	-	S4	Uncertain	F: forest openings, often associated with water. R: mature forest.	Edge & Narrow spaces
Tri-coloured bat	*Perimyotis subflavus*	END	END	S3?	Uncertain	F: forest borders, often associated with water. R: clusters of dead leaves in large diametre oak and maple trees.	Edge

Given that all of the above bat species roost in trees, that there are ample potential roosting sites within NHA Si2, and bats were observed foraging within and adjacent to NHA Si2, it is reasonable to say that bat habitat has been confirmed within NHA Si2 and also on adjacent lands to the north where they have been observed foraging over water. We note that this water also directly feeds the many wetlands present in the northern portion of the forest. What is not known is the species of bat(s) present.

Noise and light are known to negatively impact the behavior and breeding success of other animal guilds such as birds and amphibians (Longcore and Rich, 2004; Baker and Richardson, 2006; Bayne et al., 2008; Slabbekoorn and Ripmeester, 2008). Traffic noise, for example, decreases the occurrence, breeding density, and breeding success of bird species (Brotons and Herrando, 2001; Fernandez-Juricic, 2001). Similarly, several studies have shown that anthropogenic noise negatively affects the foraging behaviour of bats, reducing their ability to detect prey and resulting in avoidance behaviours (von Frenckell and Barclay, 1987; Spanger, 2006; Gillam and McCracken, 2007; Jones, 2008; Schaub et al., 2008). Experiments completed by Schaub et al. (2008) show that (Myotis) bats exhibit avoidance behaviors when exposed to consistent ambient noise up to 60 kHz, as well as variable intermittent noise ranging from 0 kHz to over 85 kHz. Other studies indicate that bats foraging 50 m away from a highway will be impacted by traffic noise (B.M.S. and A.S., unpublished data in Schaub et al., 2008).

Given that it is known that bats are using NHA Si2 and adjacent lands to the north, and that sheet flow from the north contributes to the hydrology of the wetland network (known to support amphibian breeding) within NHA Si2 (see **Figure 3.73**), it is the opinion of Aquafor Beech Limited that the minimum setback from the edge of the dripline of NHA Si2 should encompass open lands adjacent to the northern edge of the NHA, as well as provide an adequate setback from the open areas sufficient to mitigate potential impacts to the aforementioned open area and NHA Si2 from future adjacent land uses. Subject to confirmation following further study, it is therefore recommended that the VPZ along the northern portion of NHA Si2, with the exception of the small thicket area on the northwest corner of the NHA, be subject to a minimum 60 m VPZ, the first 30 m of which are to remain open (i.e. to be restored with herbaceous vegetation only; preferably grasses, goldenrod, and aster species only as these are allelopathic and thus may delay succession of woody plants into the area). It is recommended that the remaining 30 m is be vegetated using a mix of native trees, shrubs, and herbaceous species in accordance with the prescriptions provided in the paragraph below. In this way, foraging habitat for open, edge, and narrow space foraging bats will be accounted for and protected. Furthermore, it is imperative that post-development, hydrologic inputs of the same quality, quantity, velocity, etc. be allowed to enter into the aforementioned open area and also the NHA as sheet flow, with particular consideration for existing hydrologic pathways from the edge of the NHA to the wetlands within (**Figure 3.73**). As seen in the bottom photo of **Figure 3.73**, sedimentation is currently impacting wetland water quality in the area. The proposed VPZ will most likely be adequate to mitigate this impact to water quality (Castelle et al., 1994).

It is further recommended that VPZ design requirements account for noise and light attenuation. Evidence shows that buffer vegetation composition and width, respectively, are important factors in reducing light and noise impacts. Harris (1986) concluded that a mature treed evergreen buffer of approximately 6 m in width would reduce noise from adjacent infrastructure by 4 – 6 decibels (db) per metre. Without evergreen trees, the distance between the noise source and the area of concern would have to be tripled (Harris, 1986). Adjacent to commercial areas, heavily forested buffers of 32 m are required to significantly reduce noise levels (Groffman et al., 1990). Typical street traffic noise is estimated at 70 db, whereas a whisper is 20 db (Siggaoat-Copiaco, 2017). It is the opinion of Aquafor Beech Limited that noise at a whisper level will not negatively impact wildlife. Assuming an average 5 db reduction per metre, is recommended that 10 m wide dense plantings of native evergreen trees, such as Eastern White Cedar (*Thuja occidentalis*), be incorporated into the outer VPZ. Dense evergreen plantings within the VPZ will likely greatly aid in preserving the site's functions for breeding birds (Marzluff and Ewing, 2001). Dense evergreen plantings may also reduce the possibility of exotic plant species entering natural areas.

