Water AECOM

Town of Halton Hills

Southwest Georgetown Subwatershed Study
VISION GEORGETOWN
Subwatershed Strategy Report
FINAL REPORT

Prepared by:

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Project Number:

60297831

Date:

May, 2017

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May 29, 2017

John Linhardt
Executive Director of Planning and Chief Planning Official
Town of Halton Hills
1 Halton Hills Drive
Halton Hills, ON L7G 5G2

Dear Mr. Linhardt:

Project No: **60297831**

Regarding: **Southwest Georgetown Subwatershed Study**
VISION GEORGETOWN
Subwatershed Strategy Report

Attached, please find the Subwatershed Strategy Final Report for Southwest Georgetown study area (Vision Georgetown). This is prepared as background information that is intended to be used as support information for the proposed Secondary Plan and Associated Master Planning.

Sincerely,
AECOM Canada Ltd.

Ray Tufgar, P.Eng., M.Eng., MBA
Lead, North America, Water Resources, Water
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1. Introduction

1.1 Introduction

To prepare and plan for future urban development in the Southwest Georgetown Area, the Town of Halton Hills is preparing a secondary plan for the study area, referred to as “Vision Georgetown”. This area is bounded by Side Road 15 to the North, Side Road 10 to the South, Trafalgar Road to the West, and Eighth Line to the East (see **Figure 1.1.1**). This report presents the Southwest Georgetown Subwatershed Study (Subwatershed Study) which is in support of the Secondary Plan, and provides a management strategy to assist in setting policy direction for future development in the watershed. Within the study area, there are a number of catchment areas that are part of the larger individual subwatersheds that drain to the south, discharging to Sixteen Mile Creek or to Silver Creek to the East, that are part of this study. The management strategy presents the approach to manage resource use that will protect, rehabilitate, and enhance the environment within the Southwest Georgetown Subwatershed, and meets the goals and objectives set for the Subwatershed Study.

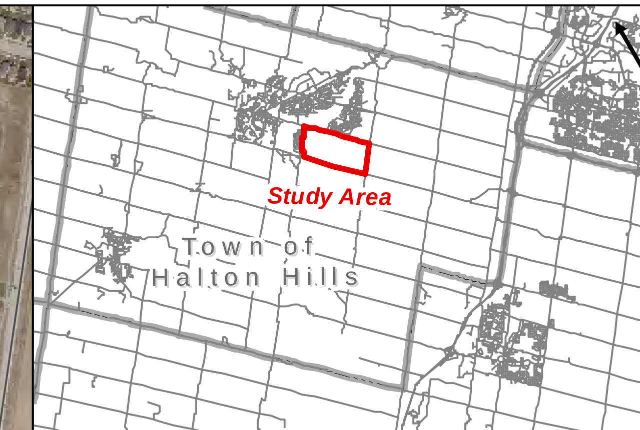
The purpose of the Subwatershed Study is:

> *“To develop a subwatershed plan that allows sustainable development while ensuring maximum benefits to the natural and human environments on a watershed basis. The subwatershed areas in this study include the headwaters of Sixteen Mile Creek and a headwater tributary of Silver Creek (part of the Silver Creek Watershed).”*

A series of goals and objectives have been developed as part of the Subwatershed Study process, which need to be met to achieve the overall study purpose. The goals and objectives relate to the management of the natural resources within the subwatershed, including aquatic resources, terrestrial conditions, fluvial geomorphology, flood and erosion protection, hydrologic and hydrogeologic conditions. The goals and objectives consider the ecosystem within the catchments, and linkages to lands outside the catchments.

The goals and objectives identified for developing a strategy for the Southwest Georgetown Subwatershed recognize the importance of developing a strong framework upon which a management strategy is based. This framework is comprised of an in depth understanding of subwatershed conditions and the ecological, hydrologic and hydrogeologic processes that support and/or influence those conditions. The fundamental characteristics of a subwatershed are a result of all of the resource conditions and processes that occur. Part of these processes is obviously linked to the activities taking place. These include not only ecologically based wildlife activities (aquatic and terrestrial) but also human activities (urban and agricultural). The analysis of a watershed to provide the understanding needed for an effective management approach, and therefore must include an assessment of:

- Watershed characteristics (environmental and land use);
- Natural processes including;
  - Hydrology, hydraulics, and hydrogeology;
  - Fluvial geomorphology;
  - Terrestrial environment (vegetation and wildlife);
  - Aquatic environment (fisheries);
  - Water quality;
  - Riparian systems; and
- Human activities.



Legend

N

General Features

Identified Reaches

Roads

Study Area

Conservation Authority Boundary*

Note

*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600

Meters

Southwest Georgetown Integrated Planning Project

Study Area

June 2016	1:10,000	Datum: NAD 83, Zone 17 Source: Chapman and Putnam, 2007. Ontario Geological Survey, MRD 228., LIO
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Figure 1.1.1

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In order to develop a management strategy that sets the future direction of the catchments in a fashion that is workable and useful, it must reflect the needs of both the subwatershed ecosystem and the community. At times these needs conflict and, as a result, an approach based upon a sound understanding of the subwatershed is necessary to ensure that the strategy developed is balanced and sustainable.

The watershed areas, in this study, cover lands both in the Conservation Halton jurisdiction (Sixteen Mile Creek) and Credit Valley Conservation jurisdiction (Black Creek, Silver Creek). As a result, staff from both Conservation Authorities have been involved in this study.

The study team has included AECOM, Beacon Environmental, Palmer Environmental and with assistance from the Town of Halton Hills, Conservation Halton, Credit Valley Conservation, Region of Halton, and the Technical Advisory Committee (TAC). The consultation process is outlined in **Section 3.2**. The Secondary Plan preparation, which this study provides the supporting information is being carried out by Meridian Planning Consultants.

1.2 Southwest Georgetown Subwatershed

Currently land use is predominantly agriculture with a small amount of rural residential. A school is located at Trafalgar and Side Road 15. There are a number of terrestrial features from an environmental perspective including wetland areas, and woodlots. Research has shown that terrestrial features play a role in setting the environmental conditions which exist in any watershed. For example, wetland areas store water during rainfall events, and augment base flows in receiving streams during dry periods. The wetlands and woodlands can provide wildlife habitat and an excellent area for nature viewing, environmental education and aesthetic features to the community. There are a number of well defined watercourses, some natural and some anthropogenic. In this particular study area, there is also a well defined and significantly incised valley feature near Side Road 15 and Eighth Line, and a smaller one on Sixteen Mile Creek, upstream of Eighth Line.

1.3 Approach to This Study

This Subwatershed Study provides a management strategy (within the context of land use changes) for the protection, enhancement and rehabilitation of natural environment features and their function. As outlined in **Figure 1.3.1**, there are four major phases in a subwatershed plan.

Phase I – Involves establishing the form, function and linkages of the water and related environmental resources. This is done by examining environmental features and functions (i.e., soils, climate, groundwater, surface waters, river systems, habitats, and wildlife) and how they interrelate. Public input is obtained at this point as part of setting the goals and objectives and carrying out the subwatershed characterization.

Phase II – Includes, further characterization of subwatershed and data collection (based on the focus provided by Phase I), detailed analysis of processes that influence watershed characteristics and impact analysis of land use changes and analysis of effectiveness of management scenarios. Additional refinement of the subwatershed characterization is carried out through the analysis.

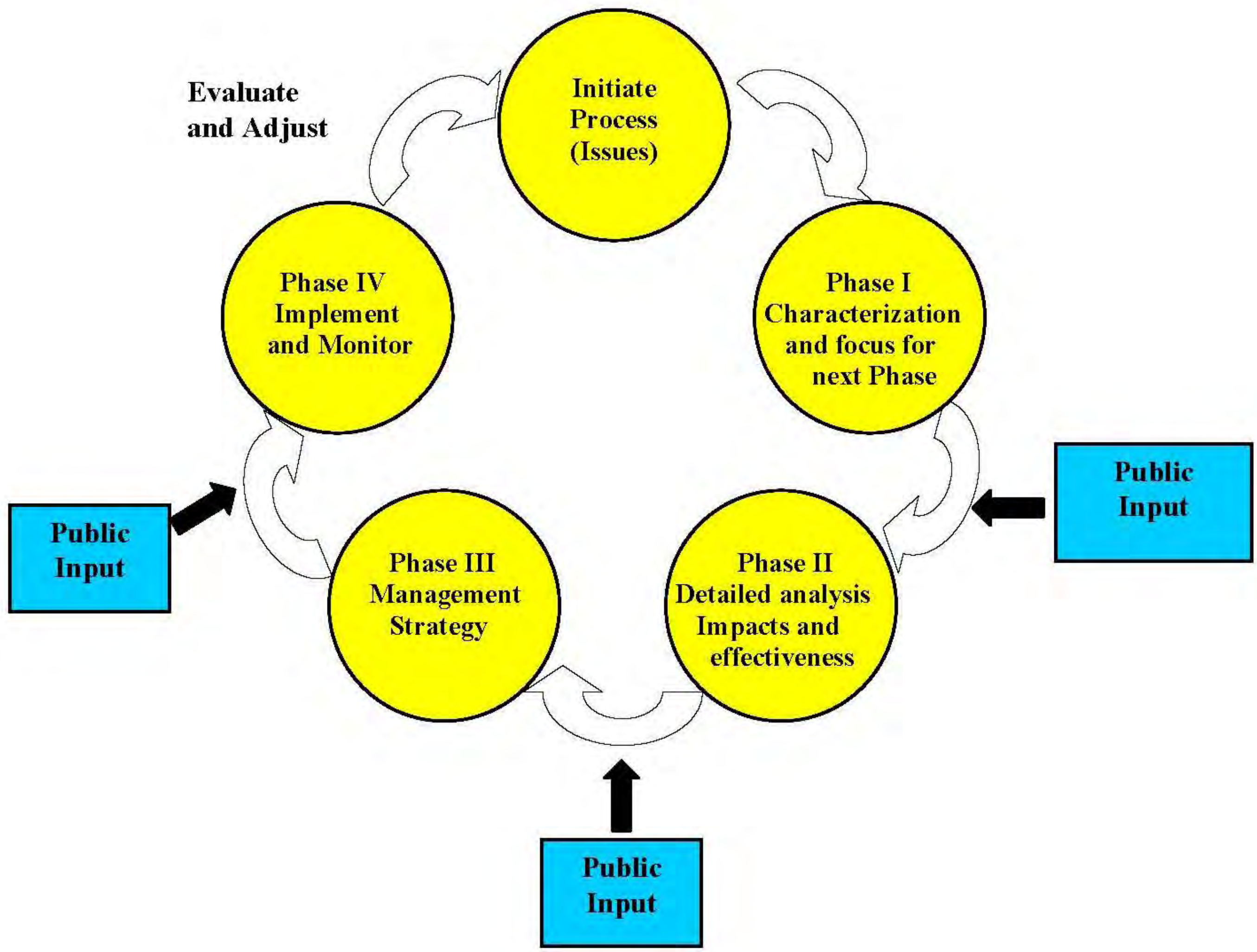
Phase III – Includes development of a management strategy and implementation plan.

Phase IV – Includes, implementation and monitoring plan and evaluation/modification of the management strategy.

The sections of this report follow the four phases outlined above, and are covered in the following sections:

- Section 4.0 – Characterization focusing on Phase I;
- Section 5.0 – Analysis covering Phase II;
- Section 6.0 – Management Strategy discusses Phase III; and
- Section 7.0 – Implementation Plan covering Phase IV.

Figure 1.3.1 Subwatershed Planning Process



1.3.1 Study Goal and Objectives

The project requirements are outlined in the Study Terms of Reference included in **Appendix A**. This includes a listing of the goals and objectives to be met in carrying out the Subwatershed Study. A summary of the study goals and objectives is outlined as follows.

The overall goal of this Subwatershed Study is to provide recommendations and a strategic framework for the sustainable management of natural resources within and adjacent to the primary study area, given its designation in Regional Official Plan Amendment No. 38 and Halton Hills Official Plan Amendment No. 10 for urban development to the 2031 planning horizon, as determined by the Sustainable Halton comprehensive planning exercise.

The study will provide sufficient detail to support the designation of a sustainable Natural Heritage System, through refinement of the Regional Natural Heritage System, as well as recommendations for a Water Management Strategy to be followed by the subsequent Secondary Plan and associated servicing studies. Future development and site specific environmental and servicing management plans must adhere to and implement these recommendations. The results of the Subwatershed Study must be compatible with that all applicable Provincial, Regional and local land use planning requirements, as well as Conservation Authority regulations.

The strategic goals and objectives for this Subwatershed Study include:

Natural Hazards

<u>Goal</u>

- To prevent, eliminate or minimize the risks to life and property caused by flooding and erosion hazards.

<u>Objectives</u>

- To ensure that new development does not create new hazards or aggravate existing hazards.
- To ensure new development is located outside and appropriately setback from flooding and erosion hazards
- To implement development standards and land use controls to prevent future development from occurring within areas prone to flooding or erosion hazards.
- To ensure that new development, including infrastructure, incorporates appropriate mitigation measures that are necessary to avoid adverse impacts to natural features, areas and systems.
- To consider cumulative impacts and changing climatic conditions when determining the characteristics and management of flooding and erosion hazards.
- To ensure runoff from development is controlled such that it does not increase the frequency and intensity of flooding, the rate of natural stream erosion or increase slope instability.
- To ensure Creek crossings (e.g. bridges and culverts) are designed appropriately to address potential channel migration without the requirements for armoring or impacting natural channel migration over the 100-year planning horizon.

Water Resources

<u>Goal</u>

- To protect, improve or restore water quality and quantity associated with surface water and groundwater features within and adjacent to and downstream of the primary study area, including their associated ecological and hydrologic functions.

Objectives

- To implement water management measures and infrastructure design that protects, restores and enhances the natural hydrologic cycle and mitigates potential adverse impacts to the natural heritage system.
- To develop robust servicing and stormwater management strategies capable of adapting to changing climatic conditions.
- To ensure fluvial processes and stream morphology are maintained or improved recognizing important habitat attributes (pools, riffles etc.), dynamic channel form and diversity contribute to maintaining a sustainable natural heritage system.
- To implement sustainable management practices, pollution prevention activities and design standards that protect, improve or restore water quality from the accelerated enrichment, contamination and increased temperatures within streams from development related pressures and activities.
- To encourage the protection, improvement or restoration of tableland and riparian vegetative cover for the protection and improvement of water quality and quantity associated with surface water and groundwater features.
- To ensure natural hydrogeologic functions are protected taking advantage of stream baseflow and groundwater discharge and recharge enhancement opportunities.

Natural Heritage

Goal

- To protect, restore, and enhance the biodiversity, connectivity and ecological and hydrologic functions of natural features, areas and systems throughout, and adjacent as appropriate, to the primary study area.

Objectives

- To ensure natural heritage features and areas, including their ecological and hydrologic functions, are appropriately protected from the potential adverse impacts of development including the use of appropriately sized vegetation protection zones (i.e. buffers).
- To adopt appropriate land use controls and development standards that protect existing natural features and areas and prevents future development from negatively impacting or occurring within the natural heritage system.
- To encourage achieving an ecological gain through the development of the natural heritage system.
- To ensure that significant natural corridors and wildlife linkages are identified, protected or enhanced through the development of the natural heritage system.
- To develop an adaptive environmental management plan, including monitoring and mitigation measures that considers pre, during and post construction and development activities.

Additional Objectives

Additionally, the following with respect to environmental and potential downstream impacts from development, should be addressed within the Sixteen Mile Creek (Subwatershed 5), Silver Creek Subwatershed and the Region of Halton Natural Heritage System:

1) The aquatic habitat in the creeks within and downstream of the subwatershed areas are maintained or where possible, enhanced.
2) Discharges from proposed land uses to the receiving watercourses do not degrade the existing levels of biological diversity and productivity, nor adversely impact on stream forms.

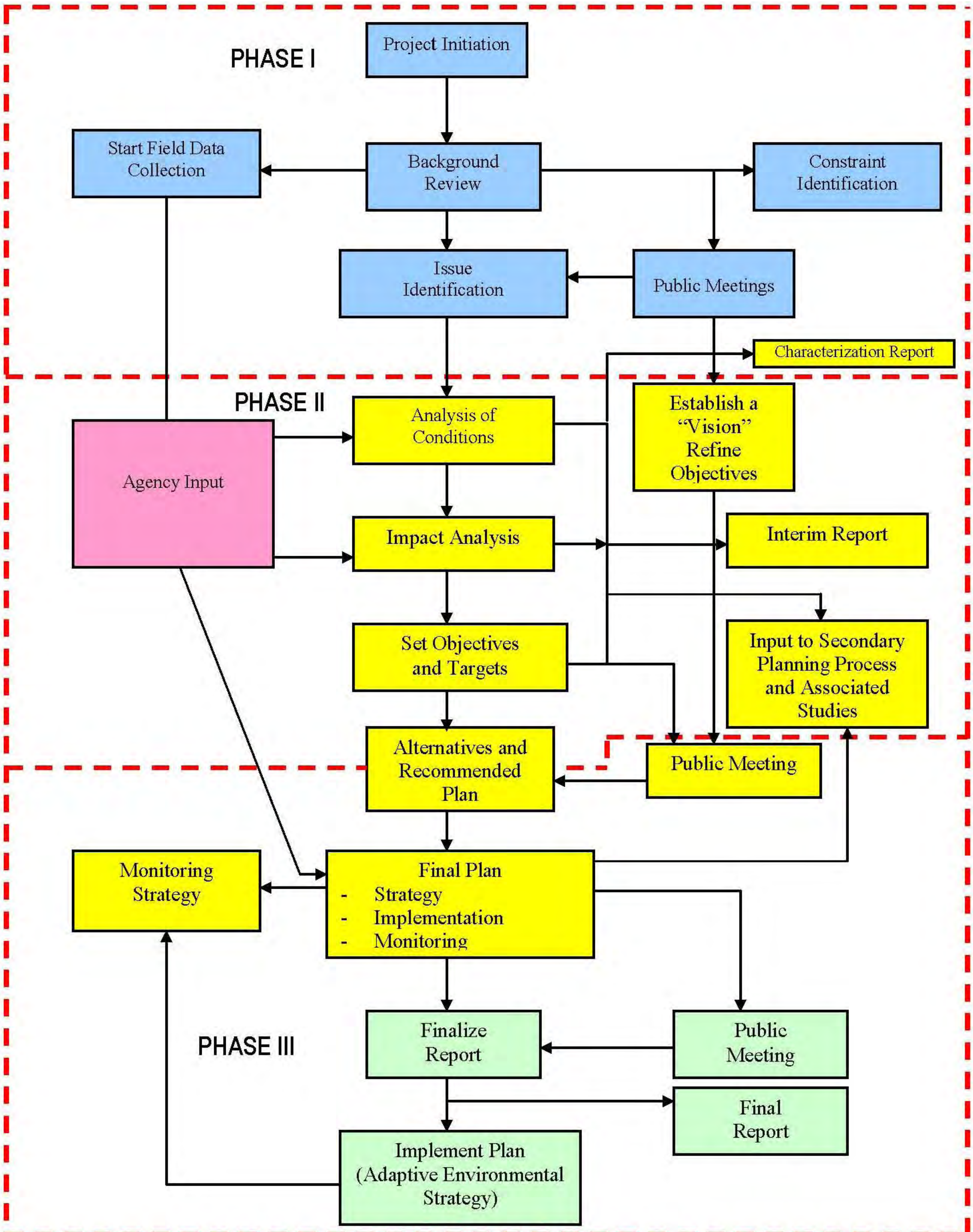
3) Any necessary alteration to the stream systems within the subwatershed incorporates the objectives of achieving natural and dynamically stable channel form and appropriate habitat characteristics.
4) Existing watercourses and drainage features are identified, and evaluated in sufficient detail, and that appropriate recommendations/strategies are established to protect, restore and manage these features and their functions.
5) A sustainable natural heritage system is established which protects, preserves and where appropriate, enhances the natural environment.
6) Groundwater resources and functions are maintained and, if possible, enhanced (including investigation of flow paths and maintenance of these paths where required), considering the aquatic habitat requirements of the stream.
7) The quality and quantity of groundwater is not adversely impacted by proposed SWM measures (i.e. infiltration basins) and/or proposed land use. Any proposed servicing does not detrimentally lower the water table or adversely affect the groundwater resources.
8) Stormwater runoff is controlled to ensure that peak flow rates and associated flood levels are not increased as a result of the proposed development.
9) Retain stormwater onsite to achieve an annual volumetric water balance relative to pre-development conditions, where feasible.
10) The prolonged discharge from detention facilities does not increase downstream peak flows or channel erosion or negatively impact stream morphology.
11) Water quality and thermal regime of stormflow from the development meets all identified requirements and is maintained or enhanced as compared to existing conditions.
12) The stormwater management system will be robust enough to adapt to the changing climate.
13) All areas regulated by the Conservation Authorities should be considered in the development of the Natural Heritage System and management strategies, as appropriate.

Study Steps

The study approach is illustrated in **Figure 1.3.2**, and outlined as follows:

- Review background information and develop a summary including:
  - Topographic mapping, air photos, and resource maps;
  - Relevant study reports;
  - Servicing information;
  - Discussion with agencies;
  - Available field information (i.e., environmental, streamflow, and groundwater);
- Prepare a list of reference material;
- Carry out site reconnaissance and collect field data;
- Carry out analysis to characterize the subwatershed;
- Prepare a characterization report;
- Work with steering committee, TAC and hold Open House meetings to solicit input;
- Carry out additional field work and detailed analysis of subwatershed conditions;
- Prepare an analysis report;
- Develop a preliminary management strategy;
- Analyze potential impacts of urban land use conditions;
- Identify management needs;
- Develop a management strategy; and
- Prepare an implementation plan.

Figure 1.3.2 Study Approach



1.4 Report Structure

The sections and information provided in this report are as follows.

Section 1.0 Outline of purpose of study and approach
Section 2.0 Discussion on subwatershed planning in general and legislative framework
Section 3.0 Outline of the public participation process followed and summary of discussions
Section 4.0 Characterization of Southwest Georgetown Subwatershed
Section 5.0 Watershed Analysis
Section 6.0 Management Strategy
Section 7.0 Implementation Plan

1.5 Sources of Information

1.5.1 Introduction

During the initial phase of this Subwatershed Study, background information was collected and reviewed. This provided a portion of the information for characterization of the catchments. Through this review, the type and amount of additional information to permit the characterization of the catchments was determined and steps carried out to collect it as part of this Subwatershed Study.

1.5.2 Background Information

The background information collected and reviewed included reports, other information such as existing field data, as well as information collected through discussions with various agencies and other groups (*i.e.,* university research groups).

The reference information that was collected and reviewed is listed in **Appendix B**. Generally, the information collected and reviewed included:

- Topographic mapping;
- Aerial photography;
- Natural heritage and environmental mapping (terrestrial and aquatic);
- Flora and fauna records and rarity status (NHIC records, SARO List, natural areas inventory);
- Geologic and hydrogeologic characterization maps and reports;
- Well records and other borehole data;
- Background reports related to:
  - Watershed and subwatershed studies;
  - Environmental Characterization;
  - Hydrogeology and geology;
  - Fluvial geomorphology;
  - Land use planning documents;
  - Servicing reports;
- Climatic data;
- Past hydrologic models developed;
- Relevant flow data; and
- Information related to external ecological linkages.

Discussions were held with all involved external agencies and groups to collect relevant data. This included: Conservation Halton, Credit Valley Conservation, Region of Halton, and MNR.

Independent field data was collected by the study team to enable the characterization and analysis of the catchments, including development of a management strategy.

Hydrogeological characterization involved review of the following data sources:

- Ontario Geological Survey (OGS) / Geological Survey of Canada (GSC) mapping and reports;
- Ontario Ministry of Agriculture and Food (OMAFRA) mapping;
- Ontario Ministry of the Environment databases (i.e., Water Well Information Service);
- Regional groundwater studies (i.e., Halton Tier 3 Water Budget Study);
- Local borehole and geotechnical data (i.e., technical reports, Regional Municipality of Halton (Halton) databases); and
- Available subwatershed characterization reports.

A monitoring program was also implemented to characterize groundwater conditions, local water use, and groundwater/surface water interactions over one field season. Monitoring began in May 2013 and was carried forward into 2014.

1.5.3 Land Use

Information on planned land use is readily available from planning documents which are applicable to the Town of Halton Hills. Available planning documents, including the Region of Halton and Town of Halton Hills Official Plans (OPs) with related schedules (including servicing), were reviewed. The available information on planned land use has been used in this phase of the study as it relates to environmental background data. It will also be used in the impact analysis to be carried out in the next phases.

2. Subwatershed Planning

2.1 Subwatershed Management Strategy

Subwatershed management is intended to augment the land use planning process, as well as provide for sound management of environmental conditions and natural resources. Subwatershed plans are based on natural drainage boundaries instead of political boundaries.

Watershed management is an evolving science. The evolution of the science is a response to the recognized need to manage our resources and guides future land use decisions. New management philosophies and tools are being developed to provide the most effective approach. The common thread through this evolution is that a broad perspective is needed to ensure that the plan meets environmental and societal needs. It is important that watershed management recognizes environmental, social and economic conditions to ensure that all three elements are included and provide an integrated approach.

The Global Water Partnership Technical Advisory Committee (2000) has described integrated watershed management as:

> *"a process which promotes the coordinated development and management of water, land and related measure in order to maximize the resultant economic and social welfare, paving the way towards sustainable development, in an equitable manner without compromising the sustainability of vital ecosystems"*

Notwithstanding an integrated approach that is typically used in subwatershed planning, the Town of Halton Hills Official Plan has adopted an "environment first" philosophy for land use planning and promotes the maintenance, restoration and enhancement of heritage features and ecological functions. The "environment first" philosophy has been included as part of developing the subwatershed Management strategy for the study area.

Subwatershed plans are typically carried out prior to the start of significant development to provide a guidance document that "sets the stage" for future land use changes. The technical studies associated with these plans contribute to a better understanding of the natural features, functions and processes on the landscape. Subwatershed plans include recommendations on what measures need to be put into place to protect the natural system and maintain and enhance its critical functions while allowing development to proceed.

Public participation is a critical component of subwatershed planning. Although a comprehensive, blended (economic, social, and environmental) approach is necessary, community needs and values should be taken into account in developing a management strategy. This will assist in facilitating acceptance of the strategy and provide a sustainable plan.

A recent evolution of watershed management is the recognition of the need to provide an adaptive environmental management (AEM) approach. Management strategies should encompass refinement of management tools and approaches, and changes in societal characteristics and needs. A management strategy must provide a direction to follow, but just as importantly it must have flexibility built in so that modifications and "fine tuning" can be carried out. A monitoring plan is one of the critical elements of a management strategy with specific targets set to be monitored. This is then used to measure the effectiveness of the management strategy in meeting the goals (and targets set). If the targets are not being met, modifications can be made to ensure that the management strategy goals can be followed.

Given the comprehensive and complex nature of the watershed, an ecosystem approach is required in developing a management strategy. The watershed ecosystem is made up of the wildlife, vegetation, people and physical landscape that occupies the watershed, and by the processes that link these components. Degradation of the quality of any of these components will affect the entire ecosystem. For example, if water is polluted and streamflows are depleted, it will have a negative impact on fish. If woodlots and wetlands are removed, there will be a loss of wildlife habitat.

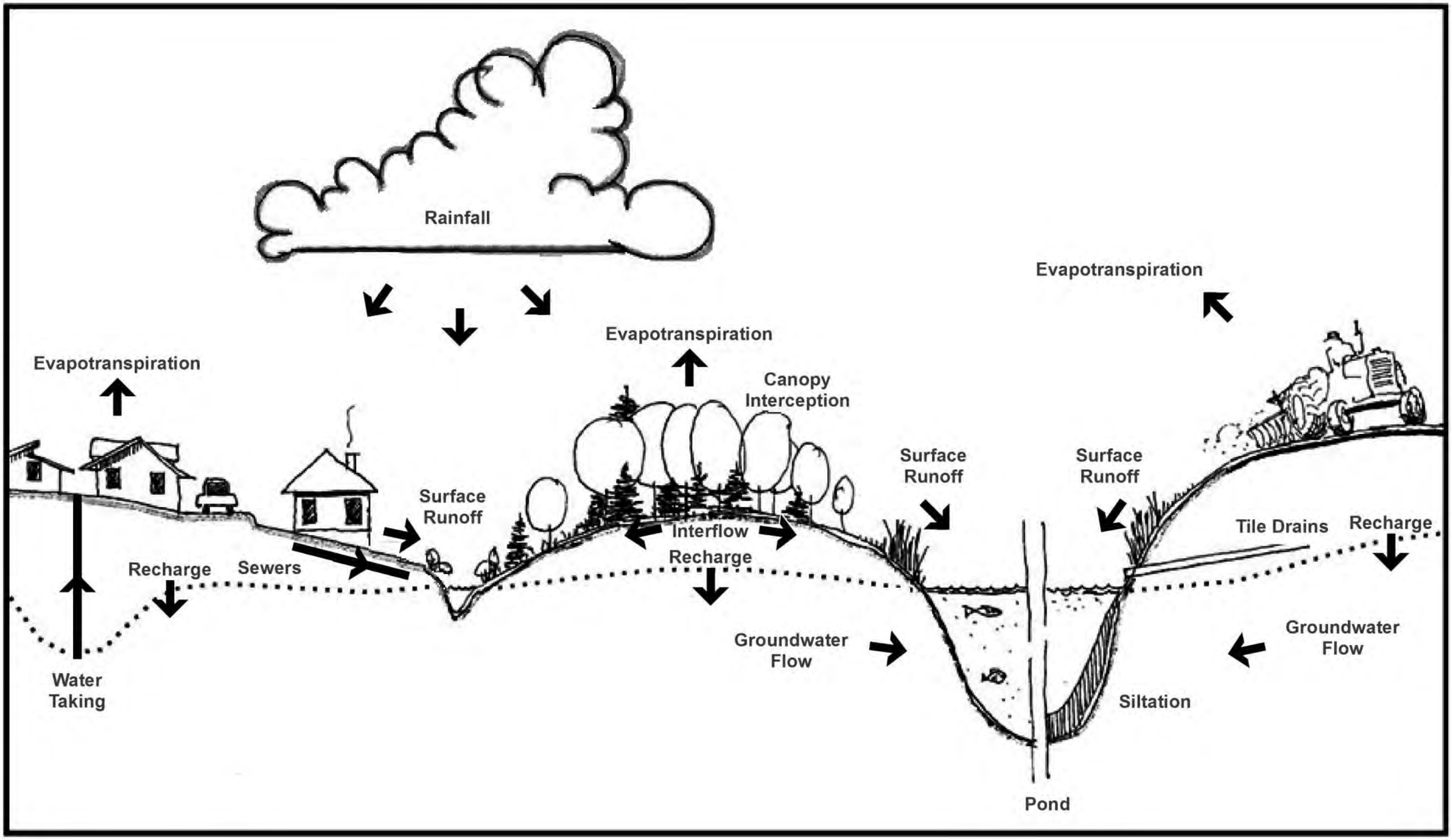
The hydrologic cycle diagram (**Figure 2.1.1**) illustrates the major components of a watershed ecosystem, the linkages between components and the major functions or processes that control the shape and quality of the watershed resources.

The major connecting link in a watershed ecosystem is the flow of water. This flow pattern is called the water budget. How and where the water flows determines the quality of the water, the shape and stability of streambanks, the health and diversity of the vegetation, and the availability of fish and wildlife habitat. In a relatively natural watershed, the flow of water is controlled by topography, soil type, and vegetation. As human use of a watershed increases, all of these characteristics can change, altering the water budget. The changed water budget then results in changes in the quantity and quality of ground and surface water, the size and shape of stream channels and the stability of streambanks, vegetation cover and fish and wildlife habitat. These unintentional changes caused by the change in water budget often reduce the ability of the human population to use and enjoy the resources of the watershed.

The ecosystem approach requires description of ecosystems, description of stresses on the ecosystems and identification of indicators of the health of the ecosystem and the impact of the stresses. An integrated set of policies and management practices must be developed which considers people as an integral part of ecosystems. This is in contrast to the more common approach of relating environmental resources to an independent human population and set of policies. Inherent in the ecosystem approach is the concept of carrying capacity. The application of the concept of carrying capacity requires an attempt to understand the limits of an ecosystem's ability to support various life forms and land use activities. Human activities are then managed in a way that does not exceed these natural limits. When the carrying capacity is respected, the ecosystem remains healthy. When the natural limits are exceeded, the health of the ecosystem declines. The ecosystem approach used in this watershed study used the concepts of carrying capacity and ecosystem health in evaluating land use scenarios and watershed management options.

The major requirement, as well as the major benefit, of the ecosystem approach is that the people planning for human modification of the ecosystem have a basic conceptual understanding of the way in which the ecosystem functions and can anticipate, with some degree of confidence, the impact of human activities on ecological functions.

Figure 2.1.1 Hydrologic Cycle Components



2.2 Subwatershed and Municipal Planning

Planning for the protection and conservation of natural resources and the management of land within the study area, is the responsibility of landowners, Provincial Agencies, Conservation Halton, Credit Valley Conservation, Halton Region and the Town of Halton Hills. Authority for such land use planning is provided by the Planning Act (R.S.O. 1990) of Ontario.

The primary method of planning at the municipal level is the Official Plan (OP). This is a legal document that is used by council and land owners as a decision making guide. The OP sets out objectives and policies that establish the basis for land pattern change and for protecting and conserving natural resources. To implement the OP's policies and objectives, municipalities pass zoning by-laws which establish certain land use rights, and restrictions, on individual properties. Area municipalities approve the creation of new lots and their supporting services through plans of subdivision and consents to sever.

Conservation Halton and Credit Valley Conservation both function under the Conservation Authorities Act. One of the main purposes is to manage, conserve and protect water-oriented natural resources throughout Halton Region. While implementation of subwatershed plans is primarily carried out through land use planning at the Town and Regional level through the Planning Act, other agencies play an important implementation role. Conservation Halton and the Credit Valley Conservation both function under the Conservation Authorities Act. Conservation Authorities have a mandate to manage, conserve and protect natural resources other than oil, gas or minerals on a watershed basis. The broad watershed goals and objectives for resource management are typically communicated through watershed-wide plans and subwatershed plans developed collaboratively with watershed municipalities and other agencies.

2.2.1 Current State of Planning

The following summary of the status of planning in the Southwest Georgetown Subwatershed provides a context for understanding how subwatershed planning objectives can be implemented by various government institutions.

- The Government of Ontario has put into place a Provincial Policy Statement that provides direction in achieving sound environmental objectives in the subwatershed. Additional legislation exists that applies to the development and implementation of subwatershed plans, including: Environmental Protection Act, Environmental Assessment Act, Planning Act, and Conservation Authorities Act.

- Within the subwatershed, growth and development is primarily controlled and directed by the Region of Halton and the Town of Halton Hills OPs and the Town's Zoning By-law. Among other matters, these policies and regulations, together with the Provincial Policy Statement, are designed to provide reasonable protection for significant natural areas such as floodplains, Environmentally Sensitive Areas and Provincially Significant Wetlands against changes in the use of land either in or adjacent to them.

- Conservation Halton and Credit Valley Conservation have enacted regulations under the Conservation Authorities Act to restrict development, alteration and interference in areas and associated allowances specified by the regulation (e.g. areas within and adjacent to valley lands, watercourses, wetlands and other hazardous lands) when public health and safety would be at risk because of naturally occurring processes (e.g. flooding, erosion) or where development could aggravate existing natural hazards or create new ones (Ont Reg 162106; Ont Reg 1601061). The administration of these regulations is guided by board approved policies. These policies compliment the Ontario Provincial Policy statement, Section 3.0 – Protecting Public Health and Safety.

2.2.2 Legislative Framework

There is a broad framework of legislation that regulates land use and other activities within a watershed and along streams. The current framework for watershed planning is illustrated in **Figure 2.2.1** and legislation related to issues is outlined in **Table 2.2.1**.

Figure 2.2.1 Legislative Framework

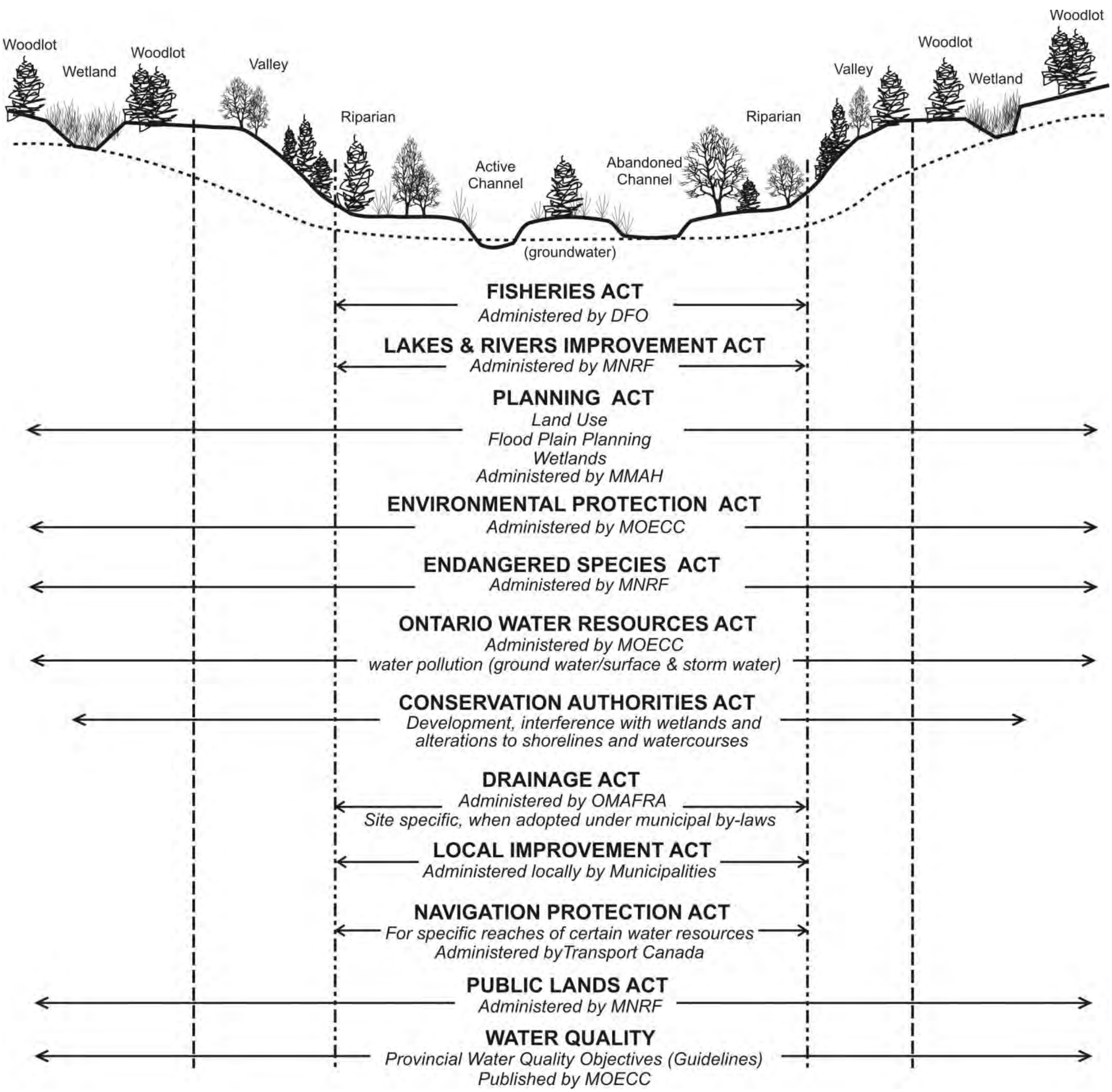


Table 2.2.1 Ontario Policies and Regulations Related To Watershed Planning

Problem/Issue	Legislation/Policy Document	Administered By
• Flood Protection Stormwater Conveyance Design	• Municipal Act • Planning Act • Building Code Act • Conservation Authorities Act and Related Regulations • Lakes and Rivers Improvement Act • Navigation Protection Act • Floodplain Criteria (1982) • Technical Guide – River and Stream Systems-Flooding Hazard Limit (2002) • Beds of Navigable Waters Act • Drainage Act • Public Lands Act • MTO Drainage Management Manual	MMAH MMAH MMAH MNRF, CA MNRF TC MNRF MNRF MNRF OMAFRA MNRF MTO
• Sediment Control During Construction	• Municipal Act • Conservation Authorities Act • Endangered Species Act • Canadian Environmental Protection Act • Lakes and Rivers Improvement Act • Ontario Water Resources Act • Fisheries Act	MMAH MNRF, CA MNRF EC MNRF MOECC DFO
• Fisheries Protection	• Endangered Species Act • Fisheries Act • Species at Risk Act	MNRF DFO MNRF
• Bacteria Control	• Ontario Water Resources Act • Canadian Environmental Protection Act	MOECC EC
• Water Quality	• Pesticides Act • Canadian Environmental Protection Act • Ontario Water Resources Act • Clean Water Act	MOECC EC MOECC MOECC

• Watershed Planning	• Conservation Authorities Act	MNRF, CA
	• Crown Forest Sustainability Act	MNRF
	• Drainage Act	OMAFRA
	• Endangered Species Act	MNRF
	• Environmental Assessment Act	MNRF
	• Canadian Environmental Protection Act	EC
	• Forestry Act	MNRF
	• Fish and Wildlife Conservation Act	MNRF
	• Historical Parks Act	MTCS
	• Lakes and Rivers Improvement Act	MNRF
	• Municipal Act	MMAH
	• Ontario Planning and Development Act	MMAH
	• Ontario Water Resources Act	MOECC
	• Aggregate Resources Act	MNRF
	• Planning Act	MMAH
	• Canada Waters Act	EC
	• Canada Wildlife Act	DFO
	• Navigation Protection Act	TC
	• Provincial Policy Statement	MMAH
	• Species at Risk Act	MNRF
	• Migratory Birds Convention Act	EC
	• Water Opportunities and Water Conservation Act	MOECC
	• Greenbelt Act	MMAH
	• Places to Grow Act	MMAH
	• Canadian Environmental Assessment Act	EC
	• Environmental Assessment Act	MEA

Agencies:	MMAH	-	Ministry of Municipal Affairs and Housing
	MNRF	-	Ministry of Natural Resources and Forestry
	CA	-	Conservation Authority
	TC	-	Transport Canada
	OMAFRA	-	Ontario Ministry of Agriculture and Food and Rural Affairs
	EC	-	Environment Canada
	DFO	-	Department of Fisheries and Oceans
	MOECC	-	Ministry of the Environment and Climate Change
	MTO	-	Ministry of Transportation
	MTCS	-	Ministry of Tourism, Culture and Sport

3. Community Participation

3.1 Introduction

Community participation is a key requirement in developing a subwatershed management strategy. Since the management strategy will guide the future environmental and aesthetic conditions in the subwatershed, it is important that the community has input in the decision making process and that the strategy reflects the goals of the overall community (society needs).

The Subwatershed Study included public participation for the purpose of identifying the key issues, developing a vision and objectives, discussing analysis findings for characterization and development of a management and Greenspace strategy.

3.2 Community Participation Process

Community participation has been provided for through the study process, and has been included as part of the process, through a number of methods. The overriding process used to facilitate input by key stakeholders included the Subwatershed Steering Committee and Subwatershed Technical Advisory Committee (TAC) for the duration of the study.

A TAC was established to provide technical support and guide the development of a management strategy for the Southwest Georgetown Subwatershed. The committee includes representatives of the community, staff members from the agencies that are most active in the management of catchments, advisory committee members, development group representatives and key members of the study consultants.

Other activities and methods used to provide for participation included:

- **Public Meetings** – Held at specific points throughout the Secondary Planning study;
- **Steering Advisory Committee** (SAC) – Formed by the Town to meet on a regular basis and provide input to the overall secondary planning process. Periodic discussions were held with this committee to provide updates on the Subwatershed Study, the process, and receive input;
- **Subwatershed Steering Committee and Subwatershed TAC** – Formed by the Town to meet throughout the Secondary Plan and Subwatershed Study process to provide input; and
- **Council Meetings** – Periodic presentations were made to Town Council to provide updates, and receive input, to the Subwatershed Study.

3.3 Subwatershed Plan Items Raised During Public Participation

A number of items and comments to be considered in carrying out the Subwatershed Study and in developing a management strategy were raised during the community participation process. A “visioning” exercise was held at the beginning of the Secondary Planning and Subwatershed process to gain input (see **Appendix C**).

These items were considered in the development of the subwatershed plan, and most were already included in the study goals and objectives. The items of consideration are summarized as follows:

- Provide a community that is as environmentally sustainable as possible and provides a model for other communities.
- Is walkable with access to trails, connected throughout the community and connects to existing trails.

- Considers nature, maintains woodlots and older trees (looks treed from the air).
- There are as many connections as possible between uses, neighbourhoods environment areas and parks.
- Build a community that goes with the “flow of the land” and preserves as much of the green/natural area.
- Build a more intense community to save as much natural forest as possible.
- Low impact development (LID).
- Preserve tress and hills.
- Trail surfaces should be pervious.
- Emphasize pervious surfaces and limit asphalt and concrete.
- Maintain natural forest and ensure that there is a net environmental gain.
- Preserve natural heritage.
- Connect natural areas.

4. Southwest Georgetown Subwatershed

4.1 Introduction

The study area is bounded by Side Road 15 to the North, Side Road 10 to the South, Trafalgar Road to the West, and Eighth Line to the East (see **Figure 1.1.1**). Although Eighth Line and Trafalgar Road do not run in a true north/south direction, they are referred to by Town of Halton staff as north/south roads and will be referred to that way in this report for consistency. This Subwatershed Study focuses on the catchment areas of the subwatersheds within the study area. However, consideration is also given to the areas of the subwatersheds outside of the study area to provide for a comprehensive understanding of subwatershed conditions and processes. This includes Sixteen Mile Creek headwaters in the South part of the site and an unnamed tributary of Silver Creek to the North.

A detailed discussion of the existing land uses, environmental features, and processes affecting those features is outlined in the following sections. This “characterization” is based on background data, field information collected, and initial analysis of that data and information.

4.2 Land Use

The existing land use throughout the study area is predominantly agricultural, but includes scattered wooded areas. Some rural residential development also exists throughout.

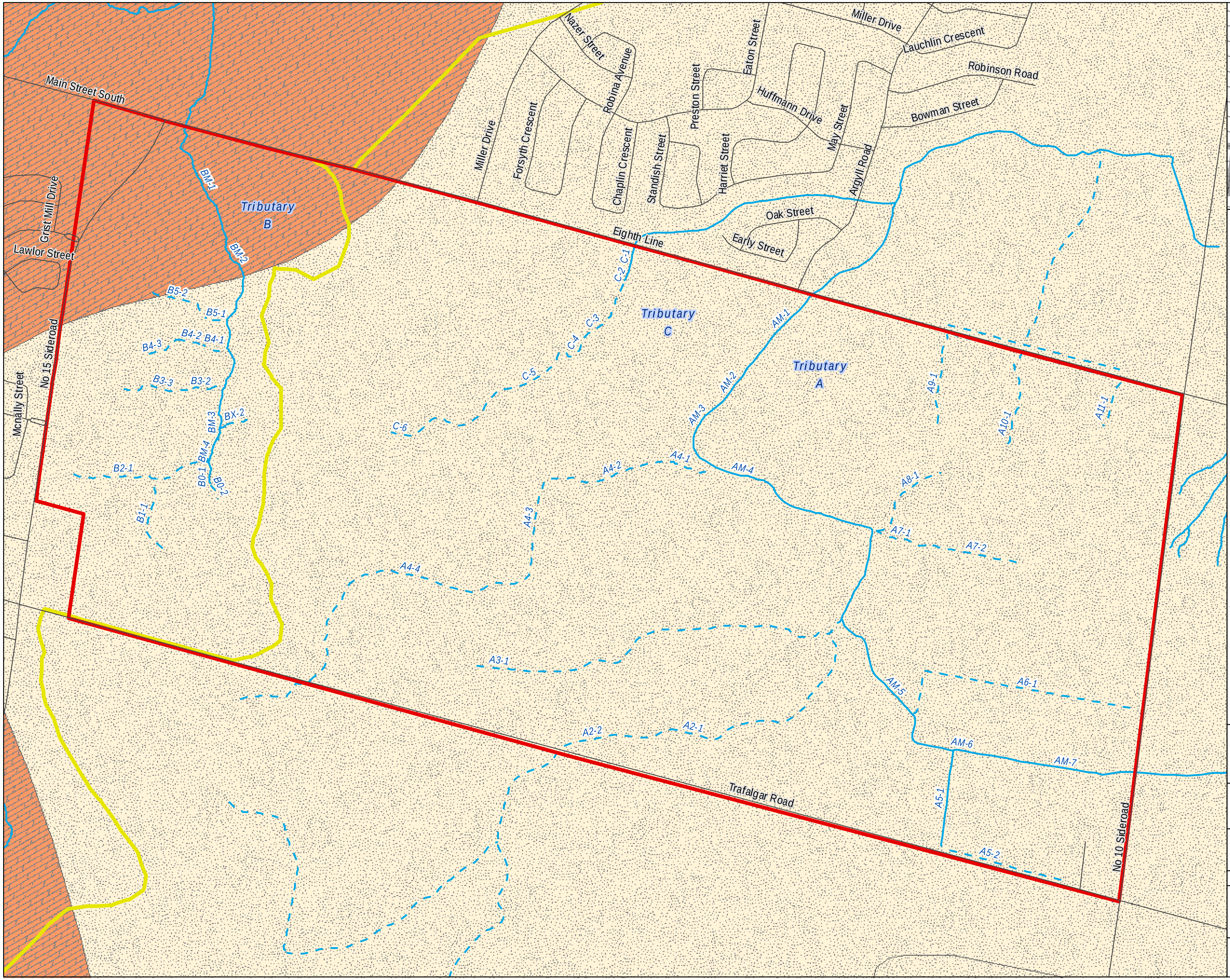
OPA 10 designates the lands as an urban area. OPA 10 has been approved by the Region of Halton and adopted by Council, but has been appealed to the Ontario Municipal Board. These lands are also subject to ROPA 38 under the Region of Halton, which is now in effect.

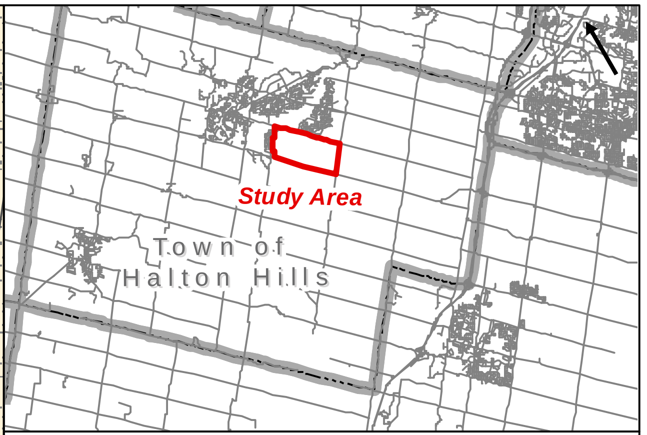
Agriculture is the dominant form of land use within the Southwest Georgetown study area. The study area and the adjacent land to the south are characterized entirely by agricultural fields with few small, isolated woodlots. Sparse hedgerows separate the agricultural fields, and few isolated domestic dwellings and farm buildings are scattered throughout. Urban development occupies the north side of the Silver Creek valley, and more recent urban development has been built along the east side of Eighth Line, down-gradient of the study area.

4.3 Physiography and Geology

4.3.1 Physiography

The study area lies within two physiographic regions as mapped by Chapman and Putnam (1984, 2007) and shown on **Figure 4.3.1**. The south slope region covers over 90% of the area, except for a small portion in the northeast corner, which is mapped within the Niagara Escarpment Region. Physiographic mapping after Chapman and Putnam (1984, 2007) is regional in nature and a more detailed position of the escarpment is provided by 1:50,000 bedrock and quaternary (**Figure 4.3.2**) mapping. For the purposes of this study, the siting of the escarpment region within the study area is considered an over-generalization, as landform characteristics more resemble those of the south slope. The south slope region is characterized by a drumlinized till plain, which in the study area comprises the clayey silt Halton Till at surface, and exhibits flat to rolling topography. Glacial outwash (spillway) deposits are associated with the Credit River which has a deeply incised valley in the northeast corner of the study area.





N

Legend

Landforms

Till Plains (Drumlinized)

Spillways

Regions

Niagara Escarpment

South Slope

General Features

Identified Reaches

Roads

Study Area

Conservation Authority Boundary*

Note

*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600

Meters

Southwest Georgetown Integrated Planning Project

Physiography

June 2016	1:10,000	Datum: NAD 83, Zone 17 Source: Chapman and Putnam, 2007. Ontario Geological Survey, MRD 22. LIO
P#: 60297831	V#: 006	

AECOM

Figure 4.3.1

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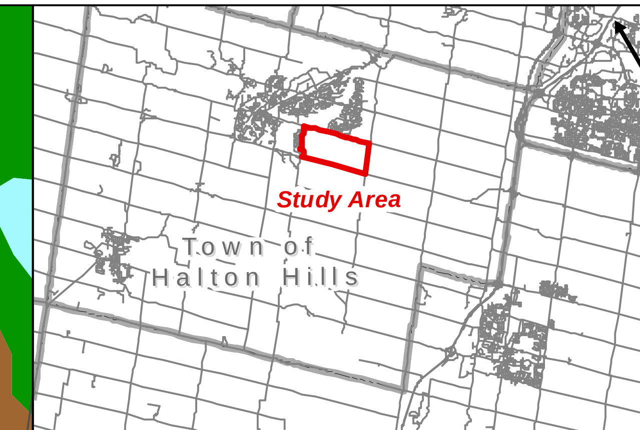

Legend

N

Surfical Geology

- Glaciolacustrine-derived silty to clayey till
- Ice-contact stratified deposits
- Sandy deposits
- Gravelly deposits
- Interbedded flow till, rainout deposits and silt and clay
- Older alluvial deposits
- Modern alluvial deposits
- Organic deposits

General Features

- Monitoring Wells
- Bedrock Valley Edge
- Cross-Sections
- Identified Reaches
- Roads
- Study Area
- Conservation Authority Boundary*

Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600
Meters

Southwest Georgetown
Integrated Planning Project

Surficial Geology

June 2016	1:10,000	Datum: NAD 83, Zone 17 Source: Ontario Geological Survey, 2010. MRD 128 , LIO
P#: 60297831	V#: 005	

AECOM

Figure 4.3.2

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The study area lies within headwater areas for the Silver Creek and the Sixteen Mile Creek subwatershed. Tributaries A and C (see **Figure 1.1.1**) are tributaries of the East Branch of the Sixteen Mile Creek. The main branches of these tributaries flow east through the clayey-silt soils of the Halton Till, and are marked by gently sloping side walls. There is significant scour and downcutting of the Tributary A channel along Reach AM-3, just after its confluence with the many side channels of the main branch. Tributary B in the north of the study area has a deeply incised valley along the main channel and flows into Silver Creek just east of the site. Topography decreases by 10 m from the top of the valley wall to the stream bed.

Surficial soils (**Figure 4.3.3**) naturally exhibit imperfect to poor drainage with ponding expected in low-lying areas and depressions (OMAFRA, 2013). This characteristic is not beneficial for crops and, as such, many of the agricultural fields are underlain by tile drains. Tile drains are installed to aid in the removal of excess water from soils, and in turn increase crop productivity. Many of the drainage pathways in the study areas have also been realigned to facilitate agricultural practices. The combination of tile drainage and the realigned drainage pathways has resulted in increased flows (at least seasonally), within the stream network that is interpreted to have aided in downcutting particularly along valleys walls of Tributaries A and B.

Tile drained areas shown on **Figure 4.3.4** include locations identified in LIO (Land Information Ontario) mapping and locations added based on field truthing and interviews with local farmers / land owners in the spring of 2014. Further evidence of tile drainage areas, particularly the location of outlets was identified through the creek walks held and are described in **Section 4.8**. An assessment of the impact of tile drainage on subsurface flows is presented in **Section 4.5.1**.