Figure 3.73: Hydrologic inputs from fields to the north into NHA Si2

3.3.9.2 Restoration and Enhancement Areas

The natural heritage system within the Elfrida Subwatershed study area largely consists of isolated features within an agricultural setting. To ensure and enhance the ecologic function of these isolated features over the long term, it is recommended that the creation and enhancement of linkages be prioritized.

As VPZs and other non-developable lands such as floodplains and erosion hazards will be restored either actively (i.e. VPZs) or passively, they are not discussed further. Due to the requirements/restrictions on vegetation height within hydro corridors and limitations to development within floodplains, it is assumed that lands within the hydro corridor spanning east to west through the study area will passively regenerate to meadow and/or thicket communities, both of which are currently scarce within the study area. Due to the maintenance requirements for the hydro corridor and the lack of representation of meadow and thicket habitats within the study area, active restoration of the hydro corridor is not recommended aside from lands which fall within Natural Heritage Restoration and Enhancement Area 2. The reader is referred to **Section 3.2.2.7** for discussion on enhancements to watercourses related to geomorphic considerations. Several natural heritage restoration and enhancement opportunities have been identified within the Elfrida Subwatershed study area:

Natural Heritage Restoration & Enhancement Area 1: Lands associated with NHA Tw1

The main block of NHA Tw1 is currently an isolated natural area which contains thicket swamp, treed swamp, and deciduous forest communities (**Figure 3.74**). It is one of the higher-quality forested habitats within the study area (second only to NHA Si2) and contains vernal pools, locally rare flora, flora with narrow habitat tolerances (i.e. those with CC values ≥7), and variable topography. Natural heritage designations applicable to the feature include significant woodland, several categories of significant wildlife habitat, and wetlands. Tributaries of Twenty Mile Creek are located north and south of the feature before confluencing in the east. In the case of the former, the tributary passes through the thicket swamp at the northern end of the feature. Additionally, on the south end of the feature, HDF #TM2-H2 forms a hydrologic connection between the sloughs within the southeast portion of the forest to a tributary of Twenty Mile Creek to the south.

Lands recommended for forest restoration and enhancements include lands between the south end of the deciduous forest and the southern tributary of Twenty Mile Creek and its associated floodplain. These lands contain HDF #TM2-H2. Lands directly east of the feature, landlocked by virtue of their location between two tributaries of Twenty Mile Creek, are also a prime candidate for forest restoration efforts. Restoration and enhancement of these two aforementioned areas will likely positively influence the ecologic function of the feature and will complement the connections and other ecologic functions gain from nearby watercourse and floodplain restoration efforts. It is recommended that future upgrades to Golf Club Road consider the incorporation of traffic calming and wildlife passages between the restored areas north of Golf Club Road and the extant orchard to the south, as applicable.

Figure 3.74: Deciduous forest within NHA Tw1, spring (left) and autumn (right)

Natural Heritage Restoration & Enhancement Area 2: Lands associated with NHA Si5 and Si6
Landlocked areas located between the tributaries of Sinkhole Creek, their associated floodplain, and NHAs Si5 and Si6 (**Figure 3.75**) represent an opportunity to enhance the aforementioned NHAs and the Stoney Creek tributaries by creating an ecologically functional connection between them. As the majority of these landlocked areas are within the hydro corridor, it is recommended that restoration efforts consider the maintenance regime and height restrictions imposed within the hydro corridor. Outside of the corridor, it is recommended that opportunities for wetland creation be explored.

Figure 3.75: Restoration area located between NHA Si5 (left) and NHA Si6 (right)

Natural Heritage Restoration & Enhancement Area 3: Lands associated with NHA Si7

NHA Si7 is an ash (*Fraxinus*) dominated woodland and a cultural meadow within and surrounded by the floodplain of Sinkhole creek, which borders the NHA to the north and south (**Figure 3.76**). Forest restoration in this area would not only mitigate the impacts of emerald ash borer (*Agrilus planipennis*), but also increase the ecologic function of the woodland and Sinkhole Creek.

Figure 3.76: NHS Si7

Natural Heritage Restoration & Enhancement Area 4: Lands associated with NHA St1

The northern portion of NHA St1 (**Figure 3.77**) occupies the site of a former 9-hole golf course that, judging by the remnant vegetation communities present, was likely built within moist forest and swamp. This feature is separated from nearby forested communities by roads but retains a hydrologic connection with a wetland/pond to the east and the treed swamp west of Upper Centennial Parkway (NHA St2). Vegetation communities within this feature include cultural savannah and various wetland communities including meadow marsh, ponds, and the globally and provincially rare Bur oak Mineral Deciduous Swamp. Wetland communities within this feature are part of a larger wetland which extends along Stoney Creek from Highland Road to the pond east of NHA St1, near Mud Street. A species of Special Concern, the Eastern wood-pewee, has been confirmed within this feature. Other natural heritage designations applicable to this feature include significant woodlands, wetlands, several categories of significant wildlife habitat, fish habitat, and watercourses (Stoney Creek).