4.3.2 Geology

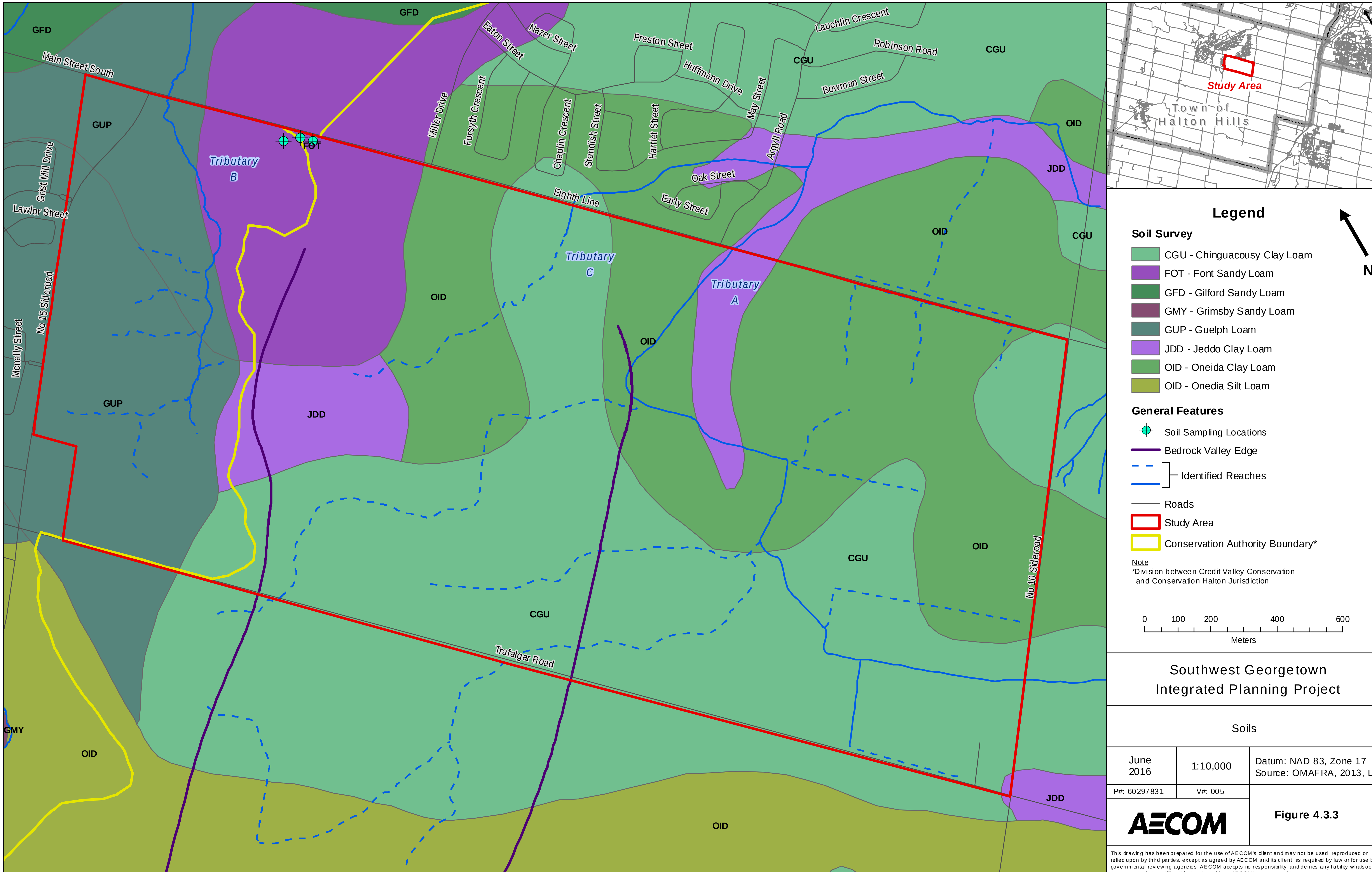
Characterization of the local bedrock geology began with work for the Conservation Authority Moraine Coalition (CAMC) / York Peel Durham Toronto (YPDT) project (CAMC, 2006). The CAMC/YPDT geological model was refined through subsurface site investigations completed as part of the Middle Sixteen Mile Creek (MSMC) (AECOM, 2010) and Halton Tier 3 (AECOM and AquaResource, 2012a) studies. Between these two projects, field work was conducted within the Southwest Georgetown study area including overburden and rock drilling, monitoring well installation, aquifer hydraulic testing, geophysics, water quality sampling, and residential water well surveys. Data from the above noted projects were used, along with field data collected for the Southwest Georgetown Study, to develop the site conceptualization presented in **Sections 4.3, 4.4** and **4.5**.

4.3.2.1 Bedrock Geology

The study area is underlain by red, argillaceous shale of the Queenston Formation (Armstrong and Dodge, 2007). This unit is Ordovician-aged, deposited during the Paleozoic Era over 440 million years ago. It is described as slightly calcareous to non-calcareous, poorly fossiliferous, thin to thickly-bedded red shale that reaches a maximum thickness of up to 150 m across its extent (Singer *et al.*, 1994). The upper 3 to 5 m of the bedrock surface is highly weathered. The weathering process creates increased permeability in the shale unit compared to deeper more competent sections.

There is a major regional unconformity associated with a long period of non-deposition between Paleozoic and Quaternary sediments in southern Ontario. During this period, extensive erosion of the bedrock surface by fluvial incision and other processes is thought to have occurred, creating regionally extensive, downstream sloping valleys in the bedrock surface. One such valley exists in the study area – the MSMC buried bedrock valley.

The bedrock valley is referred to as a buried feature since it is infilled and overlain by unconsolidated Quaternary-aged sediments. The nature of these deposits is described in **Section 4.3.2.2**. The MSMC buried bedrock valley begins just south of Eighth Line, and extends southward. Inferred extents are shown on **Figure 4.3.2**. The shape and extent of the MSMC buried bedrock valley is controlled by the topography of the bedrock surface (**Figure 4.3.5**). The base of the valley is relatively flat, maintaining an elevation between 205 and 210 mASL. The deepest portions of the valley coincide with bedrock lows just west of Trafalgar Road, about 1 km south of Side Road 15. As the bedrock surface rises northeast toward Eighth Line, northwest to Side Road 15 and Trafalgar, and southeast toward Side Road 10, the buried valley feature becomes less distinct. **Figure 4.3.6** is a cross-section through the study area that shows the bedrock surface in profile from Side Road 15 to Side Road 10 just east of Trafalgar. The section location is shown on **Figure 4.3.2**. Additional profiles of the bedrock surface are shown along Tributary A, B and C in **Section 4.8** of the report**.**



Southwest Georgetown Integrated Planning Project

Soils

June 2016	1:10,000	Datum: NAD 83, Zone 17 Source: OMAFRA, 2013, LIO
P#: 60297831	V#: 005	

AECOM

Figure 4.3.3

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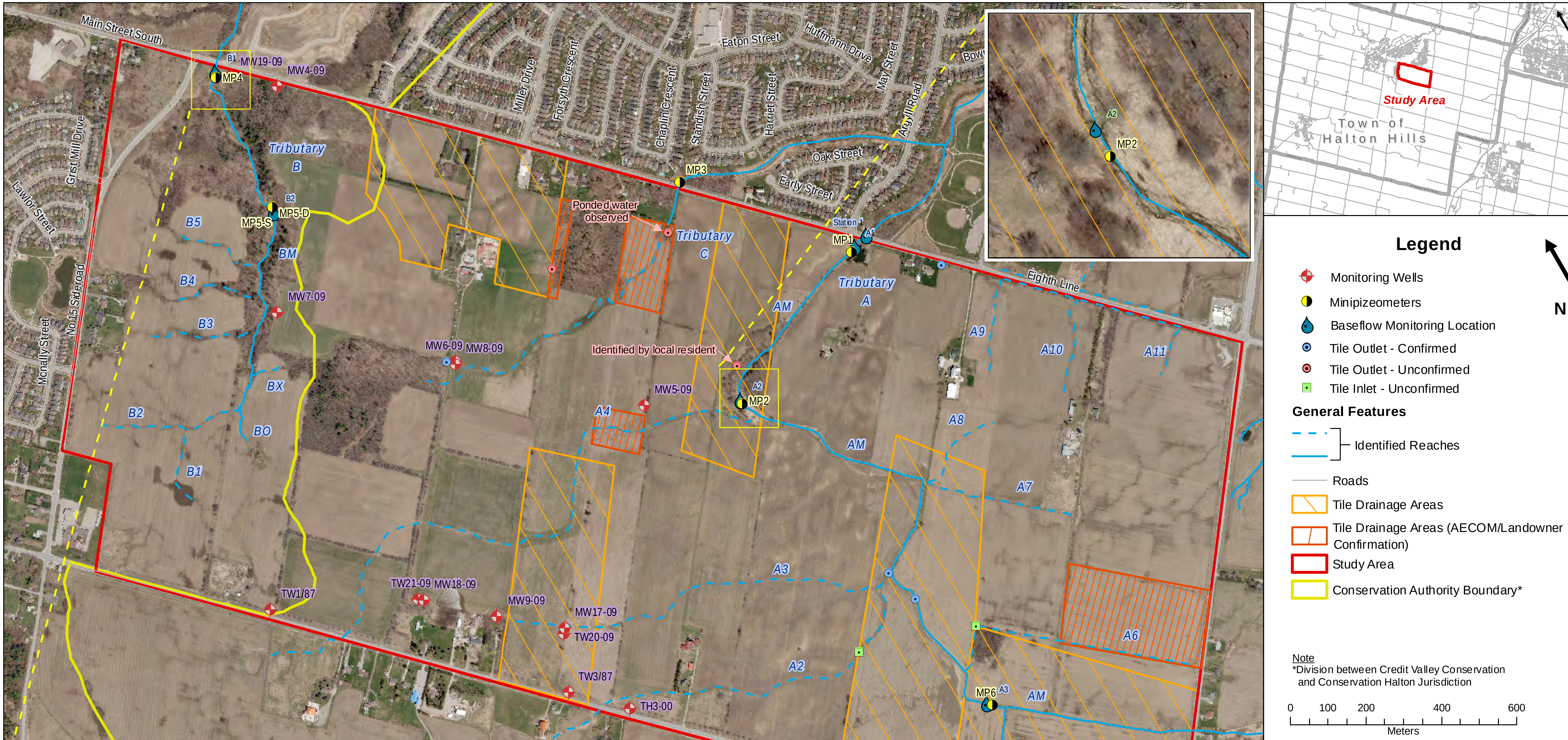


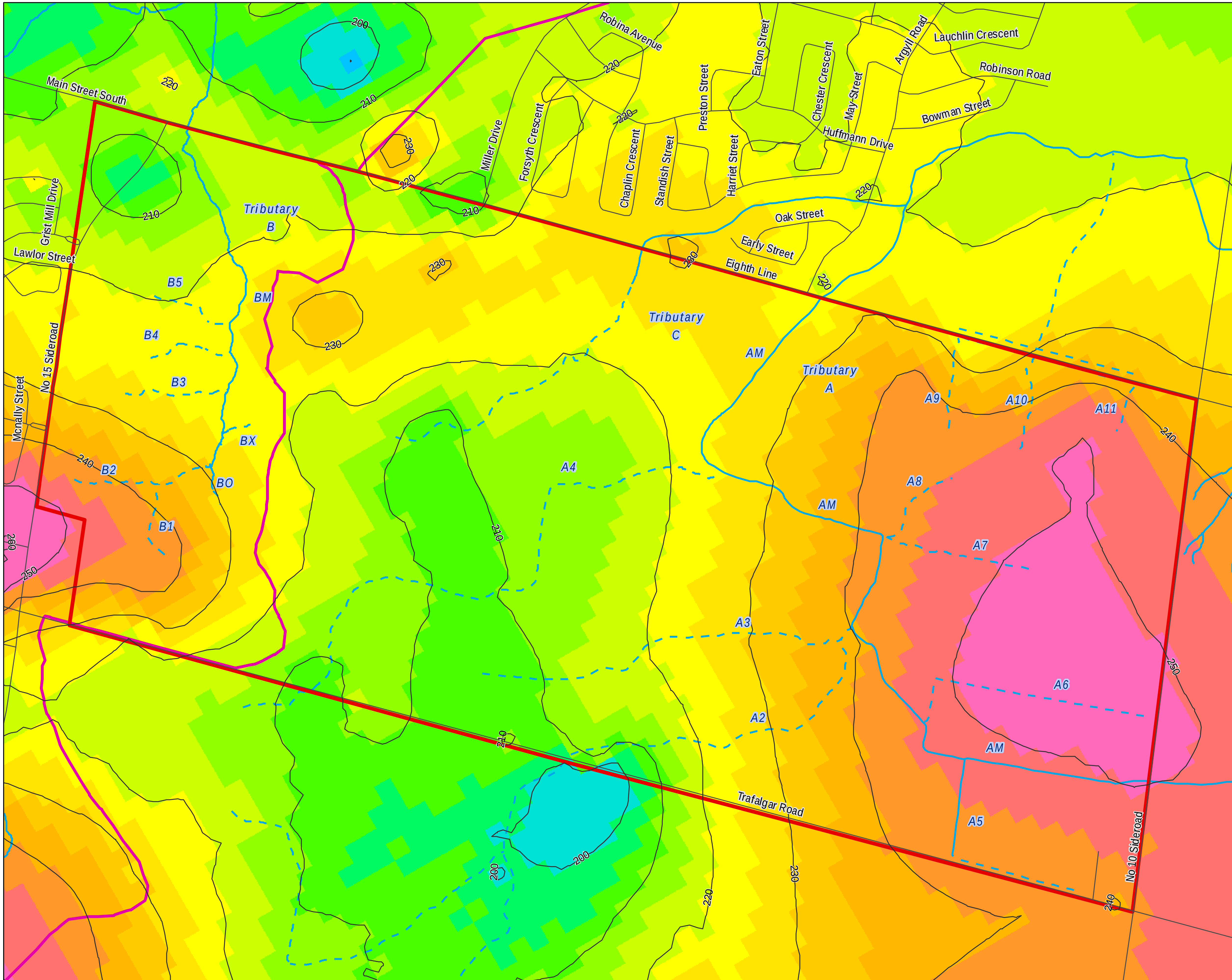
Southwest Georgetown Integrated Planning Project

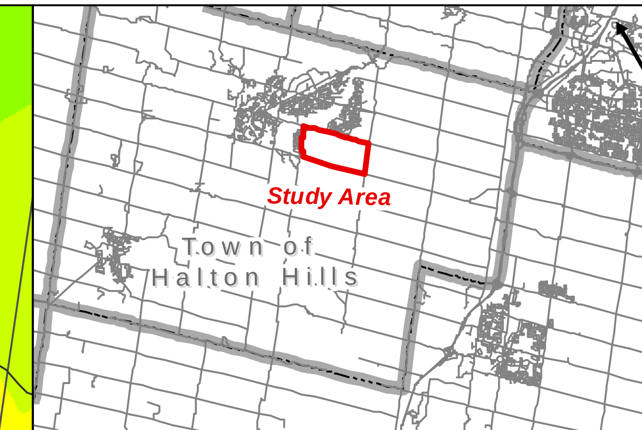
Tile Drainage Areas

July 2016	1:10,000	Datum: NAD 83, Zone 17 Source: LIO
P#: 60297831	V#: 004	

AECOM

Figure 4.3.4





Legend

N

Bedrock Topography (mASL)

High : 250

Low : 150

Bedrock Contours (10m)

General Features

Identified Reaches

Roads

Study Area

Conservation Authority Boundary*

Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600
Meters

Southwest Georgetown Integrated Planning Project

Bedrock Topography

June 2016	1:10,000	Datum: NAD 83, Zone 17 Source: AECOM & AquaResource, 2012a, LIO
P#: 60297831	V#: 005	

AECOM

Figure 4.3.5

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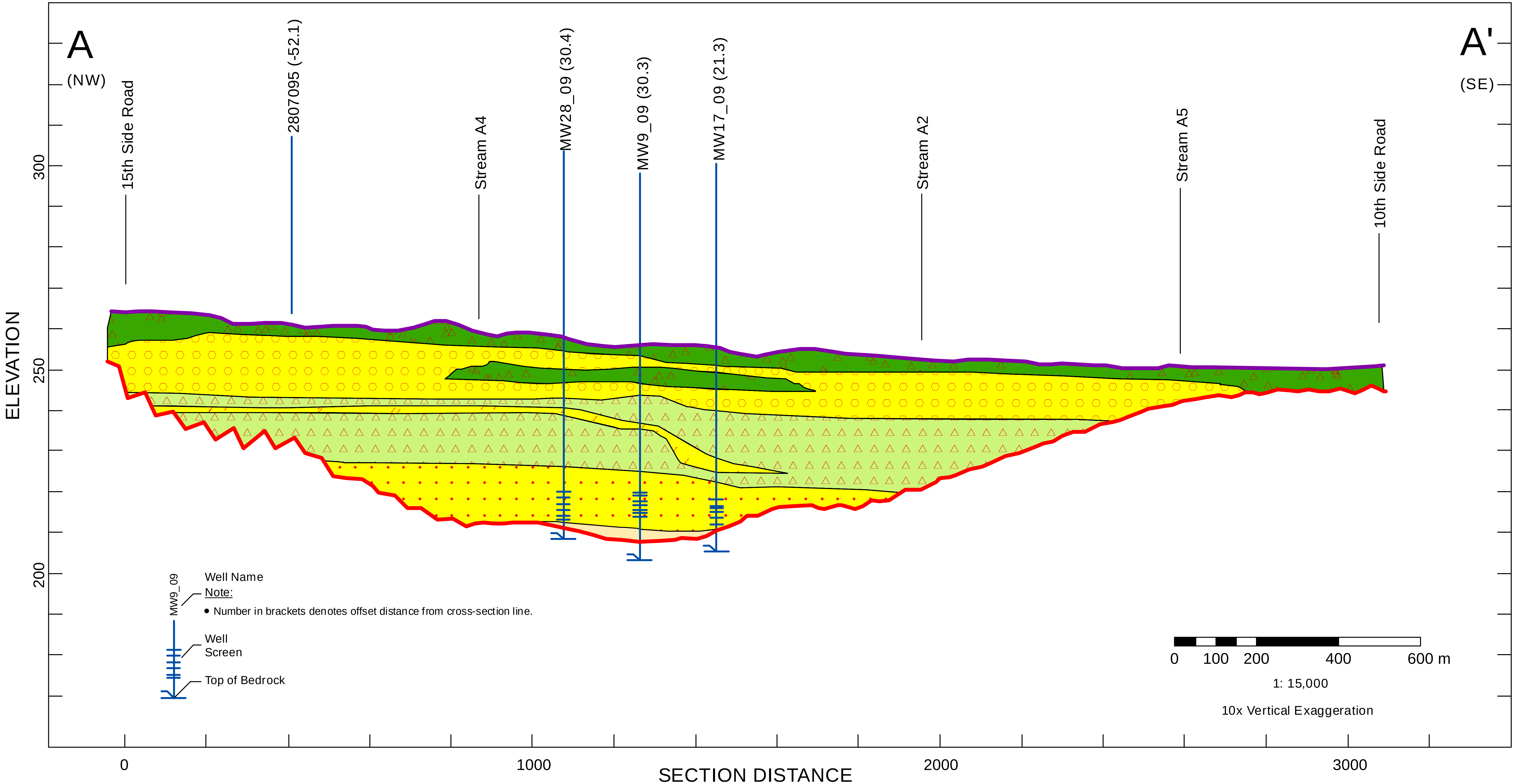


Legend

- Halton Till
- Oak Ridges (or Maple Formation Equivalent)
- Newmarket Till
- Inter Newmarket Sediments
- Thorncliff Formation (or Equivalent)
- Contact Zone
- Top of Bedrock
- Ground Surface

DO NOT SCALE THIS DOCUMENT. ALL MEASUREMENTS MUST BE OBTAINED FROM STATED DIMENSIONS.

Southwest Georgetown
Integrated Planning Project

Cross-Section A-A'

P#: 60297831	NTS	June 2016	Source: AECOM, 2010

AECOM

Figure 4.3.6

4.3.2.2 Quaternary Geology

Overlying the Queenston Formation are unconsolidated Quaternary-aged sediments (overburden), associated with the last (Wisconsinan) glacial period. During the Quaternary period, nine major glacial episodes are thought to have occurred during which there was significant erosion of the underlying strata, and deposition of thick overburden deposits. The current regional geological model advanced by the GSC consists of the following overburden units listed from youngest to oldest (CAMC, 2006):

- Modern alluvium,
- Glaciolacustrine sediments,
- Halton Till,
- Oak Ridges / Mackinaw Interstadial sediments (locally referred to as the Maple Formation);
- Northern / Newmarket Till, and
- Lower Sediments.

As this is a regional model, units may be locally absent depending on the specific depositional environment. There may also be considerable variation within each of the units. **Figure 4.3.2** shows the surficial geology in the study area (OGS, 2010). Most of the area is blanketed by Halton Till, but along Trafalgar Road and Side Road 10 there are isolated pockets of Late Wisconsinian glaciolacustrine deposits (silt and clay) above the till surface. Modern alluvium (silt, sand, gravel, clay, and organics) is found associated with the lower reaches of Tributary A and Tributary B. Tributary B, which is a confluence of Silver Creek, is also underlain by glacial outwash and terrace alluvium deposits (coarse sand and gravel) that are associated with the main valley of Silver Creek just northwest of the study area.

It is important to note the surficial geologic materials were only mapped where they achieved a minimum thickness of 1 m. Where the material was less than 1 m in thickness, it is not shown as occurring and the underlying material becomes the “mapped” unit. In contrast, the soil map (**Figure 4.3.3**) for the area defines units based on a range of factors affecting the pedogenic process that created the soil profile (OMAFRA, 2013). As a consequence, each soil map unit contains material of similar texture, drainage condition and parent material at or near the ground surface. When comparing the surficial geology and soils maps for the area, it can be seen that clay and silt loams are predominantly developed on the Halton Till, which has a fine-grained texture. Sandy loams are present to the north and east of the study area reflecting the influence of coarser-grained glaciofluvial deposits.

Borehole data from drilling completed in the study area by AECOM (2010) are provided in **Appendix D**. This data suggests that local Halton Till is a brown to reddish-brown silt to clayey-silt till with sand interbeds and stones. Meyer and Eyles (2007) note that Halton Till is often interbedded with glaciofluvial / glaciolacustrine sediments in the vicinity of the study area. Maple Formation sediments (equivalent of Oak Ridges / Mackinaw Interstadial sediments) consist mainly of sand and gravel from outwash deposits. The Northern / Newmarket Till is a dense silt till, that is differentiated into upper and lower units by the presence of an intermediate sand and gravel unit known as Inter-Newmarket Sediments (CAMC, 2007; 2009). Beneath the Northern / Newmarket Till are older deposits stratigraphically equivalent to the Lower Sediments. Regionally, this unit is an assemblage of the Thorncliffe Formation (sand, silt and clay of possible glaciolacustrine origin), the Sunnybrook Diamict (silt and clay) and the Scarborough Formation (sand). Locally however, the age and stratigraphic relationship of the Lower Sediments to these formations is unclear and the deposits are referred to as “Thorncliffe Formation or equivalent” (CAMC, 2006; Davies and Holysh, 2007). The Lower Sediments form a major aquifer in the study area, as discussed further in **Section 4.4**.

Figure 4.3.6 is an interpreted geological cross-section through the study area, developed from the CAMC/YPDT geological models (CAMC, 2006/2007/2010) and refined using site specific borehole data. The section shows that the thickness of overburden sediments ranges from 50 m in the deepest parts of the MSMC buried bedrock valley, to 10 m or less where the bedrock surface rises in the southeast toward Side Road 10.

4.4 Groundwater Flow System Characterization

The groundwater flow system is described in terms of its physical characteristics, significance as a source of water supply, and ecological function in this section. System characterization was conducted through a review of historical data as listed in **Section 1.5.2** and field data collected for this study. Field data was collected for this study to address identified gaps in the current site conceptualization. The program focused on characterisation of groundwater / surface water interactions, as sufficient site specific information on geology and hydrogeology was available from previous investigations (i.e., AECOM, 2010; historical Halton Region water level monitoring programs) including borehole drilling, monitoring well installation, aquifer hydraulic testing, water quality sampling, residential water well survey, and water level monitoring data. Field work for the Southwest Georgetown Subwatershed Study included:

- Site reconnaissance for groundwater recharge / discharge features;
- Field investigation of identified depression features in the landscape.
- Low flow stream flow monitoring at Tributaries A and B;
- Mini piezometer installations and water level monitoring at Tributary A, B and C;
- Water level monitoring at Halton Region on-site monitoring wells;
- A scoped residential water well survey, and
- Field truthing of soil and tile drain conditions.

Field program data are presented as part of the discussion of groundwater flow system characterization.

4.4.1 Regional Groundwater Flow

Regional groundwater flow is governed by the occurrence of hydrostratigraphic units. These units are defined as aquifers or aquitards based on geologic and hydrogeologic properties. An aquifer is a high permeability hydrostratigraphic unit that transmits water readily. Aquifers are typically composed of coarse grained material such as sand, gravel and cobble, or highly fractured / weathered bedrock. An aquitard is a low permeability hydrostratigraphic unit, typically composed of silt, clay, till or fractured bedrock; through which water does not flow readily. Regionally, many aquitards are considered low yield aquifers due to their ability to transmit modest volumes of groundwater. Such units may also be sources of water for low volume, long-term supply needs (i.e., domestic supply) where higher permeability aquifers are absent or too deep to reach economically.

Table 4.4.1 summarizes the regional hydrostratigraphic units present in the study area, refined for use in the Halton Tier 3 Study (AECOM and AquaResource, 2012a). The hydrostratigraphic model from the Halton Tier 3 Study is the most up-to-date refinement of regional geology for the study area. It is built on work completed for the CAMC/YPDT project (CAMC, 2006) and the precursor GSC (Logan *et al*, 2001) study.

As shown, the Halton Till unit forms a surficial aquitard that is underlain by multiple aquifers and aquitards that vary in thickness and extent. In general, hydrostratigraphic units below the Oak Ridges (or equivalent Maple Formation) are limited in occurrence to the buried bedrock valleys. Modern alluvium and upper glaciolacustrine deposits are excluded from the regional hydrostratigraphic model as they are not regionally continuous, often occurring as perched aquifer systems above the regional water table. These units may exhibit some significance to groundwater flow at a very local scale.

Table 4.4.1 Hydrostratigraphic Units within the Study Area

Geological Unit	Material Type	Primary Material	Typical Regional Thickness (m)$^{\xi}$	Hydraulic Function	Spatial Distribution
Halton Till	Overburden	silt to clay	0- 10	Aquitard	- Surficial unit - Continuous extent
Oak Ridges (or equivalent Maple Fm)	Overburden	Silt	0 - 30	Aquifer	- Buried bedrock valley infill - Continuous extent
Oak Ridges (or equivalent Maple Fm)	Overburden	silty sand to sand	0 - 10	Aquifer	- Buried bedrock valley infill - Discontinuous extent
Oak Ridges (or equivalent Maple Fm)	Overburden	sand, gravel and cobble	0 - 10	Aquifer	- Buried bedrock valley infill - Discontinuous extent with highly productive zones.
Upper Newmarket Till	Overburden	silty sand to silt / clay	0 - 15	Aquitard	- Buried bedrock valley infill - Discontinuous extent
Inter-Newmarket Sediments	Overburden	interbedded sand and silt	0 - 5	Aquifer	
Lower Newmarket Till	Overburden	silt to clay	0 - 5	Aquitard	
Lower Sediments (Thorncliffe Formation or Equivalent)	Overburden	sand, silt and gravel	0 - 5	Aquifer	- Buried bedrock valley infill - Local depressions in the bedrock surface - Discontinuous extent
Weathered Bedrock	Weathered Bedrock	weathered shale	3 - 5	Aquifer	- Continuous extent
Queenston Formation	Bedrock	shale	≤ 150	Aquitard	- Continuous extent

Notes: ξ - Typical thickness after Brunton et al. (2007, 2009) and Karrow (2005). --: Formations poorly differentiated over Study Area. Fm – Formation

Regionally, lateral groundwater flow from below the Niagara Escarpment is south and east toward Lake Ontario with flow converging at local creeks and rivers where groundwater discharge can occur. Convergence of flow is very prominent in the study area as groundwater flow is north and east toward Silver and Sixteen Mile creeks. This pattern is seen in the groundwater level contours in **Figure 4.4.1** and **Figure 4.4.2**.

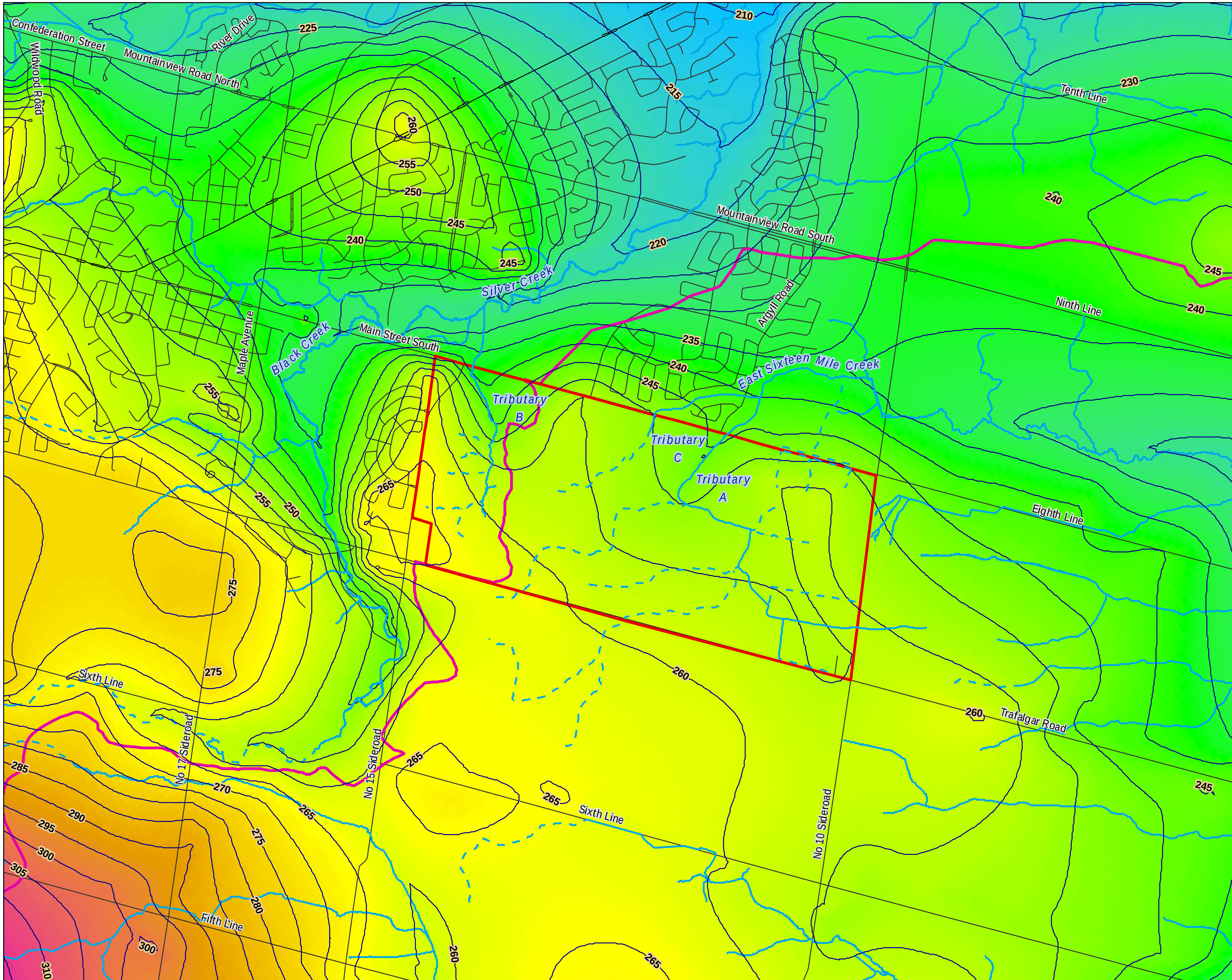
Figure 4.4.1 and **Figure 4.4.2** show interpolated surfaces for static water levels measured at water wells from the MOECC WWIS and Halton databases, developed by AECOM and AquaResource (2012a). These surfaces are regional in scale and shown here to provide the regional context for site groundwater conditions. Site specific groundwater elevation contours are shown and discussed in **Section 4.4.2.**

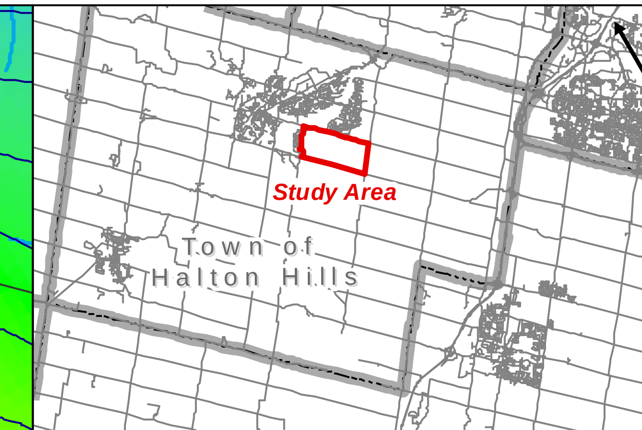
The shallow groundwater level surface (**Figure 4.4.1**) includes water levels from wells screened at or above 20 m below ground surface (bgs). Contours represent groundwater levels in the overburden and shallow bedrock units. As such, they are a considered an approximation of the water table. The deep groundwater level surface (**Figure 4.4.2**) includes water levels for wells screened below 20 mbgs. The majority of these wells were installed in permeable layers for supply purposes. As such, their groundwater levels express the average potentiometric surface within deeper aquifer units (i.e., Maple Formation, Inter-Newmarket Sediments, Lower Sediments (Thorncliffe Formation or Equivalent).

Regional estimates of annual average groundwater recharge are shown on **Figure 4.4.3**, as derived for the Halton Tier 3 study from a hydrologic model of site conditions. This model does not consider the presence of tile drains. The hydrologic model was developed using climate data from 1950 to 2010 and available topography, land cover, surficial geology, and stream flow data. The reader is referred to AECOM and AquaResource (2012b) for details on model development and calibration.

Recharge potential is largely controlled by the permeability of surficial soils. Low permeability soils (i.e., silt, clay) allow less infiltration and promote runoff, leading to lower groundwater recharge rates. The opposite is true for high permeability soils (i.e., sand, gravel), which allow greater infiltration and less runoff. Topography also affects recharge potential, as runoff water ponds in areas of low topography either evaporating, or infiltrating slowly into the subsurface over time.

Within the study area, recharge rates are lowest (< 100 mm/yr) where the surface is overlain by low permeability silt to clayey-silt soils of the Halton Till. Higher rates (200-500 mm/yr) are associated with sand and gravel outwash deposits near Tributary B, and low lying areas around Tributary A and B where runoff water ponds (**Figure 4.4.3**). The outwash deposit at Tributary B is reflected in the Significant Groundwater Recharge Area mapping completed within the Credit Valley and Halton Source Protection Areas (**Figure 4.4.4**).





Legend

N

Observed Shallow Aquifer

Groundwater Elevation (MASL)

High : 350

Low : 200

General Features

Identified Reaches

Roads

Study Area

Conservation Authority Boundary*

Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 0.5 1 2
Kilometers

Southwest Georgetown Integrated Planning Project

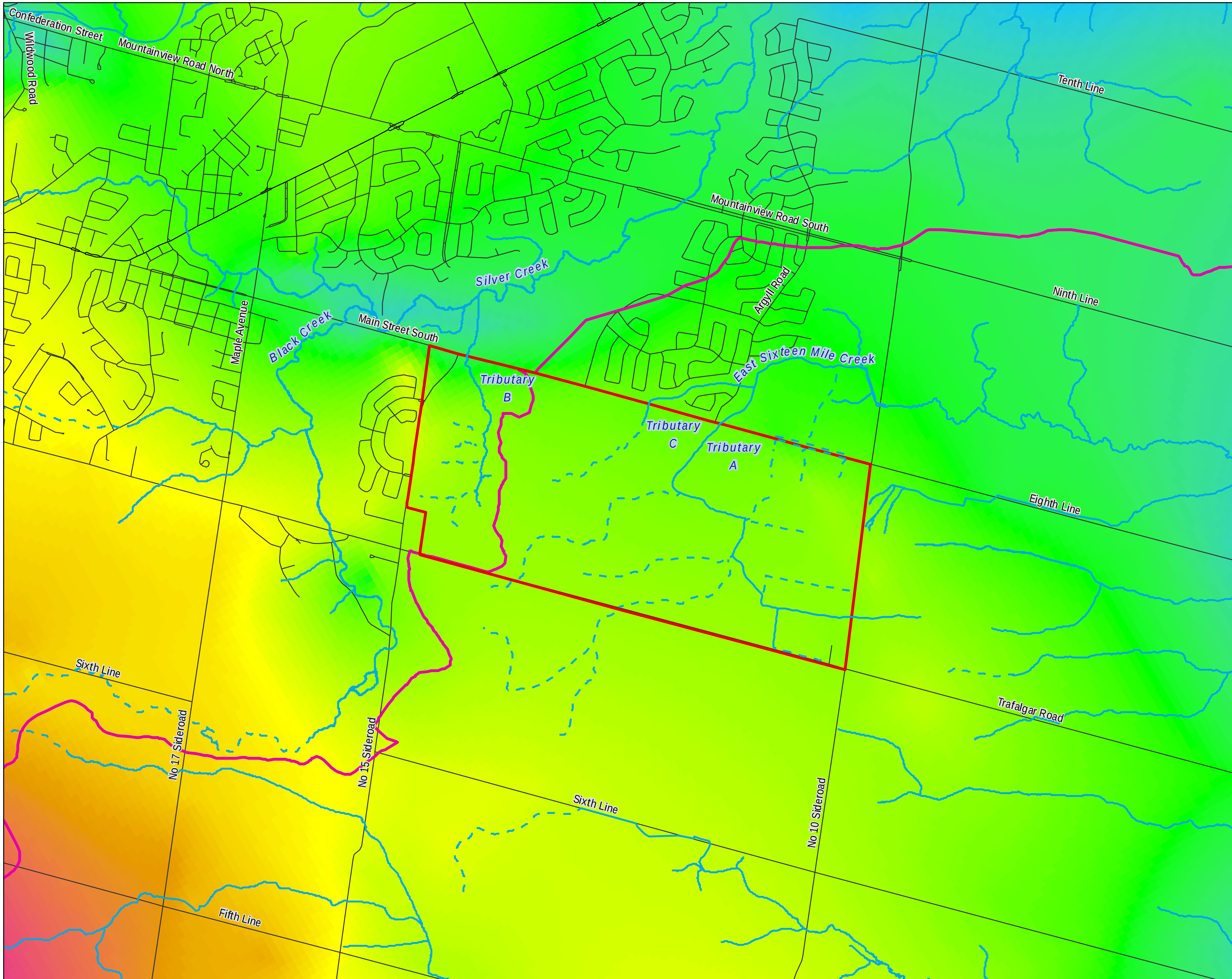
Observed Shallow Water Levels (AECOM and AquaResource, 2012a)

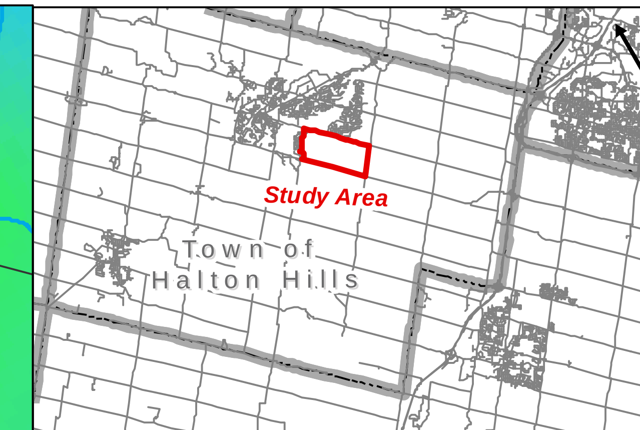
June 2016	1:25,000	Datum: NAD 83, Zone 17 Source: AECOM and AquaResource, 2012a, LIO
P#: 60297831	V#: 006	

AECOM

Figure 4.4.1

P:\60297831 SW Georgetown\900-CAD-GIS\920 GIS-Graphics\Design\Final Report





Legend

N

Observed Deep Aquifer

Groundwater Elevation (MASL)

High : 350

Low : 200

General Features

Identified Reaches

Roads

Study Area

Conservation Authority Boundary*

Note

*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 0.5 1 2

Kilometers

Southwest Georgetown Integrated Planning Project

Observed Deep Water Levels (AECOM and AquaResource, 2012a)

June 2016	1:25,000	Datum: NAD 83, Zone 17 Source: AECOM and AquaResource, 2012a, LIO
P#: 60297831	V#: 006	

AECOM

Figure 4.4.2

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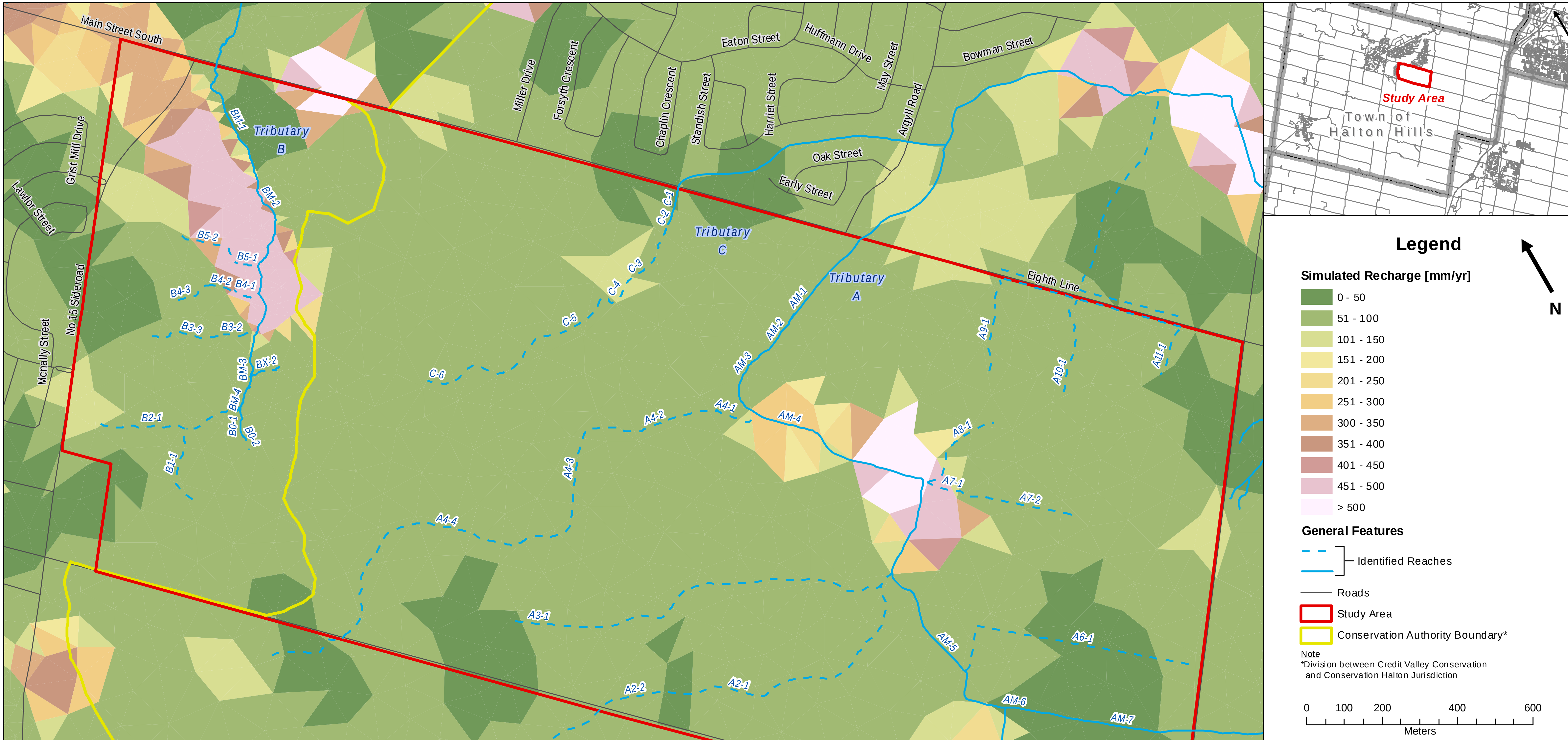

Southwest Georgetown Integrated Planning Project

Groundwater Recharge (AECOM and AquaResource, 2012b)

June 2016	1:10,000	Datum: NAD 83, Zone 17 Source: AECOM and AquaResource, 2012b, LIO
P#: 60297831	V#: 006	

AECOM

Figure 4.4.3

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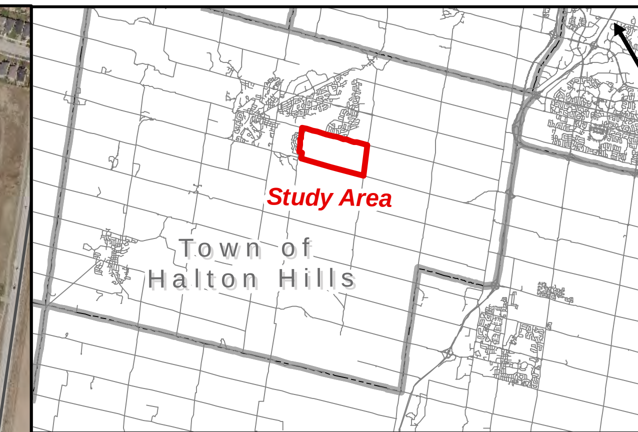

Legend

N

General Features

Identified Reaches

Roads

Study Area

WHPA-Q1/Q2

Source Protection Area (SPA) Boundary

Significant Groundwater Recharge Areas (Final)

0 100 200 400 600

Meters

Southwest Georgetown Integrated Planning Project

Significant Groundwater Recharge Areas and WHPA-Q1/Q2

May 2017	1:10,000	Datum: NAD 83, Zone 17 Source: Chapman and Putnam, 2007. Ontario Geological Survey, MRD 228, LIO
P#: 60297831	V#: 004	

AECOM

Figure 4.4.4

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4.4.2 Groundwater Flow in the Study Area

Local groundwater flow is consistent with the regional conceptualization described in **Section 4.4.1**. Shallow (< 20 mbgs) groundwater flow north of the MSMC buried bedrock valley is north toward Silver Creek. Within and south of the buried bedrock valley, flow is east toward the East Branch of Sixteen Mile Creek (**Figure 4.4.1**). In the deeper (> 20 mbgs) groundwater system, flow is generally to the east (**Figure 4.4.2**).

Most recharge to the shallow subsurface is through high permeability surficial soils. Current conceptual models (CAMC, 2006/2007/2010; and AECOM and AquaResource, 2012b) suggest these sand and gravel sediments have hydraulic conductivities ranging from $5x10^{-7}$ to $1x10^{-3}$ m/s. Recharge through the surficial Halton Till aquitard is limited because of the low permeability nature of the sediments. Hydraulic conductivity estimates for the Halton Till range from $5x10^{-8}$ to $4x10^{-7}$ m/s, which is characteristic of silt-clay or clay till soils. Site specific estimates of hydraulic conductivity for sand to fine sand units found at depth (Lower Sediments) range from $3x10^{-4}$ to $4x10^{-4}$ m/s (AECOM, 2010).

As part of this study, water levels were measured at Halton Region monitoring wells in the study area (**Appendix D**). Water levels were shallowest (<2 mbgs) at MW17_09 and TW20_09, deeper in the central portion (approximately 6 – 10 mbgs), and deepest in the northern area (approximately 10 – 20 mbgs). These results are within the range of historical water levels presented on hydrographs in Appendix D for several of the wells on site. Site-specific determinations of water table position and variability will be required prior to development of the study area, particularly in the southern portion where high water levels were observed. Given the predominance of till soils, it is not anticipated that development will significantly impact the local groundwater flow system. Potential impacts are qualified in Section 5 of this report. Development in the vicinity of Tributary B, where granular soils are present, must consider development within the context of the municipal water supply aquifer, such that transport pathways to the aquifer are not created.

The water level data suggest at least a portion of the recharge to the deeper aquifers in the buried valley is from bedrock, which in turn is recharged from overburden layers above the escarpment. Upward vertical gradients of 0.05 m/m exist between wells screened in the weathered bedrock zone and Lower Sediment aquifer. Water level data from wells screened in the Lower Sediments, suggest a north-easterly groundwater flow toward the Silver Creek valley, which is consistent with the regional patterns. **Figure 4.4.5** shows groundwater elevation contours for the study area, based on local data. Boreholes are provided in **Appendix D**.

Historical data collected along the reach of Silver Creek near the confluence of Tributary B provides a general sense of stream bed conditions along the lower reaches of Tributary B, as the underlying geology and groundwater conditions are similar. GLL (1998) and Phillips (1994) concluded that conditions along Silver Creek vary between losing (loss of surface water to the subsurface through the stream bed) and gaining (groundwater discharge to the stream) conditions. Local water table and stream levels fluctuate in response to seasonal recharge / surface water runoff patterns, and this may explain some of the variance. Measured values of groundwater discharge averaged 1.33 L/s (GLL, 1998) which is less than 1% of downstream flows in Silver Creek (313 L/s during the summer low flow period)[1]. Modelled groundwater discharge values are within the same range at < 1 L/s (AECOM and AquaResource, 2012a).

As part of the current study, minipiezometer installations[2] were completed at suspected areas of groundwater discharge, or near to surface water flow monitoring stations, to fill data gaps in the conceptual site model. In

[1] *313 L/s in August 2001 at Silver Creek and Hwy 7, data courtesy Credit Valley Conservation, as reported in AECOM and AquaResource, 2012a.*

[2] *A minipiezometer consists of a consist of 19 mm outer diameter, galvanized steel pipe with a 0.3 metre long perforated steel tipped screen that has been hand driven about 1.5 to 2.5 m in the subsurface to measure groundwater levels.*

addition, streamflows were measured under baseflow conditions, to isolate tributary reaches that have the potential for groundwater discharge.

Figure 4.4.6 shows the locations of minipiezometer and streamflow (baseflow) monitoring locations for this study, and field data are tabulated and plotted in **Appendix D**. The baseflow data for Tributary B, measured at stations B1 and B2, indicate that little flow occurred in the tributary under baseflow conditions. The tributary was consistently dry at B2 during the four field visits between June and September 2013, while the flow at B1 was below the measurement capabilities of the SonTek flow meter. A rough estimate of flow, obtained using a bucket and stopwatch, resulted in flow values below 1 L/s. Visual indicators of discharge (i.e., seepage, upwelling type groundwater discharge (D. Kelly, pers. comm.)) were observed at Tributary B along its stream banks (Reach BM-2) and streambed (Reach BM-2 into downstream portions of BM-1) (**Figure 4.4.6**). These observations generally correspond with the local till stratigraphic contact.

The mini-piezometer water levels measured in MP5S/D at flow station B2 indicate that the vertical hydraulic gradient was consistently upwards. The absence of baseflow at this station indicates that this result does not correlate with groundwater discharge occurring at this location. The mini-piezometer at flow station B1 (MP4) was consistently dry during the four field visits. This suggests that the tributary is perched above the local water table and that surface water likely infiltrates to the subsurface in this reach. This is supported by measurements in nearby monitoring wells where water levels were well below the base of the creek. Based on these results, it is concluded that the tributary conveys a small amount of seasonal baseflow that originates within BM-2, downstream of MP5s/d, and the upper portion of BM-1. This inference is supported by the thermal regime mapping that designates BM-1 as being coolwater (**Section 4.9.3.5**).

Based on the apparent perched nature of the tributary around MP4, this segment is inferred to have seasonal groundwater recharge potential. It should be noted that flow measurements were not taken downstream of MP4 and therefore flow loss (groundwater recharge) was not documented during this study. As there was no baseflow observed at B2 during the field season, it is inferred that significant groundwater discharge under baseflow conditions is unlikely upstream of this station.

The baseflow assessment conducted on Tributary A showed that there was flow in the tributary in June and July, while no flow was measured in August in September. During the June event, the baseflow measurements indicated that flow increased by 1.8 L/s between A3 and A2. In July there was no flow measured at A3 and a small amount of flow (<1 L/s) measured at A2. A consistently downward vertical hydraulic gradient was measured at MP6, located at A3, which is consistent with the baseflow observations. Therefore, this reach was evaluated as having seasonal groundwater recharge potential.

During the June and July events, the measurements at MP2, located at flow station A2, indicated that the vertical hydraulic gradient was downward. Therefore, the increased flow measured between stations A3 and A2 may have entered the tributary upstream of MP2, either as a small amount of baseflow, or via tile drain outlets. During the August and September events the vertical hydraulic gradient at MP2 was upward; however, there was no flow measured in the tributary at any of the flow stations and the water levels may not reflect natural conditions given the significant rise in the water level. Based on the data collected, minor seasonal groundwater discharge may occur upstream of A2/MP2; however, the specific location of this discharge is unknown. The seasonal nature of this potential groundwater discharge is reflected in the thermal regime data, as reach AM-3 was evaluated as being cool-warm.

Conservation Authority staff reported seepage along the banks of AM-1 and AM-3 during the spring of 2013 and seepage was also noted in 2014. This seepage is likely the result of interflow inputs to the stream rather than baseflow[3], and is thought to occur only seasonally during heavy precipitation or snow-melt events. It should also be noted that this location was identified as having a buried tile drain outlet during an interview with a local resident in spring 2014. If present, the water contributed to the shallow groundwater system by this drain outlet could be misinterpreted as groundwater discharge where it flows through the shallow sediments and into the Tributary A valley.

During the June monitoring event, baseflow decreased slightly between A2 and A1 and during the July event there was a small amount of baseflow measured at A2 (< 1 L/s) and no flow measured at A1. The vertical hydraulic gradient at MP1, located at flow station A1 was consistently upward during the field season. As demonstrated by the baseflow measurements recorded at A2 and A1, any increase in baseflow corresponding to this upward gradient was not evident upstream of flow station A1. Therefore it is inferred that minor seasonal groundwater recharge may occur between these flow stations. The vertical hydraulic gradient at MP1 was consistently upward, indicated that groundwater discharge potentially occurs here. This is reflected in the thermal regime mapping, as reach AM-1 was evaluated as being cold-cool. It should be noted that flow measurements were not taken downstream of MP1 and therefore flow gain (groundwater discharge) was not documented during this study.

There was no flow measured in Tributary C during the field season. MP3, located north of the study area, consistently had a downward vertical hydraulic gradient, indicating the potential for groundwater recharge from the stream. A cold-cool thermal regime was reported for reach C-1, which can indicate the occurrence of groundwater discharge; however, this may also be related to local tile drainage discharge. Given the absence of measureable flow in the tributary, and the consistently downward hydraulic gradient at MP3, it is inferred that groundwater recharge potential occurs north of Eighth Line.

As discussed, **Figure 4.4.7** summarizes the inferred groundwater discharge (baseflow) / recharge (surface water loss to the shallow subsurface through the stream bed) potential along stream reaches. Inferences were made through consideration of the available field and desktop data. Reaches are colour-coded based on the potential for seasonal and / or permanent conditions. Where insufficient data were available to infer conditions along a reach, it was not colour coded.

Overall, streamflow data do not suggest great potential for baseflow at Tributaries A, B and C. Vegetative indicators of discharge were not observed during the hydrogeological reconnaissance. During the summer 2013 field season, most courses were dry, contained disjointed pools of stagnant water, or had negligible flow to stagnant water. Watershed based numerical simulations show Tributary A and B to be primarily losing reaches (AECOM and AquaResource, 2012b), which further suggests there is poor potential for groundwater discharge throughout most of the study area.