As a way to potentially enhance water quality within Stoney Creek, the wetlands, and fish habitat; it is recommended that the floodplain associated with the branch of Stoney Creek that extends from Upper Centennial Parkway and joins with another tributary of Stoney Creek be actively restored to an open woodland community. This restoration will have the added benefit of providing potentially suitable habitat for wildlife, including and not limited to Eastern wood-pewee.

Figure 3.77: Wetland and cultural savannah communities within the northern portion of NHA St1

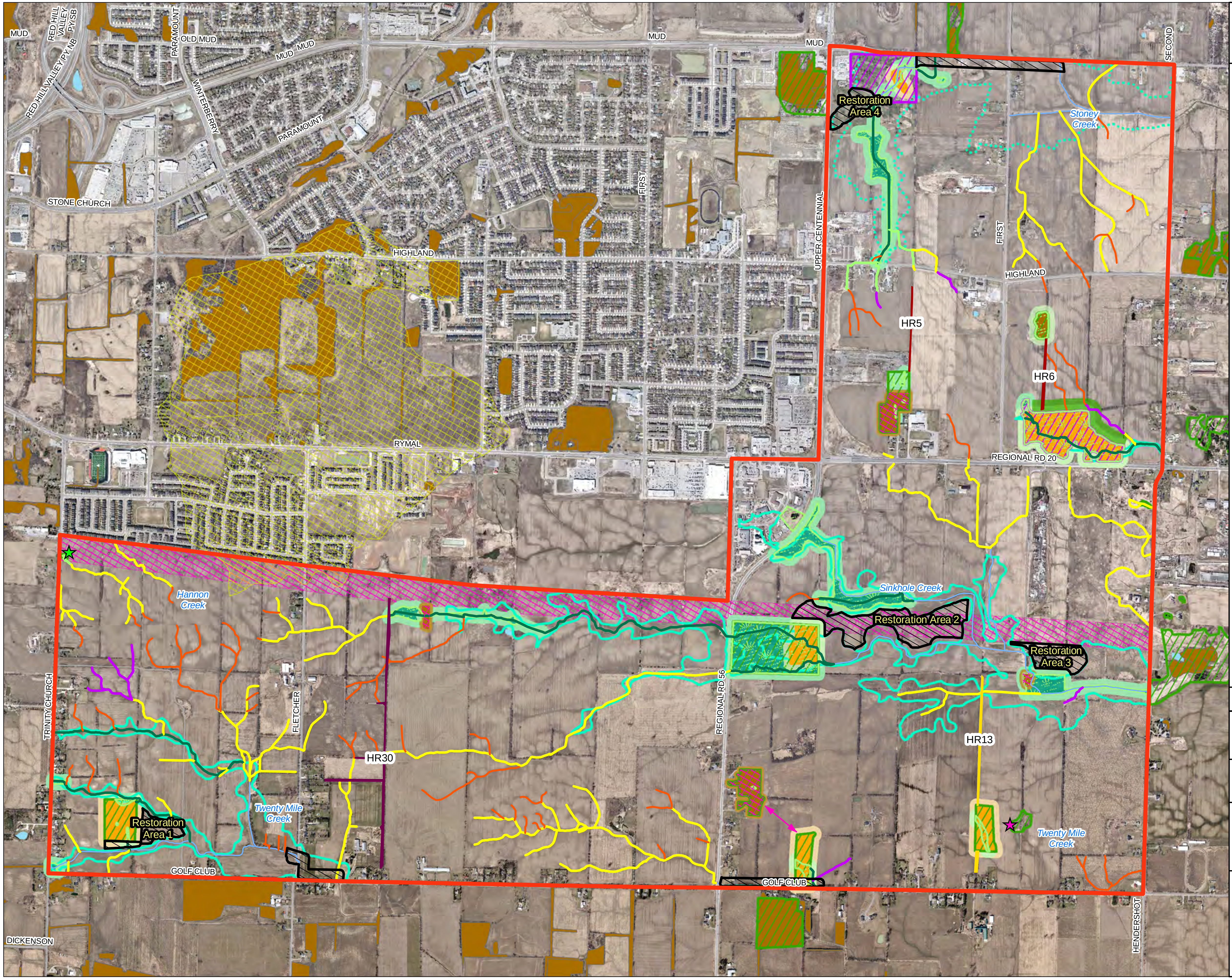
Corridor for Snakes

As detailed in **Section 3.3.5.4**, rubble piles and an abandoned well located on a demolished farmstead property east of NHS Tw4 could potentially serve as hibernation habitat for snakes. Further study will be required to confirm the area's use by snakes. Should it be determined that the demolished farmstead site is or likely is a hibernaculum site, then it is recommended that the hibernaculum site be connected to the adjacent woodland (NHA Tw4) by a vegetated corridor. The suggested location for this corridor is marked with a purple star on **Figure 4.1**.