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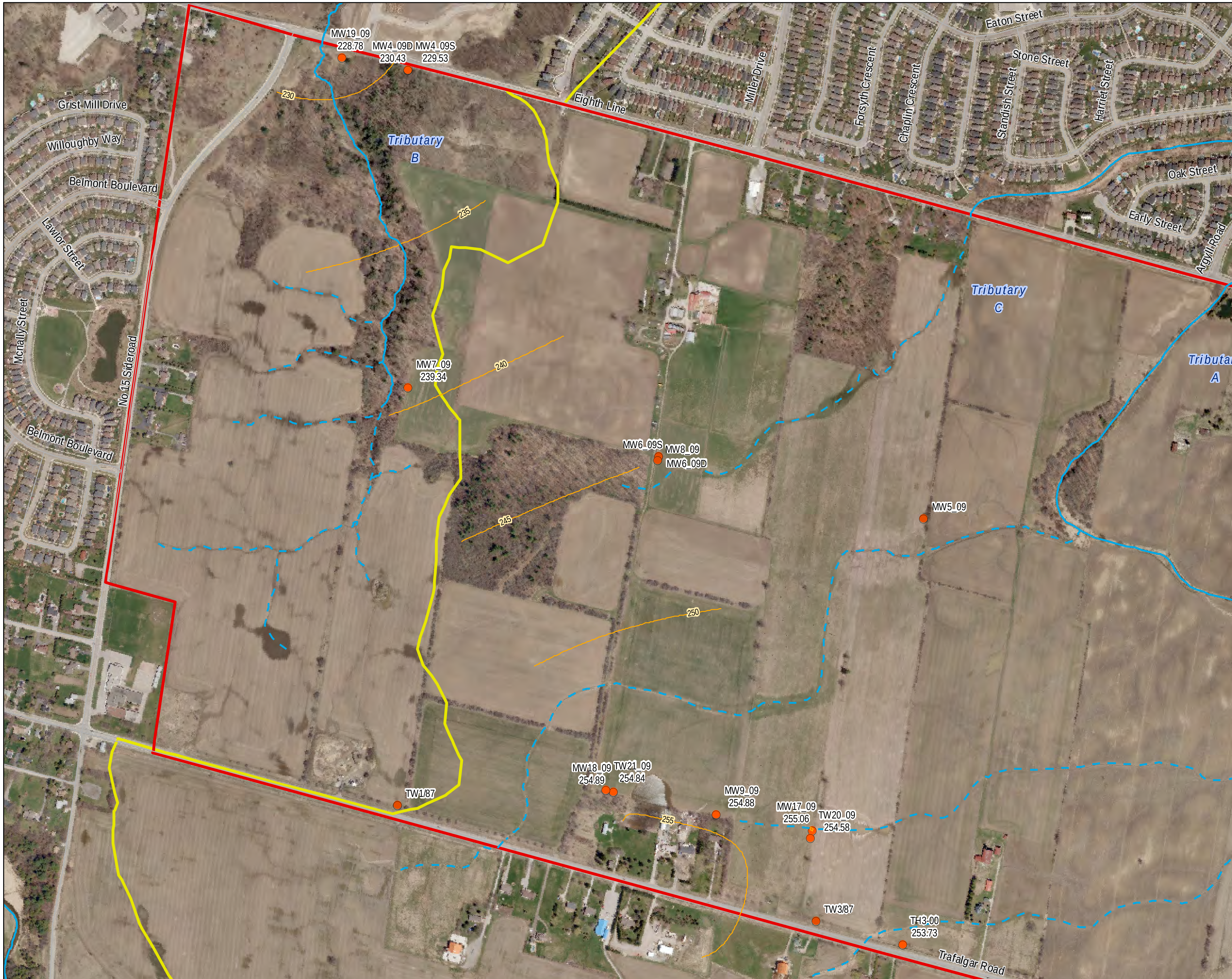
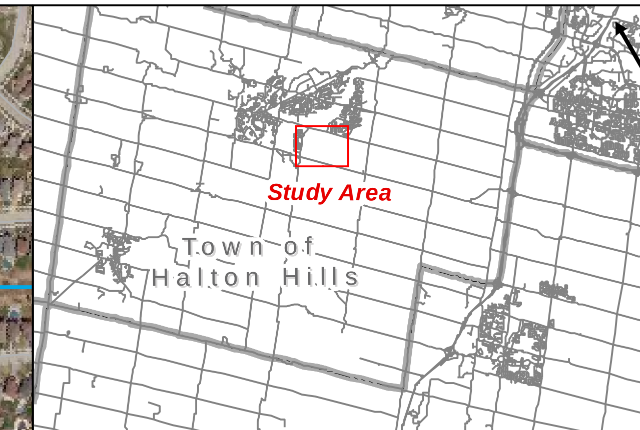
[3] *For the purposes of this study interflow is defined as recharge to the unsaturated zone that flows laterally through the subsurface until it discharges from the ground, and baseflow as discharge of groundwater to the ground surface from the water table.*





Legend

N

- Groundwater Elevation
- Groundwater Contours (1m)

General Features

- Identified Reaches
- Roads
- Study Area
- Conservation Authority Boundary*

Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400
Meters

Southwest Georgetown
Integrated Planning Project

Groundwater Elevation Contours

June 2016	1:7,000	Datum: NAD 83, Zone 17 Source: Region of Halton, LIO
P#: 60297831	V#: 006	

AECOM

Figure 4.4.5

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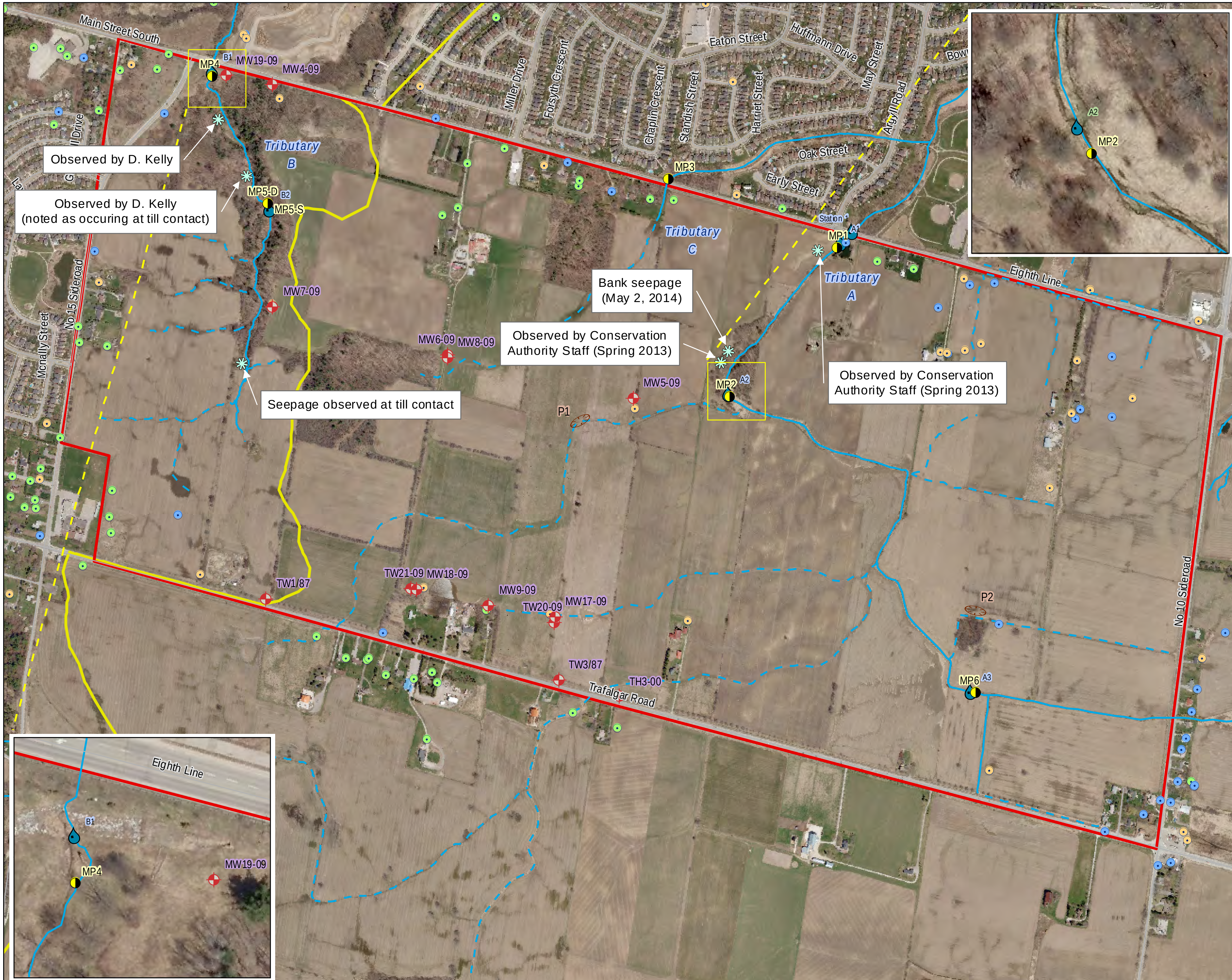

Southwest Georgetown Integrated Planning Project

Well Locations and Groundwater Monitoring

June 2016	1:10,000	Datum: NAD 83, Zone 17 Source: Region of Halton, LIO
P#: 60297831	V#: 006	

AECOM

Figure 4.4.6

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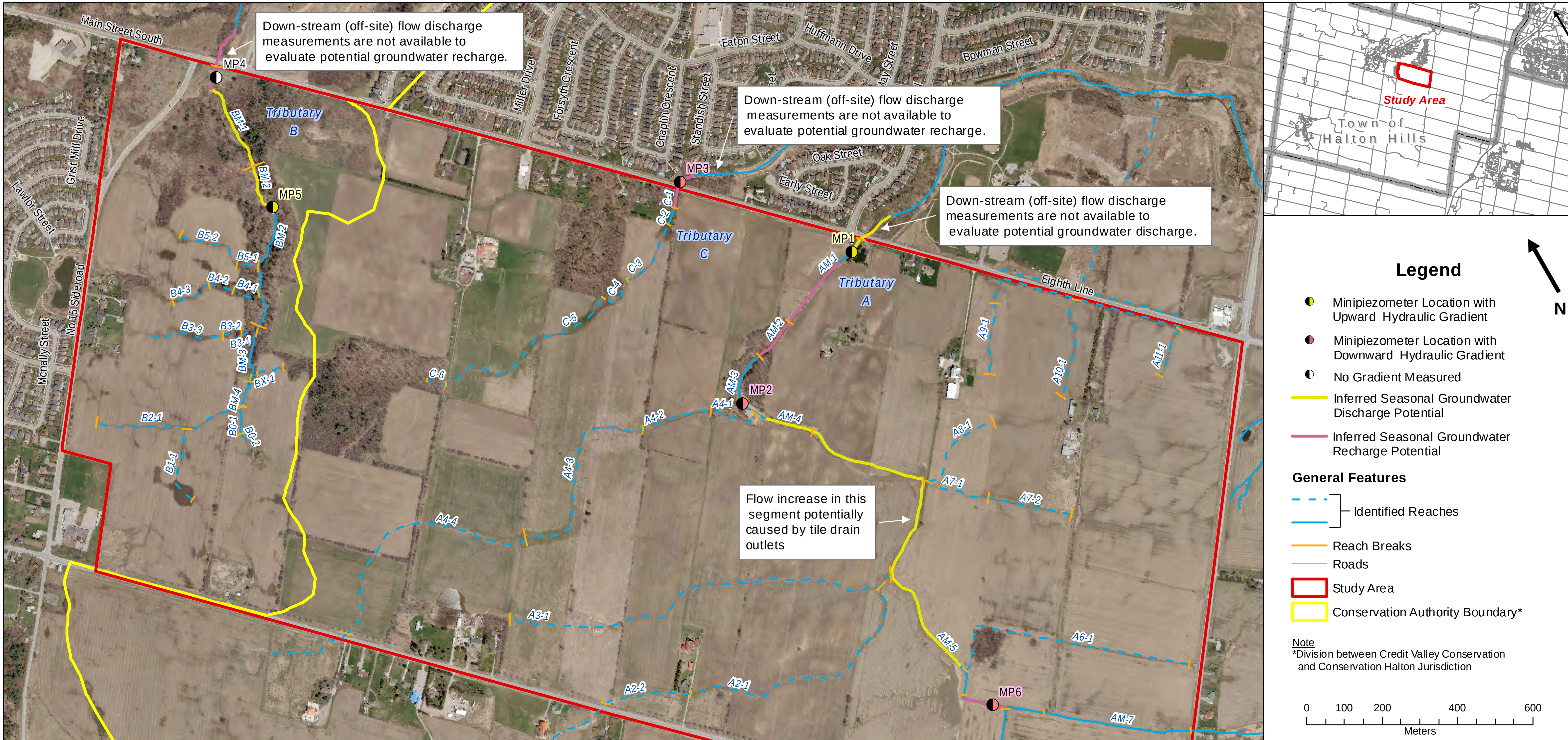

Southwest Georgetown Integrated Planning Project

Inferred Potential for Groundwater Recharge/Discharge along Stream Reaches

June 2016	1:10,000	Datum: NAD 83, Zone 17 Source: LIO
P#: 60297831	V#: 008	

AECOM

Figure 4.4.7

At least two localized depressions were noted during site reconnaissance. They are denoted as P1 and P2 on **Figure 4.4.6**. Depression P1 is located 300 m southwest of FOD-4B along Reach A4-3, and depression P2 is located at the northwest corner of the SWD that is east of Reach AM-5. At the request of the local Conservation Authorities, an investigation was completed at each depression to characterize potential groundwater linkages that relate to groundwater recharge potential and karst features[4]. At each depression, a small area ~1 to 1.5 m deep by 1 to 1.5 m wide was excavated by hand to confirm soil and water table conditions. Results confirm that soils were of clayey-silt nature, as suggested by geological and soil mapping, with a water table below at least 1.5 mbgs. No evidence was found of bedrock near surface. This agrees well with background overburden thickness and borehole data that suggest at least 10 m or more of overburden is present at each site. Each depression was found directly above or adjacent to a tile drain or associated drainage structure along the course of a ploughed through surface water feature. This suggests their origin is related to scour along the channel bed where runoff drains into underlying piping. Localized depressions are therefore not thought to be high potential recharge features. Further, due to the fact that the underlying bedrock unit is the Queenston Formation shale, karst is unlikely at the site as it is typically associated with limestone / dolostone bedrock.

4.4.3 Groundwater Use

AECOM (2010) showed through field testing in the study area that there is moderate potential for water supply in the Lower Sediments aquifer in the MSMC buried bedrock valley. Within the study area, this aquifer has a transmissivity of $4x10^{-4}$ m^2/s, a storativity of $1x10^{-5}$ and a potential yield of 650 m^3/d. Outside of the buried valley, there is limited water supply from the upper 3 to 5 m of the Queenston Shale and sand lenses within the Halton Till. Both these units supply sufficient yield to meet low volume water demands from domestic supply. A query of well use from MOECC database (MOECC, 2013a) was completed for a 500 m buffer of the study area. Data for wells located to within ± 300 m suggest a median yield from both bedrock and overburden wells of 33 m^3/day (0.38 L/s).

Approximately, half of the water wells in the area extract water from the bedrock. Most of these bedrock wells are clustered along Side Road 10 where overburden is thinnest (**Figure 4.4.6**). Data shows that water use is primarily for domestic supply, with 64% of wells being used for domestic purposes, 5% for agricultural use, 10% for public and/or monitoring use, and 4% for commercial use. The remaining wells are of unknown use.

A water well survey was conducted as part of the Southwest Georgetown study to corroborate data from the MOECC database and assess local issues of water quantity and quality. The survey was conducted at wells within and along the border of the study area. Residents reported water quantity issues at shallow dug wells during dry summers or, in one instance along Eighth Line, after residential development occurred on the east side of the road. The issue was mitigated via connection to a municipal water main.

Based on the current site conceptualization, there is a hydraulic connection between the Oak Ridges (or Maple Equivalent Formation) sediments in the north and eastern part of the study area and the aquifers that supply the Georgetown municipal supply wells to the north of the site. As such, infiltration to the groundwater system occurring in these areas has the potential to recharge the municipal supply well aquifers. Although recharge is promoted through the use of source control (LID measures), water quality protection will be necessary.

4.4.4 Groundwater Quality

Groundwater quality is influenced by native groundwater chemistry, which is a result of natural geochemical processes and, at times, anthropogenic impacts. Geochemical processes are strongly linked to the geology of the host aquifers. Groundwater from the Queenston Formation is typically hard, with high levels of sodium, chloride and

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[4] *Karst features are known to have a high recharge potential.*

sulphate (Singer *et al.*, 2003). Water quality samples from TW20_09 and TW21_09 (**Appendix M**) show elevated levels of iron in the Lower Sediments aquifer that exceed aesthetic guidelines in the Ontario Drinking Water Standards. Moderate levels of hardness are found in almost all formations due to the calcareous nature of bedrock throughout southern Ontario. The primary water quality issue reported during water well surveys conducted for the study was water hardness.

Based on a search of the Environmental Site Registry (MOECC, 2013b), there are no known contaminated sites within the study area. Local aquifers are not considered highly vulnerable to surface contamination, due to the presence of the Halton Till aquitard at surface that impedes infiltration to the lower aquifer units.

4.4.5 Drinking Water Source Protection Policy

The Clean Water Act (2006, S.O. 2006, c. 22) provides a legislative framework for protection of municipal drinking water supplies at their source. Under the act, local communities are required to assess potential threats to drinking water quality and quantity; and design and implement strategies to address identified threats. Developed strategies must be based on sound technical study and approved by local Source Protection Authorities and the province (CTC Source Protection Region (SPR), 2012a).

The Southwest Georgetown study area intersects the Credit Valley and Halton Source Protection Areas, which are part of the Credit Valley, Toronto and Region and Central Lake Ontario (CTC) and Halton-Hamilton Source Protection Regions, respectively. **Figure 4.4.4** shows the Georgetown WHPA-Q1/Q2 (CTC Source Protection Region, 2015), where certain land use activities are deemed significant water quantity threats. WHPA-Q1/Q2 for the Georgetown municipal wells was assigned a moderate risk as part of the Halton Hills Tier 3 risk assessment (AECOM and AquaResource, 2014), completed as a requirement of the *Clean Water Act,* and therefore, the Source Protection Polices that manage water quantity threats apply to future land uses in WHPA-Q1/Q2.

There are two Source Protection Plans, one for each Source Protection Area which have been approved by the MOECC that apply to the Southwest Georgetown Study Area. The plans came into effect on December 31, 2015. Under these plans, activities which reduce recharge to an aquifer (i.e., activities that increase the impervious surface of an area to prevent rain and snow melt from infiltrating to the ground) are to be restricted through the land use planning process. As such, future development in WHPA-Q1/Q2 will be subject to, for example, measures to mitigate or compensate recharge reductions (i.e., LID, off-site compensation, storm water controls) or additional hydrogeological study (at the site plan stage) to demonstrate that site recharge function, surface water flows and permitted municipal water takings can be maintained.

Figure 4.4.8 shows the Georgetown Wellhead Protection Area (WHPA)[5] (CTC Source Protection Region, 2015), where certain land use activities are deemed to be significant water quality threats. The study area intersects an Issue Contributing Area (ICA) for chloride[6], associated with the Georgetown municipal wells, where significant water quality threats can also occur (**Figure 4.4.9**).

Under the Source Protection Plan(s), restricted activities within these areas include sewage (i.e., discharge and/or infiltration from a stormwater retention pond, sanitary sewers and pipes); road salt application and storage; snow storage, and activities that reduce recharge to an aquifer. Consideration should be given to the Source Protection Plans through the Secondary Planning Process where appropriate and as part subsequent planning processes and

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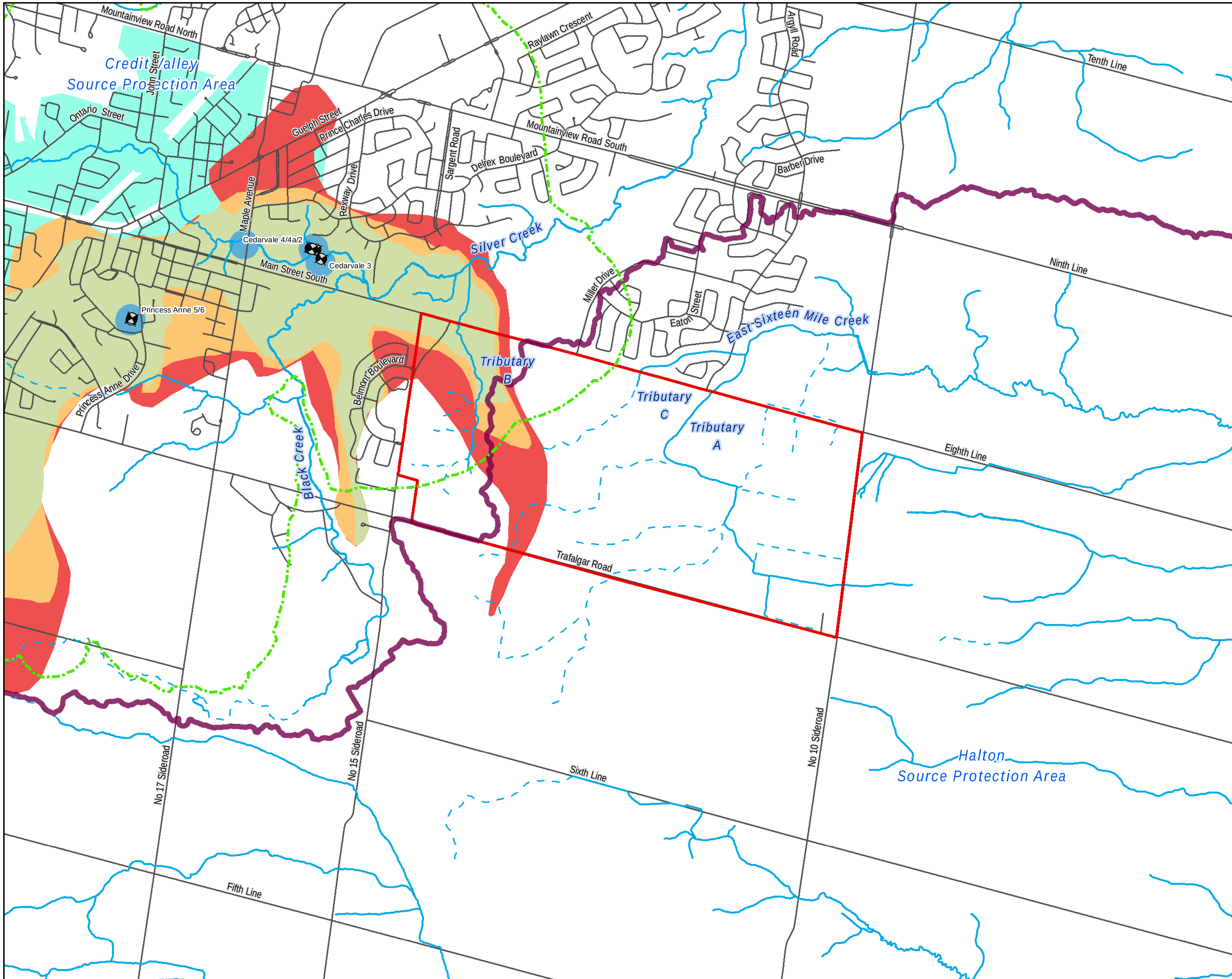
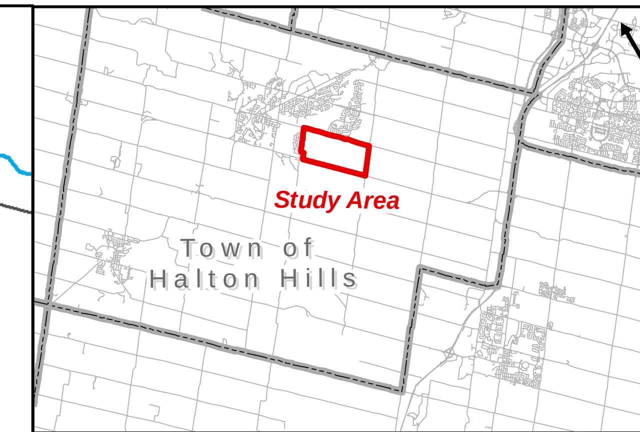
[5] *Definition: an area that is related to a wellhead and within which it is desirable to regulate or monitor drinking water threats.*
[6] *Definition: The area within a vulnerable area where activities, conditions that result from past activities, and naturally occurring conditions may contribute to the parameter or pathogen.*

related subwatershed impact studies, drainage plans and stormwater management plans/reports. These future processes and plans will be required to implement specific Source Protection Plan policies.

Finally, it should be noted that the Source Protection Plans which apply to the Vision Georgetown Secondary Plan Study Area provide transition policies. Reference should be made to the CTC policies as provisions “grandfather” existing planning applications and all future related planning applications in terms of recognizing activities as “existing” activities as opposed to “future” activities. This is important as, policies and requirements differ based on whether the activity is considered an “existing” activity or a “future” activity. For example, the CTC Source Protection Plan transition policy identifies stormwater management ponds as an “existing” activity in the study area.





Legend

N

- Georgetown Municipal Wells

WHPA

- WHPA-A
- WHPA-B
- WHPA-C
- WHPA-D
- WHPA-E
- WHPA-Q1/Q2

General Features

- Identified Reaches
- Roads
- Study Area
- Source Protection Area (SPA) Boundary

0 0.5 1 2
Kilometers

Southwest Georgetown
Integrated Planning Project

Cedarvale Wellhead Protection Area

May 2017	1:25,000	Datum: NAD 83, Zone 17 Source: AECOM and AquaResource, 2013 and LIO
P#: 60297831	V#: 009	

AECOM

Figure 4.4.8

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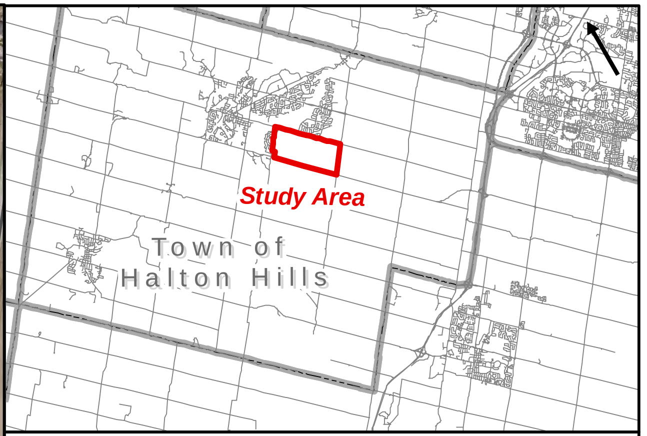

Legend

N

Georgetown Municipal Wells

Issue Contributing Area (chloride)

Source Protection Area (SPA) Boundary

General Features

Identified Reaches

Roads

Study Area

0 100 200 400 600

Meters

Southwest Georgetown
Integrated Planning Project

Issue Contributing Area (chloride)

May 2017	1:10,000	Datum: NAD 83, Zone 17 Source: Chapman and Putnam, 2007. Ontario Geological Survey, MRD 228, LIO
P#: 60297831	V#: 004	

AECOM

Figure 4.4.9

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4.5 Groundwater Balance

A qualitative groundwater balance was completed for the study area through consideration of hydrologic processes and their linkages to the groundwater regime. This was completed prior to the analysis stage of the project to aid in characterization of the study area. Data from the numerical groundwater flow model developed for the Halton Tier 3 study were used to provide a general sense of water fluxes within the system. Model results are based on regional approximations of the groundwater regime, under long-term steady-state conditions. Data was verified against groundwater level and baseflow conditions over the 2005 to 2009 period. As such they are considered suitable for providing general approximations of groundwater fluxes within the study area. Additional information on model development is included in the AECOM and AquaResource (2012b) reference. In addition, during the analysis stage of the project, a study area water balance was calculated using a modified version the groundwater model previously referenced. The results of this water balance modelling are discussed in **Section 5.4.4**. The water balance modelling discussed in **Section 5.4.4** is a detailed assessment and should be regarded as a local refinement of the results described in this section.

Precipitation to any subwatershed is evaporated, transpired by vegetation, infiltrated into the subsurface, or conveyed via run-off to a drainage feature. Water that infiltrates may reach the water table and become groundwater recharge, or it becomes perched on low permeability layers within the unsaturated zone. Where the water table intersects surface water courses, there is the potential for groundwater to discharge to streams as baseflow. Runoff may travel overland and enter surface water courses, or it may pond in local depressions where it slowly infiltrates into the subsurface. Runoff typically occurs during and immediately after precipitation events, whereas baseflow can occur at all times and, as such, has an important function in maintaining stream flows – particularly during low flow periods.

On average, the study area receives 860 mm/year of precipitation, of which 540 mm is evaporated and/or transpired (AECOM and AquaResource, 2012a). The remaining 320 mm/yr infiltrates the subsurface or becomes run-off. This is referred to as the water surplus. Within the study area, the potential for surface water runoff is high due to the presence of low permeability Halton Till soils at surface. As noted previously, groundwater recharge (**Figure 4.4.3**) is greatest at the high permeability sand and gravel outwash deposits in the lower reach of Tributary B. In addition, after storm events or sustained periods of precipitation, focused recharge may occur from areas of ponded water within low lying areas (i.e., valleys of Tributary A and B), provided evapotranspiration does not proceed at such a high rate to evaporate ponded water before it has a chance to infiltrate. Based on the historical and field data reviewed, surface water inputs (surface water runoff, precipitation) appear to be the main source of water for stream flows. However, there were observations of groundwater seepage along sections of BM-1 and BM-2, and this is likely a source of water for stream flows at Tributary B on a seasonal basis.

The groundwater balance consists of inputs (groundwater recharge, surface water lost through stream beds, subsurface flow from up gradient areas) and outputs (groundwater discharge to streams, subsurface flow to downgradient areas). The quantities stated here were derived from an analysis of the entire Tier 3 model and, as such, should be regarded as rough estimates. More refined estimates from the model after some modifications in the immediate study area are provided in **Section 5**. The water balance from the Tier 3 model applied to the project area estimated 1,075 m^3/d (12.4 L/s) of groundwater recharge over the entire study area, which is characteristic of fairly fine-grained surficial soils. Surface water loss to the subsurface through the stream bed was simulated as 1,470 m^3/d (17 L/s), occurring from Tributary B and the lower reaches of Tributary A. Subsurface flow entering the domain from up gradient areas was simulated as 2,800 m^3/d (32.4 L/s). In total groundwater inputs to the study area were 5,345 m^3/d (61.9 L/s). Outputs consisted of groundwater discharge of 101 m^3/d (1 L/s) simulated along the upper reaches of Tributary A (Reach A5-1 and parts of AM-5 and AM-6) and along Tributary A, B and C in areas downstream of the study area, as well as subsurface flows leaving the domain for downgradient areas of 5,240 m^3/d

(60.6 L/s). In total, simulated outputs were 5,341 m^3/d (61.8 L/s). The 0.07% difference between inputs and outputs is consistent with numerical model error.

4.5.1 Tile Drainage Assessment

Tile drains remove excess water from top soils, promoting faster drainage by conveying water away from fields to drainage ditches. Drainage effects are seasonal, typically during periods of snow melt and heavy rains at the start of the growing season. This causes localized and seasonal effects on the water balance of decreased runoff or depression storage and increased infiltration to either the subsurface or tile drain network. The timing and volume of water balance changes due to tile drains are dependent on a number of factors including drain size, depth, and spacing; drain outlet distance, size and condition; soil type and permeability, ground topography, and the timing of rainfall or snowmelt (Fraser and Fleming, 2001). As such, effects are difficult to characterize without site specific study.

The effects of tile drains to the water balance can be explained as follows. Infiltration (groundwater recharge) to the subsurface either becomes interflow (i.e., infiltration to the unsaturated zone that flows laterally through the subsurface until it discharges from the ground), or deep recharge (i.e., infiltration to the unsaturated zone that flows vertically to the water table from where it recharges the water table or deeper subsurface aquifers). With tile drains, a portion of infiltration is redirected from the subsurface into the drainage network. As such, lower volumes of water may be available for baseflow (i.e., discharge of groundwater to streams from the water table) and interflow. However, if tile drains outlet to the local stream system there is conceivably no net loss to the volume of subsurface flow that enters the system.

It was beyond the scope of this project to conduct field investigations to quantify tile drainage characteristics of the study area, and in turn quantify the effects of tile drainage on the local water balance. However, available site knowledge and empirical relationships have been used to approximate the volumetric impact of tile drains on shallow subsurface processes using several assumptions.

An assessment of the impact to the water balance was completed by first calculating the total catchment area for each catchment, and then calculating the area that is underlain by tiles. The locations of the tile drainage areas are shown in **Figure 4.3.4**. The area underlain by tiles was approximated using polygons available from Land Information Ontario (LIO) and through field investigation (**Table 4.5.1**). The catchment areas on site are labelled in **Figure 4.6.1**. Catchment areas A-4a, A-6, B-2 and D-1 did not have tile drainage present at the time of this assessment. Within the study area a total of 23% of the area is drained by tiles. Average annual infiltration rates for tiled areas were calculated as follows:

Recharge (mm/year) = (Recharge (m^3/yr) x Catchment Area (m^2)) x % of Catchment Area underlain by tiles
Note: Recharge rates for the study area are based on the Tier 3 Water Budget model (AECOM and Aqua Resource, 2012)

To estimate the volumetric impact of tile drains on each catchment, it is assumed that 100% of the drainage from tiles occurs between March and June each year, with approximately 75% of the infiltrated water being removed by the tile drain network (Jin and Sands, 2003). During the drier months and winter months, when baseflow and interflow are more likely to be the sole source of inflows to surface water courses, drainage is assumed negligible as soils would not contain excess water to drain. Therefore it is assumed there is a 0% volumetric impact on each catchment between July and February of each year. Infiltration is equally proportioned between interflow and deep recharge, under pre- and post-drain conditions, based on proportioning suggested by modelling studies completed for similar soil and climatic conditions (Stonybrook Consulting Inc. et al., 2010). Pre and post-drain conditions are considered to be the conditions prior to and following installation of the tile drain system.

Results suggest that over the long-term, there is minimal impact from tile drainage use to interflow and deep recharge, with only a 6% decline in volumes over the entire study area. Between catchments, the decline in interflow / baseflow volumes ranges from 5% in catchments A-1 and A-2, to 25% in catchments A-5. Results of the tile drain assessment are tabulated in **Table 4.5.1**.

Table 4.5.1 Impact of Tile Drainage (Long-Term Average Conditions)

Catchment	Total Catchment Area β (ha)	Percentage of Catchment that is Tile Drained β	Average Annual Infiltration at Tile Drained Areas ξ (mm/yr)	Percentage Change in Subsurface Flows Post-Tile Drain ξ	
				Interflow	Deep Recharge
A-1	23	19%	79.6	-5%	-5%
A-2	111	13%	108.8	-5%	-5%
A-3	52	52%	118.9	-15%	-15%
A-4	50	26%	68.9	-7%	-7%
A-4a	170	0%	0.0	0%	0%
A-5	111	27%	51.5	-25%	-25%
A-6	28	0%	23.5	0%	0%
B-1	42	1%	63.5	0%	0%
B-2	45	0%	0.0	0%	0%
C-1	71	35%	62.5	-7%	-7%
D-1	34	0%	0.0	0%	0%
All Catchments	728	23%	577.1	-6%	-6%

Notes:
β - Area calculations based on catchment delineations dated 22-January-2014.
ξ - Recharge calculations based on recharge distribution shown in Figure 4.4.3, and provided for portion of catchment within Study Area only.

Tile drains are thought to reduce the length of time over which subsurface inputs to streams occur. For example, pre-tile drains, interflow and/or baseflow may have contributed subsurface flow to local streams until the summer. Post-tile drains, inputs may end in the spring, just after the drainage season. Therefore, in tile drained areas, streams may dry up during summer drought periods because of a lack of baseflow: before tile drains were installed, streams may have been able to flow longer during drought periods.

4.6 Surface Water – Hydrology

4.6.1 Introduction

The major part of the study area is drained by East Branch of Sixteen Mile Creek and the rest is drained by Silver Creek. The drainage areas associated with the study area are illustrated in **Figure 4.6.1**. Surface water hydrology was simulated using the U.S. Environmental Protection Agency's Storm Water Management Model (SWMM5). Two models were used in this study to simulate flow hydraulics in the watercourses. SWMM5 was used to develop flow targets and the recommended management strategy to mitigate impacts of future development. The U.S. Army Corps of Engineers' Hydrologic Engineering Center - River Analysis System (HEC-RAS) model was used to determine the regulatory floodplain, and is described in **Section 4.7**.

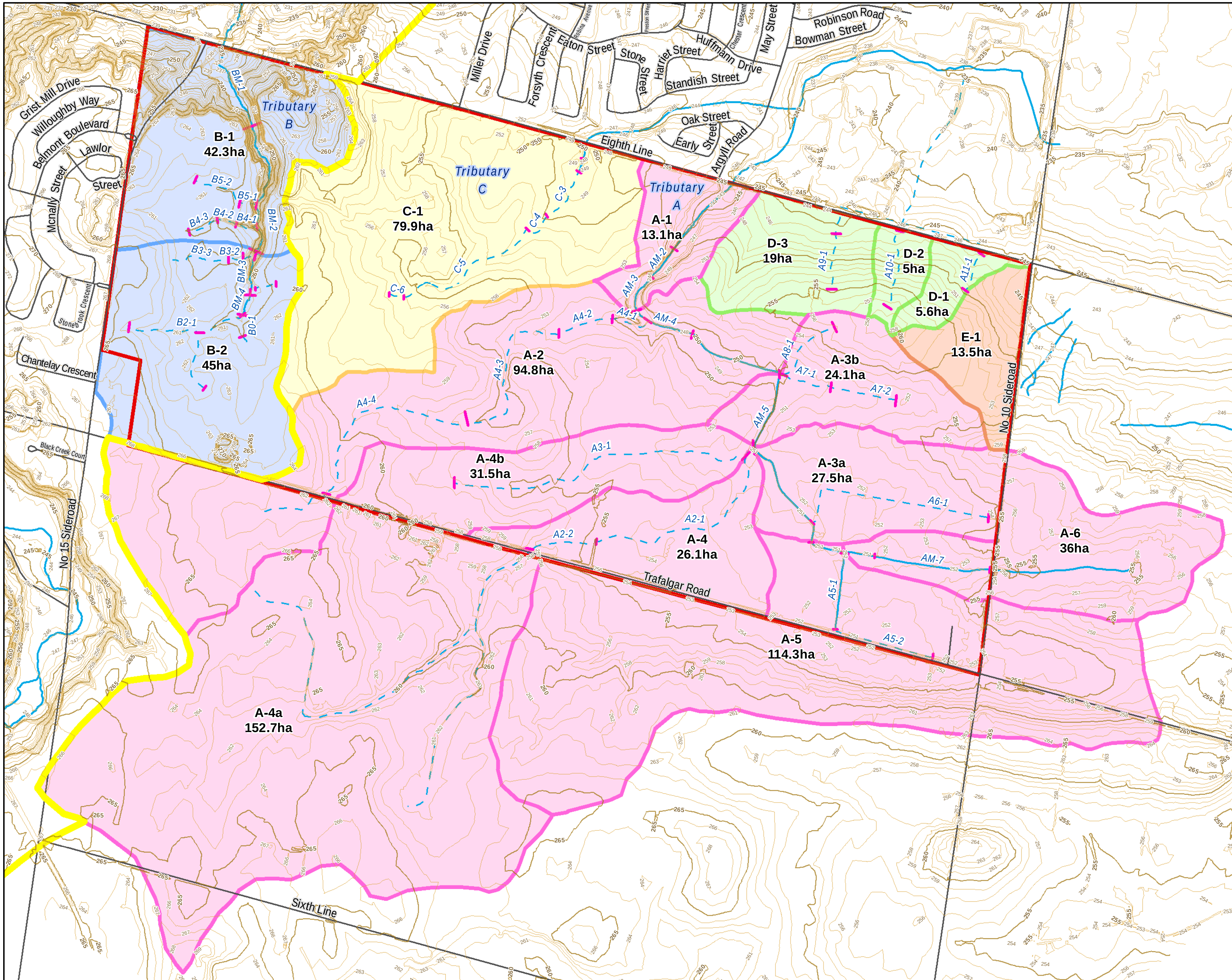
A recent version of SWMM5 (Build 5.1.011, released September 2016) was used to simulate the stormwater runoff response under existing and proposed land use conditions. SWMM5 is public-domain software and available for download, along with detailed documentation, at http://www.epa.gov/nrmrl/wswrd/wq/models/swmm/. Modeling capabilities of SWMM5 that are useful for this assessment include:

- Hydrology: The hydrologic module of SWMM5 is used to simulate the surface runoff and abstraction characteristics of land surfaces (i.e., evapotranspiration, infiltration, and surface storage) in response to meteorological inputs. It is a dynamic computer model that uses a non-linear reservoir approximation to represent overland flow. The hydrology module requires input data that describes the characteristics of local rainfall, overland flow, land use, and soil properties. Results include flow hydrographs for subcatchment areas that are used as input to the hydraulic module of SWMM5.
- Hydraulics: The hydraulic module of SWMM5 is used to simulate the conveyance, attenuation, and routing of stormwater through the watercourse. It is capable of representing the complex hydraulics of open channel watercourses, surface storage, overland flow routes, detention ponds, and control structures such as orifices and weirs. It is a dynamic computer model that accounts for the conservation of mass and momentum using the Saint-Venant equations for gradually varied unsteady flow.

The hydrologic model was developed using lumped parameters in which average representative values were determined for each subcatchment (also referred to as hydrologic unit). The calculation of area-weighted values is described in detail in the following sections for the various hydrologic parameters, which are grouped as follows:

- Surface cover parameters, which describe the imperviousness, roughness, and depression storage characteristics;
- Overland flow parameters, which describe the slope and length characteristics of shallow surface runoff; and
- Soil parameters, which characterize the infiltration properties of the underlying surface soil layers.

The final model revisions have further discretized the catchment areas adjacent to Eighth Line (A-1, D-1, D-2,D-3, and E-1), draining to the East Branch of Sixteen Mile Creek, based on current topographic information and design details from the Fernbrook (Mountainview) Phase 3 development (GHD, 2013). Catchment A-3 has also been further discretized into 2 separate catchments, A3-a and A3-b respectively. Refer to **Figure 4.6.1** for details.



Legend

N

General Features

Identified Reaches

Reach Breaks

Conservation Authority Boundary*

Major Contours

Roads

Study Area

Drainage Catchments

Tributary A

Tributary B

Tributary C

Tributary D

Tributary E

Notes
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

Topographic information provided by the Town of Halton Hills (2011)

0 100 200 400 600 800
Meters

Southwest Georgetown Integrated Planning Project

Drainage Catchments

March 2017	1:12,500	Datum: NAD 83, Zone 17 Source: Chapman and Putnam, 2007. Ontario Geological Survey, MRD 228 Conservation Halton
P#: 60297831	V#: 003	

AECOM

Figure 4.6.1

P:\60297831 SW Georgetown\900-CAD-GIS\920 GIS-Graphics\Design\Final Report

4.6.2 Climate

Environment Canada operates one climate monitoring station in the Town of Georgetown. Monthly precipitation and mean daily temperatures (from 1981-2010) for the Georgetown WWTP gauge are shown in **Table 4.6.1**. The gauge is located near Mountainview Road South and Argyll Road, just north of Georgetown South Centre. The data is representative of precipitation and temperature data expected to occur within the study area.

Table 4.6.1 Climate Data, Georgetown WWTP, 1981-2010

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C	17	15.5	25	31.5	34.5	36	37	36.5	35.5	29.5	22	20.5	37
Average high °C	-1.7	-0.2	4.6	12.1	19.1	24.4	26.9	25.8	21.4	14.3	7.3	1.1	12.9
Daily mean °C	-6.3	-5.2	-0.9	6	12.3	17.4	20	19	14.8	8.4	2.8	-2.9	7.1
Average low °C	-10.9	-10.2	-6.4	-0.2	5.3	10.4	13	12.1	8.1	2.4	-1.7	-6.9	1.3
Record low °C	-33	-31.5	-28	-13	-5	-0.5	3	0	-4	-8.5	-15.5	-29.5	-33
Precipitation mm	67.8	60	57.2	76.5	79.3	74.8	73.5	79.3	86.2	68.3	88.5	65.9	877.4
Rainfall mm	29.7	28.4	35.2	71.3	79	74.8	73.5	79.3	86.2	67.8	79.9	36.4	741.5
Snowfall cm	38.1	31.7	22.1	5.2	0.3	0	0	0	0	0.5	8.6	29.5	135.9

Source: Canadian Climate Normals 1981-2010. Environment Canada. Retrieved January 2015.

Design storm events were determined based on the Town of Halton Hills Intensity-Duration-Frequency (IDF) standards. The Town of Halton Hills IDF rainfall standards were compiled based on average data from the Toronto International Airport, Fergus Shand Dam and Heart Lake weather stations. The IDF curve parameters per return period are summarized in **Table 4.6.2**.

Table 4.6.2 Town of Halton Hills Chicago Rainfall Distribution

Parameter	Return Period					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
A	586.10	946.46	1173.48	1368.91	1622.45	1777.20
B	6.0	7.0	8.0	8.0	9.0	9.0
C	0.760	0.788	0.794	0.789	0.797	0.795

Rainfall Intensity (mm/hr) $\boldsymbol{I = A/(B+t)^C}$,
with time (t) in minutes

Using these parameters, rainfall hyetographs were developed for each return period using a 24-hour Chicago rainfall distribution, with a 5-minute interval. Additional storm distributions were assessed, including the 24-hour SCS Type II and AES distribution respectively. The 24-hour Chicago rainfall distribution was determined to be the critical distribution for the subwatershed providing the largest peak flows, and has been applied for the design storm event analysis. The design storm events include:

- 2-year return period/24-hour duration: 55.8 mm of rain
- 5-year /24-hour: 73.4 mm
- 10-year /24-hour: 87.1 mm
- 25-year /24-hour: 105.4 mm

- 50-year/24-hour: 117.8 mm
- 100-year /24-hour: 130.9 mm

The regional storm event, Hurricane Hazel, was represented by a rainfall depth of 286 mm over a 48-hour period. This event occurred in October 1954 and featured 212 mm of rainfall over a 12-hour period, preceded by 73 mm of rainfall over a period of 36 hours.

In a need to assess and adapt to changing climatic conditions, an upper bound climate change projection was used to assess the recommended SWM strategy (see **Section 6.3.5.2 – Model Results**). The online IDF Climate Change Tool developed by Western University (2014) at http://www.idf-cc-uwo.ca/ was utilized to determine the upper bound 2100 year climate change scenario using historical data from the Toronto International Airport. The upper bound climate change scenario IDF was applied to a 24-hour Chicago rainfall distribution for the 100-year climate change rainfall depth of 157.2 mm over a 24-hour period (approximately 17% increase in total 100-year depth). This possible upper bound climatic change scenario is evaluated to ensure that the recommended SWM strategy will be robust enough to function under a changing climate. It is noted that recent large storm events in Burlington, August 4th 2014, featured 196 mm over a period of 8 hours and Mississauga, July 8th 2013, featured 126 mm over a period of 24 hours respectively. These recent intense thunderstorm activities should be considered as part of the detailed design of the proposed system.

In addition to the design storm events listed above, a continuous simulation was applied using a long-term rainfall record to investigate the subwatershed hydrology in terms of frequency and period of erosive events that can entrain and transport sediment. Refer to **Section 4.6.9** for results of the continuous modeling and methodology applied to develop cumulative erosion indices. Continuous hydrologic simulation uses a long term observed rainfall record that encompasses a range of historical rainfall events as well as the dry weather periods in between. It requires a long-term observed rainfall dataset, ideally with at least a 15-minute resolution, and this was not available at either the Georgetown WWTP or Shand Dam weather stations. Rainfall data with a 5-minute resolution were available from the John Street pump station, however this only covered the period from 2004-2005 and 2007-2013.

Long-term tipping bucket rainfall data were available from the Elora Research Station, operated by the University of Guelph and located approximately 35 km west of the study area. A total of 22 years of tipping bucket data (1-minute resolution) was acquired from the Elora station, representing the period of record from 1989 through 2010. This rain gauge is not operated during the winter months and therefore only data from April through October was used as input for continuous simulation (i.e., snowmelt was not simulated). The average annual rainfall at the Elora gauge was 536 mm (for the period April through October), which is within 1% of the corresponding rainfall amount (532 mm) based on the Georgetown WWTP climate normals that are shown in **Table 4.6.1**.

Evaporation during the intense, short duration design storm events is negligible and is typically ignored. For continuous simulation however, evaporation is a significant hydrologic variable and cannot be ignored. In this study, evaporation data were input into the hydrologic model as a daily abstraction rate for each calendar month in the continuous simulation runs, including the following values during the simulation period:

- April: 1.1 mm/day
- May: 2.0 mm/day
- June: 4.9 mm/day
- July: 5.2 mm/day
- August: 4.9 mm/day
- September: 3.3 mm/day
- October: 2.3 mm/day

These values represent a total potential evaporation of 725 mm over the rainfall year (April through October). The total potential evaporation for all months in the calendar year matches the annual lake evaporation rate of 813 mm for Lake Ontario at Toronto.

4.6.3 Land Use and Existing Services

As discussed in **Section 4.2**, the existing land use is mostly agricultural with some woodlots. Some residential units are located along the roadways such as Trafalgar Road, Eighth Line, Side Road 15 and Side Road 10.

In order to reflect the unique hydrologic properties within each subcatchment, a variety of surface cover types were defined. The surface cover types used in this study are described as follows:

- Forest: Forested with heavy vegetation featuring high transpiration rates and a deep root zone;
- Meadow: Low lying shrubs and vegetation with medium to deep roots;
- Farm: Agricultural area with cultivated fields;
- Grass: Grass/turf, light vegetation or landscaped areas with a shallow root zone;
- Bare: Un-vegetated soil, loose granular materials, or legacy compacted fill;
- Wetland: Roughly half open water and half heavily vegetated;
- Bedrock: Exposed bedrock, accounts for moderate fissures;
- Gravel: Gravel and compacted granular materials in vehicular traffic areas;
- Roof: Building structures with regular rooftop construction (sloped <5:1) and materials;
- Paved: Impermeable paved surfaces (i.e., roadways, parking, driveways) ; and
- Water: Open water surface.

Surface cover types are normally interpreted using aerial photography. Characteristic hydrologic properties are then assigned to each surface cover type as shown in **Table 4.6.3**, which is based on literature values and similar studies throughout North America.

Table 4.6.3 Summary of Hydrologic Properties (by Surface Cover Type)

Surface Cover Type	% Imperv-ious	Subarea Routing	% Routed	% Imperv. Without Storage	Manning's "n"		Dep. Storage (mm)	
					Imperv-ious	Pervious	Imperv-ious	Pervious
Forest	1	Pervious	100	10	0.035	0.400	10.0	20.0
Meadow	2.5	Pervious	85	5	0.030	0.350	7.5	17.5
Farm	2.5	Pervious	75	5	0.030	0.300	6.5	12.5
Grass	2.5	Pervious	75	10	0.025	0.250	5.0	10.0
Bare	5	Pervious	50	15	0.020	0.150	5.0	7.5
Wetland	50	Pervious	50	10	0.015	0.350	0.0	15.0
Bedrock	85	Pervious	50	20	0.020	0.150	5.0	7.5
Gravel	90	Pervious	25	15	0.025	0.200	5.0	7.5
Roof	95	Pervious	10	25	0.015	0.150	2.5	5.0
Paved	95	Pervious	10	20	0.015	0.150	2.5	5.0
Water	100	Pervious	0	0	0.015	0.015	0.0	0.0

For each surface cover type, the following hydrologic parameters are given:

- Percentage of impervious cover, including any land surface that has been compacted or is covered with a layer of material such that it substantially reduces or prevents the infiltration of stormwater runoff into the ground;
- Subarea routing is a SWMM5 simulation parameter that designates the internal routing of runoff between pervious and impervious areas (in this case, “Pervious” was selected to indicate a portion of runoff from impervious areas can be discharged onto pervious areas);
- Percent routed indicates the portion of runoff that is routed between subareas (e.g., 100% indicates that all of the impervious area in the subcatchment is routed onto pervious surfaces);
- The fraction of impervious area that has no depression storage;
- Overland flow roughness factors, expressed as Manning’s “n” value for both impervious and pervious fractions; and
- Initial abstractions (i.e., depression storage losses) for both impervious and pervious fractions.

The hydrologic parameters shown in **Table 4.6.3** are used to characterize land areas that contain a mix of pervious and impervious surfaces (known as "subareas" in SWMM5). The imperviousness of a subcatchment identifies the amount of impervious area, with the remainder representing pervious subareas. In SWMM5, infiltration only occurs over pervious subareas. The subarea routing parameter allows runoff from impervious surfaces to be directed onto pervious surfaces where it can infiltrate (note: the % Routed column in the table indicates the portion of the impervious area that is directed onto pervious subareas). Roughness and depression storage parameters are distinguished according to subarea type, as shown in the last four columns of the table. When the global hydrology parameters shown in **Table 4.6.3** are cross-multiplied with the percent of surface cover type for each hydrologic unit, the resulting area-weighted surface cover parameters are determined and used as input to the SWMM5 model. **Table 4.6.4** summarizes the hydrologic parameters for existing conditions. The existing average imperviousness of all subcatchments in the study area is 5.6 percent; the effective imperviousness (after removing the portion routed to the pervious areas) is less than 2 percent.

Table 4.6.4 Existing Land Use Conditions Hydrologic Parameters

Hydrologic Unit Name	Area (ha)	% Imperv-ious	% Routed	% Imprev. Without Storage	Manning’s “n”		Dep. Storage (mm)		Slope	Width
					Imperv-ious	Pervious	Imperv-ious	Pervious		
A-1	13.1	4.0	78.2	6.0	0.030	0.313	6.9	13.8	4.2%	876
A-2	94.8	3.6	74.7	5.3	0.030	0.299	6.5	12.5	1.7%	3,161
A-3a	27.5	3.0	75.3	5.2	0.030	0.301	6.5	12.6	1.2%	1,100
A-3b	24.1	2.7	75.7	5.0	0.030	0.304	6.6	12.9	1.9%	1,097
A-4	26.1	9.5	71.2	6.5	0.029	0.291	6.2	12.3	1.5%	1,186
A-4a	152.7	5.1	74.6	5.8	0.029	0.300	6.4	12.7	1.0%	5,091
A-4b	31.5	5.9	73.4	6.0	0.029	0.294	6.3	12.3	1.6%	1,529
A-5	114.3	8.8	71.5	6.3	0.029	0.291	6.2	12.2	1.6%	3,811
A-6	36.1	5.2	74.9	5.6	0.029	0.302	6.5	13.1	1.2%	1,256
C-1	79.9	5.3	77.4	6.7	0.030	0.310	6.9	13.5	2.0%	2,664
D-1	5.6	4.2	75.3	6.5	0.029	0.295	6.4	12.4	2.8%	186
D-2	5.0	4.2	75.2	6.3	0.029	0.295	6.4	12.4	3.9%	166
D-3	19.0	5.3	73.2	5.9	0.029	0.292	6.3	12.1	3.7%	632
E-1	13.5	6.1	72.5	5.8	0.029	0.292	6.3	12.1	2.4%	451
B-1	42.3	5.6	82.9	7.3	0.031	0.337	7.7	15.8	7.9%	1,579
B-2	45.0	5.8	73.0	6.4	0.029	0.291	6.3	12.3	2.0%	1,500

4.6.4 Topography

Within the study area, the main watercourses generally run in a north easterly direction. The maximum study area elevation is approximately 267 m and the minimum elevation is approximately 244 m.

Representative overland flow paths were identified for each hydrologic unit using available digital topographic data and aerial photography. The overland flow path length and slope parameters were determined, with the slope taken as the grade difference of the land surface along the overland flow path. Overall, the average catchment slope (i.e., weighted by the area of each hydrologic unit) within the study area is approximately 2.0%. Flow path lengths were divided into the subcatchment area to give a characteristic width of overland flow, which is a SWMM5 input parameter.

To adequately reflect the timing of the hydrographs and provide appropriate runoff rates and attenuation for large catchments at this scale, the overland flow path lengths have been truncated to a maximum of 300 m. In addition to this, to ensure the hydrograph timing and routing are properly represented for large catchments, flow routing elements were also added to large catchments A-3a, A-3b, A-4a, A-4b, A-5, and A-6.

4.6.5 Physiography

Although the physiography of the study area has already been discussed in **Section 4.3**, this section will consider the effect of physiography with respect to surface water hydrology. Hydrology is a direct function of climate, surface cover (land use), and the underlying physiography. **Figure 4.3.2** shows that the majority of the area is within a till plain with low permeability, which impacts the hydrologic response of surface water generated within the study area. Given that the subject lands reflect a largely undeveloped subwatershed, the till plain physiography gives rise to surficial soils with a relatively low hydraulic conductivity and therefore generally higher surface water runoff yields compared to soils in non-till areas.

4.6.6 Soils

Figure 4.3.3 displays the study area soils. Soils in study area include Oneida, Chinguacousy, Font, Grimsby and Jeddo. Both Oneida clay loam soils, Font sandy loam soils and Grimbsy sandy loam soils are well drained. Chinguacousy clay loam soils are imperfectly drained and Jeddo clay loam soils are poorly drained. **Table 4.6.5** shows the United States Soil Conservation Service (SCS) hydrologic soil groups found in the study area. The soils have been classified into four groups from “A” through “D”. Hydrologic Soil Group A generates low runoff volumes while hydrologic Soil Group D generates high runoff volumes.

Table 4.6.5 SCS Hydrologic Soil Groups in Study Area

Soil Type	Hydrologic Soil Group
Oneida clay loam	C
Chinguacousy clay loam	C
Font sandy loam	A
Grimsby sandy loam	A
Jeddo clay loam	C

Source: Soil Map Halton County Ontario Soil Survey Report No. 43.
http://climate.weatheroffice.gc.ca/climate_normals/results_e.html?stnID=4923&prov=&lang=e&dCode=4&dispBack=1&StationName=Georgetown&SearchType=Contains&province=ALL&provBut=&month1=0&month2=12.
Canada Department of Agriculture (1971).