Corridor Between NHAs Tw2 and Tw3

At the behest of the City of Hamilton, the potential for a corridor linking NHAs Tw2 and Tw3 has been identified. The exact location and makeup of the corridor will be determined at a subsequent planning stage.

Elfrida Subwatershed Study



Legend

- Study Area

Regulatory Floodlines

- 100 Year Flood
- Regional Flood
- Restoration Areas
- Karst Sinkhole

CORE NATURAL HERITAGE FEATURES

- Watercourse
- Eramosa Karst Provincial Earth Science ANSI
- Wetlands
- Significant Woodland

Significant Wildlife Habitat

- Candidate
- Confirmed

LINKAGES

- Potential Future Snake Corridor
- Linkages
- Linkage: Conceptual Location
- Woodlands

Hedgerows (HR):

- Hedgerow Linkage: Enhance
- Hedgerow Linkage: Retain
- Hedgerow Linkage: Feature Area (consider integrating)

VEGETATION PROTECTION ZONES

PER RURAL OP:

- Wetland VPZ (30m)
- Significant Woodland VPZ (30m)
- Woodland VPZ (15m)

PER SWS:

- Wetland VPZ (60m)

HEADWATER DRAINAGE FEATURES

- Protection
- Conservation
- Mitigation
- No Managment Required
- No Access

Figure 3.71

Natural Heritage System

Date: May 2018
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

4 Summary of Existing Conditions and Limitations & Opportunities to Development

The existing environmental resources within the Elfrida Subwatershed study area were inventoried in order to identify key features and functions, delineate a Natural Heritage System, establish baseline conditions for the assessment of potential impacts from future urban development, define development limitations, and to identify potential future environmental restoration and enhancement opportunities.

A summary of the key environmental features and functions of the Elfrida Subwatershed study area are summarized below. Development limitations and opportunities are illustrated in **Figure 4.1** and **Figure 4.2**. The Limitations and Opportunities maps illustrate the aggregate Natural Heritage Features from **Figure 3.78** (which represent limitations to development) together with hazard lands (i.e. karst, floodplain, and erosion hazards), linkages identified by the City of Hamilton and as part of this study, and restoration opportunities.

4.1 Groundwater Resources

Soils within the study area are comprised of low permeability glaciolacustrine clays, ranging in depth from 2 m to over 10 m, atop dolostone bedrock. Intermittent streamflow conditions and piezometer monitoring results indicate that, other than seasonal high groundwater levels at select locations in the Twenty Mile Creek watershed, groundwater discharge to the study area watercourses is not significant. However, opportunities to maintain the existing limited groundwater recharge rates of 48 mm/year should be pursued through future urban stormwater management measures.

One (1) karst sinkhole was identified in the study area. The sinkhole is located adjacent to Trinity Church Road and the Hydro Right-of-Way and is within the Hannon Creek subwatershed. The sinkhole discharges to a spring approximately 650 m northwest of the Elfrida study area. The entirety of the sinkhole has been included as a limitation to development; a VPZ has not been applied to this feature, though a VPZ has been applied to a portion of the Conservation HDF associated with the sinkhole in recognition of Headwater Drainage Feature HC-H2's importance to the sinkhole and groundwater outside of the study area.

4.1 Surface Water Resources

The fluvial geomorphologic resources of the study area were assessed in terms of geologic setting. The study area consists of low-energy headwater drainage features which are vegetation-dominated and geomorphologically undeveloped. No locations within the study area (or immediately downstream) exhibited signs of excessive erosion and therefore no existing erosion mitigation measures are required.

Headwater drainage features (HDFs) were identified, inventoried, and evaluated using current TRCA guidelines. A number of reaches were recommended for "protection" and should remain as open watercourses at their current locations. A number of reaches were recommended for "conservation" and should also remain as open features, however, some modifications/relocation may be considered as part of future planning. Other HDFs classified as “mitigation” could either remain open or be replicated using urban lot-level and conveyance stormwater techniques such as low impact development (LID) measures, swales or wetlands.

In terms of geomorphic limitations for future development, erodible corridor widths of between 30 m to 60 m are recommended for protection of watercourses and sensitive HDFs (**Figure 4.1)**.

Hydrologic and hydraulic modeling and associated floodplain mapping were undertaken to define flood hazard lands along the major stream reaches within the Elfrida study area which will remain as open watercourses in the future urban landscape. This included stream reaches that were classified as either watercourses or Headwater Drainage Features (HDFs) identified for “Protection”, “Conservation”, or “Mitigation”.