Infiltration parameters used in the SWMM5 model were determined for the Green-Ampt method based on soil texture properties. Characteristic hydrologic properties were assigned to each soil texture as shown in **Table 4.6.6**, which are literature values taken from the Handbook of Hydrology (Maidment et. al., 1993). Infiltration parameters include:

- Capillary tension, a measure of how tightly water is held within the soil pore spaces;
- Saturated hydraulic conductivity, a measure of how quickly the water can be drained vertically; and
- Porosity (or initial soil water deficit), the volumetric fraction of water within the soil pore spaces under initially dry conditions.

Table 4.6.6 Summary of Infiltration Properties (by Soil Texture)

Soil Texture	Capillary Tension		Saturated Hydr. Conductivity			Porosity	
	(in)	(mm)	(in/hr)	(mm/hr)	(cm/s)	wet clim.	dry clim.
Sand	1.95	49.5	9.27	235.6	6.54E-03	0.346	0.404
Loamy Sand	2.41	61.3	2.35	59.8	1.66E-03	0.312	0.382
Sandy Loam	4.33	110.1	0.86	21.8	6.06E-04	0.246	0.358
Loam	3.50	88.9	0.52	13.2	3.67E-04	0.193	0.346
Silt Loam	6.57	166.8	0.27	6.8	1.89E-04	0.171	0.368
Sandy Clay Loam	8.60	218.5	0.12	3.0	8.33E-05	0.143	0.250
Clay Loam	8.22	208.8	0.08	2.0	5.56E-05	0.146	0.267
Silty Clay Loam	10.75	273.0	0.08	2.0	5.56E-05	0.105	0.263
Sandy Clay	9.41	239.0	0.05	1.2	3.33E-05	0.091	0.191
Silty Clay	11.50	292.2	0.04	1.0	2.78E-05	0.092	0.229
Clay	12.45	316.3	0.02	0.6	1.67E-05	0.079	0.203

Soil textures were assigned based on the soil series identified in the base mapping data, as illustrated in **Figure 4.3.3**. Local soils series were mapped to the appropriate texture category and infiltration parameters assigned based on coverage within each subcatchment, and is summarized in **Table 4.6.7**.

Table 4.6.7 Summary of Infiltration Properties (by Subcatchment)

Hydrologic Unit Name	Sandy Loam	Loam	Silt Loam	Clay Loam	Capillary Tension (mm)	Saturated Hydraulic Cond. (mm/hr)	Initial Moisture Deficit
A-2	0%	0%	0%	100%	208.8	2.0	0.15
A-3a	0%	11%	6%	83%	193.2	3.5	0.15
A-3b	0%	0%	0%	100%	208.8	2.0	0.15
A-4	0%	0%	0%	100%	208.8	2.0	0.15
A-4a	0%	0%	0%	100%	208.8	2.0	0.15
A-4b	7%	0%	63%	30%	175.1	6.5	0.17
A-5	0%	0%	0%	100%	208.8	2.0	0.15
A-6	0%	0%	42%	58%	191.3	4.0	0.16
C-1	0%	0%	0%	100%	208.8	2.0	0.15
D-1	34%	0%	0%	66%	175.4	8.7	0.18
D-2	0%	0%	0%	100%	208.8	2.0	0.15
D-3	0%	0%	0%	100%	208.8	2.0	0.15

Hydrologic Unit Name	Sandy Loam	Loam	Silt Loam	Clay Loam	Capillary Tension (mm)	Saturated Hydraulic Cond. (mm/hr)	Initial Moisture Deficit
E-1	0%	0%	0%	100%	208.8	2.0	0.15
B-1	0%	0%	0%	100%	208.8	2.0	0.15
B-2	31%	69%	0%	0%	95.4	15.8	0.21

Overall, the coverage of soil texture (in increasing order of runoff potential) within the study area is:

- Sandy Loam: 7.1%
- Loam: 10.7%
- Silt Loam: 20.5%
- Clay Loam: 61.7%

4.6.7 Flow Monitoring

Information has been collected on flow conditions for Sixteen Mile Creek and Silver Creek. Two monitoring sites were located on Tributary A (Sixteen Mile Creek) and one site on Tributary B (Silver Creek), and were installed May 30, 2013. The first site was located downstream of Side Road 10 and the second site on Tributary A immediately upstream of Eighth Line. Likewise, the monitoring site for Tributary B was also located immediately upstream of Eighth Line. The locations of the flow monitoring site are shown in **Figure 4.10.1**. The water level information was converted to flows through the use of discharge relationship based upon field measurement. **Table 4.6.8** below summarizes the flows collected during field visits. High flow measurements on July 9th were triggered by significant rainfall on July 8th totalling 126 mm and light rain on July 9th totalling 0.6 mm. The significant rainfall on July 31st and August 1st totaling 13.4 mm and 27.4 mm triggered a high flow measurement event. Rainfall depths were recorded from Toronto International Airport weather station.

Table 4.6.8 Creek Flows

Location	Flow (m^3/s)			
	May 30th, 2013 (Installation)	June 21, 2013 (Base flow)	July 9, 2013 (High flow)	August 1, 2013 (High flow)
Sixteen Mile Creek - SWG-A(03)	0.0154	0.0010	0.0461	0.0483
Sixteen Mile Creek - SWG-A(01)	0.0331	0.0021	0.1450	0.0426
Silver Creek - SWG-B(01)	0.0005	0.000001	0.0022	0.001

Another station was installed on Tributary C, immediately upstream of Eighth Line. The station code is C1. Flow monitoring was not possible at this station because it was found to be mostly dry except during wet weather. Station B(01) also had very minimal flow during dry weather. Most flow occurs after a rain event.

A review of the monitoring data collected indicated that significant groundwater contributions were evident in the upper reaches of Tributary A (Gauge A3). The peak observed water levels occurred several days after each rainfall event as well as large seasonal baseflow fluctuations (i.e., high baseflows in spring and low during the summer). Tributary C (Gauge C1) also showed signs of groundwater, but to a much lesser extent than Tributary A. Tributary B (Gauge B1) showed no signs of groundwater contributions in response to rainfall. A total of 31 runoff response events were observed over the period of record (June 2013 through May 2014), including 15 events in summer, 11 events in the fall, and 5 events in the spring.

Due to these observations, the hydrology model was adapted to include groundwater modeling. Aquifer parameters for SWMM5 were developed and adjusted in an attempt to match observed water levels at each monitoring site for all observed events. While a reasonable calibration to observed water levels could be achieved, the resulting groundwater discharge rates were unreasonably high, and could not be supported by available monitoring well data or results from the Halton Hills Tier 3 hydrogeological model.

Possible explanations for the discrepancy between observed water levels and groundwater discharge rates were investigated. However, since the surface water model results conflicted with the hydrogeologic analysis and modelling, it was determined that the calibration was inconclusive. As a result, a regional comparative analysis was used to validate the model as described in **Section 4.6.8**. Additional flow monitoring is recommended to further verify and/or calibrate the model parameters. It is recommend that one year of monitoring be carried out with the data used to validate the hydrology model.

4.6.8 Design Flows

SWMM5 was used to determine controlled and uncontrolled flows. Controlled flows from SWMM5 take into account channel, culvert, and storage routing. Nominal storage volumes were provided upstream of culverts to prevent node flooding. Controlled flows were used to develop flow targets and the recommended management strategy to mitigate impacts of future development. Uncontrolled flows from SWMM5 were determined by removing all culverts and storage components, such that attenuation of flows is only due to stream flow routing. Uncontrolled flows (hazard flows) provided a slightly higher peak flows in comparison to the controlled flows, due to the lack of attenuation at existing culvert crossings, particularly for more frequent events. For the uncontrolled flow modeling, culverts were removed by increasing each crossing link to a 10 m by 3 m box culvert, such that no attenuation occurs behind the culverts.

The hydrologic model was applied to the design storm events listed above under existing conditions. **Table 4.6.9** summarizes the peak surface water runoff flows throughout the study area (individual catchments - controlled flows). These flows supersede flows stated in previous report versions. The area and imperviousness are shown for each subcatchment along with the peak flowrate and volumetric runoff coefficient (i.e., total runoff volume divided by total rainfall volume) for all of the design storm events. The bottom row shows the total study area and the average area-weighted imperviousness and volumetric runoff coefficient for each storm event. Even though the study area is only 5.6% impervious, the high percentage of runoff volume, particularly for the larger rainfall events, is characteristic of poorly drained soils.

The unit-area peak discharge values (controlled flows) are shown in **Table 4.6.10** for each design storm event, the unitary discharge is shown (i.e., the peak computed flowrate divided by the total contributing area) at the terminus point of each subcatchment, at the end of an overland flow routing link of larger catchments, or at the confluence point of reaches served by multiple subcatchments. The overall unit-area peak discharge values for the four main tributaries are highlighted in bold. The rows at the bottom of the table show the range and average unitary discharge for each design storm event. It is noted that for Tributary B catchment (B-1), the 100-year peak discharge is greater than the Regional peak discharge. This is attributed to the catchment characteristics (slope and overflow length) that cause a rapid hydrologic response for high flow events. However, Regional flows are greater downstream of Eighth Line crossing due to the attenuation of Tributary B flows and increase in overall runoff volume, as presented in **Table 4.6.11**.

As noted in **Section 4.6.7**, it was determined that the calibration based on monitoring data was inconclusive. Therefore a regional comparative analysis was used to validate the model by comparing the unit-area discharge values to similar local watersheds. The average unitary discharge for all subcatchments in the study area was 5 and 92 L/s/ha for the 2-year and Regional Storm events, respectively. For comparison, the corresponding values provided by Conservation Halton (for the Boyne secondary plan in Milton) indicated 8 and 86 L/s/ha for these events respectively.

The existing condition flows for Tributary B were also compared to CVC's GAWSER model flows. GAWSER flows were provided by CVC for the 127 ha drainage area that includes Tributary B, and were normalized to unitary discharge values to compare to the Tributary B (87 ha) catchment area. **Table 4.6.12** provides a comparison between the GAWSER flows and Tributary B SWMM5 flows, upstream and downstream of Eighth Line. Attenuated flows (J1) downstream of Eighth Line provide similar unit discharge rates for the 25-100 year storm events. Post development SWMM flows will be compared and evaluated against both GAWSER and SWMM5 flows. For floodplain mapping purposes, SWMM5 uncontrolled (hazard) flows were applied. The unit-area total runoff volumes are shown in **Table 4.6.11**.

Table 4.6.9 Surface Water Runoff Summary for Individual Catchments - Existing Land Use Conditions (Controlled)

			2-yr/24-hr		5-yr/24-hr		10-yr/24-hr		25-yr/24-hr		50-yr/24-hr		100-yr/24-hr		Regional Storm	
Hydrologic Unit	Area (ha)	Imperv-iousnes s	Peak Flow (m^3/s)	Runoff C_V	Peak Flow (m^3/s)	Runoff C_V	Peak Flow (m^3/s)	Runoff C_V	Peak Flow (m^3/s)	Runoff C_V	Peak Flow (m^3/s)	Runoff C_V	Peak Flow (m^3/s)	Runoff C_V	Peak Flow (m^3/s)	Runof f C_V
A-1	13.1	4.0%	0.2	24%	0.6	38%	0.9	45%	1.4	51%	1.8	54%	2.2	58%	1.7	67%
A-2	94.8	3.6%	0.6	10%	1.7	24%	2.8	31%	4.2	37%	5.5	42%	6.8	45%	9.5	53%
A-3a	27.5	3.0%	0.2	21%	0.6	35%	0.9	42%	1.4	49%	1.8	53%	2.2	57%	2.9	65%
A-3b	24.1	2.7%	0.3	22%	0.7	36%	1.0	43%	1.6	50%	2.0	53%	2.5	57%	2.8	66%
A-4	26.1	9.5%	0.3	26%	0.8	40%	1.2	47%	1.8	53%	2.3	56%	2.8	60%	3.0	68%
A-4a	152.7	5.1%	0.5	3%	1.7	11%	2.9	17%	4.5	23%	6.1	27%	7.6	31%	13.1	38%
A-4b	31.5	5.9%	0.4	25%	1.0	38%	1.5	45%	2.2	51%	2.8	55%	3.4	59%	3.7	67%
A-5	114.3	8.8%	0.8	11%	2.3	24%	3.6	31%	5.4	37%	7.0	41%	8.6	45%	11.6	52%
A-6	36.1	5.2%	0.3	20%	0.7	35%	1.1	42%	1.7	49%	2.2	53%	2.7	57%	3.7	66%
B-1	42.3	5.6%	0.1	1%	0.2	2%	0.7	6%	1.3	10%	2.0	14%	2.7	17%	2.6	15%
B-2	45.0	5.8%	0.2	2%	0.4	6%	0.8	10%	1.4	15%	1.9	18%	2.4	22%	3.3	24%
C-1	79.9	5.3%	0.2	2%	0.8	8%	1.5	13%	2.5	19%	3.5	23%	4.4	26%	6.6	32%
D-1	5.6	4.2%	0.1	23%	0.2	37%	0.2	44%	0.4	50%	0.5	54%	0.6	58%	0.6	66%
D-2	5.0	4.2%	0.1	24%	0.2	38%	0.2	45%	0.4	51%	0.5	54%	0.6	58%	0.6	67%
D-3	19.0	5.3%	0.3	25%	0.6	39%	0.9	45%	1.4	52%	1.7	55%	2.1	59%	2.2	67%
E-1	13.5	6.1%	0.2	24%	0.4	38%	0.6	45%	0.9	51%	1.1	55%	1.3	59%	1.5	67%
Total/Average	**730.6**	**5.6%**		**10%**		**21%**		**27%**		**33%**		**37%**		**41%**		**47%**

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Table 4.6.10 Existing Land Use Conditions - Unit-Area Peak Discharge (Controlled)

		2-yr/24-hr		5-yr/24-hr		10-yr/24-hr		25-yr/24-hr		50-yr/24-hr		100-yr/24-hr		Regional Storm	
Contributing Subcatchments	**Area (ha)**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**
all of Tributary A	**520.3**	**2.4**	**5**	**4.9**	**9**	**8.4**	**16**	**13.2**	**25**	**17.2**	**33**	**21.4**	**41**	**46.8**	**90**
A-2,3a,3b,4,4a,4b,5,6	507.2	2.3	5	4.8	9	8.2	16	12.9	25	16.8	33	21.0	41	45.9	91
A-2	94.8	0.5	6	1.2	13	1.8	19	3.2	34	4.6	48	5.8	61	9.4	99
A-3a,3b,4,4a,4b,5,6	412.4	1.9	5	3.9	10	6.6	16	10.2	25	13.3	32	16.4	40	36.8	89
A-4,4a,4b,3a,5,6	388.2	1.7	4	3.7	10	6.2	16	9.5	24	12.4	32	15.3	39	34.8	90
A-3a,5,6	177.9	1.1	6	2.3	13	3.4	19	4.8	27	6.0	33	7.2	40	16.6	93
A-4 & A-4a	178.8	0.3	2	1.3	8	3.1	17	5.3	30	7.4	41	9.4	53	15.6	87
A-4a	152.7	0.4	2	1.3	9	2.7	18	4.5	29	6.0	40	7.6	50	13.0	85
A-5 & A-6	150.4	0.9	6	2.0	13	2.9	19	4.0	27	5.0	34	6.1	41	14.1	94
A-5	114.3	0.7	7	2.2	19	3.5	30	5.2	46	6.9	60	8.5	74	11.3	99
A-6	36.1	0.3	8	0.7	21	1.1	32	1.7	47	2.2	60	2.7	74	3.7	102
all of Tributary B	**87.3**	**0.1**	**1**	**0.6**	**7**	**1.4**	**16**	**2.7**	**31**	**3.9**	**44**	**5.0**	**58**	**5.9**	**68**
B-2	45.0	0.2	4	0.4	9	0.8	18	1.3	30	1.9	42	2.4	53	3.3	73
all of Tributary C	**79.9**	**0.2**	**3**	**0.8**	**10**	**1.5**	**19**	**2.5**	**32**	**3.5**	**43**	**4.4**	**55**	**6.6**	**82**
all of Tributary D	**29.5**	**0.4**	**12**	**0.9**	**31**	**1.4**	**47**	**2.1**	**70**	**2.6**	**89**	**3.2**	**109**	**3.4**	**116**
all of Tributary E	**13.5**	**0.2**	**11**	**0.4**	**28**	**0.6**	**42**	**0.8**	**63**	**1.1**	**80**	**1.3**	**98**	**1.5**	**112**
	Min:		1		7		16		24		32		39		68
	Avg:		**5**		**14**		**23**		**35**		**47**		**58**		**92**
	Max:		12		31		47		70		89		109		116

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Table 4.6.11 Existing Land Use Conditions - Unit-Area Runoff Volume (Controlled)

		2-yr/24-hr		5-yr/24-hr		10-yr/24-hr		25-yr/24-hr		50-yr/24-hr		100-yr/24-hr		Regional Storm	
Contributing Subcatchments	**Area (ha)**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**
all of Tributary A	**520.3**	**34,600**	**66**	**91,100**	**175**	**138,000**	**265**	**202,000**	**388**	**253,000**	**486**	**304,000**	**584**	**780,000**	**1,499**
A-2,3a,3b,4,4a,4b,5,6	507.2	32,900	65	87,500	173	133,000	262	195,000	384	245,000	483	294,000	580	755,000	1,489
A-2	94.8	5,460	58	16,500	174	25,400	268	37,300	393	46,800	494	56,100	592	144,000	1,519
A-3a,3b,4,4a,4b,5,6	412.4	27,700	67	71,400	173	108,000	262	158,000	383	198,000	480	238,000	577	611,000	1,482
A-4,4a,4b,3a,5,6	388.2	24,700	64	65,000	167	99,200	256	146,000	376	183,000	471	220,000	567	566,000	1,458
A-3a,5,6	177.9	14,100	79	36,100	203	53,800	302	77,200	434	95,500	537	114,000	641	288,000	1,619
A-4 & A-4a	178.8	6,290	35	20,000	112	33,100	185	51,500	288	67,000	375	82,400	461	217,000	1,214
A-4a	152.7	2,520	17	12,400	81	22,600	148	37,100	243	49,700	325	62,100	407	166,000	1,087
A-5 & A-6	150.4	11,000	73	29,200	194	43,900	292	63,800	424	79,600	529	95,400	634	237,000	1,576
A-5	114.3	7,350	64	20,300	178	30,900	270	44,900	393	56,100	491	67,200	588	170,000	1,487
A-6	36.1	4,100	114	9,210	255	13,200	366	18,600	516	22,600	627	26,700	741	67,500	1,872
all of Tributary B	**87.3**	**575**	**7**	**2,530**	**29**	**5,930**	**68**	**11,600**	**133**	**17,000**	**195**	**22,400**	**257**	**48,300**	**553**
B-2	45.0	386	9	1,870	42	3,860	86	6,970	155	9,900	220	12,800	285	30,800	685
all of Tributary C	**79.9**	**679**	**8**	**4,540**	**57**	**9,070**	**113**	**15,800**	**198**	**21,800**	**273**	**27,700**	**347**	**74,000**	**926**
all of Tributary D	**29.5**	**4,000**	**135**	**8,270**	**280**	**11,600**	**393**	**15,900**	**538**	**19,200**	**650**	**22,600**	**765**	**56,500**	**1,913**
all of Tributary E	**13.5**	**1,830**	**135**	**3,790**	**280**	**5,300**	**392**	**7,310**	**540**	**8,810**	**651**	**10,400**	**769**	**25,900**	**1,914**
	Min:		7		29		68		133		195		257		553
	Avg:		**62**		**161**		**246**		**362**		**455**		**549**		**1,393**
	Max:		135		280		393		540		651		769		1,914
	Available Rainfall:		**558**		**734**		**871**		**1,054**		**1,178**		**1,309**		**2,860**
	Avg. Runoff Coefficient:		**11%**		**22%**		**28%**		**34%**		**39%**		**42%**		**49%**

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Table 4.6.12 Existing Condition – Comparison to GAWSER Flows

Model	Area (ha)	2-yr/24-hr Peak Flow (m^3/s)	2-yr/24-hr Qunit (L/s/ha)	5-yr/24-hr Peak Flow (m^3/s)	5-yr/24-hr Qunit (L/s/ha)	10-yr/24-hr Peak Flow (m^3/s))	10-yr/24-hr Qunit (L/s/ha)	25-yr/24-hr Peak Flow (m^3/s)	25-yr/24-hr Qunit (L/s/ha)	50-yr/24-hr Peak Flow (m^3/s)	50-yr/24-hr Qunit (L/s/ha)	100-yr/24-hr Peak Flow (m^3/s)	100-yr/24-hr Qunit (L/s/ha)	Regional Storm Peak Flow (m^3/s)	Regional Storm Qunit (L/s/ha)
SWMM5 - all of Tributary B[1]	87.32	0.1	**1**	0.6	**7**	1.4	**16**	2.7	**31**	3.9	**44**	5.0	**58**	5.9	**68**
SWMM5 - all of Tributary B[2]	87.32	0.1	**1**	0.6	**7**	1.4	**16**	2.6	**30**	3.6	**41**	4.0	**46**	4.7	**54**
GAWSER[3]	127.00	1.4	**11**	2.5	**19**	3.5	**27**	4.2	**33**	4.7	**37**	5.4	**43**	9.5	**75**

Filename: SWGeorgetown_PreDevpt_XXyr_75.inp/rpt

1. *Tributary B SWMM5 Flows from Upstream of Eighth Line crossing (CJ5)*
2. *Tributary B SWMM5 Flows from Downstream of Eighth Line crossing (CJ1)*
   Filename: SWGeorgetown_PreDevpt_XXyr_60.inp/rpt
3. *CVC's GAWSER Flows from CVC Peak Flow study (2003)*

The unit-area total runoff volumes are shown in **Table 4.6.11**. For each design storm event, the unitary volume is shown (i.e., the total runoff volume divided by the total contributing area) at the terminus point of each subcatchment, or at the confluence point of reaches served by multiple subcatchments. The overall unit-area runoff volumes for the four main tributaries are highlighted in bold. The rows at the bottom of the table show the range and average unitary volume for each design storm event. The storm event rainfall depth can be expressed in the same unitary volume units (i.e., 2-year event rainfall of 55.8 mm = 588 m^3/ha). When the unit-area rainfall is divided into the corresponding unit-area runoff volume, the volumetric runoff coefficients can be calculated as shown at the bottom of the table. These match the values that were shown at the bottom of **Table 4.6.9**.

The uncontrolled flows for the watersheds are shown for each design storm event in **Table 4.6.13** and are applied in the HEC-RAS model for hazard classification to determine the regulatory floodplain (see **Section 4.7**). For reaches where the 100-year water surface elevation exceeds the Regional storm flow water surface elevation, the 100-year flow is used to delineate the Regulatory floodlines.

Table 4.6.13 Existing Land Use Condition – Hazard Classification Uncontrolled Flows

		Hydraulic Load Point		Peak Flow (m^3/s)							
Contributing Subcatchments	**Area (ha)**	**EPA SWMM**	**HEC-RAS**	**1.5-yr/24-hr**	**2-yr/24-hr**	**5-yr/24-hr**	**10-yr/24-hr**	**25-yr/24-hr**	**50-yr/24-hr**	**100-yr/24-hr**	**Regional Storm**
all of Tributary A	**520.3**	**J477.76**	**689.29**	**2.4**	**2.9**	**7.2**	**10.5**	**15.0**	**19.1**	**23.2**	**46.5**
A-2	94.8	J4441640	4441750.00	0.5	0.6	1.7	2.8	4.2	5.5	6.7	9.4
A-3a,3b,4,4a,4b,5,6	412.4	J1233.42	1233.42	1.8	2.2	5.5	8.1	11.6	14.8	17.8	36.6
A-4,4a,4b,3a,5,6	388.2	AMA2	1429.00	1.7	2.0	5.1	7.5	10.7	13.8	16.6	34.6
A-3a,5,6	177.88	J1764.95	1764.95	0.9	1.1	2.4	3.4	4.8	6.0	7.3	16.7
A-4 & A-4a	178.8	J222652.7	222652.7	0.5	0.7	2.3	3.7	5.6	7.4	9.2	15.6
A-4a	152.7	J223038.1	223199.9	0.3	0.4	1.6	2.8	4.5	6.1	7.6	13.0
A-5 & A-6	150.4	J1887.99	1887.99	0.9	1.1	2.4	3.4	4.8	6.0	7.3	16.7
A-5	114.3	J555272.5	555273	0.6	0.8	2.3	3.6	5.3	7.0	8.6	11.5
A-6	36.1	J2524	2546	0.2	0.3	0.7	1.1	1.7	2.2	2.7	3.7
all of Tributary B	**87.3**	**J5**	**5**	**0.1**	**0.1**	**0.6**	**1.4**	**2.7**	**3.9**	**5.0**	**5.9**
B-2	45.0	J7	7	0.2	0.2	0.4	0.8	1.3	1.9	2.4	3.3
all of Tributary C	**79.9**	**J1200**	**1183.33**	**0.2**	**0.2**	**0.8**	**1.5**	**2.5**	**3.5**	**4.4**	**6.6**

Filename: SWGeorgetown_PreDevpt_Hazard_XXyr_75.inp/rpt

4.6.9 Continuous Simulation and Instream Erosion Indices

SWMM5 was used to conduct the continuous hydrological simulation. The continuous model allows for the comparison of erosion indices under pre-development, uncontrolled future development, and proposed future development (with future SWM controls) conditions, and allows for the confirmation of an appropriate erosion control volume in the proposed SWM strategy. As previously discussed in **Section 4.6.2**, one minute increment continuous rainfall data from the Elora Research Station, representing the period of record from 1989 to 2010, was used for the continuous simulation.

Reaches in the Subwatershed study area have been defined and are presented in **Section 4.8.2.** Erosion thresholds have been established for the most sensitive and limiting reaches based on the CVC's guidelines (CVC, 2010) and are summarized in **Table 4.6.14.** Refer to **Section 5.6.2** for the erosion site selection and detailed threshold analysis.

The threshold analysis determined the critical hydraulic conditions (depths, velocities, discharge, shear stresses) that will theoretically start to entrain and transport bed or bank sediments within the reach. Associated critical discharge values are calculated based on channel geometry and bed / bank substrate.

For this study, the critical condition occurs first for the bed material, thus critical discharges and velocities are based on bed material entrainment. The critical discharge and velocity were subsequently averaged over the 10 cross-sections for each reach. The erosion site locations are shown on **Figure 5.6.2** and correspond to the SWMM5 junctions J477.76 (Tributary A), J1 (Tributary B), and J1100 (Tributary C). For Tributary D, reaches A9-1, A10-1 and A11-1 were not included due to the fact that they have limited channel dimension and therefore do not fit the protocols for the erosion threshold analysis.

For each SWMM5 junction point, an estimate of channel velocity for a given flow is established using the reach-averaged cross-sections parameters summarized in **Table 5.6.4.** For the purpose of the SWMM5 model, the reach-average critical velocity is calculated based on critical discharge and reach-average parameters. Minor differences are shown between the calculated critical velocity and reach-average critical velocity due to cross-section averaging effects.

Table 4.6.14 Erosion Thresholds

	Tributary A Reach AM3	Tributary B Reach BD1	Tributary C Reach C2
Critical Discharge (m3/s)	0.49	0.17	0.01
Critical Velocity (m/s)	0.55	0.48	0.27
Reach-average Critical Velocity (m/s)	0.59	0.59	0.32

Notes

1. *Critical Discharge and Critical Velocity based on average over 10 cross-sections.*
2. *Reach Average Critical Velocity based on Critical Discharge and reach average channel characteristics.*

Stream flow records were extracted from the continuous model at the erosion junction points for the period of record (1989 to 2010). The SWMM 5 flow, duration and estimated velocity at each junction point are used to evaluate the erosion velocity index. Cumulative erosion indices were calculated using the following formula (Ontario Ministry of the Environment, 2003):

$$E_i = \sum(V_t - V_C)\Delta t$$

Where: *Ei* is the erosion index
V_t is the velocity in the channel at time *t*
V_c is the critical velocity threshold
Δt is the time step

The cumulative erosion index is used to evaluate the impact of changes in flow magnitude and duration. **Table 4.6.15** below provides a summary of the erosion index (threshold exceedance x duration) at the junction points under the existing conditions.

Table 4.6.15 Existing Condition Junction Erosion Index from 1989 to 2010

Tributary A Reach AM3 J477.76	Tributary B Reach BD1 J2	Tributary C Reach C2 J1100
47	4	32

These erosion indices are used as targets for proposed development conditions. Increases in high flow frequency, duration, and magnitude could cause the existing reaches to become unstable and lead to morphological adjustment. Post development cumulative erosion indices should match existing conditions, unless more stringent control is required. It is noted that the erosion indices are relatively small for a 20-year simulation period (i.e. erosion thresholds are exceeded rarely and for brief periods), thus potential erosion along these sections is expected to be minor if post development indices are within range.

4.6.10 Hydrologic Issues to be Addressed

As with most subwatershed studies, the key issues to be addressed, as applicable to each watercourse include:
- Peak runoff quantity control;
- Maintenance of base flow rates/water balance;
- Volume of surface runoff;
- Groundwater recharge/discharge;
- Erosion protection; and
- Runoff water quality control.

4.7 Hydraulics

Two models, HEC-RAS and SWMM5, were used to simulate flow hydraulics in the watercourses.

Uncontrolled hazard flows, as described in **Section 4.6.8**, were modeled using HEC-RAS to develop the regulatory floodline and regulation limit. As previously noted, for reaches where the 100-year flow exceeds the Regional storm flow, the 100-year flow is used to delineate the Regulatory floodlines. Channel cross-sections were based on survey cross-sections and elevations from a digital elevation surface, and the model includes a hydraulic representation of all surveyed structures including the Trafalgar Road and Eighth Line crossings.

Tributary A2 includes roadway drainage conveyed by a ditch along Trafalgar Road. Accumulated debris and sediment are periodically removed as part of Halton Region operations. When the ditch was previously cleaned out, the placement of accumulated material temporarily changed the local drainage pattern, which is reflected in the current digital topographic data for the study area. It is anticipated that the original drainage pattern will be restored during the next ditch cleanout. The catchment boundaries shown in **Figure 4.6.1** reflect the original drainage pattern and this has been represented in the existing conditions model to produce the floodlines. A theoretical low flow channel was added for Tributary A2 and is further detailed below in **Section 4.7.1**.

The hydraulic network developed in HEC-RAS was also represented in the SWMM5 model, including all the watercourse reaches, culverts, and overflow channels at all road crossings in the study area. The hydraulic module of SWMM5 was applied to all of the design storm events and a hydraulic gradeline analysis was conducted on the SWMM5 controlled flows to compare the peak computed water surface elevations with road centerline elevations to identify existing road flooding concerns in the study area. Controlled flows from SWMM5 take into account channel, culvert, and storage routing.

4.7.1 Methodology

Survey data was collected throughout the site along the centerlines of the watercourse tributaries and at several cross-sections along the watercourse. The survey points were imported into GIS and shown as spot elevations with relevant data attached.

Digital elevation data sources must be field checked prior to use in a hydraulic model. In the process of setting up the cross-sections and using the survey information, inconsistencies were found between the available topographic mapping and the survey data. As a result, more accurate topographic information was made available for the study area through the land owner consultants, J.F. Sabourin and Associates Inc. (2015). The provided topographic data included 0.25 m interval LiDAR-based contours. A sensitivity analysis was conducted to confirm the accuracy of the provided topographic data with ground survey data. Survey points located within the over bank areas were used for comparison purposes. It was determined that with 95% confidence, the topographic data is within 0.48 m of the survey data and therefore is considered appropriate for use in floodplain mapping. **Table 4.7.1** summarizes the comparison between the ground survey and topographic data.

Table 4.7.1 Survey and Topographic Data Comparison

	Surface Comparison (Survey Elevation[1] – Topographic Data Elevation[2])
Mean Difference (m)	-0.08
Maximum Difference (m)	0.79
Minimum Difference (m)	-1.00
Total Number of Points	833
Points within 5cm	29%
Points within 30 cm	85%
95th Percentile (Absolute Difference) (m)	0.48

Note:

1. *Survey information from June-July 2013, November 2013, and August 2014.*
2. *Topographic data provided from J.F. Sabourin and Associates Inc. (2015).*

The survey cross-sections and topographic data were incorporated into the analysis. The hydraulic model layout was set up in GIS, by sketching stream centerlines and cross-sections where survey data was taken, and additional cross-sections in other locations. The add-on software called HEC-GeoRAS was used to digitize these centerlines and cross-sections using elevations from the digital elevation surface.

The stream centerlines and cross-sections were then exported from GIS and imported into HEC-RAS, where they are shown in the geometry file as geo-referenced. The hydraulic model, initially set up with cross-sections from the digital elevation surface, was then augmented with surveyed cross-sections. Where surveyed cross-sections existed, they were used in place the digital elevation surface cross-section. When the surveyed cross-sections were not long enough, the digital elevation surface was used for the outer edges of the cross-section. For the cross-sections that were located where there was no survey data the digital elevation cross-sections remained in the model. The cross-sections derived from the digital elevation surface did not accurately identify the low flow channel, which was evident in the surveyed cross-sections and surveyed centreline. The low flow channel characteristics evident from the surveyed cross-sections (depth, bank width) were added to the digital elevation surface cross-sections, incorporating surveyed centreline elevation. Manning's roughness values were determined for each tributary section by reviewing site photos and referencing the HEC-RAS reference manual, and input into HEC-RAS.

Nine culverts and road crossings in the study area were input into the model (see **Figure 4.7.1**). The model only includes crossing structures located along the major water course features of the study area. The 0.91 m culvert crossing on reach A5 (CJ555296.5) at Trafalgar Road has been removed from the model, as the model does not accurately represent flow through this culvert; the flow originates from multiple directions at the property line including the ditching on the north side of Trafalgar (east & west), as well as through the 0.91 m culvert (at the end of reach A5). Subcritical flow is calculated for this reach for all events, thus the water surface elevation is calculated from downstream to upstream, and is not affected by removing the structure. Additional crossing structures and un-surveyed culverts are also noted in **Figure 4.7.1.** Surveyed culvert data was used for culvert inverts, lengths, and shapes. Survey data was also obtained for the crossing deck profile, representing the surface that the flow would overtop when culvert capacity is exceeded (**Table 4.7.2**). Ineffective flow areas were added upstream and downstream of crossings if required, and expansion and contraction coefficients were adjusted as needed.

Regional storm and 100-year storm flows for the site were determined from the existing condition SWMM5 hydrology model described in **Section 4.6**. The uncontrolled hazard flows identified in **Table 4.6.13** were input into HEC-RAS. The uncontrolled flows from SWMM5 were determined by removing all culverts and storage components, such that attenuation of flows is only due to stream flow routing. Several cross-sections were not large enough to contain the flow and so some adjustments to the model were made. The cross-sections that could not contain the flow were extended in GIS, usually beyond the extents of the survey data. In some locations the digital elevation survey showed a completely flat section, indicating either the absence of sufficiently detailed topographic detail, or the location of a spill; as a result, some cross-sections weren't able to be extended. The extended cross-section data was input into HEC-RAS. The latest iteration of HEC-RAS shows that most cross-sections contain the Regional and 100-year storm flow. Cross-sections that do not contain the flow include a spill location from Reach A2-1 to A5-1 (222345.5), and the ponded area of reaches AM-6 and A5-1 (2176.63, 2126.95, 2072.56, and 2021.40) An additional spill is noted along reach A2 (223004.5) at the Trafalgar Road culvert crossing (Bridge 2530). Flows that spill onto Trafalgar Road will be conveyed south along existing ditching and spill into reach A2 downstream.

The modeling approach for A2 is based on the historical floodplain provided by reaches A2-1 and A2-2, and is consistent with the direction provided by Conservation Halton. For the purpose of hydraulic modeling and development of the regulatory floodlines, the existing Trafalgar Road ditching is modelled as an ineffective flow area along reach A2-1 and A2-2. Floodlines for reach A2-1 and A2-2 include the existing Trafalgar Road ditch to the confluence with reach A5. A theoretical low flow channel for Tributary A2-2 and A2-1 was established and applied to the model based on a manning's n of 0.035, and sized based on a 1.5 year bankfull channel flow. The general shape of the low flow channel was assigned as 0.3 m deep, 3.5 m bottom width, and a 3:1 side slope.

The HEC-RAS data was exported back to GIS, and the water level was imported as a surface. Floodlines were generated by intersecting the water surface and the ground surface (see **Figure 4.7.2**). The ground surface used is based on the study topographic data provided by JFSA (2015) and supplemental contour data provided by Conservation Halton (2013) for the downstream section of Tributary B. The water surface elevations are interpolated between cross-sections and therefore inundation widths are somewhat subjective. As summarized in

Table 4.6.13, some catchments produce a higher peak flow for the 100-year event than the regional storm event. The regulatory limit was determined by taking the maximum area of inundation of the Regional and 100-year floodline (whichever is greater).

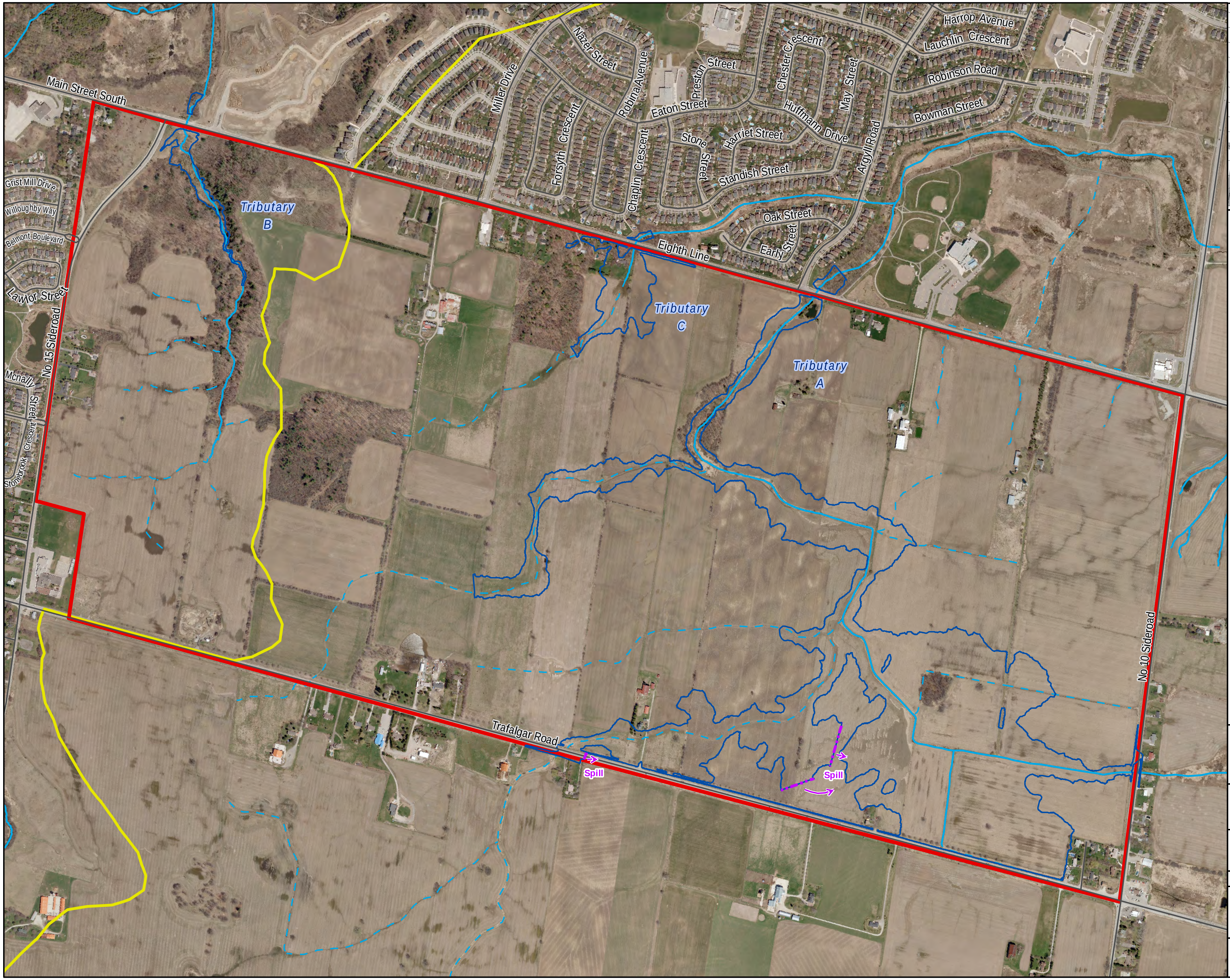
4.7.2 Results

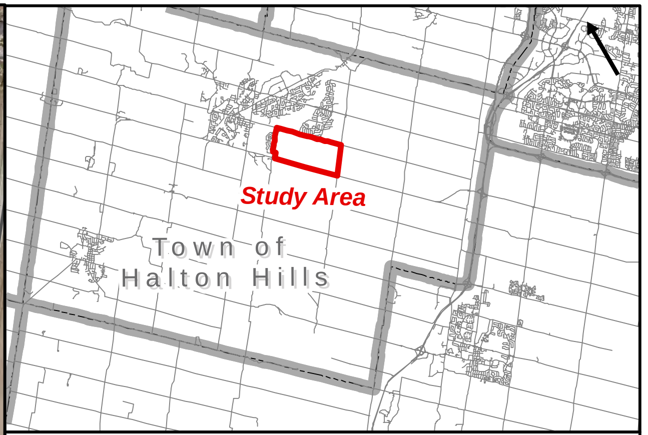
The surface water runoff flows for the Regional and 100-year Storm event shown in **Table 4.6.13** were used as input to the HEC-RAS model as steady state flows. The resulting regulatory floodlines are plotted in **Figure 4.7.2.** The 100-year and Regional storm event floodlines for Tributary A, B, and C are shown on Sheet 1 to 7 respectively in **Appendix Q**. Floodplains have been truncated for watercourses that are not to remain on the landscape as open regulated features, including the upper reaches of A4. Any potential changes to watercourses and associated floodlines will be addressed at Environmental Implementation Report/Functional Servicing Strategy (EIR/FSS) stage.

Study Area
Town of Halton Hills
Legend
N
Existing Surveyed Structures
Existing Unsurveyed Structures
Identified Reaches
Reach Breaks
Roads
Watershed Boundaries
Study Area
Conservation Authority Boundary*
Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction
0 100 200 400 600
Meters
Southwest Georgetown Integrated Planning Project
Existing Road Crossing Structures
March 2017
1:10,000
Datum: NAD 83, Zone 17
Source: LIO, Region of Halton
P#: 60297831
V#: 005
AECOM
Figure 4.7.1
This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.
P:\60297831 SW Georgetown\900-CAD-GIS\920 GIS-Graphics\Design\Final Report
Main Street South
Silver Creek
Eighth Line
Trafalgar Road
No 15 Sideroad
No 10 Sideroad
East Branch Sixteen Mile Creek
Tributary B
Tributary C
Tributary A
Bridge 1.5 CJ32 1.40m Ø
Bridge 950 CJ1000 1.43m × 2.02m
Bridge 180 CJ105.06 twin 2.42m × 3.78m
Bridge 1000 CJ881.13 0.95m × 1.50m
Bridge 150 CJ1534.07 1.40m Ø
Bridge 2530 CJ2230045 0.77m Ø
Bridge 2400 CJ222795.9 0.70m Ø
Structure #10 CJ2509.5 1.18m Ø
Structure #11 CJ555296.5 0.91m Ø
Structure #13 CJ4441640 0.92m Ø
Structure #14
Structure #15
Structure #16 0.45m Ø
Structure #17 0.70m Ø
Structure #18 0.50m Ø
Structure #19 0.46m Ø
Structure #20 0.50m Ø
Structure #21 0.60m Ø
Structure #22

Table 4.7.2 Summary of Existing Road Crossing Structures

Location	Description	Structure Name	Model Junction Names		Model Conduit Names	
			Upstream	Downstream	Culvert(s)	Road Overflow
Tributary A						
Eighth Line	twin 2.42m × 3.78m concrete box culverts	Bridge 180	J105.06	J60.29	CJ105.06	CJ105.06_HC
private road	0.95m × 1.50m concrete box culvert	Bridge 1000	J881.13	J869.45	CJ881.13	CJ881.13_HC
private road	1.40m Ø concrete round culvert	Bridge 150	J1534.07	J1516.26	CJ1534.07	CJ1534.07_HC
10th Side Rd.	1.18m Ø concrete round culvert	Structure #10	J2509.5	J2479.5	CJ2509.5	CJ2509.5_HC
private road	0.70m Ø concrete round culvert	Bridge 2400	J222795.9	J222740	CJ222795.9	CJ222795.9_HC
Trafalgar Rd.	0.77m Ø PVC round culvert	Bridge 2530	J223004.5	J222968.0	CJ223004.5	CJ223004.5_HC
Trafalgar Rd.	0.92m Ø corrugated steel round culvert	Structure #13	J4441640	J4441588	CJ4441640	CJ4441640_HC
Trafalgar Rd.	N/A	Structure #14	-	-	-	-
Trafalgar Rd.	N/A	Structure #15	-	-	-	-
Trafalgar Rd.	0.91m Ø corrugated steel round culvert	Structure #11	-	-	-	-
10th Side Rd.	0.45 Ø round culvert	Structure # 16	-	-	-	-
10th Side Rd.	0.70 Ø round culvert	Structure #17	-	-	-	-
Tributary B						
Eighth Line	1.40m Ø corrugated steel round culvert	Bridge 1.5	J2	J1	CJ2	CJ2_HC
Tributary C						
Eighth Line	1.43m × 2.02m corrugated steel box culvert	Bridge 950	J1000	J900	CJ1000	CJ1000_HC
Tributary D						
Eighth Line	0.50 Ø round culvert	Structure #18	-	-	-	-
Eighth Line	0.46 Ø round culvert	Structure#19	-	-	-	-
Eighth Line	0.50 Ø round culvert	Structure#20	-	-	-	-
Eighth Line	0.60 Ø round culvert	Structure#21	-	-	-	-
Tributary E						
10th Side Rd.	N/A	Structure #22	-	-	-	-





Legend

N

General Features

- Identified Reaches
- Roads
- Spill Location
- Regulatory Floodlines
- Study Area
- Conservation Authority Boundary*

Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600
Meters

Southwest Georgetown
Integrated Planning Project

Floodlines

March 2017	1:10,000	Datum: NAD 83, Zone 17 Source: Chapman and Putnam, 2007. Ontario Geological Survey, MRD 228
P#: 60297831	V#: 004	

AECOM

Figure 4.7.2

P:\60297831 SW Georgetown\900-CAD-GIS\920 GIS-Graphics\Design\Final Report

Table 4.7.2 summarizes the existing condition road crossings structures for the study area. For each structure represented in the hydraulic model, the location, description and structure name are given along with the corresponding SWMM5 model junction names (HEC-RAS river stations do not include the “J” prefix) and SWMM5 model conduit names for both the culverts and road overflow channels. Refer to **Figure 4.7.1** for existing crossing locations. Additional un-surveyed culverts are also noted in **Figure 4.7.1.**

The current SWMM 5 model only includes crossing structures located along the routing links of the modeled bulk catchment areas. Detailed hydraulic assessments for each culvert crossing are beyond the scope of this study. Further catchment discretization and hydraulic assessments may be completed as part of future detailed services studies (as part of the Secondary Plan).

Tributary D catchments outlet to multiple existing outlets along Eighth Line, discharging to the constructed bypass pipe through the Fernbrook Phase 3 subdivision, ultimately discharging to the East Branch of Sixteen Mile creek downstream. These culverts have been not been included as part of the routing of the current model; however, catchments have been delineated from a hydrologic perspective to assess existing flows directed to the constructed downstream by-pass pipe. Similarly the unsurveyed culvert (Structure #22) along Side Road 10 has not been included in the current hydraulic analysis. It is also noted that culverts along Side Road 10 (Structure #16 and #17) convey flows from a small portion of Catchment A-6 to existing ditching on the west side of Side Road 10 and are conveyed south to Reach AM-7.These culverts have not been included in current hydraulic assessment, due to the bulk catchment assessment for Catchment A-6.

It is noted that previous report versions included the hydraulic assessment of Structure #11 on Traflagar Road, based on flows from Catchment A-5. This structure has not been evaluated in final model version as flows from Catchment A-5 originate from multiple locations at the property line, including Structure #11 and the ditching on the north side of Trafalgar (east & west).

The SWMM5 model was applied to all of the design storm events and a hydraulic gradeline analysis was conducted to compare the peak computed water surface elevations with road centerline elevations to identify existing road flooding concerns in the study area. **Table 4.7.3** shows the model results including the junction name, location, road overtop and channel bank elevations for controlled flows (including channel, culvert, and storage routing). For each junction, the peak stage is shown along with the depth above the channel bank and road flood depth (if the peak stage exceeds the ground elevation) for each rainfall event. The number of flooding occurrences for each event is shown in the bottom row. It is noted that the hydraulic grade analysis using the SWMM5 hydraulic module is based on calculated hydrographs (i.e. unsteady flows), versus the steady state peak flows used for floodline delineation with the HEC-RAS. Therefore the hydraulic results provided by SWMM5 are inherently more conservative than the steady flow analysis completed in HEC-RAS.