Model results for the Regulatory 100-year storm were plotted on topographic mapping generated from the City’s digital elevation model (DEM) over the study area. As shown in **Figure 4.1**, the floodplains are relatively wide with potential spill of floodwaters between tributaries in some locations. This is consistent with the wide shallow flooding observed during the spring and is attributed to the very flat topography and lack of valley formations through the study area.

Water quality characteristics of the study area streams include high concentrations of phosphorus and chloride as well as elevated levels of *E. coli*, TSS, and some metals. Future urban development represents an opportunity to improve water quality through application of stormwater management facilities, including LID measures.

4.2 Natural Heritage System

The Natural Heritage System (NHS) was developed based on a detailed field program executed in 2015 and 2016. Studies completed include salamander surveys, anuran calling surveys, breeding bird surveys, 3-season botanical inventories, vegetation community classification, wetland evaluation, headwater drainage feature (HDF) evaluations, aquatic habitat assessments, and aquatic surveys. Properties, where land access was not granted, were assessed using a combination of background information (e.g. air photo interpretation, GIS layers provided by the City of Hamilton, etc.) and where possible, a visual assessment from adjacent lands. Elements of the Elfrida NHS and their respective recommended minimum Vegetation Protection Zones (VPZs), as applicable, are as follows:

- Significant Wildlife Habitat;
- Wetlands (30 m VPZ*; includes Provincially Significant Wetlands (PSWs) and other wetlands);
  *a 60 m VPZ was applied to the northern edge of NHA Si2 in recognition of the sensitive and significant hydrology in that area.
- Significant Woodlands (30 m VPZ);
- Woodlands (i.e. those that do not meet the criteria for significance) (15 m VPZ);
- Fish Habitat/Watercourses (30 m VPZ as measured from either side of the top of bank or meander belt allowance);
- HDFs;

- Linkages (as defined by the City of Hamilton); and
- Restoration Areas.

A Note on Headwater Drainage Features:
HDFs are important in maintaining primary and secondary inputs to surface water, groundwater, and fish habitat as applicable. In addition, some HDFs are considered direct fish habitat at least during part of the year. HDF management recommendations are related to their hydrologic and ecologic function and are presented below in **Table 4.1**. HDFs on lands not accessed during this study will have to be assessed as part of a future study. Furthermore, as detailed in **Section 5**, it is recommended that HDF classifications be confirmed during a wet or representative year.

Table 4.1: Summary of HDF Management Recommendations

Management Implications	HDF Classification			
	Protection	**Conservation**	**Mitigation**	**No Management Required**
Must remain open	Yes	Yes	Yes	n/a
Relocate using Natural Channel Design	Not permitted, enhancement only	May be considered, not preferred	Natural Channel Design not required[1]	n/a
Maintain or replicate groundwater or wetlands	Maintain or enhance	Maintain or replicate, restore if possible	n/a	n/a
Maintain hydroperiod	Yes	Yes	Yes	n/a
Direct connection to downstream	Yes	Yes	Yes	n/a
Replicate function through enhanced lot conveyance control	n/a	n/a	Replicate using bioswales, LID, vegetated swales or constructed wetlands	n/a

[1]Unless the management recommendations call for the restoration of lost function or enhancement and creation of fish habitat.

4.3 Restoration Opportunities

Figure 4.2 illustrates the aggregate development limitations from **Figure 4.1**, together with specific areas of linkage and restoration opportunities. The identified restoration opportunities include the following:

- **Watercourse reaches which currently act as roadside ditches**: Future road improvements/widening in these areas will likely necessitate modifications and re-alignment of these stream reaches. These works represent an opportunity to restore the stream corridor away from the road and to naturalize the stream channels.

- **Stoney Creek tributary from Upper Centennial Road**: External flows from west of Upper Centennial Road are conveyed to Stoney Creek in part via low gradient roadside ditches and in part by an ill-defined overland channel flowing northeast to an adjacent abandoned golf course. Future channel/grading works along this tributary may present an opportunity to improve conveyance of external flows via a better defined centralized drainage channel. The floodplain lands associated with this improved channel would also represent an opportunity to create savannah habitat for species-at-risk (i.e. Eastern wood-pewee) known to occur in the adjacent abandoned golf course.