Table 4.7.3 Existing Land Use Conditions - Hydraulic Gradeline Analysis

				2-yr/24-hr			5-yr/24-hr			10-yr/24-hr			25-yr/24-hr			50-yr/24-hr			100-yr/24-hr			Regional Storm		
Junction Name	**Location**	**Road Overtop Elev. (m)**	**Channel Bank Elev. (m)**	**Peak Stage (m)**	**Depth Above Bank**	**Depth Above Road**	**Peak Stage (m)**	**Depth Above Bank**	**Depth Above Road**	**Peak Stage (m)**	**Depth Above Bank**	**Depth Above Road**	**Peak Stage (m)**	**Depth Above Bank**	**Depth Above Road**	**Peak Stage (m)**	**Depth Above Bank**	**Depth Above Road**	**Peak Stage (m)**	**Depth Above Bank**	**Depth Above Road**	**Peak Stage (m)**	**Depth Above Bank**	**Depth Above Road**
Tributary A: Reach AM-1, AM-2, and AM-3																								
J0		n/a	242.0	231.62			231.7			231.8			231.9			231.9			232.0			232.0		
J60.29	d/s end of culverts at Bridge 180	n/a	242.5	242.54	0.0		242.6	0.08		242.6	0.13		242.7	0.2		242.7	0.2		242.8	0.3		242.9	0.4	
J105.06	u/s end of culverts at Bridge 180	244.98	242.8	242.70			242.9	0.12		243.1	0.33		243.4	0.6		243.5	0.8		243.7	0.9		244.9	2.1	
J138.04		n/a	243.0	242.93			243.2	0.15		243.4	0.38		243.6	0.6		243.7	0.7		243.9	0.8		244.9	1.9	
J195.83		n/a	243.5	243.50			243.6	0.12		243.7	0.22		243.8	0.3		243.9	0.4		243.9	0.4		244.9	1.4	
J228.22		n/a	243.7	243.61			243.8	0.10		243.9	0.22		244.0	0.3		244.1	0.4		244.1	0.5		244.9	1.3	
J274.82		n/a	244.1	244.10	0.0		244.3	0.19		244.4	0.32		244.5	0.4		244.6	0.5		244.7	0.6		245.1	1.0	
J299.64		n/a	244.2	244.28	0.1		244.4	0.21		244.6	0.34		244.7	0.5		244.8	0.6		244.8	0.6		245.2	1.0	
J361.59		n/a	244.8	244.58			244.8	0.06		245.0	0.27		245.3	0.6		245.4	0.6		245.5	0.7		245.8	1.0	
J404.79		n/a	244.9	244.91			245.2	0.23		245.4	0.45		245.6	0.7		245.8	0.8		245.9	0.9		246.3	1.3	
J441.39		n/a	245.5	245.18			245.3			245.5	0.04		245.8	0.3		245.9	0.4		246.0	0.5		246.5	1.0	
J477.76		n/a	245.6	245.56			245.7	0.15		245.9	0.33		246.1	0.5		246.2	0.7		246.4	0.8		246.8	1.2	
J525.66		n/a	246.3	245.87			246.1			246.2			246.4	0.2		246.5	0.3		246.6	0.4		247.1	0.9	
J574.87		n/a	246.5	246.23			246.4			246.6	0.06		246.8	0.3		246.9	0.4		247.0	0.5		247.4	0.9	
J626.25		n/a	247.7	246.99			247.1			247.3			247.5			247.6			247.7	0.0		248.1	0.4	
J689.29		n/a	247.4	247.63	0.3		247.8	0.49		248.1	0.70		248.3	0.9		248.4	1.0		248.5	1.2		248.9	1.6	
AMA4		n/a	n/a	247.71			247.9			248.2			248.4			248.5			248.6			249.1		
Tributary A: Reach AM-4																								
J726.16		n/a	248.3	247.83			248.07			248.30	0.1		248.49	0.2		248.60	0.3		248.70	0.4		249.15	0.9	
J741.53		n/a	248.3	247.97			248.19			248.39	0.1		248.56	0.3		248.66	0.4		248.75	0.5		249.19	0.9	
J784.64		n/a	248.5	248.17			248.43			248.59	0.1		248.72	0.2		248.81	0.3		248.89	0.4		249.30	0.8	
J810.50		n/a	248.5	248.37			248.55	0.1		248.68	0.2		248.81	0.3		248.90	0.4		248.98	0.5		249.37	0.9	
J837.80		n/a	248.6	248.51			248.71	0.2		248.83	0.3		248.94	0.4		249.02	0.5		249.10	0.5		249.46	0.9	
J869.45	d/s end of culvert at Bridge 1000	n/a	248.8	248.60			248.78	0.0		248.90	0.2		249.00	0.3		249.08	0.3		249.15	0.4		249.51	0.8	
J881.13	u/s end of culvert at Bridge 1000	248.85	248.8	249.00	0.2	**0.15**	249.25	0.4	**0.40**	249.36	0.6	**0.51**	249.45	0.6	**0.60**	249.52	0.7	**0.67**	249.56	0.8	**0.71**	249.73	0.9	**0.88**
J933.10		n/a	248.8	249.01	0.3		249.25	0.5		249.36	0.6		249.45	0.7		249.52	0.8		249.57	0.8		249.74	1.0	
J961.51		n/a	249.0	249.03	0.1		249.26	0.3		249.37	0.4		249.47	0.5		249.54	0.6		249.59	0.6		249.78	0.8	
J1009.21		n/a	249.4	249.08			249.28			249.39			249.49	0.1		249.56	0.2		249.62	0.2		249.82	0.4	
J1058.64		n/a	249.8	249.24			249.38			249.48			249.57			249.64			249.69			249.92	0.2	
J1097.22		n/a	249.5	249.32			249.46			249.55	0.1		249.64	0.1		249.70	0.2		249.76	0.3		249.99	0.5	
J1146.62		n/a	249.3	249.42	0.1		249.56	0.3		249.66	0.4		249.76	0.5		249.82	0.5		249.88	0.6		250.13	0.9	
J1215.03		n/a	249.8	249.61			249.81	0.1		249.94	0.2		250.05	0.3		250.12	0.4		250.16	0.4		250.37	0.6	
J1233.42		n/a	250.0	249.64			249.86			249.99			250.11	0.1		250.18	0.2		250.22	0.2		250.41	0.4	
J1251.14		n/a	250.0	249.68			249.91			250.06	0.1		250.17	0.2		250.24	0.3		250.28	0.3		250.48	0.5	
J1312.09		n/a	250.3	249.78			250.03			250.22			250.38	0.1		250.48	0.2		250.55	0.3		250.85	0.6	
J1328.03		n/a	250.3	249.84			250.08			250.28	0.0		250.44	0.2		250.54	0.3		250.61	0.4		250.92	0.7	
J1362.31		n/a	250.5	250.09			250.30			250.53	0.1		250.66	0.2		250.74	0.3		250.81	0.3		251.13	0.7	
J1400.64		n/a	250.3	250.23			250.49	0.2		250.63	0.4		250.75	0.5		250.83	0.6		250.90	0.7		251.23	1.0	
J1429		n/a	250.5	250.39			250.61	0.1		250.72	0.2		250.83	0.3		250.91	0.4		250.97	0.5		251.30	0.8	
AMA2		n/a	n/a	250.47			250.67			250.77			250.88			250.96			251.02			251.35		

Tributary A: Reach AM-5																								
J1482.68		n/a	250.7	250.51			250.72	0.1		250.83	0.2		250.94	0.3		251.02	0.4		251.08	0.4		251.41	0.8	
J1516.26	d/s end of culvert at Bridge 150	n/a	251.0	250.61			250.80			250.92			251.05	0.1		251.14	0.2		251.20	0.3		251.51	0.6	
J1534.07	u/s end of culvert at Bridge 150	251.15	250.9	250.91	0.0		251.25	0.4	**0.10**	251.37	0.5	**0.22**	251.44	0.6	**0.29**	251.49	0.6	**0.34**	251.52	0.7	**0.37**	251.68	0.8	**0.53**
J1551.87		n/a	251.0	250.91			251.26	0.3		251.37	0.4		251.44	0.4		251.49	0.5		251.53	0.5		251.69	0.7	
J1608.03		n/a	251.0	250.93			251.26	0.2		251.38	0.3		251.45	0.4		251.49	0.5		251.53	0.5		251.70	0.7	
J1671.38		n/a	251.3	250.94			251.26			251.38	0.1		251.45	0.2		251.50	0.2		251.54	0.3		251.70	0.4	
J1710.16		n/a	251.6	251.02			251.31			251.41			251.48			251.52			251.56			251.73	0.1	
J1764.95		n/a	251.5	251.12			251.41			251.48			251.54	0.0		251.57	0.1		251.61	0.1		251.75	0.3	
J1821.83		n/a	251.3	251.30			251.52	0.2		251.59	0.3		251.64	0.3		251.68	0.4		251.72	0.4		251.84	0.5	
J1860.66		n/a	251.8	251.34			251.57			251.67			251.74			251.79			251.82			251.94	0.1	
J1887.99		n/a	251.6	251.37			251.58			251.67	0.1		251.74	0.1		251.79	0.2		251.83	0.2		251.94	0.3	
AMA5		n/a	n/a	251.42			251.61			251.69			251.75			251.80			251.83			251.95		
Tributary A: Reach AM-6 and AM-7																								
J2021.40		n/a	251.5	251.43			251.62	0.1		251.69	0.2		251.76	0.3		251.80	0.3		251.83	0.3		251.95	0.5	
J2072.56		n/a	251.6	251.44			251.62			251.69	0.1		251.76	0.1		251.80	0.2		251.84	0.2		251.96	0.3	
J2126.95		n/a	251.6	251.54			251.64	0.0		251.70	0.1		251.76	0.2		251.80	0.2		251.84	0.3		251.96	0.4	
J2176.63		n/a	251.7	251.61			251.75	0.1		251.78	0.1		251.81	0.1		251.82	0.1		251.84	0.2		251.96	0.3	
J2244.43		n/a	252.0	251.75			251.80			251.82			251.84			251.85			251.87			251.97		
J2254.97		n/a	252.0	251.81			251.90			251.94			251.99			252.03	0.0		252.15	0.2		252.17	0.2	
J2299.97		n/a	252.2	252.12			252.20			252.24	0.0		252.27	0.1		252.29	0.1		252.31	0.1		252.34	0.1	
J2340.31		n/a	252.4	252.48	0.1		252.54	0.1		252.56	0.2		252.59	0.2		252.61	0.2		252.64	0.2		252.67	0.3	
J2362.75		n/a	252.6	252.63	0.0		252.72	0.1		252.76	0.1		252.80	0.2		252.83	0.2		252.85	0.2		252.89	0.3	
J2401.07		n/a	252.8	252.74			252.86	0.1		252.91	0.2		252.96	0.2		252.99	0.2		253.02	0.3		253.05	0.3	
J2433.86		n/a	253.0	252.91			253.02	0.0		253.06	0.1		253.11	0.1		253.14	0.1		253.17	0.2		253.21	0.2	
J2450.6		n/a	253.0	253.10	0.1		253.16	0.2		253.19	0.2		253.23	0.2		253.26	0.3		253.29	0.3		253.33	0.3	
J2479.5	d/s end of culvert at Structure #10	n/a	253.3	253.21			253.29	0.0		253.34	0.1		253.39	0.1		253.43	0.2		253.46	0.2		253.52	0.3	
J2509.5	u/s end of culvert at Structure #10	254.90	253.6	253.57			253.81	0.2		253.99	0.4		254.26	0.7		254.69	1.1		254.89	1.3		254.98	1.4	**0.08**
J2524		n/a	253.8	253.73			253.83	0.0		254.00	0.2		254.26	0.4		254.69	0.9		254.90	1.1		254.98	1.2	
Tributary A: Reach A2-1 and A2-2																								
J22268.08		n/a	250.8	250.58			250.67			250.78	0.0		250.88	0.1		250.96	0.2		251.03	0.3		251.35	0.6	
J222110.7		n/a	251.3	251.07			251.14			251.20			251.26	0.0		251.30	0.1		251.33	0.1		251.44	0.2	
J222181.0		n/a	251.4	251.25			251.39			251.50	0.1		251.58	0.2		251.64	0.2		251.69	0.3		251.83	0.4	
J222256.8		n/a	251.8	251.71			251.75			251.83	0.1		251.91	0.2		251.97	0.2		252.01	0.3		252.15	0.4	
J222345.5		n/a	252.0	251.83			251.89			251.97			252.06	0.1		252.09	0.1		252.12	0.1		252.23	0.2	
J222411.2		n/a	252.3	252.23			252.29	0.0		252.38	0.1		252.45	0.2		252.49	0.2		252.53	0.3		252.61	0.4	
J222445.0		n/a	252.5	252.41			252.49			252.56	0.1		252.62	0.1		252.67	0.2		252.71	0.2		252.82	0.3	
J222503.2		n/a	252.6	252.55			252.68	0.1		252.79	0.2		252.88	0.3		252.94	0.3		252.99	0.4		253.12	0.5	
J222581.8		n/a	253.0	252.84			252.91			252.97			253.02	0.0		253.05	0.1		253.08	0.1		253.17	0.2	
J222652.7		n/a	253.5	253.30			253.35			253.39			253.42			253.44			253.46			253.50		
J222721.4		n/a	253.8	253.62			253.73			253.81	0.1		253.87	0.1		253.91	0.2		253.94	0.2		254.01	0.3	
J222740	d/s end of culvert at Bridge 2400	n/a	254.0	253.74			253.91			254.02	0.1		254.06	0.1		254.09	0.1		254.12	0.2		254.18	0.2	
J222795.9	u/s end of culvert at Bridge 2400	254.41	254.2	254.25	0.0		254.57	0.3	**0.16**	254.61	0.4	**0.20**	254.65	0.4	**0.24**	254.67	0.4	**0.26**	254.69	0.4	**0.28**	254.74	0.5	**0.33**
J222831.9		n/a	254.3	254.25			254.57	0.2		254.62	0.3		254.65	0.3		254.68	0.3		254.70	0.4		254.76	0.4	
J222880.7		n/a	254.5	254.32			254.57	0.1		254.62	0.1		254.67	0.2		254.70	0.2		254.73	0.2		254.82	0.3	
J222914.5		n/a	254.8	254.74			254.84	0.1		254.93	0.2		255.01	0.3		255.06	0.3		255.10	0.3		255.22	0.5	
J222968.0	d/s end of culvert at Bridge 2530	n/a	255.5	254.84			254.93			255.01			255.08			255.14			255.18			255.31		

J223004.5	u/s end of culvert at Bridge 2530	256.99	256.0	256.16	0.2		257.08	1.1	**0.09**	257.14	1.1	**0.15**	257.18	1.2	**0.19**	257.20	1.2	**0.21**	257.21	1.2	**0.22**	257.27	1.3	**0.28**
J223038.1		n/a	256.0	256.17	0.2		257.08	1.1		257.14	1.1		257.18	1.2		257.20	1.2		257.22	1.2		257.28	1.3	
J223116.5		n/a	256.3	256.21			257.08	0.8		257.15	0.8		257.20	0.9		257.24	0.9		257.27	0.9		257.39	1.1	
J223199.9		n/a	257.0	256.84			257.09	0.1		257.18	0.2		257.25	0.3		257.30	0.3		257.35	0.4		257.51	0.5	
Tributary A: Reach A4-1, A4-2, A4-3, and A4-4																								
J44414.18		n/a	248.3	248.46	0.2		248.51	0.3		248.60	0.3		248.70	0.4		248.79	0.5		248.85	0.6		249.06	0.8	
J44452.82		n/a	248.7	248.71			248.79	0.1		248.88	0.2		248.97	0.3		249.05	0.3		249.11	0.4		249.28	0.6	
J44495.83		n/a	249.4	249.41			249.47	0.0		249.52	0.1		249.58	0.2		249.62	0.2		249.66	0.2		249.75	0.3	
J444130.4		n/a	249.8	249.97	0.1		250.04	0.2		250.11	0.3		250.19	0.3		250.23	0.4		250.27	0.4		250.34	0.5	
J444160.3		n/a	250.1	250.20	0.1		250.23	0.1		250.27	0.2		250.32	0.2		250.36	0.3		250.39	0.3		250.47	0.4	
J444198.8		n/a	250.4	250.37	0.0		250.42	0.1		250.50	0.2		250.59	0.2		250.66	0.3		250.72	0.4		250.82	0.5	
J444266.6		n/a	250.5	250.76	0.2		250.81	0.3		250.84	0.3		250.90	0.4		250.94	0.4		250.97	0.4		251.05	0.5	
J444328.7		n/a	251.2	251.25	0.1		251.27	0.1		251.31	0.1		251.33	0.2		251.34	0.2		251.36	0.2		251.40	0.2	
J444380.8		n/a	251.4	251.54	0.2		251.58	0.2		251.63	0.3		251.66	0.3		251.66	0.3		251.68	0.3		251.74	0.4	
J444460.7		n/a	251.9	252.02	0.1		252.09	0.2		252.21	0.3		252.30	0.4		252.34	0.4		252.37	0.5		252.43	0.5	
J444521.1		n/a	252.3	252.42	0.1		252.45	0.1		252.49	0.2		252.53	0.2		252.56	0.2		252.59	0.3		252.65	0.3	
J444543.8		n/a	252.5	252.63	0.1		252.66	0.1		252.71	0.2		252.76	0.2		252.80	0.3		252.82	0.3		252.89	0.4	
J444594.6		n/a	252.8	253.11	0.3		253.18	0.4		253.27	0.5		253.37	0.6		253.44	0.7		253.49	0.7		253.62	0.8	
J444655.7		n/a	253.4	253.51	0.1		253.56	0.2		253.64	0.3		253.72	0.4		253.77	0.4		253.81	0.4		253.91	0.5	
J444726.7		n/a	253.7	253.75	0.1		253.78	0.1		253.81	0.1		253.86	0.2		253.89	0.2		253.92	0.2		253.99	0.3	
J444793.7		n/a	254.0	254.19	0.2		254.22	0.2		254.26	0.3		254.30	0.3		254.32	0.3		254.34	0.3		254.38	0.4	
J444867.4		n/a	254.5	254.63	0.1		254.66	0.1		254.70	0.2		254.75	0.2		254.78	0.3		254.81	0.3		254.87	0.3	
J444936.3		n/a	255.2	255.33	0.1		255.35	0.1		255.39	0.1		255.43	0.2		255.46	0.2		255.49	0.3		255.53	0.3	
J4441008		n/a	255.6	255.78	0.1		255.81	0.2		255.85	0.2		255.91	0.3		255.95	0.3		255.98	0.3		256.05	0.4	
J4441090		n/a	256.2	256.35	0.1		256.38	0.2		256.46	0.3		256.53	0.3		256.57	0.4		256.60	0.4		256.67	0.5	
J4441201		n/a	257.8	257.81	0.0		257.85	0.1		257.91	0.1		257.97	0.2		258.01	0.2		258.04	0.3		258.10	0.3	
J4441280		n/a	258.2	258.23	0.1		258.27	0.1		258.33	0.2		258.39	0.2		258.43	0.3		258.47	0.3		258.53	0.4	
J4441342		n/a	258.6	258.72	0.1		258.77	0.2		258.84	0.3		258.91	0.3		258.96	0.4		259.00	0.4		259.08	0.5	
J4441419		n/a	259.1	259.26	0.1		259.31	0.2		259.39	0.3		259.48	0.4		259.53	0.4		259.57	0.5		259.67	0.6	
J4441488		n/a	259.7	259.80	0.1		259.83	0.2		259.88	0.2		259.95	0.3		260.00	0.3		260.04	0.4		260.13	0.5	
J4441559		n/a	260.1	260.26	0.2		260.32	0.2		260.41	0.3		260.51	0.4		260.59	0.5		260.64	0.5		260.77	0.7	
J4441588	d/s end of culvert at Structure #13	n/a	260.5	260.63	0.1		260.66	0.1		260.71	0.2		260.76	0.2		260.79	0.3		260.81	0.3		260.87	0.3	
J4441640	u/s end of culvert at Structure #13	262.15	261.3	261.62	0.4		262.13	0.9		262.34	1.1	**0.19**	262.43	1.2	**0.28**	262.47	1.2	**0.32**	262.50	1.3	**0.35**	262.57	1.3	**0.42**
J4441665		n/a	261.5	261.63	0.1		262.13	0.6		262.34	0.8		262.43	0.9		262.47	1.0		262.50	1.0		262.57	1.1	
J4441750		n/a	261.8	261.81	0.0		262.13	0.4		262.35	0.6		262.43	0.7		262.47	0.7		262.51	0.7		262.58	0.8	
Tributary A: Reach A5-1																								
J555272.5		n/a	251.8	251.70			251.77	0.0		251.82	0.1		251.86	0.1		251.90	0.2		251.93	0.2		252.03	0.3	
J555210.0		n/a	251.7	251.65			251.74	0.1		251.78	0.1		251.82	0.2		251.85	0.2		251.88	0.2		252.00	0.3	
J555130.6		n/a	251.5	251.62	0.1		251.72	0.2		251.76	0.3		251.79	0.3		251.82	0.3		251.84	0.3		251.98	0.5	
J55560.97		n/a	251.5	251.47			251.61	0.1		251.69	0.2		251.75	0.2		251.80	0.3		251.83	0.3		251.96	0.5	
Tributary B																								
J0		n/a	233.75	231.62			231.73			231.81			231.89			231.94			231.97			232.00		
J1	d/s end of culvert at Bridge 1.5	n/a	235.50	232.90			232.99			233.05			233.11			233.15			233.16			233.18		
J2	u/s end of culvert at Bridge 1.5	239.05	236.87	234.43			234.67			234.93			235.29			235.77			236.35			237.27	0.4	
J3		n/a	237.84	235.87			235.95			236.00			236.05			236.09			236.35			237.27		
J4		n/a	238.73	238.59			238.63			238.67			238.71			238.74	0.0		238.77	0.0		238.79	0.1	

J5		n/a	241.25	240.73			240.81			240.89			240.97			241.03			241.08			241.11		
J6		n/a	242.83	241.80			241.93			242.00			242.08			242.13			242.18			242.25		
J7		n/a	245.64	244.66			244.71			244.76			244.82			244.86			244.90			244.95		
Tributary C																								
J900	d/s end of culvert at Bridge 950	n/a	248.01	246.95			247.07			247.13			247.18			247.21			247.23			247.29		
J1000	u/s end of culvert at Bridge 950	249.78	248.02	247.08			247.37			247.54			247.74			247.94			248.15	0.1		248.92	0.9	
J1100		n/a	248.32	248.22			248.28			248.31			248.34	0.0		248.36	0.0		248.38	0.1		248.92	0.6	
J1115		n/a	248.83	248.67			248.75			248.79			248.83			248.86	0.0		248.88	0.0		248.95	0.1	
J1150		n/a	249.89	249.60			249.70			249.75			249.80			249.84			249.87			249.93	0.0	
J1200		n/a	251.61	251.42			251.46			251.48			251.51			251.53			251.55			251.58		
			Road Flooding Occurrences:			**1**			**4**			**5**			**5**			**5**			**5**			**6**

Notes:
1. Depth Above Bank indicates the depth (m) that the peak flood stage rises above the approximate channel bank and rounded to the nearest decimal.
2. Depth Above Road indicates the depth (m) that the peak flood stage rises above the road centerline elevation or top of ground at a culvert crossing.
Filename: SWGeorgetown_PreDevpt_XXyr_75.inp/rpt

The hydraulic performance can be indicated by the largest design storm event that does not yield any road flooding. For example, if a road crossing does not flood for a 25-year event but does show flooding for the 50-year event, it is said to provide a 25-year level of service. A road crossing that floods for a 2-year event is said to provide a <2-year level of service. The existing level of service provided at each road crossing is shown in the final column of **Table 4.7.4** according to the SWMM5 results. All three of the internal private roads indicate overtopping for the 2-year design storm event. The culverts along Eighth Line show the best hydraulic performance, with Tributary A, B and C passing the Regional Storm without overtopping.

Table 4.7.4 Summary of Existing Level of Service

Location	Description	Structure Name	Service Level Provided
Tributary A			
Eighth Line	twin 2.42m × 3.78m concrete box culverts	Bridge 180	Regional
private road	0.95m × 1.50m concrete box culvert	Bridge 1000	<2-yr
private road	1.40m Ø concrete round culvert	Bridge 150	2-yr
10th Side Rd.	1.18m Ø concrete round culvert	Structure #10	100-yr
private road	0.70m Ø concrete round culvert	Bridge 2400	2-yr
Trafalgar Rd.	0.77m Ø PVC round culvert	Bridge 2530	2-yr
Trafalgar Rd.	0.92m Ø corrugated steel round culvert	Structure #13	5-yr
Tributary B			
Eighth Line	1.40m Ø corrugated steel round culvert	Bridge 1.5	Regional
Tributary C			
Eighth Line	1.43m × 2.02m corrugated steel box culvert	Bridge 950	Regional

Filename: SWGeorgetown_PreDevpt_XXyr_75.inp/rpt

Table 4.7.5 shows the peak computed flowrates for the various design storm events and compares these to existing culvert capacity. For each culvert, the existing full-flow capacity is shown along with the peak flow and full-flow ratio (percentage of the peak computed flowrate compared to the full-flow capacity). Occurrences that exceed 85 percent of the culvert capacity are highlighted in red.

Table 4.7.5 Existing Land Use Conditions - Flow and Culvert Capacity Analysis

Conduit Name	Structure, Location	Full-Flow Capacity (m^3/s)	2-yr/24-hr Peak Flow (m^3/s)	2-yr/24-hr Q_p/Q_{full}	5-yr/24-hr Peak Flow (m^3/s)	5-yr/24-hr Q_p/Q_{full}	10-yr/24-hr Peak Flow (m^3/s)	10-yr/24-hr Q_p/Q_{full}	25-yr/24-hr Peak Flow (m^3/s)	25-yr/24-hr Q_p/Q_{full}	50-yr/24-hr Peak Flow (m^3/s)	50-yr/24-hr Q_p/Q_{full}	100-yr/24-hr Peak Flow (m^3/s)	100-yr/24-hr Q_p/Q_{full}	Regional Storm Peak Flow (m^3/s)	Regional Storm Q_p/Q_{full}
Tributary A																
CJ105.06	Bridge 180, Eighth Line	66.8	2.4	4%	4.9	7%	8.4	13%	13.2	20%	17.2	26%	21.4	32%	46.2	69%
CJ881.13	Bridge 1000, private road	5.2	1.8	35%	3.9	75%	6.5	126%	10.1	195%	13.2	255%	16.3	315%	36.8	711%
CJ1534.07	Bridge 150, private road	2.5	1.1	43%	2.1	82%	3.1	124%	4.5	179%	5.7	227%	6.9	276%	16.4	656%
CJ2509.5	Structure #10, 10th Side Rd.	2.6	0.3	11%	0.7	28%	1.1	43%	1.7	64%	2.2	81%	2.7	101%	3.7	139%
CJ222795.9	Bridge 2400, private road	0.3	0.3	102%	1.0	336%	2.4	808%	4.2	1408%	5.9	1962%	7.5	2496%	13.0	4338%
CJ223004.5	Bridge 2530, Trafalgar Road	0.4	0.4	83%	1.3	315%	2.7	650%	4.5	1068%	6.0	1440%	7.6	1806%	13.0	3100%
CJ4441640	Structure #13, Trafalgar Road	1.0	0.5	54%	1.2	123%	1.8	181%	3.2	329%	4.6	468%	5.8	593%	9.4	957%
Tributary B																
CJ2	Bridge 1.5, Eighth Line	10.50	0.1	1%	0.6	6%	1.4	14%	2.7	25%	3.8	37%	5.0	48%	5.2	50%
Tributary C																
CJ1000	Bridge 950, Eighth Line	1.39	0.1	9%	0.8	59%	1.5	109%	2.5	181%	3.5	249%	4.4	316%	6.3	451%

Filename: SWGeorgetown_PreDevpt_XXyr_75.inp/rpt

Notes:
1. Culvert full-flow capacity based on Manning's equation.
2. Peak computed flowrates that exceed 85% capacity are highlighted.

4.8 Physical Stream Conditions and Functions – Fluvial Geomorphology

The drainage network within the study area includes predominantly headwater channels from both the Silver Creek and the East Branch of Sixteen Mile Creek subwatersheds. Headwater channels, or “fingertip” tributaries, are the exterior links of the drainage network, meaning that they originate at the source and receive water from no other channels. Interior links are the sequence of channels that bring water from various areas of a watershed to a downstream outlet point.

The origin, form, structure, and development of the drainage network and watercourses on a land surface are primarily due to the interaction between geology and hydrology. Geologic history determines landscape physiography, characteristics of floodplain materials, and hence resistance to erosion. Hydrology determines the magnitude of flows that are conveyed by the watercourse, thereby influencing the size of the watercourse. The effects of hydrology and geology are moderated by vegetative cover, land use, and alterations to the watercourse (i.e., by animal or human actions). Over time, a watercourse develops a channel form that is adjusted to, or in equilibrium with, the modifying and controlling factors of channel form.

Watercourses receive water and sediment from adjacent and upstream watershed areas and convey these downstream through their drainage network. Since any part of the drainage network is part of a spatial continuum, understanding of channel conditions and functions should be based on an assessment completed at a range of spatial scales. The spatial hierarchy that will be used in this study proceeds from Subwatershed → drainage network → branch → reach → site → feature scales (**Figure 4.8.1**). Reaches along each branch of the drainage network were first defined based on a review of aerial photography and mapping and then refined during subsequent field reconnaissance. **Figure 4.8.2** presents the drainage network pattern within the study area and labels all branches.

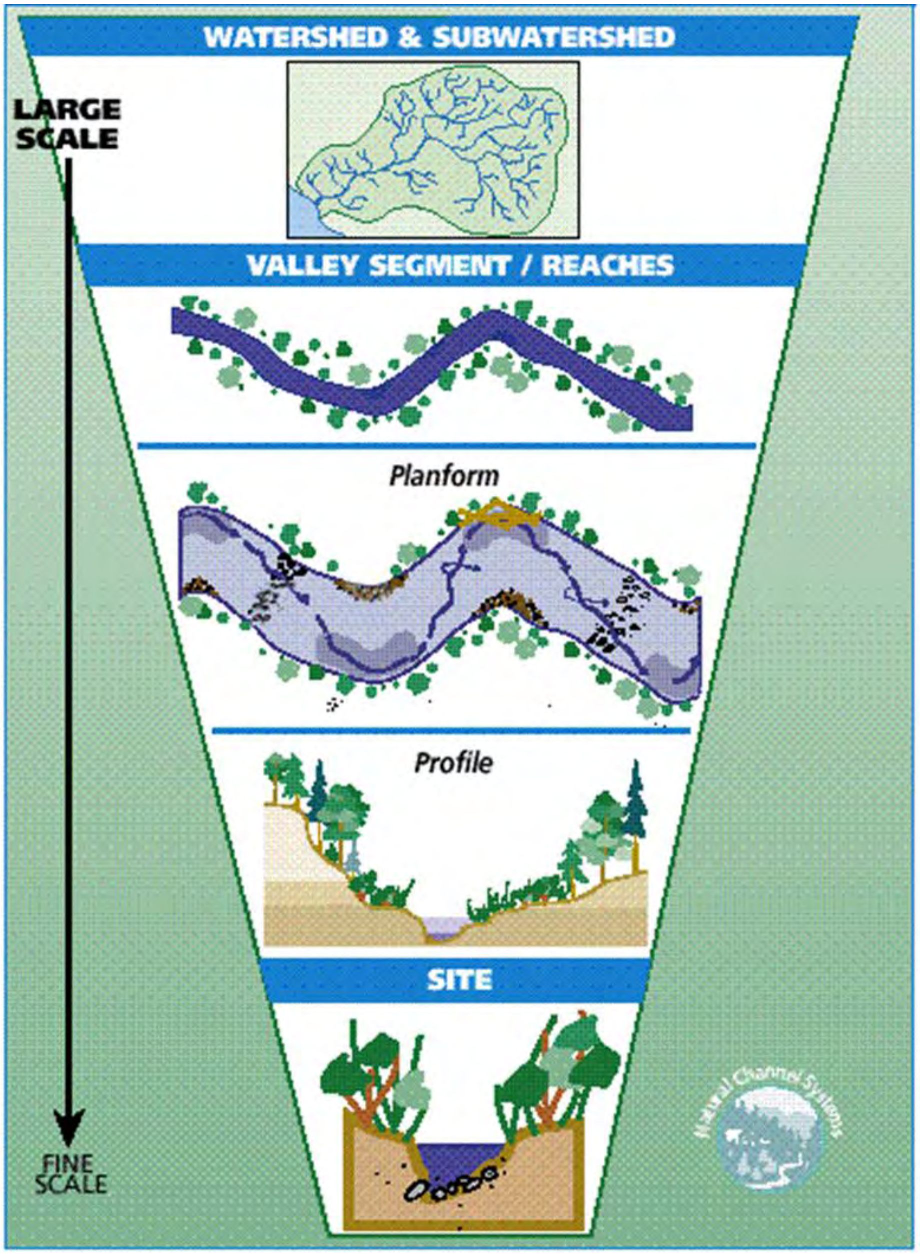
Since watercourses become adjusted to the factors affecting channel form and respond to any change in modifying or controlling influences, a review of temporal changes along the spatial continuum broadens understanding of channel form and functions. This is accomplished both through a background review of documents and review of historical aerial photography and mapping, where available.

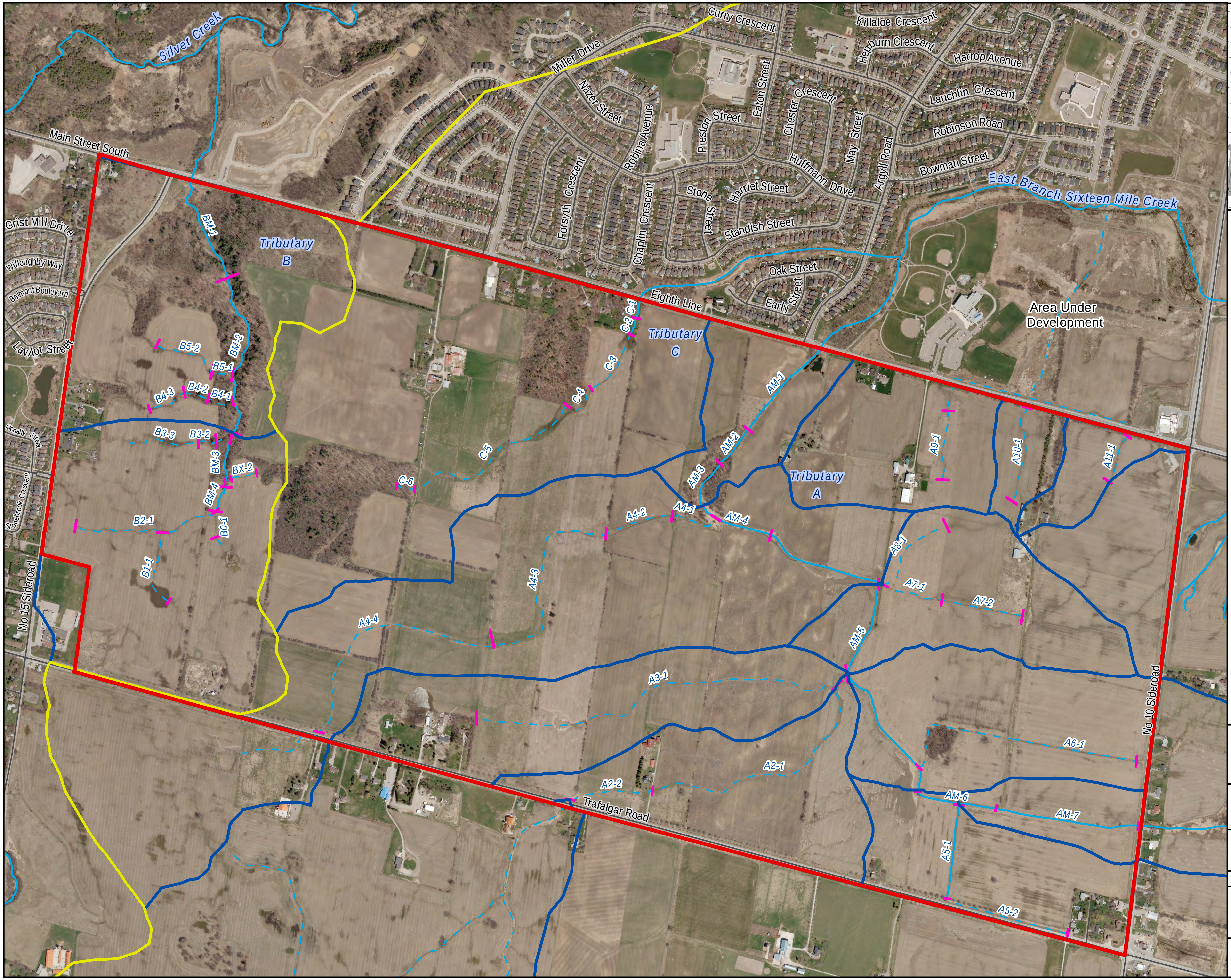
The geomorphic assessment completed in this study included both desktop and field components. Analyses were completed at a range of spatial and temporal scales to gain insight into existing channel conditions and functions. This understanding provides the basis from which an appropriate management plan can be developed that considers the role of study area watercourses within the context of their respective drainage networks.

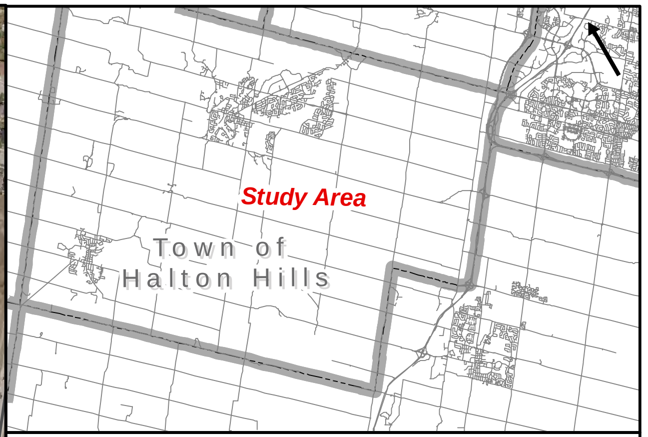
4.8.1 Historical Assessment

Assessment of historical conditions provides insight into the type and extent of changes that have occurred within a study area both with respect to anthropogenic and natural processes. An historic air photo record can also be used to determine the channel’s response to historic changes (i.e., straightening, alteration in land use). Analysis of channel form through the air photo record can document the evolutionary tendencies of watercourses which can be used to anticipate future channel changes. Included in the historical analyses were aerial photographs from: 1965 (scale 1:20,000), 1972 (scale 1:12,000), 1993 (1:8,000), 2004 (digital), and 2007 (digital). Copies of the 1965 and 1972 historical images are in **Appendix E**.

Figure 4.8.1 Spatial Hierarchy of Analyses







Legend

N

- Identified Reaches
- Reach Breaks
- Roads
- Watershed Boundaries
- Study Area
- Conservation Authority Boundary*

Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600
Meters

Southwest Georgetown
Integrated Planning Project

Drainage Network

March 2017	1:10,000	Datum: NAD 83, Zone 17 Source: LIO, Region of Halton
P#: 60297831	V#: 004	

AECOM

Figure 4.8.2

P:\60297831 SW Georgetown\900-CAD-GIS\920 GIS-Graphics\Design\Final Report

4.8.1.1 Land use

Land use and land cover dictates ground surface permeability and infiltration capacity, the availability and relative stability of sediment, and flow regime characteristics. The volumes of surface water runoff and sediment, and the rate of their delivery to the watercourse determines general channel capacity.

Review of the historical aerial photographs revealed very few changes in land use practices during the period of record. By the year 1965, agricultural land use is well-established within and surrounding the study area, and channelization of several watercourses to form agricultural drainage ditches had already occurred along Tributary A. With the exception of residential development in the Tributary B subwatershed (between 1993 and 2004) few other land use/land cover changes were identified through the historical air photo review within the Tributary A, B and C subwatershed areas within, or upstream of, the study area.

Sparse hedgerows separate the agricultural fields. Wooded areas are most abundant in the Tributary B and C subwatersheds and are sparse within the Tributary A subwatershed. The density of the woodlots appears to have increased since 1965.

Low density rural residential development and farms occur along Trafalgar Road, Eighth Line and Side Road 15. Dense urban residential development occurs within the Tributary B subwatershed, but north of Side Road 15. Urban development also occurs east of Eighth Line, downstream of the study area. It is important to note, that the majority of the residential development that has occurred within the watershed has occurred downstream of the study area.

The lack of land use change within the study area and upstream watersheds suggests that the drainage network has generally adjusted to the controlling and modifying influences of channel form.

4.8.1.2 Channel Form

The agricultural land within the study area is drained by numerous small watercourses which, due to the scale of the aerial photographs, could not always be observed, even when viewed stereoscopically. **Table 4.8.1** provides a summary of observations made during review of the historical air photos using the following classifications:

- Visible – channel is well defined and visible (i.e., crisp banks visible)
- Evident by shading – no defined banks observed, diffuse channel pattern
- Poorly or not visible – no evidence of channel on floodplain

Table 4.8.1 Review of Historical Channel Form

Tributary	1965 (1:20,000)	April 1972 (1:12,000)	April 1993 (1:8,000)	2007
A	• Main branch straightened prior to 1965 and tends to follows field boundaries • Visible: main, A5, A6 (connection to main branch visible) • Evident by shading branches: A4, A7, A8, A9. A10, A11 • Poorly or not visible	• Visible: main, A2, A4 A5, • Evident by shading branches: A3, A4 (upstream sections), A6, A7, A8, A9. A10, A11 • Poorly or not visible branches: • Shading of other portions of the study area suggest that additional swales	• Visible: main, A2 (middle portion), A3 (lower), A4 • Evident by shading branches: lower portions of A2, A3 (upper), A4 (upper), A5, A6, A7, A8, A9, A10, A11 • Shading of other	• Visible: main, A4 (lower portion), A5, • Evident by shading branches: A2, A3, A4, A7, A8, A9, A10, A11 • Poorly or not visible branches: A6 (lower portion)

Tributary	1965 (1:20,000)	April 1972 (1:12,000)	April 1993 (1:8,000)	2007
	branches: A2 (upstream portion) , A3, A4 (portions) • shading suggests connection of A6-1 to main branch AM-5 (running on NE side of triangular group of trees • shading suggest swale north of A9, north of farmhouse, orientated East to West	may exist in the study area especially towards Southwest extent of property • Shading suggests swale North of A9, north of farmhouse	portions of the study area suggest that additional swales may exist in the study area especially towards Southwest extent of property, and West of AM-5, AM-4 • Shading suggest swales, both north of A9, north of farmhouse, and another one just south of the next farmhouse to the North • Manmade pond is observed on West side of Farmhouse (Farmhouse in Southeast portion of property) just north of A7-2	
B	Not reviewed	• Visible: Main (upstream of woodlot), B3, B4, BM-2 • Evident by shading: BX (upper), B1, B2, B3, B4, B5 • Poorly or not visible: BX (lower), B0, B1, B4 (upper), BX-2 • B2 evidence by shading, suggests B2 swale extends further North • Main branch obscured by wooded valley • Shading to the north of the valley suggest that additional swales may exist in the study area	• Visible: Main (upstream of woodlot), B1, B2, B4 (upstream of woodlot) • Evident by shading: BX, B3 (upper), B4 (upper) B5 • Poorly or not visible: • Main branch obscured by wooded valley but BM channel is visible where crossing of Eighth Line occurs • B1 shading suggests swale extends further to the West	• Visible: • Evident by shading: • Poorly or not visible:
C	• Poorly visible overall, but sometimes evident by shading	• Tributary is visible for downstream portion and then evident through shading of the floodplain. The network appears to extend north towards the Tributary B valley	• Overall, the tributary is visible, though sometimes only through shading • Pooling upstream of woodlot that flanks Eighth Line	• The unmapped but extended drainage network of Tributary C visible in historic air photos is barely visible in the 2007 air photo

Tributary	1965 (1:20,000)	April 1972 (1:12,000)	April 1993 (1:8,000)	2007
			• The network appears to extend north towards the Tributary B valley	• Shading is evident in 2009 photo

Results of the historical air photo review indicate that a well-defined channel does not occur along each branch or within each reach. Further, shading of the land surface suggests that there may be additional drainage features that were previously not mapped. Review of the air photos indicate that cultivation patterns/practices generally appear to be unaffected by the drainage features. Planting and ploughing occur through the watercourses which is typical for features that are dry for the majority of the planting/ growing season.

4.8.2 Drainage Network and Drainage Basin Morphometry

The position of watercourses along a drainage network provides insight into their general role and functions as part of the larger spatial continuum. Examination of drainage network characteristics involves both planform and profile analyses. Quantitative analyses of drainage network characteristics is referred to as drainage basin morphometry.

The study area is drained by watercourses from two different watersheds; Silver Creek and Sixteen Mile Creek. The drainage divide occurs towards the north end of the property. Although visually evident in review of study area mapping, **Table 4.8.2** reveals that Sixteen Mile Creek Tributary A drains the largest proportion of the study area (i.e., 59%) and that Sixteen Mile Creek Tributary C and Silver Creek Tributary B drain similar areas (i.e., 16 - 17 %).

Table 4.8.2 Drainage Area of Drainage Features

Watercourse	Drainage Area (km^2)		Proportion of Study Area
	Total	In Study Area	
Sixteen Mile Creek Watershed	6.30	4.26	83%
Tributary A	5.20	3.03	59%
Tributary C	0.80	0.80	16%
Tributary D	0.30	0.30	6%
Tributary E	0.14	0.14	3%
Silver Creek Tributary B	1.20	0.87	17%
Total	**7.50**	**5.13**	100%

Drainage Network

The drainage network of any watercourse consists of both external (i.e., beginning of streams, no other channel flows into them) and internal links (i.e., water flows into and out of them). External links are headwater channels and are assigned an order of one (1) within the Horton-Strahler stream order scheme. Ephemeral swales that are connected to the drainage network only during precipitation events are often referred to as zero-order channels. When two first order channels join, then the channel downstream of the confluence is a 2nd order channel. Similarly when two 2nd order channels join, then the resultant channel is a 3rd order. This pattern continues along the entire drainage network.

Stream order classification for the mapped study area watercourses was completed and revealed that 60% of the drainage features are first order channels (**Table 4.8.3**) and 26% are second order channels. This finding confirms that the study is a headwater region of the Silver Creek and Sixteen Mile Creek watersheds. Since no distinction was made as to whether the mapped features were ephemeral, and unmapped features (i.e., those that were shaded on air photos) were not included, it is likely that the actual number of first order channels differs somewhat from what is reported here. Nevertheless, the results are indicative of a headwater classification.

The total length of all drainage features within the study area is quantified by watercourse and subwatershed in **Table 4.8.3** and by branch in **Table 4.8.4**.

Table 4.8.3 Overview of Channel Length and Stream Order

Watercourse	Channel Length in Study Area (km)	Proportion of Study Area Channels (%)	Stream Order Total Channel Lengths (m)		
			Order 1	Order 2	Order 3
Sixteen Mile Creek	8.93	77	5.54	1.58	1.81
Tributary A	7.64	66	4.57	1.58	1.81
Tributary C	0.97	8	0.97		
Other Tributaries	0.61	3	0.34		
Silver Creek Tributary B	2.66	23	1.22	1.44	
Study Area Total	11.59	100	6.78	3.02	1.81
Percent of Total Length			**58%**	**26%**	**16%**

Table 4.8.4 Overview of Branch Characteristics

Branch ID	Branch Length (m)	Drainage Area (km^2)	Max Slope (%)	Average Slope (%)
A2	937.59	1.79	4.15	0.66
A3	1090.94	0.32	11.45	0.82
A4	1563.53	0.76	13.42	0.87
A5	604.83	1.12	15.18	1.81
A6	346.83	0.10	2.96	0.66
A7	398.91	0.16	2.3	0.66
A8	270.51	0.04	5.78	2.41
A9	191.57	0.02	6.47	4.65
A10	280.95	0.03	8.59	4.08
A11	133.33	0.01	4.45	2.89
AM	2398.64	5.20	20.71	1.63
B0	124.68	0.09	4.33	1.52
B1	215.28	0.15	3.43	0.46
B2	419.13	0.23	4.99	1.23
B3	294.74	0.09	25.48	3.52
B4	256.62	0.08	100.32	8.02
B5	236.47	0.08	77.46	6.59
BM	1019.15	0.87	45.89	4.7
BX	94.94	0.02	5.49	2.55
C	965.51	0.80	21.49	1.04

Bifurcation Ratio

Bifurcation ratio is the ratio of the number of streams of one order divided by the total number of streams in the next highest order and is also sometimes referred to as the law of stream numbers. The higher the ratios, the more stream branches there are coming into a watercourse. Characteristics of the drainage network are highly influenced by geology and climate of the subwatershed. Bifurcation ratios reported by Horton (1945) and Strahler (1957) range from 2-4 and are typically around 3. Chorley (1969) suggests that values between 3 and 5 are typical for areas in Southern and Eastern Ontario where glacial deposits (i.e., till) comprise the overburden materials (Chorley, 1969).

Review of data for the current subwatershed indicates high bifurcation ratios for the Silver Creek Tributary (B) and values that are within Chorley's (1996) range for Sixteen Mile Creek Tributary A (**Table 4.8.5**). Higher ratios indicate that there are numerous tributaries that bring water from the subwatershed to the main channel. This would confirm that soils are less permeable. The surface routing of water as indicated through the bifurcations has implications for the hydrograph of the watercourse: watercourses with higher bifurcation ratios, route water more quickly from low order stream segments to higher order receiving channels leading to a relatively rapid response to a precipitation event, and peakiness in the event based hydrograph.

Table 4.8.5 Bifurcation Ratio of Study Area Watercourses

	Stream Order (number of segments)			Bifurcation Ratio		
	1	2	3	1:2	2:3	Average
Sixteen Mile Creek	9	2	1	4.5	2	3.25
Tributary A	8	2	1	4	2	3
Tributary C	1					
Other tributaries						
Silver Creek Tributary B	6	1		6		

Drainage Density

The drainage network that develops on a landscape is determined by precipitation patterns (i.e., how much precipitation falls on the ground) and characteristics of the ground surface that affect how the precipitation is distributed with respect to evaporation, infiltration, or runoff (i.e., geology, soils, vegetation, topography) Knighton (1998). Drainage density is a measure that represents the length of channel available to drain water within a study area and is simply expressed as the ratio of channel length (km) per km^2 of drainage area. In natural watercourses, a low drainage density (i.e., fewer watercourses) typically indicates more infiltration (more permeable materials) and less runoff, resulting in longer lag times and lower peak flows. A higher drainage density indicates a proportionally larger number of watercourses that convey water over a less pervious landscape.

Review of **Table 4.8.6** reveals that the drainage densities for Tributaries A and B are similar and the drainage density is lower for Tributary C. The drainage density of Tributaries A and B are generally larger than those reported elsewhere within the Credit River watershed and Greater Toronto Area but lower than those in the Huttonville Creek and Springbrook watershed which are situated in proximity to Georgetown (**Table 4.8.6**).

Factors that influence the drainage density ratio include:

- Clayey silt to silty soils (i.e., lower permeability),
- Human alterations of drainage patterns (i.e., tile drains, piping, topographic regarding) will alter the drainage density that might naturally exist within any given area.

- Stream order and scale of mapping included in the assessment. The active drainage network (i.e., that which conveys flows) will expand and contract through time, in response to fluctuations and magnitude in precipitation patterns and antecedent soil moisture conditions (Gregory and Walling, 1968). Thus, during precipitation events, ephemeral zero-order channels (i.e., swales etc.), become an active part of the drainage network. When these features are included, the drainage density increases as demonstrated by CVC (2009) where the drainage density increased for headwaters of Subwatershed 19 from 1.34 to 1.63.

Table 4.8.6 Comparison of Study Area Drainage Density with Other Nearby Watersheds

Watershed	Drainage Density (km/km^2)
Sixteen Mile Creek	2.63
Tributary A	3.52
Tributary C	1.21
Other Tributaries	1.42
Silver Creek Tributary B	3.06
Southwest Georgetown Study area	2.72
Data Reported in Other Studies	
Derry Green and Boyne Survey Lands – Average Regional Drainage Density (AMEC, 2013)	2.73
Credit River: Subwatershed 19 (Monora and Mill Creek- headwaters) (CVC, 2009)	1.34
Credit River: Subwatershed 19 (Monora and Mill Creek- headwaters) including all zero order features (CVC, 2009)	1.63
Credit River: Subwatershed 17 (Shaw’s Creek – many headwater channels) (CVC, 2006)	1.84
Credit River: Subwatersehd 16 (Caledon Creek) (CVC, 1997)	1.33
Credit River: Subwatershed 13 (East Credit)	1.92
Credit River: Subwatershed 7 Huttonville Creek (TSH *et al.*., 2004)	4.17
Credit River: Subwatershed 8a Springbrook Creek (TSH *et al.*., 2004)	4.23
Carruther’s Creek (TRCA, 2000a)	2.08
Duffins Creek (TRCA, 2000b)	1.5

Drainage density assessment will be considered in more detail and on a sub-catchment basis, in order to set targets and guide the stream management strategy during the impact assessment stage of the study.

Drainage Network Profile

In natural watercourses, the profile of the channel adjusts to a downstream control point (i.e., lake level or downstream receiving watercourse), resulting in a concave up configuration with steep headwaters, a range of slopes through the middle, and gently slopes towards the outlet. These three zones typically correlate with sediment erosion, transport and depositional zones. While this is the ‘classic model’, if other control points exist (i.e., geologic outcrop, structure), then the profile may repeat the concave profile and corresponding processes. When knickpoints occur in the profile (i.e., either as a control point, or human action) and if it occurs in erodible geologic materials, then it may be expected that headward retreat of the knickpoint will occur through time. Such information is useful when anticipating future channel processes.

Figure 4.8.3 provides the profile of the main branch of each study area tributary. Review of the figure clearly reveals distinct changes in the overall slope of the channel profile, including an apparent knickpoint along Tributary B. **Table**

4.8.7 summarizes the general slope within each major segment along the tributaries. These are considered to be relatively steep, given the general headwater classification of these watercourses. Since slope affects the stream power of flows, it follows that where the slope steepens along the profile, the flow energy (i.e., stream power) also increases and may be accompanied by an increase in erosion. Similarly, where the slope decreases, a decrease in flow energy may suggest depositional processes. General observations regarding the longitudinal profile of each tributary is summarized below, followed by more detailed discussion in **Section 4.8.6**.

Tributary A – a typical concave profile from the origin of the channel to ~ 1000m upstream of the tributary confluence where a knickpoint occurs. The channel has an overall steeper grade for the downstream 1/3 of the profile.

Tributary B – a pronounced knickpoint, or drop, occurs along the upstream third of the profile after which there is a more gradual grade towards the tributary's confluence with Silver Creek. Silver Creek is situated within a valley.

Tributary C – a generally consistent slope along the entire length of the tributary to its confluence with the East Branch of Sixteen Mile Creek. A potential steep channel section towards the downstream end of the tributary (i.e., from upstream of Argyll Rd to the tributary confluence).

Figure 4.8.3 Profile of Main Branch along Each Tributary

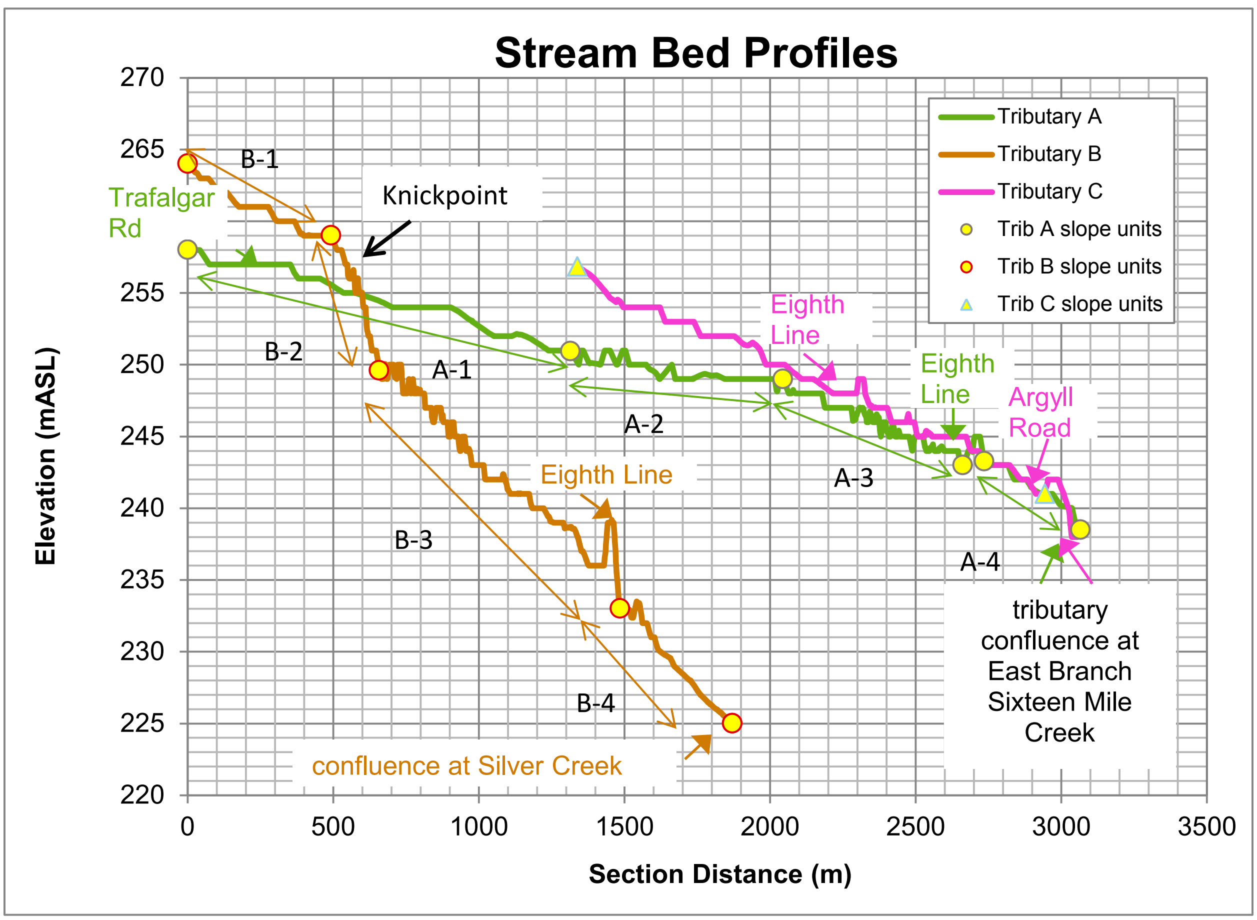


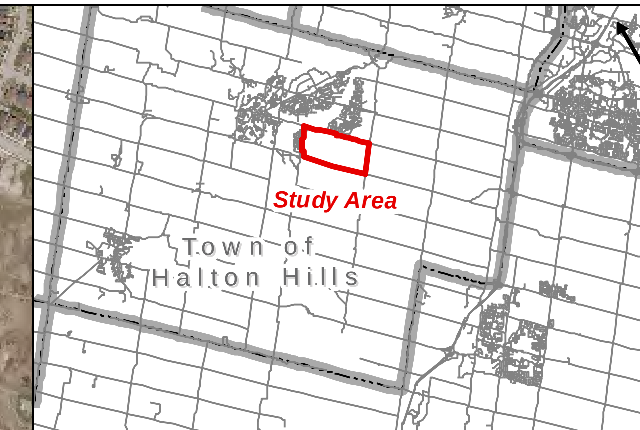
Table 4.8.7 Overview of Slope Units along the Longitudinal Profile of Each Tributary's Main Branch

Tributary	Slope unit	Average slope (%)	Tributary	Slope unit	Average slope (%)
A	1	0.54	B	1	1
	2	0.25		2	5.7
	3	0.85		3	1.87
	4	1.33		4	2.34
C	1	0.91			

4.8.3 Reach Morphology

To facilitate the recording of information, and assessment of channel conditions along each tributary and each branch, reaches were defined. Reaches are lengths of channel that are affected by a relatively homogenous set of controlling and modifying factors such that the morphology and channel processes within the reach are similar. Reach breaks typically occur where there is a change in riparian vegetation, hydrology (addition of a tributary), geology, grade or channel characteristics. Delineation of reach boundaries typically begins with a review of mapping (topographic, geology) and air photo review and is refined during reconnaissance level field investigations. Usually, reaches have a minimum length of a few hundred meters. In this study, given the variability in channel form and headwater characterization, and the need for determining appropriate management strategies for these drainage features, reaches were defined without consideration of their length.

In total, 47 reaches were defined along study area watercourses based on both desktop analyses and field verification. All reaches were assigned a unique identifier reflecting their tributary and branch (see **Figure 4.8.4)**. The upstream drainage area, length and slope of each reach are summarized in **Table 4.8.8** and **Table 4.8.9** to provide a general context for further discussion of channel form and function in **Section 4.8.6**.



Legend

- Identified Reaches
- Reach Breaks
- Roads
- Study Area
- Conservation Authority Boundary*

N

Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600
Meters

Southwest Georgetown Integrated Planning Project

Reach Delineation

June 2016	1:10,000	Datum: NAD 83, Zone 17 Source: LIO, Region of Halton
P#: 60297831	V#: 003	

AECOM

Figure 4.8.4

P:\60297831 SW Georgetown\900-CAD-GIS\920 GIS-Graphics\Design\Final Report

Table 4.8.8 Overview of Reach Properties (from upstream to downstream) along East Branch Sixteen Mile Creek Tributaries

Reach ID	Drainage Area (km^2)	Reach Length (m)	Min. Elevation (m)	Max. Elevation (m)	Max. Slope (%)	Avg. Slope (%)	Stream Order	Surficial Geology
Tributary C								
C-6	0.037	51	256.12	256.84	1.75	1.4	1	Halton Till
C-5	0.252	521	251.54	256.12	6.25	0.89	1	Halton Till
C-4	0.42	104	250	251.54	5.57	1.66	1	Halton Till
C-3	0.523	194	248.17	250	1.91	0.94	1	Halton Till
C-2	0.599	47	248	248.17	2.19	0.36	1	Halton Till
C-1	0.799	49	248	249	21.49	2.09	1	Halton Till
Tributary A								
AM-7	0.360	394	251.85	254	3.81	0.55	1	Halton Till
AM-6	1.504	222	251.06	252	1.86	0.78	2	Halton Till
AM-5	4.253	999	249	252	18.47	1.26	3	Halton Till
AM-4	5.072	209	248	249	18.51	1.48	3	Halton Till
AM-3	5.092	139	246.11	248	12.42	1.47	3	Halton Till
AM-2	5.109	170	245	247.01	20.71	5.88	3	Halton Till
AM-1	5.203	289	243	245.62	19.1	3.02	3	Halton Till
A2-2	1.590	230	255	256.97	4.15	0.86	1	Halton Till
A2-1	1.788	708	251	255	2.51	0.59	1	Halton Till
A3-1	0.315	1091	250	257.2	11.45	0.82	2	Halton Till
A4-4	0.451	691	255.68	261.01	4.07	0.8	1	Halton Till
A4-3	0.612	544	251.94	255.68	8.26	0.69	1	Halton Till
A4-2	0.688	189	250.55	251.94	2.98	0.8	1	Halton Till
A4-1	0.758	139	248	250.55	13.42	2.05	1	Halton Till

Reach ID	Drainage Area (km^2)	Reach Length (m)	Min. Elevation (m)	Max. Elevation (m)	Max. Slope (%)	Avg. Slope (%)	Stream Order	Surficial Geology
A5-2	0.491	343	251	252.72	15.18	3.15	1	Halton Till
A5-1	1.122	262	251.92	252	0.41	0.05	1	Halton Till
A6-1	0.101	347	252	254.28	2.96	0.66	1	Halton Till
A7-2	0.116	223	251	252.39	1.73	0.66	1	Halton Till
A7-1	0.163	176	250.19	251	2.12	0.75	1	Halton Till
A8-1	0.035	271	251.1	256	5.78	2.79	2	Halton Till
A9-1	0.015	192	245.83	254.74	6.47	4.65	1	Halton Till
A10-1	0.027	281	245.98	257.44	8.59	4.08	1	Halton Till
A11-1	0.010	133	245.87	249.73	4.45	2.89	1	Halton Till

Table 4.8.9 Overview of Reach Properties (from upstream to downstream) along the Silver Creek Tributary

Reach ID	Drainage Area (km^2)	Reach Length (m)	Min. Elevation (m)	Max. Elevation (m)	Max. Slope (%)	Avg. Slope (%)	Stream Order	Surficial Geology
Silver Creek								
BM-4	0.328	79	259	259	5	0.58	2	Halton Till
BM-3	0.450	157	250	259	65	8.14	2	Halton Till
BM-2	0.705	474	241	250	45.89	5.60	2	Maple fm
BM-1	0.873	314	236	241	31.96	2.66	2	Halton Till
BX-2	0.019	76	258	260	5.49	2.80	1	Halton Till
BX-1	0.023	19	258	258	3.19	1.56	1	Maple fm
B0-2	0.082	49	260	261	2.49	1.39	1	Halton Till
B0-1	0.094	75	259	260	4.33	1.60	1	Halton Till
B1-1	0.145	215	261	262	3.43	0.46	1	Halton Till
B2-1	0.225	419	259	261	4.98	1.30	2	Halton Till
B3-3	0.056	201	260	261	6.19	0.63	1	Halton Till
B3-2	0.063	50	258	260	9.50	3.13	1	Halton

Reach ID	Drainage Area (km^2)	Reach Length (m)	Min. Elevation (m)	Max. Elevation (m)	Max. Slope (%)	Avg. Slope (%)	Stream Order	Surficial Geology
								Till
B3-1	0.089	43	251	258	25.48	17.24	1	Maple fm
B4-3	0.036	113	259	260	10.49	0.90	1	Halton Till
B4-2	0.071	67	257	259	15.01	6.31	1	Maple fm
B4-1	0.080	77	248	257	100.32	19.43	1	Maple fm
B5-2	0.035	180	259	261	3.63	0.93	1	Halton Till
B5-1	0.076	57	247	259	77.46	23.71	1	Maple fm

4.8.4 Channel Characteristics

Insight into the characteristics, conditions and general functions of each drainage feature within the study area was gained through reconnaissance level field investigations. A photographic inventory of each reach was collected and is presented in **Appendix F**. During the field investigation, it became apparent that the drainage network was characterized by a diversity of channel form, ranging from shallow swales with no defined channel to well-defined watercourses exhibiting bankfull dimensions and well-developed channel morphology.