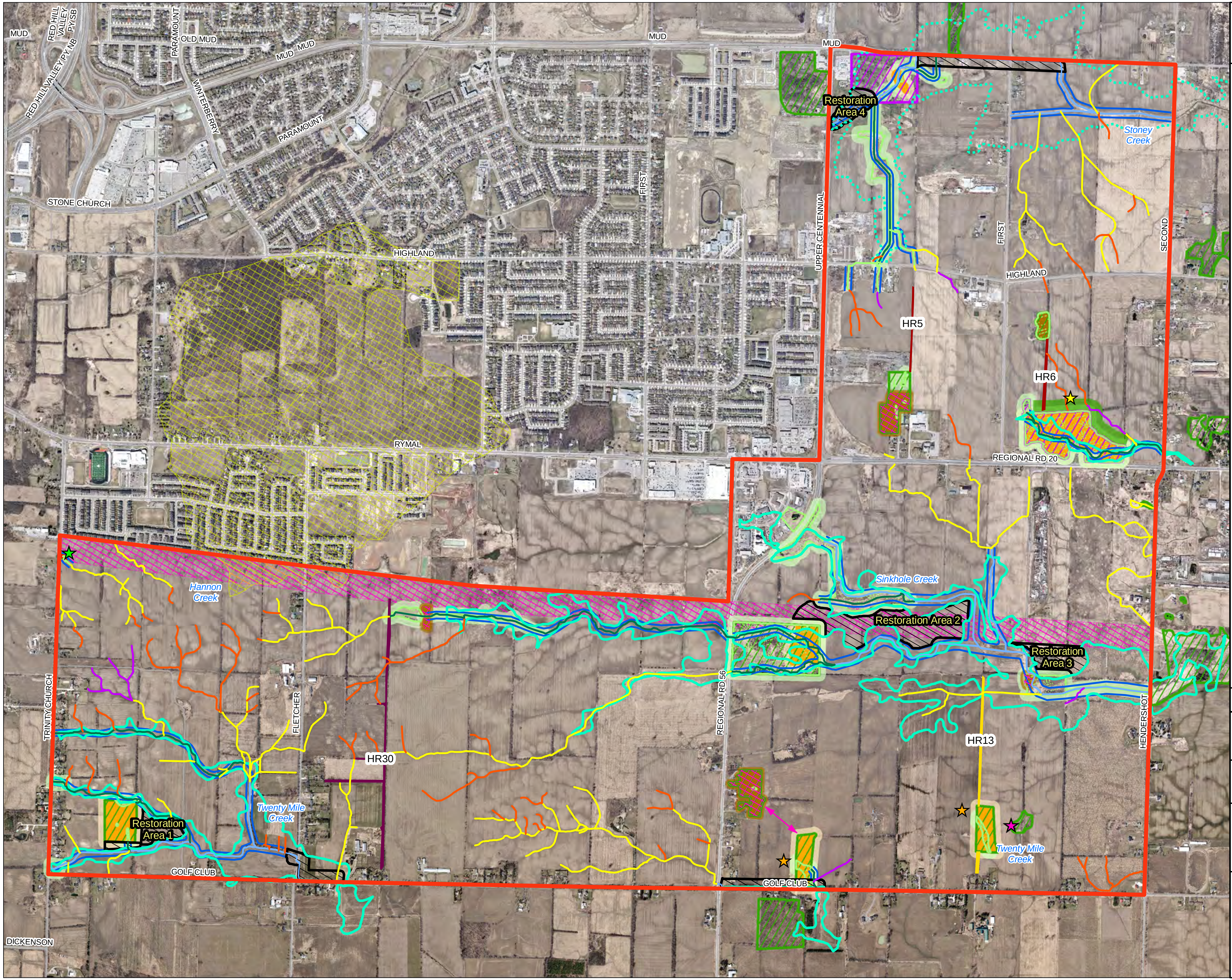
- **Spill area in Stoney Creek**: future urban development adjacent to Stoney Creek should consider grading works to eliminate the potential spill to the east.

- **Woodland features:** As detailed in **Section 3.3.9,** lands adjacent to NHA Tw1 and NHA St1 have been identified as priority areas for restoration.

- **Sinkhole Creek / Hydro Corridor**: restoration of the landlocked "island" created by the Sinkhole Creek floodplain is recommended as a means of connecting wetlands to the north (NHA Si6) with woodlands and wetlands to the southwest (NHA Si5), as well as strengthening the linkage function of the hydro corridor and watercourses.

- **Re-vegetation**: Given the isolation of terrestrial natural heritage features on the landscape, it is recommended that restoration of linkages, including and not limited to the hydro corridor, hedgerows, the linkage between NHAs Tw2 and Tw3, and stream corridors, be prioritized.

- **Potential Corridor for Snakes**: Pending the confirmation of snake hibernaculum east of NHA Tw4, a corridor linking the hibernaculum with NHA Tw4 is recommended.