Characteristics of the headwater drainage features were documented to fulfill requirements outlined in the 2009 TRCA/CVC Headwater Drainage Feature Assessment guideline document. This included measures of channel dimensions, observations of channel form and linkages to the adjacent floodplain and the overall drainage network.

Along well developed watercourses, measures of channel form were collected at intervals along the reach and overall channel stability was assessed using the Rapid Geomorphic Assessment (RGA) tool. Although the RGA is intended for evaluating the stability of watercourses situated within an urban environment and is therefore not strictly applicable to rural and headwater features, the RGA does provide a useful method of assessing four geomorphic processes (aggradation, degradation, widening, planform adjustment) by recording the presence/absence of key indicators. Results of the evaluation are tabulated and compared to a table to assess whether the watercourse is “in regime”, stressed/transitional, or adjusting towards a new channel form.

In addition, the location of tile outlets entering the surveyed reaches was observed in the field during a subsequent site visit on May 2, 2014, which aimed to ground truth available tile drainage information with the assistance of local landowners (see also **Section 4.5.1**). A total of nine outlets were observed, five to the main branch of Tributary A and four within the subcatchment of Tributary C. No tile outlets were observed along Tributary B. It should be noted that only three locations were confirmed as active with the landowner (see **Figure 4.3.4**) and that the observation of an unconfirmed tile outlet can only be used to infer the potential for flow input. The location of the outlets observed in the field is referenced within the reach descriptions below and subsequently summarized in **Section 4.8.4.4**. The potential impact on channel function is discussed in **Section 4.8.6.5**.

4.8.4.1 East Branch Sixteen Mile Creek: Tributary C

Tributary C, with a drainage area of 0.97 km^2 at its outlet into Sixteen Mile Creek, is the shortest tributary in the study area and is a first order channel (**Figure 4.8.4**). Review of recent aerial photography reveals a single branch of channel that begins near, or within, a woodlot that separates Tributaries B and C (**Figure 4.8.4**). Photos demonstrating site conditions are presented in **Appendix F**. A summary of field measures and observations of channel morphology are in **Table 4.8.10** and further detail as required for the CVC/TRCA Headwater Drainage Features Guideline are in **Appendix G**.

During the April and June (2013) site walks, Tributary C appeared to originate from within a woodlot and specifically at the end of a tile drain that discharged into a shallow defined channel. Both woodlots along this tributary (Reach C6 and C4) were characterized by a hummocky topography containing shallow surface depressions filled with standing or slow moving water. The well-defined shallow channels of Tributary C in Reaches C6 and C4 flowed through, or adjacent to, the woodlots. These channels demonstrated a subtle bed morphology and some variability in substrate materials (poorly organized accumulations of pebbles). The channel was considered to be well connected to its floodplain.

When not situated within the woodlot, Tributary C occupied a shallow topographic depression in a “rolling” topography but did not show evidence of a defined channel cross-section or profile. The location of Reach C5 was inferred during the April 2013 field visit by the presence of moist soil near the upstream end based on topography. Reach C3 was inferred by the concentration of exposed gravels along the feature`s path. Neither reaches appeared to disrupt or affect land cultivation (i.e., corn stems were continuous through the feature) and thus are likely intermittent or ephemeral channels. Although the historical air photos revealed a tributary to the east of the woodlot that joined into Reach C5, no such drainage features were identified during the field investigation (**Figure 4.8.4**).

Pooling of water at the downstream end of Reach C3 occurred within the cultivated field, receiving surface water from adjacent agricultural fields and potentially from a tile outlet (see **Figure 4.3.4** for tile outlet location). This pooled water represented a source for the defined channel (Reach C-2) that slightly meandered through the maintained grassy lawn associated with a residential property situated along Eighth Line. Immediately upstream of Eighth Line (Reach C-1) the tributary occupied a topographic low point and defined as a standing pool with poorly defined channel form and was choked with vegetation. Water from the roadside ditches enters Reach C-1 at this location. Downstream of Eighth Line, Tributary C joins Tributary A at the East Branch of Sixteen Mile Creek. The watercourse downstream of Eighth Line consists of multiple, low flow meandering channels within a wide valley floor. The channel boundaries remain poorly defined within this area. The valley floor is composed of unconsolidated fine sediment and vegetation.

Table 4.8.10 Overview of Tributary C Reach characteristics (June 20, 2013)

Reach	Width (m)	Depth (m)	Bank angles (o)	Substrate	Bed Morphology	Observations
C-6	0.96	0.10	$25\text{-}32^0$	Soil and pebbles	Moderate pool-riffle forms	In woodlot
C-5	n/a	n/a	n/a	Silty clay loam soil	Not defined	Not defined, cultivated field
C-4	0.58	0.12	$27\text{-}55^0$	Soil and pebbles	Poorly defined	In or beside woodlot, vegetation in channel affects bed morphology
C-3	n/a	n/a	n/a	Silty clay loam soil	Not defined	Not defined, cultivated field
C-2	0.49	0.06	n/a	Silty clay loam soil	Poorly defined	Maintained lawn
C-1	n/a	n/a	n/a	Silty clay loam soil	Poorly defined	Poorly defined channel in ditch. Standing water,

In summary, channel form appeared to be defined when banks were vegetated (woodlot or lawn) and was poorly or not defined in agricultural fields where the land was cultivated. Review of background information presented in this chapter revealed that the surficial geology is Halton Till, which accounts for the silty clay loam soils observed during the field investigation. The longitudinal profile of Tributary C showed a generally consistent slope of 0.91% (based on a DEM derived profile).

Four tile outlets were located within the subcatchment area of Tributary C (**Figure 4.3.4**), although only one of the outlets directly to reaches within the study area. This outlet is a buried, unconfirmed outlet located at the downstream end of Reach C-3, potentially contributing flow to Reach C-2. Two unconfirmed outlets also enter the opposite side of the woodlot associated with Reach C-4. The fourth outlet is a confirmed outlet that enters the roadside ditch along Eighth Line, with flows subsequently flowing northwards and eventually entering the downstream end of Reach C-1 at the upstream side of the road culvert at the edge of the study area.

4.8.4.2 East Branch Sixteen Mile Creek: Tributary A

Originating in agricultural fields upstream of Trafalgar Road, Tributary A flows through the study area and crosses under Eighth Line before continuing to its confluence with the East Branch of Sixteen Mile Creek (**Figure 4.8.4**). Evident on **Figure 4.8.2**, Tributary A drains both the largest portion of the study area (64%), and has the most extensive drainage network (7.64 km; 66% of study area channel length). Six branches were identified within the Tributary A drainage network (**Figure 4.8.2**). Representative photos of each reach within the Tributary A drainage network are presented in **Appendix F**. A summary of field measures and observations is presented in **Table 4.8.11** and **Table 4.8.12**. A summary of the factors to consider to complete the Headwater Drainage Feature Assessment (CVC/TRCA, 2009) is presented in **Appendix G**.

Main Branch

The main branch of Tributary A is well defined and the channel has been straightened and heavily modified channel along most of its length. Standing water in reaches AM6 and AM7 occupied the entire bottom width of the channel. Vegetation was well established on the channel bed in AM7, but absent in AM6. Upstream of AM7, on the east side of Side Road 10, the tributary presents as a grassed swale that flows adjacent to a residential side yard. A 0.05 – 0.08 m thick layer of loose silt covered the channel bed in Reach AM6. Although no actual outlet was identified, the potential presence of a tile outlet within Reach AM-6 was inferred by the presence of a broken clay pipe along the bank just downstream of the confluence with Reach A5-1. The watercourse at this location has been straightened and channelized. Similar to upstream, the channel banks downstream of the tile outlet are relatively steep with scour identified along both banks. Exposed roots with overhanging vegetation line both banks. The channel bed is composed of fine, unconsolidated sediment, with no bar features and poorly defined bed morphology.

In Reaches AM5 and AM4, the channel retains a straightened heavily modified form (~ 1.3 m deep). Within the channel, a defined sinuous low flow channel with a developing riffle-pool morphology occurs, both of which are indicative of the channel`s attempt to re-establish a natural planform, cross-section and profile configuration. Undercutting and subsequent bank failure processes were observed, resulting in slumped bank materials along the toe of the channel bank. In-stream vegetation (tall grasses) was discontinuous within the channel in both of these reaches and was less visible in spring (April 24, 2013) than in summer (June 21, 2013). Substrate materials consisted of occasional exposed till, soft silt and sandy deposits on the channel bottom (i.e., predominantly pools) that are up to 0.18 m thick; riffles were composed of gravels and small cobbles. During a precipitation event on April 24, 2013, floodplain depression storage was observed and flow from the agricultural fields drained directly into Reach AM5; evidence of surface water conveyance from the fields to the tributary were also evident along Reach AM4. Overall, channel form became increasingly better defined and developed in the downstream direction. While water appeared to be “standing’’ in reach AM5, it was flowing through reach AM4.

Three tile outlet locations were identified within Reach AM-5. Two unconfirmed buried locations in the upper and middle portions of the reach were inferred by the presence of large rock and concrete along the left bank (looking downstream). The potential outlets did not appear to have a strong influence on channel definition. Banks on the right bank were steep with exposed roots and bare in some locations, whereas the left bank was gradual and grass covered. The channel bed is composed of unconsolidated fine material with poorly defined bed morphology. Herbaceous vegetation growing within the channel was also identified. The third, confirmed tile outlet was identified just upstream of the confluence with Reaches A3-1 and A2-1. Downstream of this outlet, and the confluence, the low flow channel begins to meander and becomes narrower and deeper. Unconsolidated fine sediment exists along the channel bed with poorly defined bed morphology. Herbaceous vegetation is also growing along the channel bed and at times, deflects the low flow towards the channel banks. Bank erosion was also identified downstream along both channel banks.

Table 4.8.11 Overview of Tributary A Reach characteristics (June 20 and 21, 2013)

Reach	Width (m)	Depth (m)	Substrate	Bed Morphology	Key Observations
AM-7	3.2 – 4.6	0.1-0.6	Soft silt	Undefined	Straightened ditch, choked with vegetation, some depositional bar (medial, lateral) formation, poor floodplain connection
AM-6	2 – 3.3	0.3-0.5	sand	Poorly developed	Straight ditch, no instream vegetation, standing water, algae in water, soft sediment on channel bottom
AM-5	1.4 – 3.7	0.35 – 0.66	Till, soft sand with some pebbles	Developing pool-riffle forms, medial bars	Defined channel in ditch, discontinuous instream vegetation, sinuous channel developing in ditch, depression storage in floodplain and drainage from fields into channel, accumulation of soft sediment on bed
AM-4	2	0.74	Till, silt, sand, pebbles, cobbles	Moderate pool-riffle development	Defined channel in ditch, sinuous planform development, some instream vegetation, local till exposure on bed, bank erosion, accumulation of soft sediment on bed
AM-3	2.55	0.61	Till, gravels	Well developed pool-riffle	Defined alluvial channel, till exposed on channel bed, knickpoints, active bank undercutting and slumping, meandering planform, well developed bed morphology, terracing in floodplain.
AM-2	5.25-5.85	0.5-0.55	Gravels, cobbles, till	Well developed pool-riffle	Well developed alluvial channel within woodlot, lower grade than AM-3, variability in bed materials, terracing in floodplain, root controlled knickpoints in profile
AM-1	2.18-2.5; local: 4.12	0.5-0.8	Sand and pebbles	Well developed pool-riffle	Well developed bankfull channel in narrow grassy corridor (ditch) with increasing sinuosity in downstream direction

In Reach AM3, the general setting of Tributary A changes to one with a wider riparian zone and vegetative buffer, including development of a woodlot. The channel bed begins to incise into the underlying Halton Till unit. Terracing was observed at different elevations in the floodplain, indicating several periods of downcutting and channel shifting within the valley that has now formed; the channel appeared to be incised. Depression water storage was evident in the floodplain /lowest terrace, with some of the drainage features resembling meander scars (i.e., abandoned as the channel downcut) that drain to the main channel. Along the channel bed profile, two knickpoints were observed (0.12 m and 0.52 m high) contributing to the incised and relatively deep channel form. The bed morphology consists of pool-riffle forms. Substrate consisting of gravels and cobbles occurs at riffles and finer sediment occurs in pools. Banks are relatively high (2 m) and steep; cantilever bank failure was observed where banks were undercut. The planform assumes a meandering pattern. Dominant geomorphic processes observed in this reach include degradation and planform development. Results of the rapid geomorphic assessment suggest that this reach is "in transition" through the dominant process of planform adjustment, degradation and widening.

Discussions with the landowner resulted in the identification of a tile drain outlet that drains adjacent fields into Reach AM-3. The outlet was not identified in the field, but a small channel at the valley toe was identified. Where this channel converges with the main channel, a drop of approximately 0.30m exists between the two beds. Within the main channel, a mid-channel bar has formed upstream and adjacent to the confluence with this small channel. Mid-channel bars typically form where the channel has widened and the flow can no longer transport the sediment. Similar to upstream, both banks of the main channel are relatively steep with exposed roots and undercutting. Fallen and leaning trees are located along the outside of a slight bend in the channel, downstream of the outlet channel.

A noticeable change in the overall channel bed grade occurs at Reach AM2 within the wooded area and connectivity to the floodplain improves in the downstream direction. The channel morphology assumes a meandering riffle-pool planform configuration that shows evidence of active planform development processes (undercut banks, bank slumping). The bed morphology is characterized by well-developed riffle-pool bed morphology, and exhibits diversity in substrate materials (i.e., fine grained pools, cobble-pebble riffles, till exposure). The channel remains entrenched and some terracing was observed within the valley. Connectivity to the floodplain improved in the downstream direction. Vegetated medial bars that may have been remnants of failed bank materials were within the channel. Results of the Rapid Geomorphic Assessment (RGA) suggest that Reach AM2 is transitional with a dominant process of planform adjustment.

As Tributary A emerges from the woodlot, the setting and channel configuration of the watercourse changes. In Reach AM-1 the tributary becomes situated within a narrow grassy corridor that appears to be situated within an old heavily modified channel due to its high banks, straight planform, and terraced appearance. A bankfull channel is defined within the bottom of this feature. The channel width decreases and depth increases in comparison to Reach AM-2. The bed morphology consisted of well-developed pool-riffle forms in which an expected variability in bed materials was observed (pebbles and gravels in riffles and flats, finer sediment in pools). Active bank undercutting and slumping was observed, indicating that the channel is working towards regaining a meandering form. Sinuosity increases in the downstream direction. Drainage from the surrounding agricultural fields enters the main channel through unmapped swales.

Branch A2

Branch A2 originates upstream of Trafalgar Road and enters the study area to a well vegetated floodplain with a drainage feature that is not defined or poorly defined (Reach A2-2). Dense grasses and wildflowers occupy the location where the drainage feature is inferred. The dry (June 21, 2013) feature was situated in silty soil and no evidence of coarser substrate observed. Measurement of channel dimensions was possible locally, where some channel definition was evident.

Reach A2-1 was not defined. The location of the drainage features could however, often be inferred either by differences in surface soil texture, or by grassy vegetation in subtle topographic lows. In other locations, evidence of surface water storage in shallow depressions was inferred but no defined drainage feature could be measured.

Poor channel definition along Branch A2 is a result of the diversion of flows upstream of Trafalgar Road. The watercourse upstream of Trafalgar Road is not in fact connected to Reach A2-2 downstream of Trafalgar Road. It currently connects to Reach A5-1 through the road side ditch along Trafalgar Road. A site visit was undertaken on May 2, 2014 to confirm the nature of this flow diversion in more detail. Upstream of Trafalgar Road, water flows through a grassy swale feature, joining the roadside ditch upstream of Trafalgar Road, before flowing underneath

Trafalgar Road. Once on the downstream side of Trafalgar Road, flow continues within the road side ditch and is not connected downstream to Reach A2-2. In order for it to connect to Reach A2-2 the channel would have to over top its banks, which are 1.0 to 1.5 m high. The ditch located on the downstream side of Trafalgar Road subsequently flows southeast towards Side Road 10. The downstream connection is currently located at Reach A5-1, where it converges with Reach A5-2.

Branch A3

Upstream of Branch A3, no drainage feature was visible in the agricultural field. The feature becomes somewhat defined downstream of a barbed wire fence along the southwest corner of a private residential/farm. Vegetation surrounds and is in, the feature which is situated in silty loam soil, within a planted corn field. Where defined, measurements of the channel were made (width=0.82 m, depth=0.07 m). No channel bed morphology was evident. Along most of its length, the channel is poorly or not defined and thus is a continuous part of the topography and fields. A CSP was observed along this branch, confirming that water does flow along the general orientation of this branch. The width of a “wet patch” of soil was 3.65 m.

Table 4.8.12 Overview of Tributary A Branch characteristics (June 21 and 25, 2013)

Reach	Width (m)	Depth (m)	Substrate	Bed Morphology	Key Observations
A2-2	0.65	0.10	Silt loam soil	undefined	Poorly defined, situated in dense grass and wildflower planting
A2-1	n/a	n/a	Silt loam soil	Undefined	Not defined; width of moist soil is 3.2 m
A3-1	0.8 – 1.2	0.05 – 0.09	Silt loam soil	Undefined	Poorly defined
A4-4	1-3.5 0.4 (low flow)	0.05 – 0.15 (0.02 low flow)	Sandy silt soil with small pebbles	Undefined	Poorly defined. Position noted by unvegetated corridor amidst corn and wheat fields *(measurements reflect width of unvegetated corridor amongst wheat fields)*
A4-3	0.6	0.07	Silty clay loam soil	undefined	Not defined except for short distance at upstream end at transition into corn field. Local scour hole in grassy patch along drainage feature
A4-2	1.5 - 2	0.15 – 0.21	Silty clay loam soil	Poorly developed	Defined channel in narrow vegetated corridor. Loss of form at downstream end
A4-1	0.55-1.7	0.13-0.45	Gravel substrate	Poorly developed	Defined channel in well vegetated corridor; high root control on banks; undercut banks; poorly connected to floodplain
A5-2	2.9 – 4.6	0.4	Soft sediment (organics, silt)		Not defined in straightened heavily modified channel, choked with cattail and reeds *(measurements reflect width of drain)*
A5-1	3.1-3.4	0.2-0.25	Silty sand,	Poorly developed	Straightened and vegetated heavily modified channel, defined low flow channel with developing sinuosity
A6-1	0.8-0.9	0.1	Pebbles (1 – 4 cm), silt loam soil	Undefined	Defined channel with sinuous sections, alternating bars
A7-2	0.7 – 1.2	0.1-0.2	Pebbles (0.5-1 cm), silt loam	Poorly developed	Straight heavily modified channel in upper portion then defined banks with sinuous planform
A7-1	2.8*	0.05*	Silt loam soil	undefined	Not defined or very poorly defined feature. (note: measurement reflect width of moist soil)
A8-1	0.6	0.1 – 0.2	Silty soils,	Poorly	Defined channel within agricultural field, poor bed

Reach	Width (m)	Depth (m)	Substrate	Bed Morphology	Key Observations
			some pebbles	developed	morphology. Loss of definition at downstream end
A9-1	0.5 – 0.9	0.1 – 0.35	Silty soils, exposed till	Pseudo pool-riffle forms	Defined cannel, definition decreases with decreasing slope; no defined channel at downstream end
A10-1	n/a	n/a	Sandy silt soil	Poorly developed	Opportunistic drainage feature occupies established furrows
A11-1	0.53 - 0.57	0.04-0.07	Sandy silt soil with pebbles	Poorly developed	Channel definition most pronounced where the landscape is steepest. Loss of channel definition in downstream direction

Branch A4

Branch A4 is the second longest component of the Tributary A network and enters the study area through a culvert under Trafalgar Road. Four reaches were defined along this branch which was observed to be dry during the field assessment (June 20, 2103). Reaches A4-4 and A4-3 were either poorly, or not defined. A short section of a defined low flow channel was observed in Reach A4-4. This reach was generally visible only as an area of unvegetated sandy silt soil with small pebbles, within otherwise planted wheat and corn fields. Some channel definition occurs at a grassy hedgerow. Upstream of Trafalgar Road, the branch is undefined as it flows through a meadow. Reach A4-3 was not defined except at the transition from the vegetated field of Reach A4 to the corn field of Reach A4-3. The position of Reach A4-3 was inferred from a shallow depression in the topography and/or occurrence of some vegetative growth along it. Along this reach, a 3.5 m wide and 0.8 m deep hole with scoured banks was present within an isolated grassy patch that was situated along the drainage feature. The origin of this hole was not clear but was determined not to be a hydrogeologic feature by the study team hydrogeologists.

Reaches A4-2 and A4-1 were defined channels situated within an increasingly wider vegetated buffer towards the branch confluence with Tributary A's main branch. A complete loss of channel form occurs at the transition from Reach A4-2 to A4-1. The defined channel in both reaches had a poorly developed bed morphology. Substrate materials consisted of a silty loam soil with some accumulations or occurrence of pebbles (2 – 6 cm). Evidence of undercut banks was found in Reach A4-1

Overall, the increasing effectiveness of hydraulic forces in defining channel morphology occurs with distance downstream, and especially in Reach A4-1.

Branch A5

This branch is a straightened drainage ditch that originates at Trafalgar Road. Reach A5-2 lacked a defined channel, was choked with cattail, and had an accumulation of soft sediment (organics, silts) on the bed. Any variability in channel bed morphology was due to in-channel vegetation rather than exhibiting natural bed from development. Reach A5-1, also situated in a drainage ditch, exhibited a defined low flow channel within a larger vegetated heavily modified channel. Substrate materials consisted of silty clay sediment with accumulations of soft (0.09m thick) silty sand deposits. Medial and alternating lateral bars were present, indicative of a developing sinuous planform. Some grasses occurred within Reach A5-1.

Flows along Reach A5-1 are currently augmented by the diversion of flows via the Trafalgar Road ditch from upstream of Reach A2-2 (see previous description under Branch A2).

Branch A6

Branch A6 is situated with an agricultural field (corn) and occupies a slight topographic depression in the landscape. The channel has defined banks, a slight sinuous configuration and poorly developed bed morphology in silty or sandy soil. Pebbles (1 – 4 cm) were observed along the channel. Land cultivation occurs through the drainage feature. The presence of water within the drainage feature transitions from standing water to saturated soil and then decreased to relatively dry ground by the end of Reach A6-1). Water was observed within the upstream end of the drainage feature, and was situated within the upstream portion of the branch but at the downstream end of the reach. The channel loses definition and thus there is no direct link to the main branch of Tributary A.

Branch A7

Branch A7 begins as a dry (June 25, 2013), defined, straight, shallow and vegetated ditch that decreases in depth and definition in the downstream direction. In Reach 7-2, where the channel is no longer contained in a ditch and there is no instream vegetation, the drainage feature has developed some sinuosity and exhibits pseudo riffle-pool features. Silty loam soils are the dominant substrate materials along with pebbles ranging from 1 – 8 cm that are poorly organized on the channel bed. In Reach 7-1, the drainage feature is not defined and its location is inferred to coincide with the broad topographic depression in the landscape and a concentration of "clean" pebbles (1 – 2 cm).

Branch A8

Branch A8 exhibits both a straight planform (in what appears to be a furrow adjacent to a row of corn) and a developing sinuous configuration. The small, dry (June 25, 2013), drainage feature is situated within silty soil and has a poorly developed bed morphology. Some accumulation of pebbles was observed within the drainage feature. Land cultivation occurs through the drainage feature. The loss of individual corn plants in or adjacent to this branch may be due to flows within the channel.

Branch A9

The upstream end of this branch contains a well-defined dry (June 25, 2013) drainage feature situated within a relatively steep landscape. As the slope decreases, the channel becomes less well defined, and loses definition upstream of Eighth Line. The channel is situated in silty loam soils with occasional accumulations of pebbles and has incised into underlying till materials. The channel bed profile demonstrates development of pool-riffle type features and several knickpoints. Channel depth increases at knickpoints.

To the north of this branch, a tile drain was identified discharging into the Eighth Line roadside ditch, which then flows toward Side Road 10. Minor erosion was identified adjacent to and across from the outlet structure.

Branch A10

Branch A10 coincides with opportunistic occupation of tire tracks within a vegetated agricultural field. At the upstream end of this branch, some evidence of channel initiation was observed which conveyed water (June 25, 2013) into well-established furrows in the field. Overall, this reach was considered to be depression storage rather than part of a continuous surface channel.

Branch A11

Branch A11 initiates within a relatively steep landscape and has a defined sinuous form along most of its length. Bed morphology consists of poorly developed pool-riffle type features. The substrate materials consist of sandy silt soil with some pebbles. Accumulations of pebbles occur sporadically along the channel length. The definition of Branch A11 decreases towards Eighth Line where its position can only be inferred from a slight topographic depression. Multiple poorly defined flow paths were observed but no defined channel at the downstream end of the reach. Land cultivation occurs through Branch A11. Where the channel is defined, few corn plants were observed within the channel.

4.8.4.3 Silver Creek: Tributary B

Tributary B, a second order watercourse, is situated in the northern portion of the study area and drains to Silver Creek (**Figure 4.8.4**). The watercourse differs markedly from the Sixteen Mile Creek tributaries due to the ~ 10 m elevation drop that occurs as the main branch of the tributary cuts through a valley side en route to Silver Creek. The Tributary B watershed extends to the north of the study area into the residential development that is situated along Side Road 15. Surface water runoff is routed through stormwater management and has thus altered the surface drainage network of this watercourse. Within the study area, the topography is relatively flat and marked by incidental shallow surface water depressions.

Main Branch

Four reaches were defined along the main branch of Tributary B, corresponding to areas of distinct change in channel slope and/or setting (**Figure 4.8.4, Table 4.8.13**).

Table 4.8.13 Overview of Tributary B reach characteristics (June 25, 2013)

Reach	Width (m)	Depth (m)	Substrate	Bed Morphology	Observations
BM-4	0.8	0.25	Silty soil and pebbles	Developing	Defined channel in grassy corridor. Standing water in channel
BM-3	1.9 – 2.1	0.4 – 0.5	gravel/cobble (1 – 28 cm), till exposure	Riffle/run-pool	Defined channel occupied bottom of valley. Large woody debris accumulations creating stepped profile. Undercut banks, sinuous form, groundwater seepage at till contact
BM-2	2.6 – 3.8	0.15 – 0.4	Sand deposits, gravel, cobbles	Developing pool riffle	Defined channel in wider valley, sediment accumulation as medial bars and sediment wedges, valley wall contacts (sandy unit) groundwater seepage at exposed clays.
BM-1	0.95 – 3.1	0.1 – 0.6	Sand, native soils, some cobble	Poorly developed and developing	Valley opens up, and channel grade decreases, channel loses definition and assumes a multiple pathway route over the floodplain before becoming concentrated into two dominant channels. Accumulation of sand widespread within channel and floodplain.

BM-4

Reach BM-4 receives drainage from Branches B0, B1 and B2 and is a second order channel. The reach is situated on the tablelands and is a well-defined alluvial drainage feature situated within a narrow vegetative buffer. Substrate consists of sandy silt soils and pebbles.

Application of the Rapid Geomorphic Assessment yielded a stability index value of 0.22. This coincides with a channel that is classified as 'in regime'. The dominant processes that scored highest for this reach included planform adjustment and degradation (channel bed lowering).

BM-3

Reach BM-3 begins as the channel enters a wider and increasingly woody corridor. The channel becomes noticeably steeper and incised, exposing till materials on the channel bed that are overlain with accumulations of cobble and gravel. Small knickpoints were observed along the channel profile. Substrate materials varied and included coarse accumulations of sediment (1 – 28 cm). Valley walls were steep. The planform is sinuous, following the valley trend.

Sections of this reach are overgrown, with vines, fallen trees, and woody debris blocking passage through the channel.

Groundwater seepage was observed at the interface between till and the overlying sandy silt soils. Roots from bankside vegetation appeared to infiltrate the high banks to the till contact. At the BX tributary confluence, the channel was ~ 1.6 m deep. Standing water was observed within pool features near the upstream of the reach. No water was observed through the majority of this reach. A large volume of woody debris was observed along the channel, both as fallen tree trunks straddling channel banks, and as debris accumulations within the channel. The configuration of twigs and small woody debris within the channel provided evidence of recent flow events through the channel. Woody debris jams that spanned the channel width, created grade control points upstream of which sediment had accumulated and/or resulted in artificial knickpoint features. Towards the downstream end of this reach, the valley opens up and the channel no longer occupies the entire bed of the valley but, instead has access to a narrow vegetated floodplain.

The dominant channel processes within this reach include aggradation, degradation and planform adjustment. These processes are expected, given the steepness of the reach and its position along the profile of a headward migrating valley.

BM-2

Reach BM-2 begins at the confluence of Branch B3 and extends until the valley opens up noticeably (**Figure 4.8.4**). Branches B4 and B5 flow into this reach. The overall channel grade of the valley is more gradual than in Reach BM-3. The valley widens and the channel does not typically occupy the width of the valley bottom. Instead, a low floodplain or vegetated bars often occur along the channel. In several locations, terraces are observed within the lower valley which is indicative of several periods of downcutting in the history of this valley's development.

Numerous valley wall contacts occur through the reach as the channel meanders within the valley. The unvegetated erosion scars consist of sandy sediment which, in conjunction with gullies observed along the valley wall, provide a local source of sand to Reaches BM-2 and Reach BM-1. Substrate materials consist of accumulations of pebbles and small cobbles in addition to sand deposits. Sediment is trapped behind woody debris and occurs as medial and lateral bars. Till is exposed locally in the lower valley walls and on the channel bed. Some seepage is observed at the junction between the till and overlying sandy units. While this reach was considered to be dry, there were several areas where standing water was observed in pool features.

The dominant process observed in this reach was aggradation. Both channel bed incision and planform adjustment are other processes that were observed within this reach. These processes are expected given the channel's location within a developing valley and the exposed sandy sedimentary units.

BM-1

Reach BM-1 begins as the valley width opens and the channel bed gradient lowers. The channel widens and banks become lower so that flows are able to occupy the entire valley bottom, as indicated by the extensive deposition of sand which interferes with the establishment of vegetation in several areas. Bed morphology along the tributaries' profile becomes less well defined and consists primarily of accumulations of sand. In the middle of this reach, the channel becomes poorly defined, with multiple flow paths evident in the floodplain. Reach BM-1 becomes redefined a short distance downstream into two defined channels, each situated along a valley wall. The northern channel is better defined than the southern channel.

As the valley opens up further, vegetation changes to grasses and herbaceous species and the channel becomes well defined once again, assuming a narrow and deeper form. The northern channel becomes dominant and has a sinuous form. The southern channel joins the main channel at the CSP culvert under Eighth Line. The floodplain is clearly depositional, with fresh accumulations of sand visible in the vegetation.

Reach BM-1 was determined to be "in adjustment" with the dominant processes of aggradation and planform adjustment contributing to observed channel instability.

Branch BX

Branch BX joins the main branch of Tributary B from the south and originates near the drainage divide between the Silver Creek and Sixteen Mile Creek watersheds (**Figure 4.8.4, Table 4.8.14**). On June 19, 2013, a shallow wide depression containing standing water was situated at the head of Reach BX-2, adjacent to a woodlot. The drainage feature in this reach was dry and undefined. A flow path could be discerned within the shallow topographic low by the presence of slightly moist soil.

Reach BX-1 begins within 7 m of the vegetated buffer that is situated along the top of the valley wall. The reach enters the densely vegetated area where it maintains a defined form and then abruptly (drop of 0.7 m) incises through the valley wall to the main branch of Tributary B (Reach BM-3). The head of the knickpoint is situated within/under a 0.3 – 0.45 m thick root mat associated with the local vegetation. Review of stratigraphic conditions within the steep gully revealed the following stratigraphy within a 1.61 m deep channel section situated a few metres downstream of the knickpoint: 1.46 m thick sandy silt over exposed till. Groundwater seepage was observed at the till/sand contact. An exposed root network was exposed at the slope surface, under which the gully was forming.

Table 4.8.14 Overview of Tributary B Branch conditions (June 19, 2013 and June 25, 2013)

Reach	Width (m)	Depth (m)	Substrate	Bed Morphology	Observations
BX-2	0.15	0.01	Silty sand soil with	Poorly defined, may have subtle development	Undefined channel in slight topographic depression with slightly moist soil (~ 0.95 m wide). *(measurement represents slight definition towards downstream end of reach)*
BX-1	0.15-0.93	0.01 – 0.14	Silty sand soils and pebbles (05-3.5 cm)	Poorly defined	Reach begins within agricultural field and incises abruptly into the valley wall, a short distance into the woody vegetation. Very well connected in field and valley edge vegetation until it becomes a gully.
B0-2	_	_	Silty sand soil with few pebbles	_	Undefined, evidence of flow path with dimensions of ~ 1 m wide.
B0-1	0.86 - 2.76	0.1 - 0.37	Silty sandy soil, 0.5 – 3.5 cm pebbles	Developing pool-riffle	Defined channel with developing bed morphology, standing water in pools, developing sinuosity, stable
B1-1	0.7 - 0.8	0.05-0.09	Silty soil	Undefined	Undefined channel in agricultural field feature within shallow and broad depression in landscape. Channel defined within local naturalized vegetated area *(measures reported in table)* and contains both vegetated and unvegetated portions.
B2-1	1.3 – 2.15	0.02 – 0.22	Silty soil	undefined	Poorly defined channel within agricultural field, location inferred by slightly moist soil (1.3 – 1.8 m wide), otherwise undefined. Channel only defined near hedgerow. *(Measures reflect local channel definition through hedgerow)*
B3-3	_	_	Silty soil	Undefined	Undefined in agricultural field, originates from wide shallow depression containing stagnant pool, poorly defined downstream of this pool
B3-2	1.2 -1.25	0.2 -0.3	Silt loam, boulders and gravel	Developing	Defined channel within vegetated area. Channel is overgrown with vegetation.
B3-1	_	_	_	_	Gully within valley wall, (*inaccessible for measurement)*
B4-3	_	_	Silty soil	undefined	Undefined in agricultural field
B4-2	1.1 – 1.5	0.15 – 0.2	Silty soil with some cobbles and boulders	Undefined or poorly developed	Defined channel in vegetation along top of valley wall.
B4-1	_	_	_	_	Gully within valley wall, (*inaccessible for measurement)*
B5-2	_	_	_	_	Undefined channel
B5-1	1.4 – 2.5	0.45	Coarse sand,	Bed morphology	Gully within valley wall, active erosion of gully wall, large volume of woody debris and roots on channel bed.

Reach	Width (m)	Depth (m)	Substrate	Bed Morphology	Observations
			pebbles, cobbles (2 – 24 cm)	affected by large woody debris	

Branch B0

Branch B0 has two reaches (**Figure 4.8.4, Table 4.8.14**). Reach B0-2 is a poorly defined channel that is situated directly within the agricultural field and is cultivated. The reach links a small vegetated terrestrial feature to BO-1 and although Reach B0-2 is not defined by any banks, indication of its position within the landscape was visible through cracking of smooth soils (i.e. similar to ground surface that remains after evaporation of a ‘puddle’) and slight evidence of a topographic low.

Reach BO-1 is a defined watercourse with a narrow (< 1 m wide with local increases to 4.7 m) grassy riparian buffer that is situated within an agricultural field. Standing water was situated within some pools (June 19, 2013) in the developing bed morphology. The channel appeared to be incised in a larger channel feature and stable. Medial bars were observed and some grass was within the channel.

Branch B1

Branch B1 originates within a cultivated agricultural field (soybean) (**Figure 4.8.4, Table 4.8.14**). The dry channel was undefined and difficult to locate in the field. A localized vegetated area occurs along this branch in which a channel was clearly defined; evidence of mud cracking in an unvegetated wider portion of the drainage feature suggests it has contained standing water. Once the channel emerges from the vegetated area, it resumed its undefined form. The feature could sometimes not be located.

Branch B2

Branch B2 originates within the cultivated agricultural field (soybean) and was not defined upstream of the Branch B1 confluence (**Figure 4.8.4, Table 4.8.14**). The location of this drainage feature was inferred from slightly moist soil (width 1.3 – 1.8 m) in the agricultural fields (i.e., poorly defined). A defined channel was observed immediately upstream of, and within the hedgerow. Branch B2 was undefined from the hedgerow to its confluence with Branch B0.

Branch B3

Branch B3 originates near a wide shallow depression containing stagnant water (June 25, 2013) within a cultivated agricultural field (soybean) (**Figure 4.8.4, Table 4.8.14)**. Downstream of the pool, the channel is undefined (Reach B3-3), but a flow path could be discerned in the landscape where plants had not become established.

Reach B3-2 is a defined channel that begins at the edge of the vegetation, situated along the top of the valley wall. The channel is overgrown with vegetation. Reach B3-1 is defined as the section of channel that drops steeply in a gully to the branch confluence with Tributary B (Reach BM-3). Due to access limitations (vegetation overgrowth and steep slope), no measurements of channel form could be obtained.

Branch B4

Original mapping of Branch B4 indicates that the origin of this drainage feature occurs north of Side Road 15 **(Figure 4.8.4, Table 4.8.14**). This area, now supporting a urban residential development is drained through stormwater management practices that divert water from upstream of Side Road 15 to Eighth Line. The upstream most reach (B4-3) appears to originate from a small woodlot situated at the rear of a residential property on the south side of Side Road 15 (**Figure 4.8.2**) but was undefined in the cultivated field. Definition of the reach begins at the edge of the vegetation along the top of the valley wall Reach B4-2).

Reach B4-2, similar to Reach B3-2, is a defined channel that begins at the edge of dense vegetation that flanks the valley wall. Herbaceous vegetation occurs within the channel; no vegetation occurs in the channel once the drainage feature enters the wooded area. The channel contains poorly developed or undefined bed morphology. Substrate materials contain some coarser pebbles/cobbles (12, 15 cm).

Reach B4-1 is a gully feature that has cut through the valley wall. Due to access limitations (vegetation overgrowth and steep slope), no measurements of channel form could be obtained.

Branch B5

Review of aerial photography suggests that the drainage feature associated with Reach B5-2 originates from an east west oriented wooded area that is perpendicular to the general orientation of Branch B5 (**Figure 4.8.4, Table 4.8.14**). The drainage feature, situated within a cultivated agricultural field is not defined. Branch B5 becomes defined immediately upstream of the vegetated buffer that occurs along the edge of the valley.

Reach B5-2 begins at the edge of the valley vegetation and consists of a defined channel that has incised into the valley wall, forming a V-shaped gully. Active undercutting and soil exposure were evident along the gully walls, including leaning trees (i.e., indicative of slope instability). Woody debris accumulations at the base of the channel obscured the channel bed. Substrate materials consisted of predominantly of a gravel bed, including few cobbles and boulders.

Reach B5-1 is a gully feature that has cut through the valley wall. Due to access limitations (vegetation overgrowth and steep slope), no measurements of channel form could be obtained.

4.8.4.4 Location of Tile Outlets

The presence of tile outlets observed in the field along specific reaches has been described in the previous sections. The location of the observed outlets is illustrated in **Figure 4.3.4** and details are summarized in **Table 4.8.15**.

Table 4.8.15 Location of Tile Outlets

Tributary	Reach	Outlet to Surveyed Reach?	Location	Status
C	C-4	No	Opposite side of woodlot to the watercourse.	Unconfirmed
	C-3	Yes	Downstream end of reach potentially providing flow to Reach C-2.	Unconfirmed, Buried
	C-1	No	Enters roadside ditch along Eighth Line. Flows directed north enter downstream end of Reach C-1 just upstream of road culvert at the edge of the study area.	Confirmed

Tributary	Reach	Outlet to Surveyed Reach?	Location	Status
A	AM-6	Yes	No actual outlet identified. Potential presence of tile outlet inferred by the presence of a broken clay pipe along the bank just downstream of the confluence with Reach A5-1.	Unconfirmed, Buried
	AM-5	Yes	Suspected location inferred in upper reach by large rock and concrete along the left bank. No strong influence on channel definition.	Unconfirmed, Buried
	AM-5	Yes	Upstream of confluence with Reaches A3-1 and A2-1. Narrowing and deepening of channel downstream related to confluence not just tile outlet.	Confirmed
	AM-3	Yes	Small channel at the valley toe was observed with associated mid-channel deposition, potentially related to sediment supply.	Confirmed, Buried

4.8.5 Classification

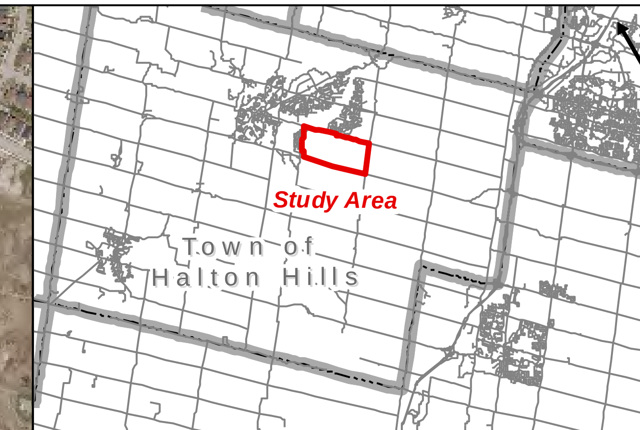
4.8.5.1 Channel Form

Review of the field site conditions outlined in **Section 4.8.4** and demonstrated through the air photo record in **Appendix E**, reveal a diversity of channel forms ranging from undefined channels that are coincident with moist soil conditions, to well defined channels that are actively incising into the landscape. Almost all watercourses have been modified, either through historic straightening, or through cultivation practices associated with agricultural land use.

Since channel form is due to the interaction of controlling and modifying influences, it follows that watercourses situated within a similar setting (geology, vegetation, land use, drainage area) would have a similar morphology. Grouping “like” reaches into a classification scheme can be useful in understanding the diversity of channel forms, the dominant factors that contribute to their morphology and the role of these features within the overall drainage network. Within the study area, it was evident that the local presence of vegetation appeared to account for a defined channel form along a branch which was otherwise undefined or poorly defined, suggesting that local spatial influences are important determinants of channel form. In this study, six classes of channel form were identified, each of which is summarized below (see **Figure 4.8.5)**.

Undefined

Reaches classified as undefined included those which did not exhibit channel banks. These features were visible in the landscape only by spatial differences in soil moisture conditions leading to mottling of soils and/or provided some indication of surface flow (i.e., loss of crop along path of feature). Often, undefined features were situated in slight topographic lows and were integrated in the landscape (i.e., cultivation occurred directly through the feature). Given the lack of definition, hydraulic and site conditions were insufficient to enable channel initiation to occur. These drainage features were most often ephemeral or contained no surface flow. It is likely that, during periods of high surface runoff, these features become an extension of the more active drainage network, contributing both sediment and water to the downstream watercourse. For some of these features, such as Reach A9-1, where a tile drain outlets into the Eighth Line roadside ditch to the north of the reach, it is likely that tile drains have reduced portions of the active surface drainage network.



Legend

N

Channel Classification

- Alluvial
- Defined
- Heavily Modified
- Gully
- Poorly defined
- Undefined

General Features

- Identified Reaches
- Reach Breaks
- Roads
- Study Area
- Conservation Authority Boundary*

Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600
Meters

Southwest Georgetown Integrated Planning Project

Channel Form Classification

June 2016	1:10,000	Datum: NAD 83, Zone 17 Source: LIO, Region of Halton
P#: 60297831	V#: 003	

AECOM

Figure 4.8.5

P:\60297831 SW Georgetown\900-CAD-GIS\920 GIS-Graphics\Design\Final Report

Within the study area, nine reaches were classified as “undefined” (**Table 4.8.16**). Results from the flow assessment analyses indicated that these features typically containing no flow or ephemeral flow regimes (**Section 4.8.5.2**). Undefined watercourses represent 21% of the total drainage network length.

Poorly Defined

Poorly defined reaches were often associated with small drainage features that did not exhibit defined banks or bed morphology. These features were identified in the field due to other indicators including:

- bare soil within an otherwise vegetated area
- dried or cracked soil, indicative of previous flow or standing water
- accumulation of “clean” pebbles/small gravel in general configuration as drainage direction
- subtle defined banks
- presence of moisture or standing water but not associated with any channel form within vegetated areas

Most of the poorly defined watercourses were integrated into the landscape and cultivated. Due to soil moisture conditions or occasional flow, the success of plantings within the drainage feature was sometimes compromised. Poorly defined watercourses, similar to undefined watercourses, appear to lack the energy conditions necessary to define a channel. The upstream portion of Reach A2-2, which is classified as a poorly defined channel, is no longer connected to the downstream reaches as the flow is diverted into the roadside ditch along Trafalgar Road and connected to Reach A5-1. Redirection of this water would impact the geomorphology of reaches A2-2 and A2-1 as the energy conditions are lowered due to less water to entrain and transport sediment and therefore, define a channel.

Within the study area, nine drainage features were classified as “poorly defined”. In addition, the upstream reaches of A2-2, A4-4 and AM-7 would be classified similarly. The flow regime of these watercourses was defined typically “no flow” but could also be ephemeral or intermittent (**Table 4.8.16**, **Section 4.8.5.2**). Poorly defined reaches represent 28% of the total drainage network length and are thus the most common form in the study area.

Defined

Watercourses were classified as “defined” when channel banks were clearly discernible in the field, indicative of a concentration of flow. Features within the channel also provided indication of flow and a shear dominated flow regime. Even within very small defined drainage features, a subtle bed morphology could sometimes be discerned. In other cases, some spatial sorting of grain sized and/or a “thalweg” could be identified.

The defined watercourses ranged in dimensions and if sufficiently small, were cultivated through regular land use practices. The success of plantings within the channel was typically compromised. If the channels were larger, then a vegetative buffer might be established around them. The presence of measurable banks indicates that flow through these channels is sufficient to erode and transport sediment. In several instances, a defined channel section occurred along an otherwise undefined or poorly defined reach and coincided with the presence of vegetation (i.e., grassy hedgerow) and tile drains, suggesting that local effects could alter channel forming processes. Reach C2 is an example of a defined reach where directly upstream, a tile drain outlets into the undefined Reach C3 and the downstream reach (Reach C1) is classified as poorly defined.

Review of field data indicates that eleven reaches were classified as “defined”. The dominant flow regimes associated with these channel forms included “ephemeral” and “intermittent” (**Table 4.8.16, Section 4.8.5.2**). Defined watercourses represent 13% of the drainage network channel length.

Alluvial

Alluvial channels are those that are self-forming. Banks are clearly defined and typically at a bank full elevation and flows have sculpted substrate materials into a definable bed morphology. Within the study area, the defined channels were situated within woodlots, manicured lawns. Five reaches were classified as alluvial watercourses, representing 10% of the total channel length. Almost all alluvial reaches conveyed perennial flow. This is expected since a well-established bankfull channel requires a full range of flows within the annual hydrograph to define its form. An example of an alluvial reach is AM-3. The combination of tile drain outlets upstream and within this reach, as well as the upstream realigned drainage pathways has resulted in increased flows (at least seasonally) within the stream network. This can be interpreted to have contributed to the degradation and planform adjustment identified within this reach during field reconnaissance.

Gully

Reaches defined as gullies were those channels that were steep and deeply incised. The cross-section shape was “v” shaped with a narrow channel at the bottom of the gully and high banks/valley walls. Many of these features were characterized by abundant large woody debris accumulations, fallen trees into the channel or onto the top of channel banks. This is associated with the degradational tendency of the channels leading to oversteepening of the valley walls/banks and undercutting. All of the observed gullies occurred along Tributary B and had incised into Halton Till materials. Bed morphology was often poorly developed or developing towards a step-pool form. Given the steep and associated high energy conditions of flows within gullies, and potential for continued channel bed lowering and resultant instability, gullies develop self-stabilizing forms that increase stability of the channel. Self-stabilizing forms were observed along the channels, indicating that there is sufficient woody debris and natural materials for their formation. When such materials are not present (i.e., large woody debris removal from managed watercourses), then the rate of channel bed incision may be relatively high, and leads to more pronounced effects on valley wall erosion and stability.

In total, five reaches were classified as gullies (**Table 4.8.16**). Since gullies are associated with topography and the much lower base level of the receiving watercourses, their presence is less dependent on flow regime (i.e., the flow regime of study area gullies was dominated by ‘no flow’). Rate and magnitude of gully evolution, however, is affected by flow regime. More frequent flows (perennial, intermittent) would be associated with more rapid gully development (See **Section 4.8.6.2**). While gullies represent only 3% of the total channel length in the drainage network, these features likely affect proposed development planning more than any others.

Heavily Modified

The “heavily modified” classification refers to channels that have been straightened, typically in conjunction with agricultural activity. The capacity of the channels is often greater than necessary to convey “bankfull” flows from the study area and is intended to reduce flooding of adjacent fields. Where tile drains are present, such as within Reaches AM4 and AM5, these then are discharged into the channel. Periodic maintenance of heavily modified reaches may occur to maintain conveyance capacity (i.e., reduce flooding potential on the landscape). In heavily modified channels that have a low gradient and small surface flows, then vegetation typically establishes within, and chokes the channel. Bed morphology may or may not become established within the heavily modified channel. All heavily modified reaches within the study area occurred along the Tributary A drainage network (**Table 4.8.16**).

Where heavily modified channels convey sufficient flows and are not maintained, then a defined low flow channel may form within larger channel. That is, since channels are rarely straight in nature, given time and opportunity, watercourses will work toward regaining a natural configuration that is in balance with the factors that determine channel form. Indeed, Rhoads and Herricks (1996) have established a ditch classification scheme for the various stages that occur as a channel changes from a straightened planform to one with a sinuous established alluvial form.

Eighth reaches were classified as heavily modified, representing the second largest proportion of the total drainage network (i.e., 25%). Given that these are anthropogenically modified forms, their configuration and presence is independent of flow regime. Indeed, the flow regimes conveyed through the drains range from “no flow” to “perennial” (**Table 4.8.16**, **Section 4.8.5.2**).

4.8.5.2 Flow Assessment

Assessment of surface flow conditions within each reach was documented during each field visit undertaken by the study team (**Appendix H**). Observations were summarized and evaluated according to the criteria presented within the CVC/TRCA Headwater Drainage Feature Assessment Interim Guidelines (2009). Evaluation of results demonstrated that all flow description classes were represented in the study area (**Table 4.8.17**). The flow regime for each reach was summarized according to channel form in **Table 4.8.16**.

Table 4.8.16 Overview of Channel Classification and Associated Flow Regimes

Channel Form Class	Study Area Reaches	Total Reaches	Total Length (km)	Catchment Area (km^2)	Typical flow regime
Undefined channels	• A2-1, A3-1, A4-3 (except for local definition), A7-1, A9-1 (local definition) • BX-2, B4-3 • C3, C5	9 (19%)	2.52 (21%)	0.02 – 1.79	Intermittent (1) Ephemeral (4) No flow (4)
Poorly defined	• A2-2, A4-4, A10-1, A11-1 • B0-2, B1-1, B2-1, B3-3 • C1	9 (19%)	3.36 (28%)	0.01 - 1.59	Intermittent (2) Ephemeral (2) No Flow (5)
Defined	• A4-2, A4-1, A6-1, A7-2, A8-1 • B0-1, B3-2, B4-2, B5-2, • C2, C4, C6	11 (23%)	1.52 (13%)	0.04 – 0.76	Intermittent (4) Ephemeral (5) No flow(2)
Alluvial	• AM-2, AM-3, A7-2, • BM-4, BM-2, BM-1	5 (11%)	1.18 (10%)	0.12 – 5.11	Perennial (4) Intermittent (1)
Gully	• BM-3, BX-1, B3-1, B4-1, B5-1	5 (11%)	0.35 (3%)	0.02 – 0.45	Intermittent (1) Ephemeral (2) No flow (3)
Heavily Modified	• AM-1, AM-4, AM-5, AM-6, AM-7, A5-1, A5-2, A7-2	8 (17%)	2.94 (25%)	0.12 – 5.20	Perennial (3) Intermittent (3) Ephemeral (1) No flow (1)

Reaches upstream of A2-2, A4-4 and AM7 were poorly defined, undefined and undefined, respectively.

Results of hydrologic modeling (**Section 4.6**) were used to quantify the 2 year flow event for each reach (**Table 4.8.17**). The hydraulic model (**Section 4.7**) was reviewed to assess the capacity of the Tributary A drainage features. Results of the analyses indicate that the capacity of reaches AM-5 to AM-7 along Tributary A is equivalent to the 50 or 100 year flow event (**Table 4.8.17**).

4.8.6 Channel Functions and Processes/Characterization

The Southwest Georgetown study area is dominated by headwater, low-order channels which predominantly drain agricultural land. These channels have been affected by agricultural activity (cultivation, straightening) due to their small size and ease of modification by agricultural practices. Although the location of most of the drainage features was inferred from review of aerial photography, field observations determined that almost half were undefined or poorly defined (i.e., 21% undefined, 28% poorly defined).

Characteristics of the drainage network are influenced by the geology of the area and land use/cover. As such, quantification of the drainage density and bifurcation ratios suggest that the area has a greater drainage efficiency than other watercourses within the Credit Valley Subwatershed. This may be attributable to the surficial geology materials in which the drainage network has established. Given the geology materials and headwater characteristics of the study area, it follows that first order channels are most abundant in the drainage network.

The following sub-sections will provide an overview of key characteristics for the entire study area and then focus on items relevant to each subwatershed.

4.8.6.1 Headwater Drainage Features

Headwater channels typically make up between 70 – 80 % of the drainage network in terms of both flow and channel length (Meyer et al, 2003; Vought et al., 1995). Specific roles attributed to headwater streams as it pertains to channel form and functions include (Dunne and Leopold, 1978, Schollen et al., 2006):

- hydrograph moderation through flow attenuation and storage,
- source of sediment,
- excess sediment storage,
- contribution of organic energy inputs that sustain aquatic biota and contribute to the productivity of the downstream watercourse (Wallace et al. 1997),
- nutrient retention and uptake (Alexander et al. 2000, Peterson et al. 2001),
- temperature moderation,
- habitat for terrestrial and aquatic species and biota (Morse et al, 1993); and
- groundwater recharge

Defining the upstream limit of a headwater channel is difficult since the stream head position changes with time in response to fluctuations and magnitude in precipitation patterns and antecedent soil moisture conditions (Gregory and Walling, 1968). This was demonstrated in the field where channel form changed invariably from undefined to defined and back to undefined. Headwater channels may be discontinuous features that become active parts of the drainage network only during precipitation events. Thus, the length of the drainage network depends on the surface flow generated during precipitation events. Where the soil conditions and the intensity of rainfall events enable infiltration of precipitation, then less surface flow is generated. As infiltration potential decreases (i.e., antecedent moisture condition, high intensity of precipitation), then surface depressions may temporarily store water. Additional runoff would link surface depressions and dry swales to enable continual downstream flow conveyance to receiving streams.