Elfrida Subwatershed Study

Legend

- Study Area

HAZARDS

Status

- 100 Year Flood
- Regional Flood
- Geomorphic Constraint (varies 33 to 66m)
- Karst Sinkhole

NATURAL HERITAGE SYSTEM

- Restoration Areas

CORE NATURAL HERITAGE FEATURES

- Watercourse
- Eramosa Karst Provincial Earth Science ANSI
- Wetlands
- Significant Woodland

Significant Wildlife Habitat

- Candidate
- Confirmed

LINKAGES

- Linkage: Conceptual Location

Hedgerows (HR):

- Hedgerow Linkage: Enhance
- Hedgerow Linkage: Feature Area (consider integrating)
- Hedgerow Linkage: Retain
- Woodlands
- Potential Future Snake Corridor
- Linkages

VEGETATION PROTECTION ZONES

PER RURAL OP:

- Wetland VPZ (30m)
- Significant Woodland VPZ (30m)
- Woodland VPZ (15m)

PER SWS:

- Wetland VPZ (60m)

HEADWATER DRAINAGE FEATURES

- Protection
- Conservation
- Mitigation
- No Managment Required
- No Access

MANAGEMENT CONSIDERATIONS

- Collect overland flow at point to maintain wetland hydrology
- Sheet flow, special considerations for vernal pools in wetland, and wildlife

Figure 4.1

Detailed Summary of Limitations and Opportunities to Development

Date: May 2018
Data Source: City of Hamilton 2016

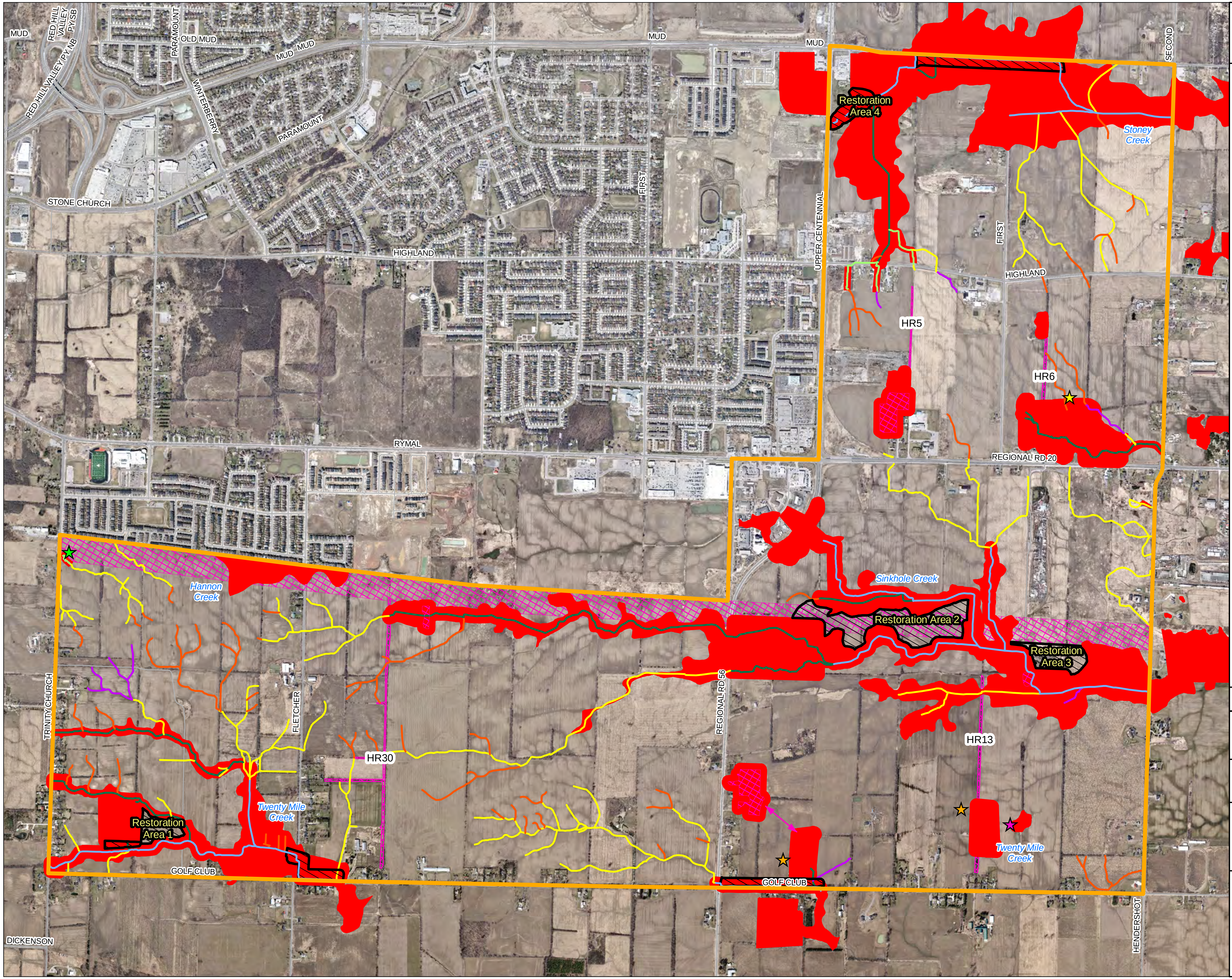
0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