Initiation of a defined channel feature occurs where there is sufficient energy and flow to erode surface materials. Geomorphic study and prediction of channel initiation typically relies on drainage area and slope (i.e., Montgomery and Dietrich, 1989) which essentially quantifies stream energy (i.e., drainage area as a surrogate for flow). Review of study area data (**Table 4.8.16** and **Table 4.8.17**) revealed the following key findings:

- Catchment area > 0.23 km^2: 74% in this range are Intermittent or perennial
- Catchment area < 0.23 km^2: 92% in this range are ephemeral or “no flow”
- Catchment area alone is not a predictor of channel form (Table 4.8.15)
- Alluvial channels occurred only in catchment areas larger than 0.33 km^2

The headwater channel characteristics and roles identified in the scientific literature and summarized above are relevant to the study area. Further discussion of headwater channel functions, from a multi-disciplinary perspective is provided in **Appendix I**. Results from this study have revealed that several branches and reaches within the drainage network are undefined or poorly defined and were characterized as conveying “no flow”. These features may become extensions of the drainage network when the infiltration capacity of the soils are exceeded. Thus, although the nearly 50% of the drainage network that was classified as “undefined” or “poorly defined” and which was typically associated with a “no flow” or “ephemeral” flow regime may appear to be insignificant, they become relevant components of the drainage network during those precipitation events which produce abundant runoff).

The relatively high drainage density, in comparison to other Credit Valley watersheds, suggests that the study area is well drained by surface channels due to the underlying geology. This indicates that water is drained relatively quickly from the landscape and routed to the receiving channel. In addition to the drainage network, review of the topography revealed shallow depressions in the fields, which contained standing water during rainfall events. Further, although swales and defined channels are assumed to be the only conduits of water to a drainage network, field observations confirmed that there are multiple unmapped areas of surface water conveyance to the reaches (i.e., overland flow). Human alterations, such as the creation of tile drains, can also influence the drainage density rate as drains are thought to reduce the length of time over which subsurface inputs to the stream occurs. Tile drains identified during fieldwork discharge directly into the heavily modified and alluvial reaches, as well as the roadside ditches, therefore promoting faster drainage by conveying water away from fields to these reaches. Tile drains were also identified in undefined channels where standing water was present after a rainfall event and then routed to defined channels.

Defined headwater channels tend to be erosive, supplying sediment to downstream channels. They also tend to have storm-driven, flashy discharge regimes. Although each headwater channel provides only a small amount of sediment and water to the overall basin, since they are numerous, changes in the throughput of sediment and water produces cumulative effects through the watershed.

The predominant geomorphological functions of this drainage network and associated watershed area include:

- Water and sediment delivery to the downstream watercourses
- Surface water depression storage
- Attenuation of downstream hydrograph

Any stream corridor management plan needs to be cognizant of the unique nature and sensitivity of a headwater subwatershed area. Failure to protect the function of headwater streams has elsewhere reported to lead to:

- Loss of hydrologic retention capacity, leading to an increased frequency and intensity of flooding downstream, and to lower base flows (i.e., Dunne and Leopold, 1978);
- Increased frequency and intensity of flooding that results in increased channel erosion downstream (i.e., Trimble, 1997);
- Reduced retention of sediments in headwater channels that leads to excess sediment transport downstream (Waters, 1995);
- Reduced sediment loading can lead to erosion downstream.

Table 4.8.17 Overview of Reach Classifications

Tributary Branch/Reach	Catchment area (km^2)	Average Slope (%)	Channel Classification	Flow Regime	Meander Belt Applicable?[1]	2 Year Flow (cms)[2]
Tributary B						
BM-4	0.328	0.58	Alluvial	Intermittent	No	0.12
BM-3	0.450	8.14	Gully	Intermittent	No	0.16
BM-2	0.705	5.6	Alluvial	Perennial	No	0.10
BM-1	0.873	2.66	Alluvial	Perennial	No	0.12
BX-2	0.019	2.8	Undefined	Ephemeral	No	0.01
BX-1	0.023	1.56	Defined/Gully	Ephemeral	No	0.01
B0-2	0.082	1.39	Poorly defined	Ephemeral	No	0.03
B0-1	0.094	1.6	Defined	Ephemeral	No	0.03
B1-1	0.145	0.46	Poorly defined	Ephemeral	No	0.05
B2-1	0.225	1.3	Poorly defined	Ephemeral	No	0.08
B3-3	0.056	0.63	Poorly defined	Ephemeral	No	0.02
B3-2	0.063	3.13	Defined	Ephemeral	No	0.02
B3-1	0.089	17.24	Gully	Ephemeral	No	0.03
B4-3	0.036	0.9	Undefined	Ephemeral	No	0.01
B4-2	0.071	6.31	Defined	Ephemeral	No	0.01
B4-1	0.08	19.43	Gully	Intermittent	No	0.01
B5-2	0.035	0.93	Defined	Ephemeral	No	0.01
B5-1	0.076	23.71	Gully	Ephemeral	No	0.01
Tributary C						
C-6	0.037	1.4	Defined	Intermittent	No	0.01
C-5	0.252	0.89	Undefined	Ephemeral	No	0.07
C-4	0.420	1.66	Defined	Intermittent	No	0.12
C-3	0.523	0.94	Undefined	Ephemeral	No	0.15
C-2	0.599	0.36	Defined	Intermittent[3]	No	0.17
C-1	0.799	2.09	Poorly defined	Intermittent	No	0.22
Tributary A						
AM-7	0.360	0.55	Heavily Modified	Intermittent	Yes	0.22
AM-6	1.504	0.78	Heavily Modified	Intermittent[3]	Yes	0.93
AM-5	4.253	1.26	Heavily Modified	Perennial[3]	Yes	1.85
AM-4	5.072	1.48	Heavily Modified	Perennial	Yes	2.29
AM-3	5.092	1.47	Alluvial	Perennial[3]	Yes	2.30
AM-2	5.109	5.88	Alluvial	Perennial	Yes	2.32
AM-1	5.203	3.02	Heavily Modified	Perennial	Yes	2.36
A2-2	1.590	0.86	Poorly defined	No flow[4]	No	0.69
A2-1	1.788	0.59	Undefined	No flow	No	0.78
A3-1	0.315	0.82	Poorly defined, Undefined	No flow	No	0.14

Tributary Branch/Reach	Catchment area (km^2)	Average Slope (%)	Channel Classification	Flow Regime	Meander Belt Applicable?[1]	2 Year Flow (cms)[2]
A4-4	0.451	0.8	Poorly defined	Ephemeral	No	0.20
A4-3	0.612	0.69	Undefined	Ephemeral	No	0.28
A4-2	0.688	0.8	Defined	Ephemeral	Yes	0.31
A4-1	0.758	2.05	Defined	Intermittent	Yes	0.34
A5-2	0.491	3.15	Heavily Modified	Ephemeral	No	0.30
A5-1	1.122	0.05	Heavily Modified	Intermittent[4]	Yes	0.68
A6-1	0.101	0.66	Defined	Ephemeral	No	0.06
A7-2	0.116	0.66	Drain and defined	No flow	No	0.05
A7-1	0.163	0.75	Undefined	No flow	No	0.07
A8-1	0.035	2.79	Defined	No flow	No	0.02
A9-1	0.015	4.65	Undefined	No flow	No	0.02
A10-1	0.027	4.08	Poorly defined	No flow	No	0.03
A11-1	0.010	2.89	Poorly defined	No flow	No	0.01

1. *See **Section 4.8.7.1** Meander Belt Widths for details.*
2. *Estimates of the 2 year flow were prorated by area for each branch/reach based on the nearest downstream flow node (see **Table 4.6.10** for details).*
3. *Potential flow inputs at tile outlet locations (see **Section 4.8.4.4**).*
4. *Existing condition flow altered due to diversion of flow from upstream of Reach A2-2, along Trafalgar Road roadside ditch to Reach A5-1 see **Section 4.8.4.2**).It is noted that the hydrologic and hydraulic modeling is based on historical drainage for Reach A2-2 to Reach AM-5.*

4.8.6.2 Tributary A

Tributary A has the largest drainage network within the study area and is also the most impacted through historic alterations of channel form and through contemporary cultivation activities. Although no evidence of the historic channel pattern of the main branch of Tributary A was evident in the air photo record, straightening typically reduces channel length and thereby increases the energy of flows conveyed through the channel in comparison to pre-existing conditions. Tile drains occur within the subwatershed, with several discharge points located along Reach AM-3, AM-4, AM-5, and AM-6, these increase the rate of water delivery to the receiving watercourse. Although all reaches along Tributary A may have been historically altered, Reaches AM-2 and AM-3 are naturalized and demonstrate alluvial channel forms. The channel is also working to regain a natural form in Reaches AM1, AM4 and AM-5.

Under existing conditions, the main branch of Tributary A is a dominant feature in the landscape and upstream of the woodlot.

Branch A2 is a dominant component of the Tributary A network. Although the drainage area is significant, the channel is undefined or poorly defined. This is due to the current diversion of flows from upstream of Branch A2, along the Trafalgar Road ditch to Reach A5-1 (see **Section 4.8.4.2**).

Review of the channel bed profile (**Figure 4.8.3**) and underlying surficial geology clearly reveals a generally concave up profile configuration (**Figure 4.8.6**) in Halton Till materials. The presence of clayey surface materials would be expected to reduce infiltration and contribute to overland flow patterns. This may, in part, account for a somewhat higher drainage density than reported in other headwater watersheds. It is likely that use of tile drains have reduced portions of the active surface drainage network, remnants of which are visible on aerial photography and/or which were identified as undefined features during the field inventory. Five potential tile outlets were identified along the main branch of Tributary A. However, only two of these outlets could be confirmed as active by the landowner and there was limited inferable impact on channel definition or geomorphological characteristics (see **Section 4.8.4.4**).

4.8.6.3 Tributary B

Tributary B is the most pronounced feature within the study area due to the deeply (up to 25 m high) incised valley. Review of site conditions revealed numerous valley wall contacts along the watercourse with some soil movement/slips (see **Appendix J** for geotechnical report). The predominant soil unit that was observed within the valley comprised Halton Till which has fine grained (silty) texture with some sand, clay and gravel. Sand and gravel was noted in the bottom of the upper valley but this material is believed to be thin (<1.0 m) and derived from erosion of the till (see geotechnical report in **Appendix J**). Alluvial stream deposits occur in the flat muddy area at the lower end of the valley. These recent deposits are expected to be < 3.0 m thick. No bedrock was exposed in the valley bottom.

The Tributary B drainage network has a similar density as that of Tributary A, reflecting the influence of the Halton Tills. The topographic landscape of the watershed is similar to the Tributary A watershed with its mottled appearance (on air photos) and surface depression storage elements.

The bifurcation ratio of Tributary B is considered to be relatively high, indicative of more efficient routing of the landscape (i.e., relatively more low order features that deliver water to the higher order receiving channels) (see discussion in **Section 4.8.2**).

The profiles of all watercourses tend to develop a concave configuration that is adjusted to a downstream base level control point (i.e., Silver Creek). For Tributary B, although Silver Creek is the base point towards which the profile would be adjusting, Eighth Line serves as a local control point since the grade of the channel is determined by the invert of the culvert. Review of the DEM generated channel bed profile (**Figure 4.8.7**) reveals a steep channel bed profile with a marked knickpoint through Reach BM-3. Given that the knickpoint is made of erodible materials (i.e., not hard bedrock), it is expected that headward knickpoint regression will occur, in conjunction with continued development of the Tributary B valley, until a lower grade concave up profile is attained. Upstream projection of slope unit BM-3 and the tableland channel profile (**Figure 4.8.3**) suggests that head of the valley may move 210 m upstream from its current position (**Figure 4.8.7**). Reviewing of mapping suggest that this point would occur either north of Side Road 15, or west of Trafalgar Road, depending on the trajectory of headwater movement.

Review of site conditions suggests that the Tributary B valley, especially through reaches BM3 and BM-2 is continuing to evolve. Through Reach BM-2, terracing observed within the valley bottom suggests that the valley has experienced several episodes of downcutting and thus deepening. In addition to defining erosion setbacks, consideration of the future expected valley form should be given when planning for adjacent land development.

Review of the channel bed profile (derived from DEM analysis) in the context of regionally available stratigraphic data (sources), suggests that the tableland reaches, including Reach BM-4 are situated within the uppermost Halton Till (silty clay) unit (**Figure 4.8.7**). All of the gully reaches (BX-2, B3-1, B4-1, B5-1) and Reach BM-3 along the main branch were steep and likely cut through the Halton Till into the Maple Formation (see **Section 4.3**). Observations of exposed till on the channel bed and of sand accumulation and exposure occurred in Reach BM-2 and BM-1. The sediment that originates from the valley along the Main branch of Tributary B is a source of sediment for the downstream watercourse. Further discussion of gully form and processes are described in **Section 4.8.5.1** and in **Section 4.8.7** within the context of erosion hazards.

Reach B1 is classified as intermittent, but has an undefined form. This apparent anomaly can be accounted for by the direct source of water within a vegetated depression, situated at the head of the reach.

4.8.6.4 Tributary C

The topographic setting and drainage network characteristics of Tributary C and its watershed varies from the remainder of the study area. Most notable is the single channel in its drainage network and the rolling topography. The drainage density of this subwatershed is much lower than in the remainder of the study area which, in addition to the single channel which was alternately classified as defined or undefined (**Table 4.8.16**) suggest that the area is not as quickly drained. Result of the flow assessment (**Table 4.8.17**) suggests that the watercourse conveys flows intermittently or ephemerally. There is a potential tile outlet located at the downstream end of Reach C-3 that may provide additional flow to Reach C-2. However, the pooling of water observed at this location is within a cultivated field and may also relate to receipt of surface waters from adjacent agricultural fields.

Review of the DEM generated channel bed profile (**Figure 4.8.3** and **Figure 4.8.8**) reveals a gradual slope that, within the study area, is situated on the Halton Till surficial geology unit. No concern for downcutting.

4.8.6.5 Influence of Tile Drains

As discussed in **Section 4.5.1**, tile drainage areas are present within the study area and historical data and site observations have been used to infer their influence on groundwater processes. Tile drainage may have historically reduced the active surface drainage network, with the location of the associated tile outlets influencing channel definition along receiving reaches due to additional flow inputs. As described in **Section 4.5.1 and Section 4.8.4** and summarized in **Section 4.8.4.4**, efforts have been made to locate tile drainage areas and outlet locations within the study area. The presence of tile drainage is predicted to have a limited influence on groundwater processes and only three tile outlet locations were confirmed as active with the landowner. Potential limited contemporary impacts on flow, channel definition and geomorphological processes were inferred along Reaches C-2, AM6, AM5 and AM3 (**Section 4.8.4.4**). While these tile drains will not be functional under the development scenario within the study area, the development will be associated with a stormwater management plan to manage additional overland flows associated with the increase in impervious area. As part of the latter, flows to maintain stream functionality along the tributaries currently potentially influenced by tile outlet inputs should be considered.

4.8.7 Erosion Hazards

Erosion is a natural process that occurs along all watercourses but becomes a hazard when this interferes with human activity, poses a threat to life and property, adversely affects water quality, or contributes to degradation of aquatic habitat. Delineation of erosion hazards, especially within the context of a subwatershed study that is intended to inform Secondary Development Plans, requires clear understanding of the stream and valley corridor configuration to ensure that appropriate landscape features are assessed. Findings from the geomorphologic and geotechnical assessments confirm that the watercourses are situated in both confined and unconfined settings.

Evaluation and delineation of erosion hazards within the study area included assessments of valley slopes and of watercourse tendencies. Analyses included both field and desktop components to define stable slopes and meander belts and are intended to be conservative so that they may be refined in the future during the EIR/FSS stage (Environmental Implementation Report/Functional Servicing Study).

4.8.7.1 Meander Belt

The meander belt refers to the lateral extent of floodplain occupation by a meandering watercourse both now and into the future. This includes natural planform evolution, and both cross-valley and downvalley migration. Protecting the meander belt area from encroachment within an urban development context serves the dual purposes of enabling a continuity of natural channel processes and of protecting public and private property and structures from erosion.

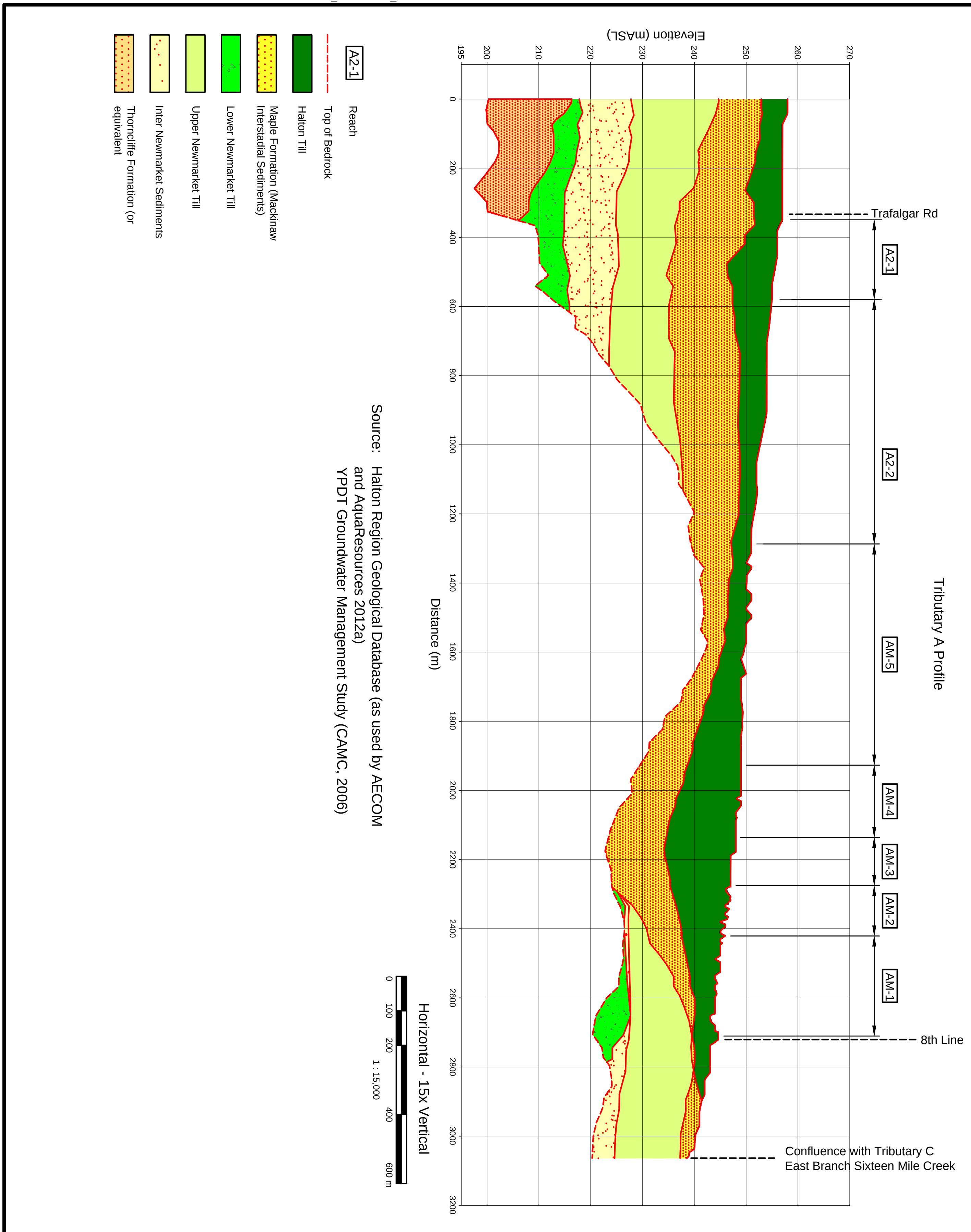
The ability of a channel to create its own channel form and to actively migrate across the floodplain presumes a shear dominated watercourse. This is in contrast to a watercourse whose position in the landscape, and channel form, is determined by other factors such as vegetation, topography, and groundwater.

Meander belt widths were estimated for reaches that exhibit a defined channel and contain perennial or intermittent flows with downstream connectivity.

A complete list of reaches for which the meander belt appeared to be an applicable approach to defining a channel corridor/erosion hazard limit is presented in **Table 4.8.17.** Meander belt width assessment was not considered applicable to the following reaches for the reasons stated below:

- Branch A2 and upper reaches of A4 (A4-4 and A4-3) since there is no defined channel along these reaches and therefore no channel dimensions on which to base even an empirical meander belt width.
- Tributary B – Slope stability analysis is the appropriate tool to define erosion risk for this tributary in a defined, deep valley (see **Section 4.8.7.3**)
- Tributary C - Reaches C-6, C-4 and C-2 are short localised sections in woodlots and a grassy lawn areas alternating with undefined/poorly defined reaches that are currently cultivated. There is therefore only ephemeral through flow along the length of this tributary. The use of meander belt width (a measure of erosion risk) is therefore not considered applicable in this case.

Any considerable change to these reaches, including realignments and/or changes to the channel dimensions will require that the meander belt be reassessed.

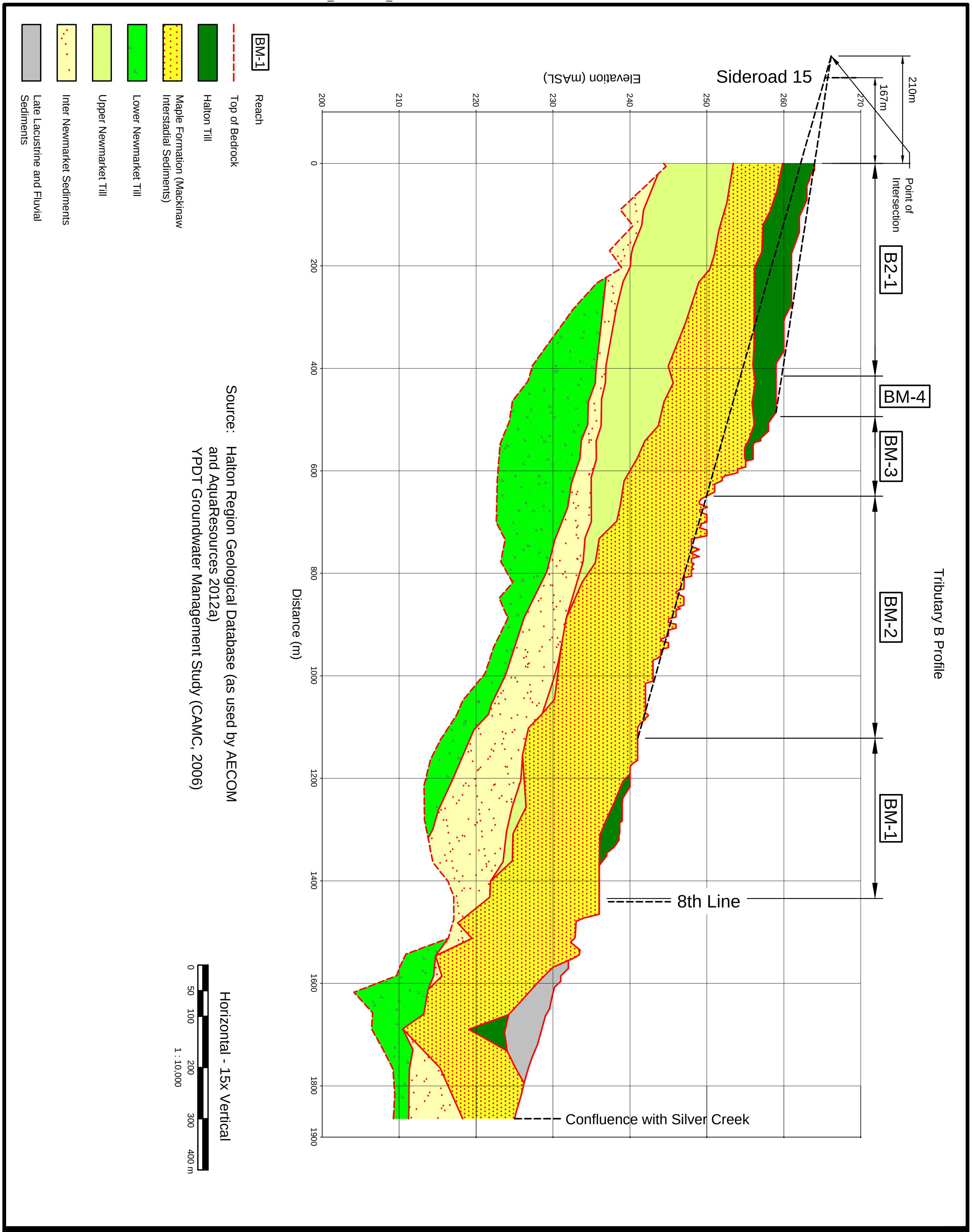


TRIBUTARY A CENTERLINE PROFILE WITH UNDERLYIING GEOLOGY
SOUTHWEST GEORGETOWN

AECOM

Project No.: 60297831 Date: 2013-08-22

Figure 4.8.6

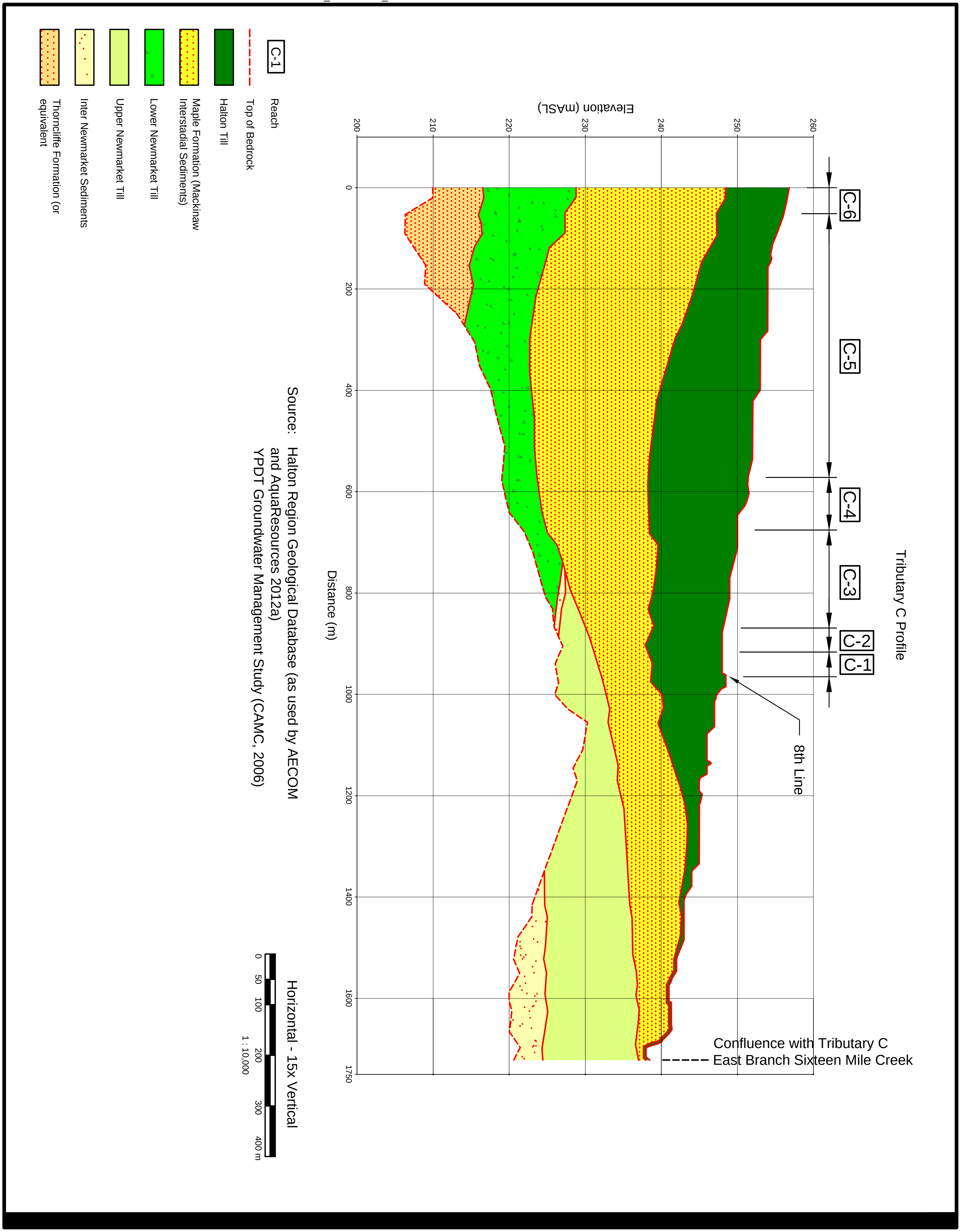


TRIBUTARY B CENTERLINE PROFILE WITH UNDERLYIING GEOLOGY
SOUTHWEST GEORGETOWN

AECOM

Project No.: 60297831 Date: 2013-08-22

Figure 4.8.7



TRIBUTARY C CENTERLINE PROFILE WITH UNDERLYIING GEOLOGY
SOUTHWEST GEORGETOWN

AECOM

Project No.: 60297831 Date: 2013-08-22

Figure 4.8.8

At the subwatershed level, delineation of the meander belt is typically based on a desktop review of topographic mapping. However, given the lack of a meandering form along most of the “defined” and “heavily modified” features, and limited visibility of alluvial features within the woodlots/valley for the air photo record, the meander belt could not be defined with this method. Instead, the meander belt was quantified as per TRCA (2004) Meander Belt Width Delineation Procedure which recommends that, when watercourses have been straightened and surrogate reaches are unavailable, that empirical relations be used instead to quantify the belt width. Input parameters include; upstream drainage area, 2 year flow event and slope. These parameters were derived using GIS analysis of the reach and catchment areas. The 2 year flow data reported in **Section 4.6** was extrapolated to all reaches upstream of the downstream flow node. The equations applied the two times factor of safety to account for anticipated changes in hydrology.

As previous stated, meander belt widths were estimated for reaches that exhibit a defined channel and contain perennial or intermittent flows with downstream connectivity (see **Table 4.8.17, Figure 4.8.5**). The TRCA empirical relation (TRCA, 2001) was developed for watercourses within the TRCA jurisdiction (**Equation 1**) and was considered applicable to the Tributary A main branch, (Reaches AM-1 to AM-6) with the exception of Reach AM-3 which is confined (see **Section 4.8.7.2**) and lower reaches of branch A4 only (Reaches A4-1 and A4-2). Estimates of the 2 year flow were prorated by area for each branch based on the nearest downstream flow node. Preliminary results of meander belt widths are presented in **Table 4.8.18**.

Equation 1: $M_b = -14.827 + 8.319 \ln(\Omega \times A_d)$ $r^2 = 0.74$ [Note: $\Omega = \gamma Q_2 S$]

Where M_b is the meander belt width (m); Ω is stream power (W/m^2); A_d is drainage area (km^2); γ is the specific weight of water (9792.3 kg m^{-2} s^{-2} at 20 °C), Q_2 is 2 year discharge (m^3/s), S is the longitudinal channel slope, and -14.827 and 8.319 are empirical coefficients of calibration.

Table 4.8.18 Preliminary Meander Belt Width Results for Reaches AM-1 to AM-6 (excluding AM-3)

Method	Defining Parameter	Mb – Preliminary Meander Belt Width (m)				
		Reach AM-1	Reach AM-2	Reach AM-4	Reach AM-5	Reach AM-6
TRCA (2001) Empirical Formula	Stream Power (W/m^2) and Drainage Area (km^2)	53.37	58.63	46.98	42.40	24.04
TRCA plus 2 standard errors (standard error = 8.63)		70.63	75.89	64.24	59.66	41.30

Results of the TRCA approach were not considered sufficiently conservative for Reaches AM7 and A5-1. It was considered more appropriate to base the meander belt width estimates for these two reaches on empirical relationships to depth (Collinson, 1978 (**Equation 2**)), drainage area (NRCS, 2007 (**Equation 3**)) and two equations representing the minimum and maximum estimates based on channel width (Williams, 1986 (**Equation 4**) and Malavoi et al,1998 (**Equation 5**)). Preliminary results of meander belt widths are presented in **Table 4.8.19**.

Equation 2: $M_b = 65.6 D_{max}^{1.57}$

Where M_b is the meander belt width (m); D_{max} is the maximum channel depth (m).

Equation 3: $M_b = 120 A_w^{0.43}$

Where M_b is the meander belt width (m); A_w is drainage area (mi2) (drainage area is converted to km^2)

Equation 4: $M_b = 4.3*W^{1.12}$
Where M_b is the meander belt width (m); and W is channel width (m).

Equation 5: $M_b = 10W$

Where M_b is the meander belt width (m); W is bankfull width (m)

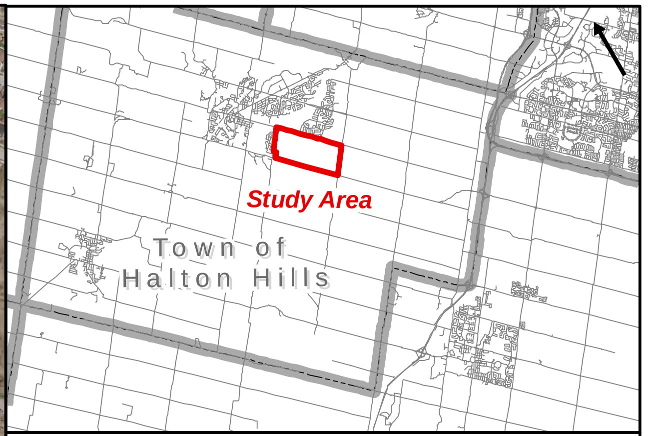
Table 4.8.19 Preliminary Meander Belt Width Results for Reaches AM-7 and A5-1

Method	Defining Parameter	Mb – Preliminary Meander Belt Width (m)	
		Reach AM-7	Reach A5-1
Collinson (1978) Empirical Formula	Maximum Depth (m)	29.4	7.4
NRCS (2007) Empirical Formula	Drainage Area (km^2)	15.7	25.5
Williams (1986) Empirical Formula	Width (m)	23.8	16.9
Malavio *et al.*. (1998) Empirical Formula	Width (m)	46.0	34.0
Average of Empirical Formulas		29	21

Results of the meander belt analyses are presented in **Table 4.8.20** and illustrated in **Figure 4.8.9**. These meander belts may be over-estimates of the actual meander belt and thus should be reviewed during detailed land use planning.

Table 4.8.20 Meander Belt Estimates for Defined, Alluvial and Selected Heavily Modified Features

Reach	Channel Form	Meander Belt (m)
AM-7	Heavily Modified	29
AM-6	Heavily Modified	42
AM-5	Heavily Modified	60
AM-4	Heavily Modified	65
AM-2	Alluvial	76
AM-1	Heavily Modified	71
A4-2	Defined	23
A4-1	Defined	36
A5-1	Heavily Modified	21



Legend

N

- Potential Head of Valley (Future)
- Potential Regression of Watercourse (Future)
- Conservation Halton 15m Erosion Setback[1]
- Erosion Hazard Limit
- Meander Belt

General Features

- Identified Reaches
- Reach Breaks
- Roads
- Study Area
- Conservation Authority Boundary[2]

Note
1. Credit Valley Conservations 14m erosion setback regulation was applied to the tributary B erosion hazard limit
2. Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600
Meters

Southwest Georgetown
Integrated Planning Project

Erosion Hazard Delineation

March 2017	1:10,000	Datum: NAD 83, Zone 17 Source: LIO, Region of Halton
P#: 60297831	V#: 004	

AECOM

Figure 4.8.9

P:\60297831 SW Georgetown\900-CAD-GIS\920 GIS-Graphics\Design\Final Report

4.8.7.2 Tributary A: Confined Reach AM3

For the purposes of erosion hazard delimitation, a confined system is defined as follows according to the Ministry of Natural Resources Erosion Hazard Technical Guidance:

> *"The watercourse is located within a valley corridor, either with or without a floodplain, and is confined by valley walls. The watercourse may be located at the toe of the valley slope, in close proximity to the toe of the valley slope (less than 15 m) or removed from the toe of the valley slope (more than 15 m) (MNR, 2001)."*

Reach AM3 along Tributary A meanders through a defined valley within which the valley walls are between 5m to 6m high. The channel is therefore considered to be confined, with alternate valley wall contact on the left and right bank within the reach. The empirical approach adopted for other reaches along this tributary is not appropriate for confined reaches, for which slope stability must also be taken into account.

For the purposes of calculating slope stability setbacks, the protocol outlined in CVC "Slope Stability Definition and Determination Guideline" was applied (CVC, 2011) based on field measurements taken at a typical valley cross section. According to the CVC guidance, the erosion hazard limit should comprise a Toe Erosion Allowance, a Stable Slope Allowance and an access easement.

Conservation Halton have indicated that reach AM3 is considered as a major valley system. Under Conservation Halton's Policy this means that a 15m development setback is required from the stable top of slope. Comments from Conservation Halton with regard to this study confirm that this 15m setback includes the 6m erosion hazard allowance, and should be termed an "Erosion Hazard Allowance". The overall erosion hazard limit in this case, therefore includes the following components:

- Toe Erosion Allowance: The available guidance provides a table of values for the minimum toe erosion allowance when the river is within 15 m of the slope toe (MNR, 2002, CVC, 2011). A value of 8m is appropriate for the type of soil present (cohesive soils, silty clays, clayey silts) and where active erosion is evident.
- Stable Slope Allowance: The determination of the location of a stable top of bank is based on a minimum stable slope allowance of 3:1 ratio according to the guidance. Where the slope is already shallower than 3:1 ratio, the slope component is zero.
- Erosion Hazard Allowance: The erosion hazard allowance is a development setback required by Conservation Halton and is 15m for major valley systems. It includes for emergency access to erosion prone areas, provides construction access for regular maintenance and access to erosion sites, and provides protection against unforeseen or predicted external conditions, as recommended by MNR (2001).

A schematic illustrating the different components of the setbacks for Reach AM3 is shown in **Figure 4.8.10** and the relevant values provided in **Table 4.8.21**. It is notable that the southwest (right) valley slope at the location where the field measurements were taken was already shallower than the 3:1 ratio, therefore, in practice the setback would be 23 m from the existing bank top (8m toe erosion allowance and 15 m erosion hazard allowance).

Figure 4.8.10 Schematic of Erosion Hazard Considerations for Reach AM3

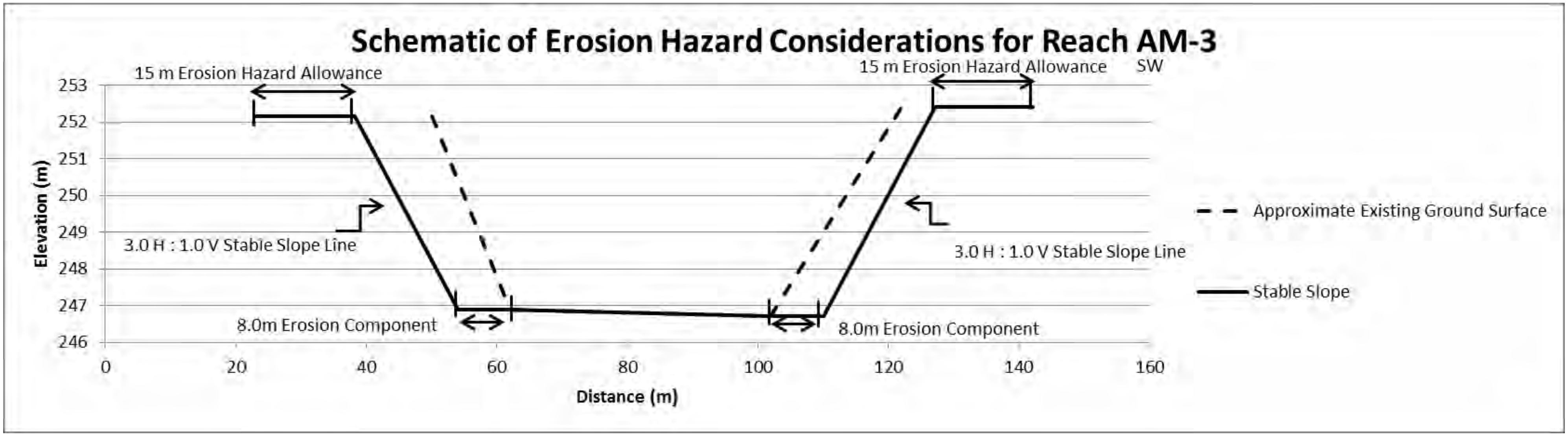


Table 4.8.21 Erosion Hazard Components for Reach AM3

Slope	Toe Erosion Allowance (m)	Top of Bank Height (m)	Stable Slope Horizontal Distance (m)	Erosion Hazard Allowance (m)	Erosion Hazard Width (m) from Slope Toe
Left Valley Slope	8	5.27	15.81	15	38.81
Right Valley Slope	8	5.70	17.10	15	40.1

The location of the slope toe from the watercourse varies throughout the reach with the channel meandering from one side of the valley to the other. The described approach is therefore conservative in applying a constant toe erosion allowance. The width of the valley also varies along the reach. Where the field measurements were taken, the valley floor was approximately 40m wide, giving a total erosion hazard width across the stream corridor of 118.91m.

4.8.7.3 Tributary B: Slope Stability Setbacks

As noted in **Section 4.8.6**, Tributary B flows through a relatively narrow and deep (up to 25 m high) valley. Given the valley form and confined condition of Tributary B within it, the meander belt is not an appropriate tool for defining the erosion hazard around this watercourse. Instead, the erosion hazard was defined according to the requirements outlined within the MNR (2002) Technical Guide: River and Stream Systems: Erosion Hazard Limit document. A geotechnical investigation of the study area was completed to inform the erosion hazard assessment. The geotechnical report and analytical results are in **Appendix J**. A summary of relevant findings, as they pertain specifically to the slope stability analyses is provided below, followed by a discussion of gully evolution

- Slopes are up to 25 m high and are generally inclined between 19 and 42^{o} to the horizontal
- Some steeper sections coincided with soil movements/slips.
- Erosion noted in the bottom of the tributary valley is more lateral than downward. The gradients are much steeper in the gullies than in the main valley and this leads to more downward erosion than lateral erosion (and the downward erosion leads to major side slope failures) within these gullies.
- The predominant soil unit that was observed within the valley comprised Halton Till which are mainly clayey silt and can be considered as a cohesive soil. This results in an 8m toe erosion allowance (CVC Geotechnical Guidelines, 2014). A preliminary geotechnical analysis was carried out on Tributary C (**Appendix J**). Additional boreholes and geotechnical laboratory testing are required at the EIR stage to conclusively determine the lithology of the Halton Till at the site, and determine the long term stable slope line.

The total setback from top-of-bank typically ranges from 25 to 50 m at Tributary B. The spatial extent of the erosion hazard limit is demonstrated on **Figure 4.8.9**. A borehole and a slope survey was completed to confirm the stable slope estimate of 3:1 along Tributary B (refer to **Appendix J**). Additional testing will still be needed at the EIR / FSS stage.

An additional preliminary assessment of the valley ‘gullies’ off of the main stem of Tributary B has also been completed to confirm the general location of the long term stable slope limit. **Figure 4.8.11** to **Figure 4.8.16** show the setbacks for Reach B5-1, B4-1, B4-2, B3-1, B3-2, and BX-1. It should be noted that these reaches are within the jurisdiction of CVC, and therefore an access allowance of 6m was applied (as required according to CVC, 2011), as opposed to the 15m development setback (erosion hazard allowance) specified by Conservation Halton.

All reaches, except B4-1, have existing slopes greater than 3 :1, therefore the total setback is based on the 8m Erosion allowance and the 6m Access Allowance, resulting in total setback from top-of-bank of 14m on both sides of the valley. Reach B4-1 has a larger setback due to the fact that the left valley slope (looking downstream) has a slope less than 3:1. This results in a total setback of 14m on the right bank and 23m on the left bank.

As noted within **Section 4.8.6.3**, the Tributary B valley, especially through reaches BM-3 and BM-2 has not yet attained a long term stable configuration and headward knickpoint regression is expected (see **Figure 4.8.9** for spatial extent). Continued development of the valley form is also expected, both through slope adjustments of exposed valley walls/banks as the Reach BM-3 portion adjusts to the incision and gully formation, and through reach BM-2 where the valley development has started to create a valley bottom and/or narrow floodplain. Evidence of terracing within the floodplain suggests that the watercourse has experienced several episodes of downcutting and that over time, continued valley wall retreat may occur.

Figure 4.8.11 Schematic of Erosion Hazard Considerations for Reach B5-1

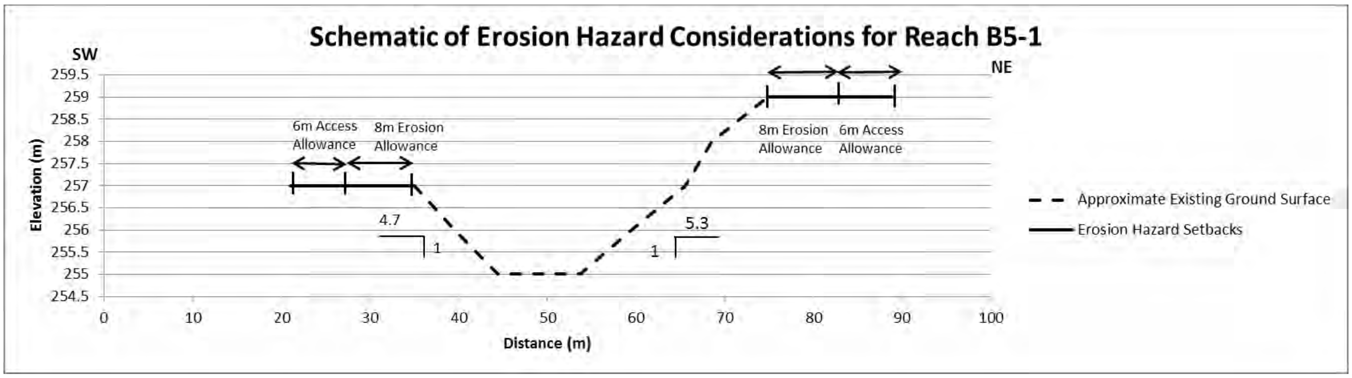


Figure 4.8.12 Schematic of Erosion Hazard Considerations for Reach B4-1

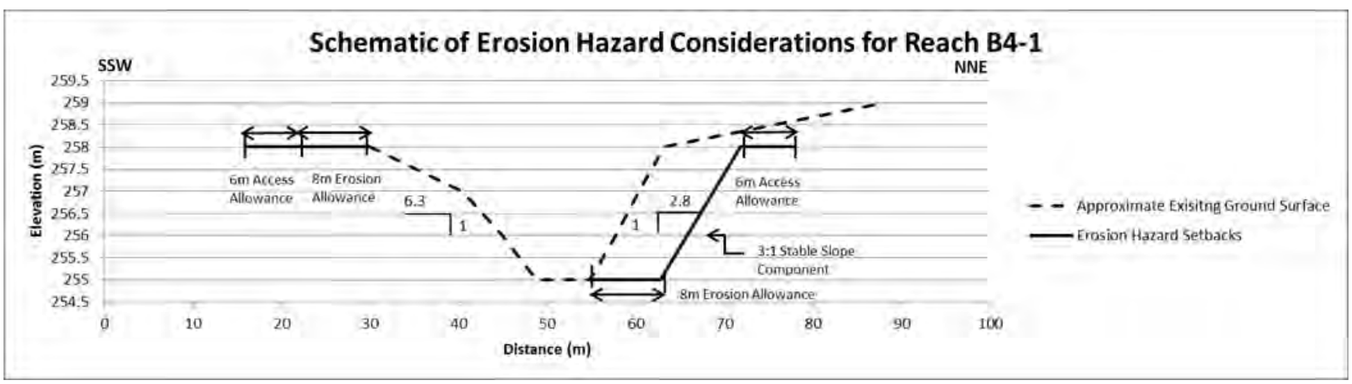


Figure 4.8.13 Schematic of Erosion Hazard Considerations for Reach B4-2

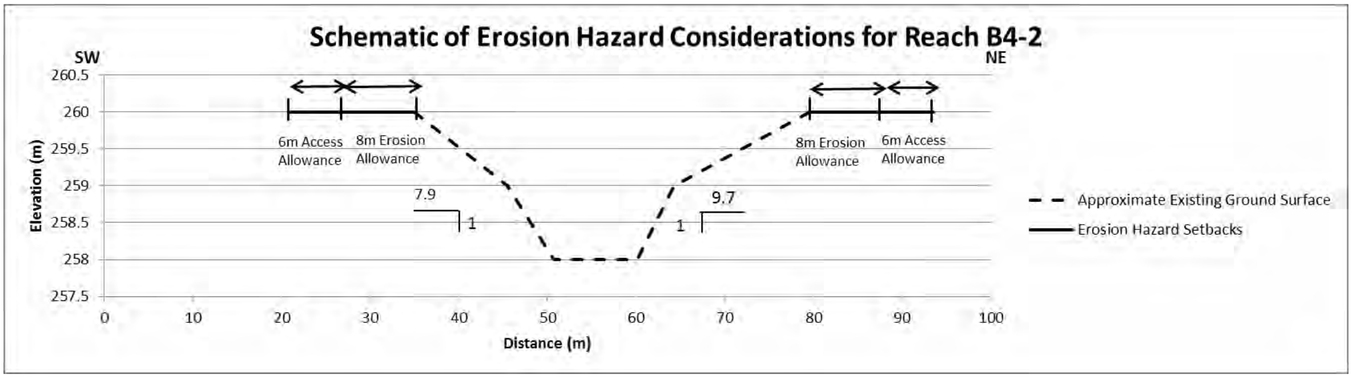


Figure 4.8.14 Schematic of Erosion Hazard Considerations for Reach B3-1

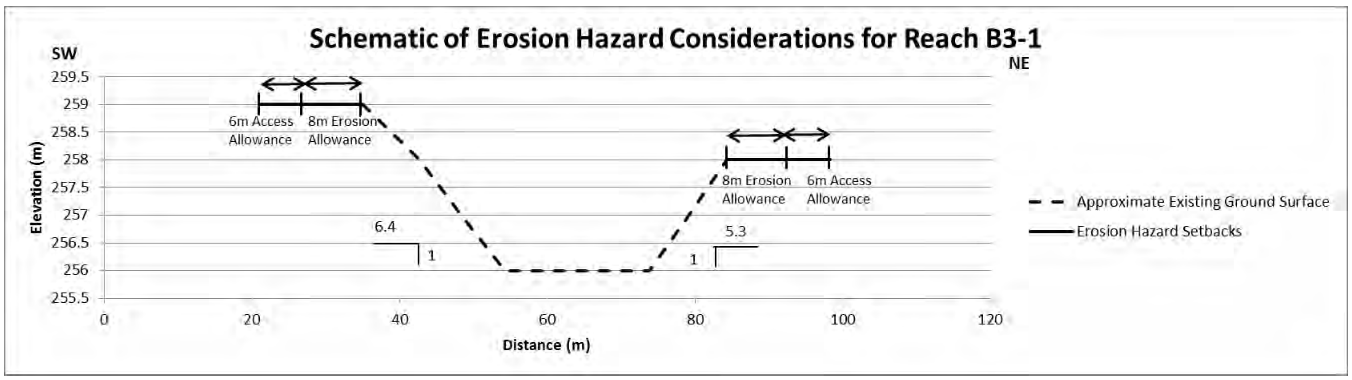


Figure 4.8.15 Schematic of Erosion Hazard Considerations for Reach B3-2

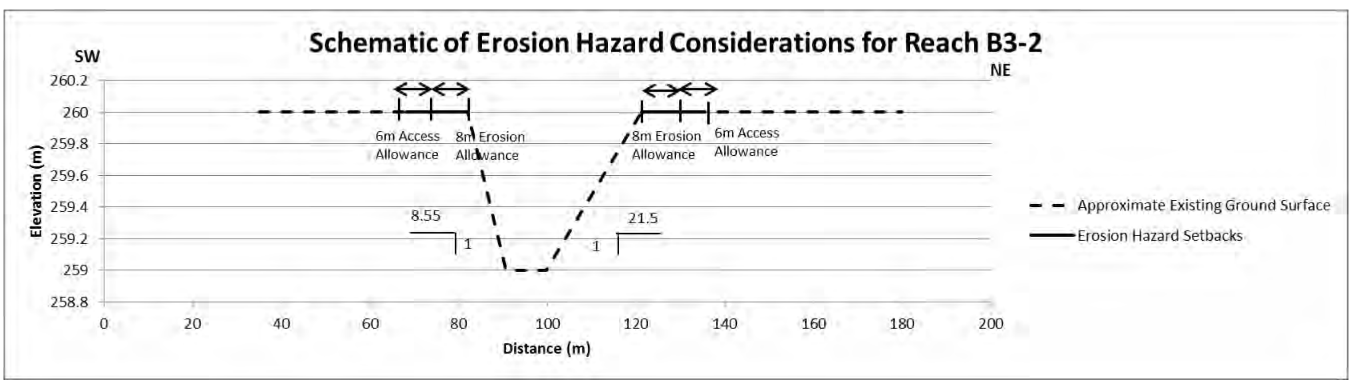
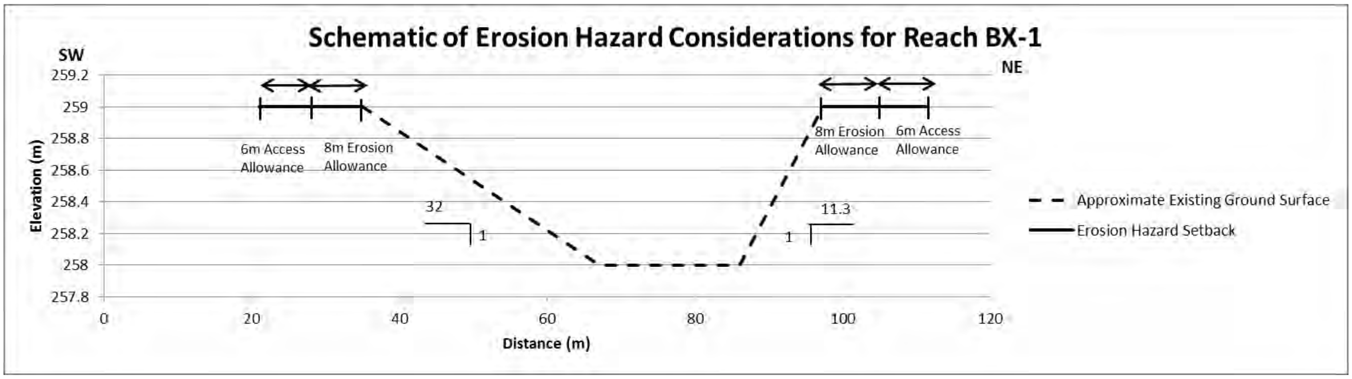


Figure 4.8.16 Schematic of Erosion Hazard Considerations for Reach BX-1



The geotechnical consultant (**Appendix J**) has recommended that the top-of-bank be surveyed in the field in order to allow detailed mapping of the setback on a plan. It may be possible to stabilize the gullies (Reaches B5-1, B4-1, B3-2, BX-1) by redirecting water flow away during site development, and partial infilling of the bottom. Such action would also reduce the bifurcation ratio of the Tributary B drainage network. Any actions that would reduce the forces that contribute to incision within the valley (i.e., reduce peak flows, reduce duration of flows) could reduce the rate of headward knickpoint regression and overall valley incision in Reach BM-3. Natural heritage functions would need to remain unaltered before this action would be considered acceptable.

Steep watercourses, such as BM-3, tend to develop self-stabilizing forms. In the study area, these forms included development of large woody debris jams. When regular maintenance and removal of large woody debris occurs, then the natural supplies needed to create the self-stabilizing forms may not be sufficient. When the mechanism for self-stabilization are absent, then the channel will incise and degrade more rapidly. Thus, future land management is recommended to consider the importance of natural large woody debris and sediment sources in promoting development of a stable feature within the landscape.