Elfrida Subwatershed Study



Legend

- Study Area
- Limitation To Developement
- Restoration Areas
- Watercourse
- Karst Sinkhole

LINKAGES

- Linkages
- Linkage: Conceptual Location
- Potential Future Snake Corridor

HEADWATER DRAINAGE FEATURES

- Protection
- Conservation
- Mitigation
- No Managment Required
- No Access

MANAGEMENT CONSIDERATIONS

- Collect overland flow at point to maintain wetland hydrology
- Sheet flow, special considerations for vernal pools in wetland, and wildlife

Figure 4.2

Limitations and Opportunities to Development

Date: May 2018
Data Source: City of Hamilton 2016

0 0.5 1
Kilometers

N

Hamilton

Aquafor Beech Limited

5 Preliminary Recommendations for Further Study

The following section outlines recommendations for further study based on the Phase 1 work completed to date. Further recommendation(s) may be introduced following further analysis as part of Phases 2 and/or 3 of the Subwatershed study.

The Land Access map in **Appendix H** illustrates which lands were accessed as part of the study and which were not due to inadequate landowner permissions. As previously mentioned, **lands not accessed during this study will have to be evaluated as part of future studies**, as applicable. The limitations to development illustrated on lands not accessed as part of this study represent an assessment of the best available information at the time of this study. Where possible, features on inaccessible lands were evaluated from adjacent properties and/or roadsides. Available background information, including air photos and mapping provided by the City of Hamilton, were also used as assessment tools.

Natural Heritage Recommendations

Species-at-Risk and other Species of Conservation Concern: COSEWIC and COSARRO meet yearly to assess the status of SAR in Canada and Ontario, respectively. Species' status updates (i.e. uplisting or delisting) have the potential to impact the natural heritage assessments and designations contained in this report. Accordingly, it is recommended that at each subsequent planning stage the status and presence of SAR be revisited to ensure compliance with Planning Act requirements and the Ontario Endangered Species Act (2007).

Furthermore, it is recommended that surveys for two SAR trees, butternut and Eastern flowering dogwood, be completed in NHAs Si5, Tw2, and Tw3 as well as in hedgerows and on residential properties.

Watercourses: For improved accuracy in classifying the thermal regime of watercourses, it is recommended that continuous temperature monitoring between July 1st and August 31st be conducted in later planning stages. Monitoring outside of a drought year will improve the accuracy of the classification.

Terrestrial Wildlife: It is recommended that anuran calling surveys be repeated in future studies as the 2016 results may have been impacted by the unique climatic conditions.

As a measure of due diligence, it is recommended that surveys for milksnake be undertaken during all subsequent planning stages to ensure that if this reclusive species is present within the Elfrida Subwatershed study area, it is given due consideration. Further investigation of potential snake hibernacula, including but not necessarily limited to the area identified in the former homestead property northeast of NHA Tw4 (see **Appendix I**), is also recommended.

As mentioned in **Section 3.3.9.2**, opportunities for the incorporation of wildlife passages and traffic calming should be explored at subsequent planning stages.

Lastly, it is recommended that surveys for bats be undertaken in all treed habitats within the study area. Survey methodology should follow that of the Guelph District MNRF's *Bat and Bat Habitat Surveys of Treed Habitats* document (MNRF 2016) or subsequent update.

Vegetation Protection Zones: As detailed in Section 3.3.9.1, the widths of the preliminary minimum VPZs presented in this report are to be reviewed at subsequent planning stages and may be augmented (i.e. increased or decreased) based on the recommendations of an approved Environmental Impact Statement (EIS).

Linkages: The location and makeup of a linkage between NHAs Tw2 and Tw3 shall be determined at a subsequent planning stage. It is further recommended that all linkage locations and designs, including and not limited to hedgerows identified for retention and/or enhancement (see Section 3.3.2.8), compliment the ecological form and function of neighbouring natural heritage features/areas so that functional ecological linkages may be realized.

Headwater Drainage Features: As mentioned previously, the findings of the Phase 1 report represent conditions extant at the time of assessment, and in some cases are limited by land access restrictions. In cases where land access restrictions have limited the assessment of HDFs (both on lands not accessed and those downstream), further study will be required at a subsequent planning stage in consultation with the City of Hamilton and the appropriate Conservation Authority. Also, in select cases (e.g. where topography results in servicing constraints) the City of Hamilton and the Conservation Authority may, at their discretion, consider flexibility for development implementation of HDFs provided the valued ecosystem features and functions of the HDF and related natural heritage features are given due consideration with Conservation Authority and City policies, as applicable. In such cases, further detailed studies may be required.

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