4.9 Natural Environment Existing Conditions

4.9.1 Vegetation

4.9.1.1 Methodology

Site visits were conducted on April 24, May 9, 14, June 21, and July 23, 2013 by Beacon Environmental terrestrial ecologists to document and characterize the vegetation within the secondary plan area. Vegetation communities were mapped and described according to the Ecological Land Classification (ELC) System for Southern Ontario (Lee et al, 1998). This involved delineating vegetation communities on an aerial photograph of the area, compiling a list of plant species in each community, and ranking the dominant plants species in each vegetation strata (canopy, subcanopy, understory, and ground layers). Soil samples were also taken in representative communities. Species of conservation concern, features of interest and sensitivity and evidence of disturbance were noted (**Appendix K**).

4.9.1.2 Vegetation Communities

Vegetation communities within the secondary plan area are shown on **Figure 4.9.1**. Much of the secondary plan area is comprised of active agricultural crop lands dominated by ploughed fields and row crops. The study area was divided into four main “natural feature” blocks (Blocks A-D, see **Figure 4.9.1**) where vegetation communities are more or less contiguous and primarily associated with a tributary feature. The following is a discussion of the vegetation communities within each of Blocks A, B, C and D.

Block A

This block includes vegetation communities associated with Tributary A, which originates at the southern corner of the plan area by a small isolated woodland and extends north and east to Eighth Line. This block includes the following vegetation communities:

- Unit 1a: Fresh-Moist Lowland Deciduous Forest (FOD7)
- Units 6b and 6c: Dry-Fresh Sugar Maple-White Ash Deciduous Forest (FOD5-8)
- Units 9h and 9i: Dry-Moist Old Field Meadow
- Unit 10: Reed Canary Grass Mineral Meadow Marsh (MAM2-2)
- Unit 18c: Cultural Thicket (CUT1)
- Unit 22: Fresh-Moist Sugar Maple Deciduous Forest (FOD6)
- Unit 23: Cultural Woodland (CUW1)
- Unit 24: Fresh-Moist Lowland Deciduous Forest (FOD7)
- Unit 26: Open Water Aquatic (OAO)

Legend

- Study Area
- Block
- ELC Communities
- Unclassified Watercourse
- Intermittent Watercourse
- Permanent Watercourse
- Subwatersheds
- Significant Woodlands [ROPA38, Section 115.3(1)]

Unit	Vegetation Community/Ecosite	ELC Code	Unit	Vegetation Community/Ecosite	ELC Code
1	Fresh-Moist Lowland Deciduous Forest	FOD7	15	Dry-Fresh White Pine Mixed Forest	FOM2
2	Redtop Mineral Meadow Marsh	MAM2	16	Black Locust Cultural Woodland	CUW1
3	Willow Mineral Deciduous Swamp	SWD4-1	17	Dry-Fresh White Ash Deciduous Forest	FOD4-2
4	Hawthorn Cultural Thicket	CUT1	18	Cultural Thicket	CUT1
5	Deciduous Cultural Woodland	CUW1	19	Dry-Fresh Deciduous Forest	FOD4
6	Dry-Fresh Sugar Maple-White Ash Deciduous Forest	FOD5-8	20	Barren	N/A
7	Fresh-Moist White Pine-Hardwood Mixed Forest	FOM9-1	21	Forb Mineral Meadow Marsh	MAM2-10
8	Fresh-Moist Poplar Deciduous Forest	FOD8-1	22	Fresh-Moist Sugar Maple Deciduous Forest	FOD6
9	Dry-Moist Old Field Meadow	CUM1-1	23	Cultural Woodland	CUW1
10	Reed Canary Grass Mineral Meadow Marsh	MAM2-2	24	Fresh-Moist Lowland Deciduous Forest	FOD7
11	Dry-Fresh Sugar Maple-Beach Deciduous Forest	FOD5-2	25	Hedgerow	H
12	Fresh-Moist Sugar Maple-Hemlock Mixed Forest	FOM6-1	26	Open Water Aquatic	OAO
13	Fresh-Moist Sugar Maple-Hardwood Deciduous Forest	FOD6-5	27	Cattail Mineral Shallow Marsh	MAS2-1
14	Black Walnut Cultural Woodland	CUW1			

Existing Vegetation Communities

Figure 4.9.1

SW Georgetown IPP RPP

First Base Solutions Web Mapping Service 2010

UTM Zone 17 N, NAD 83

0 125 250 500 Meters

1:10,000

BEACON ENVIRONMENTAL

Project 213002
August 2014

ELC Unit 1a is a small mesic deciduous forest patch, situated near the southern corner of the secondary plan area. Dominant canopy species include Green Ash (*Fraxinus pennsylvanica)*, Freeman's Maple (*Acer* x *freemanii*), Bur Oak (*Quercus macrocarpa*), and Ironwood (*Ostrya virginiana*), among others. The subcanopy consists predominantly of Green Ash, White Elm (*Ulmus americana*), and Common Buckthorn (*Rhamnus cathartica*). The understory includes Wild Red Raspberry (*Rubus idaeus* ssp. *strigosus*), Green Ash, Common Buckthorn, and Choke Cherry (*Prunus virginiana*). Dominant ground flora include Yellow Trout Lily (*Erythronium americanum*), Garlic Mustard (*Alliaria petiolata*), Running Strawberry-bush (*Euonymus obovata*), and Enchanter's Nightshade (*Circaea lutetiana*).

The current assemblage of species in this woodland is indicative of a mesic forest environment. However, the presence of a number of large Freeman's Maple suggests that swamp conditions likely existed in the past in this area, particularly on the northeast side where swamp may have been removed. There is an intake for an agricultural drain in the northern corner of this woodland that drains water to Tributary C. This has resulted in a localized change (drying) in the hydrology of the woodland. It is suspected that drainage conditions were altered as a result of agricultural development which resulted in drier conditions within the forest patch.

Unit 10 consists of a narrow band of meadow marsh vegetation along Tributary A. These features are dominated by Reed Canary Grass (a ubiquitous wetland grass in Southern Ontario), with occasional patches of Narrow-leaved Cattail (*Typha angustifolia*). Unit 26 is an off line pond adjacent to Tributary A and appears to be maintained by a permanent pump found beside the pond. There is limited wetland vegetation or function found in this unit likely due to the steep banks and absence of suitable shallow water. The area provides potential breeding amphibian habitat.

Units 6b, 6c, and 22 form a forest patch centred on Tributary A, which is dominated by mid-aged to mature Sugar Maple, with White Ash, Basswood, Red Oak (*Quercus rubra*), and Bitternut Hickory (*Carya cordiformis*), among others. Units 6b and 6c occur on the upland slopes and unit 22 is a narrow band situated within the floodplain. This forest block supports a number of spring ephemerals including Yellow Trout Lily, May-apple (*Podophyllum peltatum*), Bloodroot (*Sanguinaria canadense*), and Cut-leaf Toothwort (*Cardamine concatenata*). Yellow Trout Lily is particularly abundant within Unit 6b. Large mature trees including cavity trees are found along the edge of Unit 6b, including a group of trees on the south end. Unit 18c is a cultural thicket located on a higher ridge adjacent to Tributary A with a tributary that flows through the thicket, which include hawthorn, buckthorn with the ground cover largely dominated by grasses such as Smooth Brome. Woody debris and cover along the boundary of Unit 18c and 6b may provide habitat opportunities for wildlife.

Unit 9h is a meadow dominated by common old field grasses and forbs. This feature extends eastward as a narrow band along the upper banks of Tributary A. Within this area there is a small wetland component of Reed Canary Grass and Spotted Jewelweed along lower banks. Unit 9i is an area of overgrown grass situated around a dug pond (Unit 25).

Unit 24 is a very small lowland woodland patch situated along Tributary A at Eighth Line, which consists of Manitoba Maple (*Acer negundo*), Black Walnut (*Juglans nigra*), and Reddish Willow (*Salix x rubens*). Adjacent to this, is a cultural woodland comprised of White Cedar (*Thuja occidentalis*) and Black Walnut, which appear to have been planted along a dug pond (Unit 23).

Block B

This block is located on the east side of the secondary plan area along Eighth Line. It is comprised of mature forest, woodland, meadow, and thicket communities including:

- Unit 9g: Dry-Moist Old Field Meadow (CUM1-1)
- Unit 13: Fresh-Moist Sugar Maple-Hardwood Deciduous Forest (FOD6-5)
- Unit 14a and 14b: Black Walnut Cultural Woodland (CUW1)
- Unit 18b: Cultural Thicket

Unit 13 comprises the majority of Block B. This mature forest community has a canopy of Sugar Maple (*Acer saccharum*), Ironwood, Beech (*Fagus grandifolia*), American Basswood (*Tilia americana*), and other hardwoods, as well as occurrences of Easter Hemlock (*Tsuga canadensis*). Yellow Trout Lily is abundant in the spring. The woodland also supports a variety of other native ground covers include Enchanter's Nightshade, White Trillium, Running Strawberry Bush, various violets (*Viola conspersa, V. pubescens, V. sororia*), and Zig-zag Goldenrod (*Solidago flexicaulis*), among others.

Unit 14a and 14b are situated on the north side of the Block B. This woodland feature has a relatively open canopy of mid-aged Black Walnut, with occurrences of Bur Oak and Green Ash. The ground flora is dense with vines including Thicket Creeper (*Parthenocissus vitacea*) and Riverbank Grape (*Vitis riparia*) as well as herbs such as Enchanter's Nightshade, Avens (*Geum* spp), and Spotted Jewelweed (*Impatiens capensis*).

Unit 9g is a small moist old field meadow on the north side of the woodland block, which consists of typical old field species as well as some wet meadow vegetation along a small drainage. Dominant vegetation includes various grasses, Tall Goldenrod (*Solidago canadensis* var. *scabra*), Ellecampane (*Inula helenium*), and Spotted Jewelweed.

Unit 18 is small thicket community at the southern corner of the block, which is comprised of a mix of tall shrubs, notably Staghorn Sumac (*Rhus hirta*), Common Buckthorn, Hawthorns, and Common Apple (*Malus pumila*).

Block C

Block C is situated within the north-central portion of the secondary plan area and is comprised of a mix of forest, woodland, thicket, and wetland including the following:

- Unit 3c: Willow Mineral Deciduous Swamp (SWD4-1)
- Unit 4: Hawthorn Cultural Thicket (CUT1)
- Unit 5: Deciduous Cultural Woodland (CUW1)
- Unit 6a: Dry-Fresh Sugar Maple-White Ash Deciduous Forest.
- Unit 7: Fresh-Moist White Pine-Hardwood Mixed Forest (FOM9-1)
- Unit 8e: Fresh-Moist Poplar Deciduous Forest (FOD8-1)

Unit 3c is a small swamp community with an open canopy of willow, Trembling Aspen, and White Elm. The ground flora are dominated, almost exclusively, by Blunt Broom Sedge (*Carex tribuloides*). This community supports a small permanent pool (perhaps drying up in late summer) that supported an active breeding amphibian area as recorded from the 2013 surveys. Although no direct surficial connection in the form of a channel was observed between this area and Tributary B, outflow during high surface water events from the pool is toward Tributary B through BX-2 (see **Section 4.9.3** below). This creates a hydrological link between Block C and D across the subwatershed boundary (see **Figure 4.9.1**).

Unit 4 is situated along the western side of woodland block and extends in a narrow band along the northern edge. It is dominated by hawthorns (*Crataegus* spp), with occasional Black Walnut (*Juglans nigra*), Green Ash, and Common Buckthorn. Dominant ground flora includes Enchanter's Nightshade, mosses, avens (*Geum* spp.), and Thicket Creeper (*Parthenocissus vitacea*). Overall plant diversity is quite low, given the disturbed nature of the feature as well as the heavy shade below the hawthorns. Soils are sandy clay loam, with mottles evident at approximately 50 cm below grade, indicating very fresh soil moisture conditions.

Unit 5 is situated near the southwest corner of the woodland block. Canopy closure is approximately 50-60%, and consists of mostly of Green Ash, Black Cherry (*Prunus serotina*), White Pine (*Pinus strobus*), Black Walnut, and Trembling Aspen (*Populus tremuloides*). The subcanopy is dense with hawthorns and Common Buckthorn. Ground covers are relatively sparse and include species typical of disturbed woodlands, notably Enchanter's Nightshade, Garlic Mustard, Thicket Creeper, Wild Strawberry, and White Avens (*Geum canadense*). This woodland also contains inclusions of old field and meadow marsh vegetation, which established along old farm tracks.

Unit 6a, situated on the eastern side of the woodland block, is dominated by mid-aged to mature Sugar Maple, in association with White Ash (*Fraxinus americana*), American Basswood (*Tilia americana*), American Beech (*Fagus grandifolia*), and Ironwood (Ostrya virginiana), among others. The subcanopy and understory is dominated by Sugar Maple regeneration, with lesser amounts of White Ash, Ironwood, American Beech, and Choke Cherry. Ground flora cover and diversity is quite high, particularly in the spring with Yellow Trout Lily, White Trillium (*Trillium grandiflorum*), and other native wildflowers typical of mature Sugar Maple forests. Garlic Mustard is also scattered throughout and abundant is some areas. Soils are loam to sandy loam.

Unit 7, situated central portion of the woodland block, is a mature mixed forest community with a canopy of White Pine mixed with various hardwoods, notably Trembling Aspen as well as Green Ash, Red Maple (*Acer rubrum*), Sugar Maple, Bitternut Hickory (*Carya cordiformis*), and White Birch (*Betula papyrifera*), among others. The understory consists mostly of Common Buckthorn, Green Ash, Choke Cherry, and raspberries (*Rubus* spp.).

Within this forest, small-scale variations in topography have created a complex of shallow depressions supporting vernal pools in the spring and wetland flora in the summer. Ground flora diversity is fairly high, likely due to the complex microtopography supporting varying growing conditions. Dominant groundcovers include mostly common mesic forest species, notably Herb Robert, Garlic Mustard, Enchanter's Nightshade, and various ferns and sedges. Soils are loam to sandy loam, with mottles evident at approximately 50 cm, indicating moderately moist conditions.

Unit 8e is a small appendage at the northern corner of the woodland block, which is dominated Trembling Aspen.

Block D

This block is situated at the northern corner of the plan, primarily along Tributary B. This area is comprised predominantly of mid-aged to mature deciduous and mixed forests, as well as successional areas and several small wetlands. The following vegetation communities are included in Block D:

- Unit 1b: Fresh-Moist Lowland Deciduous Forest (FOD7)
- Unit 3a and 3b: Willow Mineral Deciduous mp (SWD4-1)
- Unit 8a, 8b, 8c, and 8d: Fresh-Moist Poplar Deciduous Forest (FOD8-1)
- Unit 9a, 9b, 9c, 9d, 9e: Dry-Moist Old Field Meadow (CUM1-1)
- Unit 11: Dry-Fresh Sugar Maple-Beach Deciduous Forest (FOD5-2)
- Unit 12a and 12b: Fresh-Moist Sugar Maple-Hemlock Mixed Forest (FOM6-1)
- Unit 16a and 16b: Black Locust Cultural Woodland (CUW1)
- Unit 15 Dry-Fresh White Pine Mixed Forest (FOM2)
- Unit 17a and 17b: Dry-Fresh White Ash deciduous Forest (FOD4-2)
- Unit 18a: Cultural Thicket (CUT1)
- Unit 19: Dry-Fresh Deciduous Forest (FOD4)
- Unit 20: Barren

- Unit 21: Forb Mineral Meadow Marsh (MAM2-10)

Block D contains a large tract of mature deciduous and mixed forest on very steep valley slopes, which includes ELC units 11, 12, and 15.

Unit 11 is dominated by Sugar Maple, in association with American Beech, White Ash, Black Cherry, and other hardwoods. Sugar Maple regeneration is abundant in the subcanopy and understory. The forest supports a high diversity and cover of spring wildflowers and other native ground covers, including Yellow Trout Lily, Virginia Waterleaf (*Hydrophyllum virginianum*), Wild Leek (*Allium tricoccum*), and White Trillium (*Trillum grandiflorum*).

Units 12a and 12b are mature mixed forest situated on steep lower valley slopes, which are dominantly of Eastern Hemlock (*Tsuga canadesis*) with Sugar Maple, White Ash, and Yellow Birch (*Betula allegheniensis*). Ground flora is generally sparse, but includes various ferns, Canada Mayflower (*Maianthemum canadense*), Wild Ginger (*Asarum canadense*), Jack-in-the-Pulpit, and Yellow Trout Lily.

Unit 15 is dominated by White Pine in association with hardwoods such as Black Locust and Sugar Maple. Dominant ground covers in this area include Virginia Waterleaf (*Hydrophyllum virginianum*), Garlic Mustard, False Solomon's Seal (*Maiantheumum racemosum*), and Yellow Trout Lily.

There are several mid-aged forest communities which are contiguous with the mature valleyland forests, which include ELC units 1b, 8a, 8c, 8d, 16, and 17.

Unit 1b is a small young to mid-aged lowland forest adjacent to Eighth Line which is comprised of predominantly of Green Ash and Black Locust.

Units 8a, 8c, and 8d are mid-age forests dominated by Trembling Aspen. Unit 8b is a small patch of Trembling Aspen that is not contiguous with the larger valley forest.

Unit 16 is a large woodland along Eighth Line comprised almost exclusively of young to mid-aged Black Locust which has regenerated on disturbed lands that were formerly used for aggregate extraction. Ground flora is dominated by Smooth Brome Grass.

Unit 17a and 17b are young to mid-aged forests comprised of White Ash in association with White Elm, Black Walnut, Red Oak, Trembling Aspen, and Black Cherry. Unit 17a is situated primarily on tableland and 17b occurs on a steep slope. Understory trees and shrubs include raspberries, White Ash, Common Buckthorn, and Black Walnut. Along the margins and in areas with less canopy cover, the ground flora is dominated by old field species, notably Tall Goldenrod and meadow grasses. In more established areas with greater canopy cover, the ground flora is comprised of woodland herbs such as Enchanter's Nightshade, Avens (*Geum* spp.), and Wild Strawberry (Fragaria virginiana), among others. A seepage area within Unit 17b supports wetland herbs and grasses such as Spotted Jewelweed, Rice Cutgrass (*Leerisa virginica*), Joe-pye Weed (*Eupatorium maculatum*), and Fowl Manna Grass (*Glyceria striata*).

Unit 19 is a scrubby forest patch with a mix of Trembling Aspen, Black Cherry, and Bitternut Hickory. Common Buckthorn is dense in the subcanopy/understory. This feature, though disturbed, supports a number of native ground covers including an abundance of Yellow Trout Lily, as well as scattered occurrences of Virginia Waterleaf, White Trillium, Jack-in-the-Pulpit, Blue Cohosh (*Caulophyllum gigantea*), and Bloodroot.

Wetlands within Block D included Willow swamp and meadow marsh. Unit 3b is a mid-aged swamp community situated within a sandy outwash in the floodplain at the northern corner of the block. This feature has a sparse to open canopy of Reddish Willow, Manitoba Maple, and White Elm. Ground flora is typical of moist to wet lowland forests, including Spotted Jewelweed, Forget-me-not (*Myosotis scorpioides*), Ostrich Fern (*Mattecia struthiopteris*), and Sweet Coltsfoot (*Tussilago farfara*). Iron staining observed in the watercourse and the early, robust growth of Ostrich Fern along unit 3b suggests the likelihood of localized groundwater contributions. The presence of dense patches of Ostrich Fern to the north of unit 3b along the toe of the ravine slope is also indicative groundwater expression near the surface.

Unit 21 is a small meadow marsh contiguous with unit 3b. This feature is consists of common wetland forbs, notably Purple Loosestrife (*Lythrum salicaria*), Joe-pye Weed, Panicled Aster (*Symphyotrichum lanceolatum*), and Sweet Coltsfoot.

Unit 3a is another willow swamp feature, which is situated up stream of the large valley forest. This small pocket wetland is surrounded by agricultural fields and appears to be sustained through "perched" surface water conditions resulting from an area of Halton Till. This material is known to hold surface water as infiltration rates are low and this has resulted in the development of a wetland pocket. The wetland has an open canopy of young to mid-aged Reddish Willow (*Salix* X *rubens*). Ground flora is dominated by Narrow-leaved Cattail (*Typha angustifolia*) and Reed Canary Grass. Overall diversity is quite low, likely due, in part, to past and ongoing agricultural disturbances. Soils are clay loam with mottles evident at 10 cm below grade, indicating very moist conditions.

Successional communities within Block D include old field meadow (Units 9a, 9c, 9d, 9e, 9f) and a cultural thicket dominated by Staghorn Sumac and Common Buckthorn (Unit 18a).

Other areas

Lands situated outside the four blocks described above are dominated by active agriculture fields with occasional hedgerows (ELC Unit 25), patches of old field meadow (ELC unit 9f and 9j), and existing residential/commercial areas. Within the agricultural fields there are a number of small depressions, which collect water during the spring. Most of these low spots are ploughed and farmed for crops. However, one small depression, ELC Unit 2, was found to support some wet meadow vegetation.

ELC Unit 2 consists of common wetland species typical of disturbed agricultural areas including Redtop (*Agrostis gigantea*), Foxtail Sedge (*Carex vulpinoidea*), smartweed (*Polygonum aviculare, P. periscaria*), Scentless Mayweed (*Matricaria perforata*), and rushes (*Junus* sp.). Soils are sandy loam, with mottles appearing at 10 cm below grade, indicating very moist conditions.

There is a series of vegetation units surrounding homesteads along Trafalgar Road that consist of old field (Unit 9k), cultural thicket (Unit 18d), cultural woodland (Unit 23b), hedgerows and two small wetlands. The wetlands are represented by Unit 21b (MAM2-10, 0.18 ha in size) and Unit27 (MAS2-1, 0.08 ha in size). The meadow marsh (MAM2-10) is dominated by Panicled Aster, Annual Ragweed, and Willowherbs, with occurrences of Beggar's Tick, Grass-leaved Goldenrod, Creeping Thistle, Bebb's Sedge, Curly Dock, and Reed Canary Grass. Broad-leaved and Narrow-leaved Cattail are scattered throughout. It appears that this feature may be periodically ploughed. The shallow marsh (MAS2-1) is dominated by Broad-leaved and Narrow-leaved Cattail, with occurrences of Beggar's Tick, Bebb's Sedge, Panicled Aster, and Bittersweet Nightshade.

4.9.1.3 Flora

To date, a total of 219 species of vascular plants have been identified in the secondary plan area. Sixty-nine species (32%) are considered non-native in Ontario according the Natural Heritage Information Centre (NHIC). This ratio of native to non-native species is fairly typical for sites in southern Ontario. As listed in **Table 4.9.1** no species that are considered to be rare in Halton Region (Crins et al, 2006) were identified. Nine species are considered uncommon in Halton Region (Crins et al, 2006). For the CVC watershed, seven species are considered to be rare (Credit Valley Conservation, 2002). These species are listed in **Table 4.9.1**.

Table 4.9.1 Regionally Rare and Uncommon Plants Occurring in Secondary Plan Area

Scientific Name[1]	Common Name[1]	Status			Location (ELC unit)
		S-Rank[2]	CVC/Peel[3]	Halton[4]	
Carex hirtifolia	Pubescent Sedge	S5	rare	HU	12, 15, 19
Carex tribuloides	Blunt Broom Sedge	S4S5	rare	HU	4c, 5
Caulophyllum giganteum	Blue Cohosh	S5	rare	H?	6a, 11, 19
Dicentra canadensis	Squirrel-corn	S5		HU	11
Dicentra cucullaria	Dutchman's Breeches	S5	rare	HU	11
Galium aparine	Cleavers	S5	rare		5
Impatiens pallida	Pale Jewel-weed	S5	rare		11, 16
Symphyotrichum urophyllum	Arrow-leaved Aster	S4	rare	HU	4
Hackelia virginiana	Virginia Stickseed	S5		HU	?
Claytonia virginica	Narrow-leaved Spring Beauty	S5		HU	
Prunus pensylvanica	Fire Cherry	S5		HU	?

[1]Nomenclature from FOIBIS (Newmaster and Ragupathy, 2012)
[2]Provincial status (Natural Heritage Information Centre). S4 = apparently secure; S5 = secure
[3]Regional Status for CVC Watershed/Peel Region (CVC, 2002)
[4]Regional Status for Halton (Crins et al, 2006). HU = Uncommon; H? = requires further study

4.9.2 Wildlife

4.9.2.1 Methodology

Amphibians

Breeding amphibian surveys were undertaken during the evenings after dusk on the dates noted below during suitable temperature conditions to listen for calling males. The survey dates are spread out so as to record different amphibian species that call during different times in the spring. These surveys were conducted to record the presence or absence of breeding amphibians from potentially suitable habitat. We utilized protocol from Marsh Monitoring Protocol (2008) during the assessments. The CWS survey method provides an indication of amphibian abundance during the breeding season using the following scale:

0 no calls;
1 individuals of one species can be counted, calls not simultaneous;
2 some calls of one species simultaneous, numbers can be reliably estimated; and
3 full chorus, calls continuous and overlapping (not countable).

All areas that contained potential breeding amphibian habitat (ponds, wetlands, etc.) were surveyed from a distance that would enable calling amphibians to be heard.

Anuran Call Count Survey Dates

Survey Date and Time	Surveyor	Weather
Apr. 18, 2013, 9:20pm-12:05am	Y. Scholten	Temp.: 15 -19 ^{o}C, Wind: 1, Precip.: damp hazy
May 21, 2013, 9:00pm-12:30pm	Y. Scholten	Temp.: 16 -18 ^{o}C, Wind: 0-2, Precip.: hazy/fog, damp.
Jun 28, 2013, 9:30pm-12:20am	Y. Scholten	Temp.: 17-18 ^{o}C, Wind: 0-1, Precip.: periods of light rain

Incidental observations of amphibians were also recorded during daytime site investigations. Woodland vernal pools were surveyed visually to locate amphibian egg masses, where these could be observed without undue disruption or disturbance to the habitat itself.

Where suitable log or bark cover was located, and could be lifted and searched without destroying the object, amphibians were sought opportunistically in wooded areas where salamanders are likely to make use of such cover.

Breeding Birds

Breeding bird surveys were undertaken when most breeding birds are singing (i.e., between late May and early July on the dates noted below). These surveys were conducted during morning hours, approximately from dawn until 10:00 am during suitable weather conditions. All birds that were either heard or seen using the site were recorded by means of walking surveys that would record all singing birds in the surveyed area. All birds observed or heard singing, in suitable habitat, were assumed to be breeding on-site.

All habitats were surveyed including agricultural fields, with particular attention paid to non-row crop fields (i.e., hayfields, old fields and pasture) to detect possible presence of Bobolink (*Dolichonyx oryzivorus*) and Eastern Meadowlark (*Sturnella magna*).

Breeding Bird Survey Dates

Survey Date & Time	Surveyor	Weather
Jun. 07, 2013, 6:00 am – 10:30 am	Y. Scholten	Temp.: 12 ^{o}C, Wind: 1, Cloud cover: 10/10, Precip.: light sporadic rain.
Jun. 10, 2013, 5:30 am – 9:30 am	Y. Scholten	Temp.: 15 ^{o}C, Wind: 0-1, Cloud cover: 9/10, Precip.: Light – moderate rain.
Jun. 17, 2013, 7:00 am – 10:30 am	Y. Scholten	Temp.: 19 ^{o}C, Wind: 1-2, Cloud cover: 7/10, Precip.: Rain, then clearing.
Jul. 01, 2013, 5:45 am – 11:00 am	Y. Scholten	Temp.: 17 ^{o}C, Wind: 1-2, Cloud cover: 10/10, Precip.: None.

Reptiles

Snake surveys were conducted by two methods:

1. Visual Encounter Surveys (VES) were conducted by actively searching for snakes during daytime site investigations. These were conducted during the morning hours from dawn to late morning, depending on cloud cover and ambient temperatures.

2. 28 Snake Covers were deployed in the spring (early May) and checked at regular intervals (approx. 2-weeks apart) thereafter during morning site surveys. The covers used were black polyethylene sheet plastic measuring 1.1 m x 1.6 m and secured to the ground with pegs or staples used for landscape fabric. These were located in sunny to partial shade locations (as much as microtopography and vegetation would allow) in a variety of habitats throughout the site. These included forest, forest-edge and meadow habitats and the cover sheets were situated to be approximately 150 to 200 m apart.

Covers were placed at habitat edges as much as possible since snakes are known to frequent edge habitat where various hunting opportunities overlap with varied thermoregulation sites. These animals can readily move to open, sunny areas to warm themselves, or retreat into shade or cover to cool off, or find refuge from rain or predators. It has the added benefit of making surveying more efficient and allows greater survey coverage.

Odonata (Dragonflies and Damselflies) and Butterflies

Odonates were surveyed incidentally by visual observation on May 21, June 07, 10, 17 and July 01, 2013. The majority of possible habitat types were sampled in these surveys, including woodland, wetlands, old fields and agricultural fields. These surveys were not conducted with a net and were based on visual observations. Additional formal surveys following standard protocol for odonata and butterflies were completed in 2014 on June 21st, July 12th and August 10th. Butterfly and most dragonfly/damselfly species were identified using binoculars. However, some species of bluet, meadowhawk and spreadwing were netted and examined using a hand lens (and released afterwards).

Owls

Surveys were completed using a modified version of the Atlas of Breeding Birds of Ontario Standardized Owl Survey Instructions Manual (Reference TBD). Each station was surveyed for approximately 20 minutes and consisted of:

- 2 minutes of passive surveys;
- 3 rounds of Saw-whet Owl (*Aegolius acadicus*) surveys;
- 3 rounds of Eastern Screech-Owl surveys;
- 3 rounds of Barred Owl (*Strix varia*) surveys; and
- 3 rounds of Great-horned Owl surveys.

Each species specific round consisted of approximately 30 seconds of active surveys where calls were broadcasted from the survey station which was immediately followed by 1 minute of passive listening. Passive surveys were also completed while traveling between survey stations.

Winter Wildlife

A winter wildlife survey generally involves identifying the tracks of wildlife in fresh snow to gauge the presence of the mammals present in a given area. Winter wildlife surveys were competed on January 30 and March 13, 2014 following fresh snow within past 24 to 48 hours during each survey. Compared to recent years there was above average snow cover, with snow pack last into early April. Average snow cover was between 0.45 m to 0.6 m during the surveys. Tracks were identified to species were possible and approximate numbers of animals or tracks were recorded. Any other wildlife signs were noted.

Incidental observations of other wildlife species, including mammals, were made during field investigations that were being carried out for other purposes.

4.9.2.2 Amphibians

Amphibians (frogs, toads and salamanders) are an important part of the ecosystem, in part because of their relatively large biomass and importance to the food web. The animals may make considerable seasonal movements between breeding and summer foraging habitat. They concentrate in preferred breeding areas (pools and wetlands) and so are sensitive to loss or disturbance of these areas. Thus, there is a need to assess and identify amphibian breeding, summer and winter habitat.

Based on review of aerial photographs, land classification mapping and knowledge of the study area, potential amphibian breeding sites were surveyed by auditory call count and visual observation in April, May and June, 2013. A total of six species were detected this way:

- American Toad (*Bufo americanus*)
- Spring Peeper (*Pseudacris crucifer*)
- Wood Frog (*Rana sylvatica*)
- Grey Treefrog (*Hyla versicolor*)
- Green Frog (*Rana clamitans*)
- Red-backed Salamander (*Plethodon cinereus*)

These are all common species in Ontario. They are all listed as either Common or Abundant in the Halton Region Natural Areas Inventory, 2006 Vol.2 Species Checklist. The breeding amphibian survey results are provided in **Table 4.9.2** below.

Table 4.9.2 Breeding Amphibians Recorded from the Study Area, April – June 2013

Survey Location	Survey Date	Species Observed	Species-Call Code (est. number of individuals calling)
BA1	Apr. 18, 2013	-	no calls
	May 21, 2013	American Toad	AMTO-2 (2)
	Jun 28, 2013	Green Frog	GRFR1 (3)
BA1a	Apr. 18, 2013	American Toad, Spring Peeper	AMTO-3 (6+), SPPE-1 (1)
	May 21, 2013	-	no calls
	Jun 28, 2013	-	no calls
BA2	Apr. 18, 2013	American Toad, Spring Peeper	AMTO-3 (6+), SPPE-1 (3)
	May 21, 2013	American Toad, Gray Treefrog	AMTO-3 (6+), GRTR-2 (5+)
	Jun 28, 2013	-	no calls
BA3	Apr. 18, 2013	Wood Frog, American Toad, Spring Peeper	WOFR-3 (6+), SPPE-1 (1), AMTO-2 (3)
	May 21, 2013	-	no calls
	Jun 28, 2013	Gray Treefrog	GRTR1 (1)
BA3a	Apr. 18, 2013	Wood Frog, American Toad, Spring Peeper	WOFR-1 (1), SPPE-1 (1), AMTO-2 (2)
	May 21, 2013	-	no calls
	Jun 28, 2013	-	no calls
BA4	Apr. 18, 2013	American Toad, Spring Peeper	SPPE-1 (2), AMTO-1 (1)
	May 21, 2013	-	no calls
	Jun 28, 2013	-	no calls
BA4a	Apr. 18, 2013	American Toad	AMTO-2 (3)
	May 21, 2013	-	AMTO-2 (2)
	Jun 28, 2013	-	no calls

Survey Location	Survey Date	Species Observed	Species-Call Code (est. number of individuals calling)
BA5	Apr. 18, 2013 May 21, 2013 Jun 28, 2013	American Toad - -	AMTO-2 (4) no calls no calls
BA5a	Apr. 18, 2013 May 21, 2013 Jun 28, 2013	- - -	no calls no calls no calls
BA6	Apr. 18, 2013 May 21, 2013 Jun 28, 2013	- - -	no calls no calls no calls

The results of the breeding amphibian surveys are further described based on the four natural feature Blocks (A, B, C, and D) as illustrated on **Figure 4.9.2**.

Block A

BA5

The meadow marsh community (MAM2-2, unit 10) along Tributary A was recorded to support four American Toads calling on April 13, 2013, and no calling amphibians in May or June. Adult Green Frogs were not heard calling along Tributary A on any of the survey nights, however, adults were observed in the water in Tributary A on June 07, 2013. This suggests that they may breed in the area.

BA 5a

Tributary A flows adjacent to but not through a small pond adjacent to Eighth Line before the stream crosses the road (see **Figure 4.9.2**). No amphibian calls were heard from this pond during the 2013 surveys. However, based on the observation of adult Green Frogs along Tributary A on June 07, 2013, it is possible this species uses this pond and/or slow-flowing portions of the upstream reach of Tributary A for breeding, though this has not been confirmed.

BA6

Tributary A flows adjacent to but not through the fresh-moist lowland forest (FOD7, unit 1a) that was surveyed for breeding amphibians. No amphibian calls were heard from this small woodlot and no vernal pools were observed during the 2013 surveys.

Block B

BA4

During surveys in the Block B woodland west of Eighth Line one American Toad and two Spring Peepers were heard calling on April 02, 2013, two American Toads in May and no calls were heard from this area in June. There are some low lying areas with inclusions of deciduous swamp along the north edge (CUW1, unit 14a) where the Spring Peeper activity was heard (in April) along with one American Toad.

BA4a

To the south of the Block B woodlot, there is an intermittent area of rainwater/melt-water pooling on the edge of the agricultural field adjacent to the residential houses. In April and May, this was the location of the majority of the American Toad activity in this area.

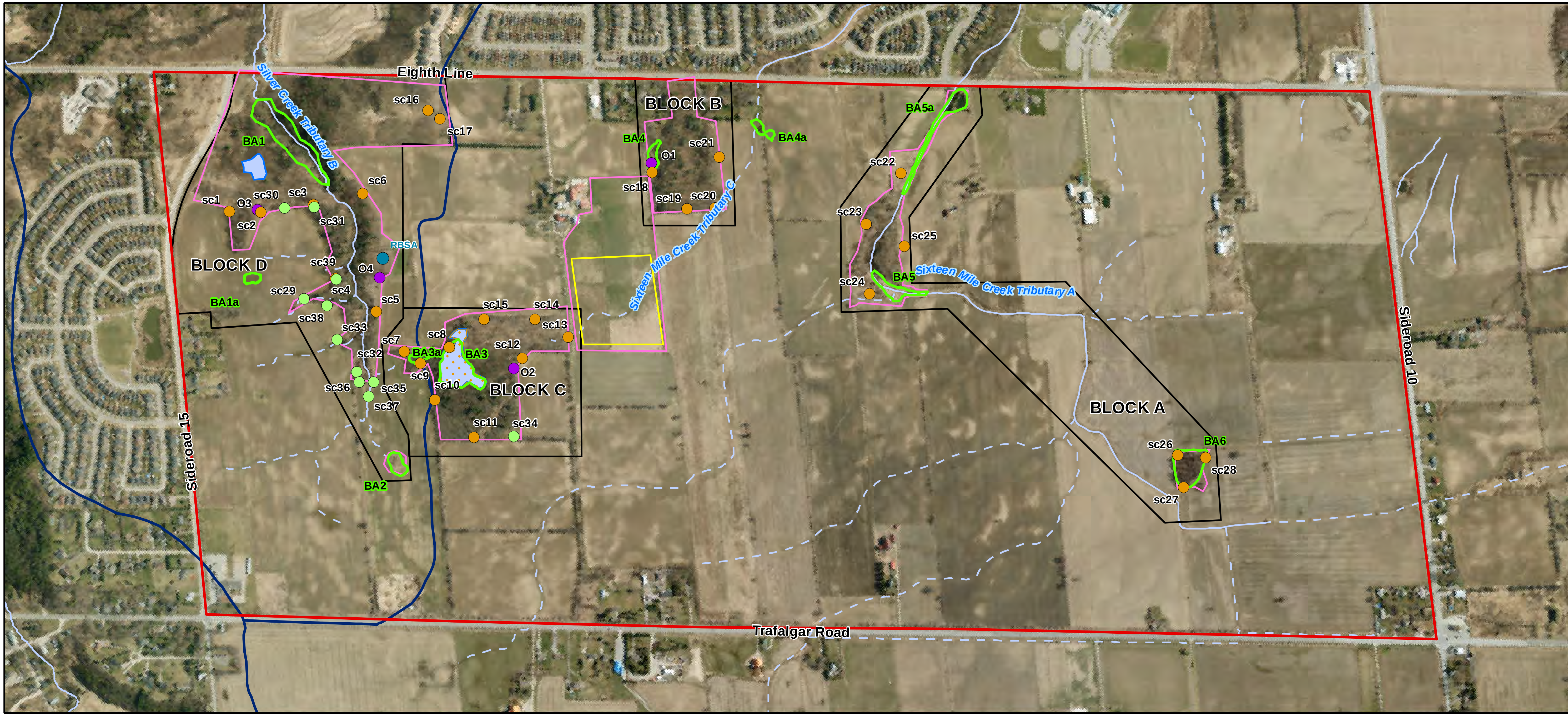
Block C

BA3

The fresh-moist mixed forest (FOM9-1, unit1) in the central part of Block C supports a series of scattered vernal pools of varying size and depth where there were a number of Wood Frogs (6+) calling in April, together with small numbers of Spring Peepers (1) and American Toads (3). In May, no calls were heard from BA3 as many of the pools started to dry. In late June one Grey Treefrog was calling from this area.

BA3a

There is a shallow permanent pool associated with a mineral deciduous swamp (SWD4-1, unit 3c) at this breeding amphibian station. The fresh-moist deciduous forest (FOD8-1, unit 8e) that surrounds the amphibian habitat provides a vegetated connection between Blocks C and D. The pool supports breeding amphibian habitat with calls recorded only in April consisting of small numbers of Wood Frogs, American Toads and Spring Peepers. Calling activity was not heard from BA3 during the May or June surveys, although daytime observations (June 17, 2013) found large numbers of frog (species not confirmed, but thought to be possible Spring Peepers due to small size) and American Toad tadpoles present in the water. An adult Wood Frog was also observed near the edge of this community on July 01, 2013 during a daytime survey.



Legend

- Study Area
- Block
- Breeding Amphibian Survey Point
- Breeding Amphibian Survey Area
- Vernal Pools

Snake Survey Locations

- Covers Installed
- 1 or more Specimens Found
- Owl Survey Point

Breeding Bird Habitat Blocks

- Bobolink – est. 7 pairs (Jun. 05/13, Jun. 17/13, Jul. 01/13.)
- Breeding Bird Habitat Blocks

- Subwatersheds
- Unclassified Watercourse
- Intermittent Watercourse
- Permanent Watercourse
- Significant Wildlife Habitat [ROPA38 Section 115.3(1)]

Survey Location	Survey Date	Species Observed	Call Code (est. number of individuals calling)
BA1	Ap.18/13	-	no calls
	My 21/13	American Toad	AMTO-2 (2)
	Jn 28/13	Green Frog	GRFR1 (3)
BA1a	Ap.18/13	A. Toad, Spring Peeper	AMTO-3 (6+), SPPE-1 (1)
	My 21/13	-	no calls
	Jn 28/13	-	no calls
BA2	Ap.18/13	A. Toad, Spr. Peeper	AMTO-3 (6+), SPPE-1 (3)
	My 21/13	A. Toad, Gray Treefrog	AMTO-3 (6+), GRTR-3 (5+)
	Jn 28/13	-	no calls
BA3	Ap.18/13	Wood Frog, Spr. Peeper, A. Toad	WOFR-3 (6+), SPPE-1 (1), AMTO-2 (3)
	My 21/13	-	no calls
	Jn 28/13	Gray Treefrog	GRTR1 (1)
BA3a	Ap.18/13	Wood Frog, Spr. Peeper, A. Toad	WOFR-1 (1), SPPE-1 (1), AMTO-2 (2)
	My 21/13	-	no calls
	Jn 28/13	-	no calls
BA4	Ap.18/13	Spr. Peeper, A. Toad	SPPE-1 (2), AMTO-1 (1)
	My 21/13	-	no calls
	Jn 28/13	-	no calls
BA4a	Ap.18/13	A. Toad	AMTO-2 (3)
	My 21/13	A. Toad	AMTO-2 (2)
	Jn 28/13	-	no calls
BA5	Ap.18/13	A. Toad	AMTO-2 (4)
	My 21/13	-	no calls
	Jn 28/13	-	no calls
BA5a	Ap.18/13	-	no calls
	My 21/13	-	no calls
	Jn 28/13	-	no calls
BA6	Ap.18/13	-	no calls
	My 21/13	-	no calls
	Jn 28/13	-	no calls

Snake Survey Location	Species Found	Date
sc29	Red-bellied Snake, Eastern Garter Snake	May 16, 21, July 01
sc30	Red-bellied Snake	16-May
sc31	5 Red-bellied Snakes	17-Jun
sc32	Red-bellied Snake	17-Jun
sc33	Red-bellied Snake	17-Jun
sc34	Eastern Garter Snake	1-Jul
sc35	Red-bellied Snake	1-Jul
sc36	Red-bellied Snake	1-Jul
sc37	Red-bellied Snake	1-Jul
sc38	Red-bellied Snake	1-Jul
sc39	Red-bellied Snake	1-Jul

Existing Wildlife Features

Figure 4.9.2

SW Georgetown IPP RPP

First Base Solutions Web Mapping Service 2010

UTM Zone 17 N, NAD 83

0 125 250 500 Meters

1:10,000

BEACON ENVIRONMENTAL

Project 213002
August 2014

Block D

BA1

Small numbers of American Toad (2 on May 13, 2014) and Green Frog (3 on June 28, 2013) were heard calling within the ravine stream of Tributary B. West of this area in the farm fields on the tableland were well-flooded and had many American Toads plus a few Spring Peepers were calling (see BA1a below). Also in the BA1 area, a Red-backed Salamander was located under a decaying log during a daytime survey on July 01, 2013 (see "RBSA" on Wildlife Map). This woodland has not been exhaustively surveyed for this species, and it is reasonable to assume that there is a population of Red-backed Salamanders present in this woodland. This is a terrestrial species which (unlike many other amphibian species) does not return to water to breed and consequently will not be located by surveys focused on the nearby water bodies or pools.

BA1a

A large area of rainwater/melt-water pooling was found on April 18, 2013 in the ploughed field on the tableland west of Tributary B. This area supported many calling American Toads (6+) and a Spring Peeper. This pool dried up thereafter (though rain events refilled it temporarily) and subsequent visits did not detect activity at this location. This pool and others formed on the agricultural fields were observed to support the majority of the American Toads in the study area. This species is well adapted to exploiting ephemeral pools where the tadpoles develop quickly and leave the pool before it dries completely (depending on weather conditions and periodic replenishment of the pools from rain events).

BA2

A small chorus of American Toads (6+) were heard calling in April and May, as were three Spring Peepers in April and about 5 Grey Treefrogs in May. By late June this area was somewhat drier, although still saturated, and no calls were heard.

No amphibian egg masses were observed during the spring surveys, which included several visual inspections of vernal pools and the pond. A Red-backed Salamander was located by Visual Encounter Searching on July 01, 2013. It was found under a decaying log along the upper slope of the Tributary B ravine forest (Block D: see **Figure 4.9.2**, label "RBSA").

No Species at Risk (SAR) amphibian species were detected during the 2013 surveys. The species present have varying sensitivity to disturbance. The American Toad is able to benefit from the extensive farm fields available here and is widespread throughout the site. Toads are abundant partly owing to their capacity to tolerate varying conditions and human disturbance.

Spring Peepers and Gray Treefrogs require seasonally flooded areas for breeding as well as marshy vegetation (Spring Peepers) or wooded areas (Treefrog) for shelter and feeding throughout the season. They are somewhat tolerant of human disturbance.

Wood Frogs are more sensitive to human disturbance and require well wooded forests or swamps to thrive.

Green Frogs require slow streams, ponds or other permanently flooded habitat for breeding and avoid shallow or seasonally flooded areas, as their tadpoles overwinter in the water body, maturing the following year.

Red-backed Salamanders prefer high quality woodlands with abundant leaf litter and fallen woody debris, especially decaying logs and standing dead trees (snags), in which they hunt, find shelter and lay their eggs. The female parent salamander broods and guards the eggs and hatchling salamanders. This species is fairly tolerant of human activity provided woodland habitat and its habitat elements (rotting logs, moist humus and abundant leaf litter) are conserved.

Vernal Pools

Vernal pools are generally small to medium sized areas of standing water found in forest depressions or other upland areas on the natural landscape. Vernal pools are also called ephemeral pools, as they are "short-lived", meaning that the standing water within them typically dries up at some point during the late spring or summer period. Vernal pools provide habitat diversity to forests and opportunities for various fauna and flora, often providing breeding habitat for amphibians. For amphibian eggs to mature successfully to a stage where they can survive outside of the vernal pool, it is typically necessary for standing water to last into June to early July (depending on the species and onset of spring conditions). Vegetation in and surrounding the pool, such as shrubs and emergent wetland plants, provides habitat structure allowing females of some species to attach their egg masses.

Vernal pools were located in the fresh-moist mixed forest (FOM9-1, unit7) community within the Block C woodland, as well as in the dry-fresh deciduous forest (FOD4-2, unit 17a) community on the tablelands to the north of the Block D ravine forest (see **Figure 4.9.2**).

The vernal pools of Block D exist in the wooded tableland north of the ravine. The pools were observed during daytime surveys in April, May and June. There were two main pools with additional scattered depressions that were shallow and covering an area approximately 50 to 60 m across. The pools had moderate structure, with emergent shrub and regenerating tree stems as well as some downed woody debris within and along the edge of the pools. The forest floor consisted of leaf litter with little herbaceous vegetation at the time of the surveys. The vernal pools appeared to be of moderately good quality as potential amphibian breeding habitat. However, no amphibian breeding activity was heard or seen at this location and the pools dried down in late April to mid-May (depending on depth), which helps to explain the lack of observations. No amphibian egg masses were observed here during daytime investigations. Rainy weather in June caused them to temporarily flood again, but again with no resultant breeding activity recorded. Despite the lack of amphibian observations from this vernal pool, the feature provides habitat diversity and is very likely used by other wildlife.

The vernal pools in Block C are considered a complex or aggregate of pools in an area of approximately 80 x 130 m in size. The scattered pools are surrounded by upland mixed forest. The pools are considered to be of higher quality and function (compared to those in Block D), with greater depth and longevity. These pools varied in size with some smaller (a few meters in width) and some larger (up to about five to seven meters in width). The pools had good structure, with emergent grass and forb vegetation, shrub and tree stems within and along the perimeter as well as downed woody debris. The trees in this forest are of varied size, with some older specimens present, and correspondingly, there is more large downed woody debris enriching the forest floor. The presence of decaying logs and standing snags greatly enriches the forest and contributes to support and provide habitat for a diversity of wildlife, including amphibians. Although amphibian egg masses are often difficult to detect, daytime visual observations of the vernal pools in April and May were undertaken. There were no egg masses observed. However, the vernal pools in Block C are located where four different species of breeding amphibians were heard calling (see **Table 4.9.2**), including Spring Peepers, Wood Frogs, American Toads and Gray Treefrogs. Thus these pools appear to provide amphibian breeding habitat. Though no salamander species have been observed at this location to date, the habitat may be suitable for these animals. Vernal pool quality is considered to be low to moderate based on the longevity of the pools and extent of habitat structure (i.e., emergent shrubs/vegetation for attachment of eggs).

4.9.2.3 Birds

A total of 44 breeding bird species were observed on the site (**Appendix L**) over 4 survey dates (June 07, 10, 17 and July 01, 2013). Four additional species were noted by Halton Conservation staff on May 14, 2013 during a site walk consisting of Black-throated Blue Warbler (*Setophaga caerulescens*) in Unit 7/6a, Spotted Sandpiper (*Actitis macularius*) in Unit 9j, Warbling Vireo () in Unit 9i and Canada Goose (*Branta canadensis*) in Unit 6c. Most species recorded, as well as the most abundant species in the study area, were common, rural, disturbance-tolerant species. The most abundant species were: Savannah Sparrow (*Passerculus sandwichensis*), Song Sparrow (*Melospiza melodia*), American Goldfinch (*Spinus tristis*), Red-winged Blackbird (*Agelaius phoeniceus*), American Robin (*Turdus migratorius*), and Killdeer (*Charadrius vocifereus*).

Of these, seven species are 'area sensitive' (The Black-throated Green Warbler (Setophaga virens) observed on May 13, 2013 is considered to be a non breeding migrant). These are: White-breasted Nuthatch (*Sitta carolinensis*), Hairy Woodpecker (*Picoides villosus*), Pileated Woodpecker (*Dryocopus pileatus*), Black-and-White Warbler (*Mniotilta varia*), American Redstart (*Setophaga ruticilla*), Savannah Sparrow (*Passercula sandwichensis*) and Bobolink (*Dolichonyx oryzivorous*). The first five of these are woodland/forest species found in the woodlots onsite. The last two species, Savannah Sparrow and Bobolink, are grassland species that are found in open habitat including agricultural fields, especially fallow and hay fields, throughout Ontario.

Two of the species found are listed as SAR, Threatened Species in Ontario: Bobolink and Barn Swallow (*Hirundo rustica*) (THR). Additionally, Eastern Wood Pewee (*Contopus virens*), which is ranked Special Concern both federally and provincially, was found. Also the Wood Thrush (*Hylocichla mustelina*), which is rank Threatened federally and Special Concern provincially was found in the forest stands of Block A and B.

None of the species observed are provincially "rare" (i.e. critically imperiled, imperiled or vulnerable as ranked by Natural Heritage Information Centre) (S1-S3 rank).

The results of the breeding bird surveys are further described based on the four natural feature Blocks (A, B, C, and D) as illustrated on **Figure 4.9.2**.

Block A

The forest complex along Tributary A is small but supports some degree of habitat diversity, including meadow marsh (MAM) and thicket (CUT) communities at the western end, and old field meadow (CUM) and meadow marsh (MAM) communities at the eastern end with a central deciduous forest in between (see **Figure 4.9.1** and **Figure 4.9.2**). The central forest community is large enough to support some forest species such as Northern Flicker (*Colaptes auratus*), a species that is enough of a generalist to utilize a mosaic of open and treed communities), White-breasted Nuthatch, Red-eyed Vireo (*Vireo olivaceus*) and Great Crested Flycatcher (*Myiarchus crinitus*). This forest community is not very large, but it may be large and undisturbed enough to support a few breeding pairs of forest species. In the varied communities at the edges of the forest complex of Block A, species typical of those habitats were found. For example, Brown Thrasher (*Toxostoma rufum*) was found in the cultural thicket, while Common Yellowthroat (*Geothlyphis trichas*) was found in the meadow marsh. In the meadow on the east, were Song Sparrow and Savannah Sparrow. A Warbling Vireo (Vireo gilvus) was observed near the man-made pond along Eighth Line, while species such as Spotted Sandpiper (Tringa solitaria) were observed in open old field meadows and areas of standing water in fields.

The isolated woodland did not exhibit high levels of avian activity or diversity, most likely due to the features' small size and isolation. The fresh-moist lowland deciduous forest (FOD1, unit 1a) does support some forest species as well as generalists like the American Robin. Woodpeckers such as Northern Flicker, Downy Woodpecker (*Picoides pubescens*) and Red-bellied Woodpecker (*Melanerpes carolinus*) were repeatedly observed in this woodland. Of the other species present, most, such as the Blue Jay (*Cyanocitta cristata*), Chipping Sparrow (*Spizella passerina*), Song Sparrow, American Robin and Northern Cardinal (*Cardinalis cardinalis*), are tolerant generalist species. The Eastern Towhee (*Pipilio erythrophthalmus*), however, is a scrubland and forest species that is usually more reclusive and moderately sensitive to disturbance. Species characteristic of wetlands were not found at either of these small wetland communities.

Block B

This forest complex is somewhat less diverse than the forest community along Tributary A. However, the overall rectangular shape of the woodland reduces the edge-to-interior ratio to make it more attractive to certain forest species. Hairy Woodpecker (*Picoides villosus*), Downy Woodpecker, Northern Flicker, Eastern Wood Pewee, Wood Thrush, Red-eyed Vireo, Baltimore Oriole (*Icterus galbula*) and Indigo Bunting (*Passerina cyanea*) are species typically associated with wooded areas, although most of these are tolerant of a wide range of tree density and will utilize open and disturbed woodlands frequently.

Block C

The woodland area associated with Block C is connected to Block D and the Tributary B ravine by a narrow treed strip of vegetation communities including deciduous swamp (SWD4-1, unit 3e) that supports a pool and deciduous forest (FOD8-1, unit 8e). No wetland species of birds were observed from this area, other than the Common Yellowthroat, a species which often exhibits a preference for marshes, swamps and other wet or wetland habitats. The species found here are characteristic of forest habitat, such as Red-bellied Woodpecker, Downy Woodpecker, Eastern Wood Pewee, Great Crested Flycatcher, White-breasted Nuthatch, Red-eyed Vireo, American Redstart (*Setophaga ruticilla*), Black-and-white Warbler (*Mniotilta varia*), Baltimore Oriole and Indigo Bunting.

Some of the species present (White-breasted Nuthatch, Black-and-white Warbler, American Redstart) are area sensitive and may be present in part due to the close connection between Block C and D.

Additionally, one or more Red-tailed Hawks were observed in the vicinity of Block C and the Block D ravine forest to the north on multiple days during the 2013 surveys. No stick nests were found during spring 2013 site investigations but it is possible that a mated pair of this species is utilizing one of these two woodlots as nesting habitat. Observed hawk behaviour included hunting, circling while calling in agitation and on one occasion (June 07, 2013), carrying a snake (potentially a Garter Snake, judging by size and commonness of the species in the vicinity) in its talons as it flew towards the Tributary B ravine forest from Block C.

Block D

The ravine forest complex along Tributary B is the largest and most diverse habitat within the study area. It includes wetland (along the stream), upland meadow and thicket, as well as mixed and deciduous forest, of which some is relatively open, while other areas are dense and have dense undergrowth. Not surprisingly, it was found to have the largest diversity of bird species present (mostly forest or generalist species), including four area sensitive species. These were the Pileated Woodpecker (Dryocopus pileatus), Black-and-white Warbler, American Redstart, Black-throated Green (Dendroica coronata) and White-breasted Nuthatch. The only characteristically wetland species found was the Common Yellowthroat, which inhabits the swamp and thicket habitat along the stream at the bottom of the ravine.

Isolated Swamp of Block D: This isolated SWD is situated in the fields west of Block C, at the western end of Block D. As with the isolated swamp of Block A, this northwestern isolated swamp is very small and the birds observed there (Song Sparrow, American Robin and Savannah Sparrow) are highly tolerant field or generalist species making use of the few trees and shrubs present there. Species characteristic of wetlands were not found at either of these small wetland communities.

Pasture Field

There is a pasture located between Block B and C that is actively being used for grazing by the operational farm still present in this area for a flock of sheep. This field is permitted in places to grow relatively dense and tall, particularly to the west end of it. This gives the field a tall grass-forb character that provides habitat for grassland birds, and in particular Bobolink. Savannah Sparrows are abundant here, with Song Sparrows being the second most common species. However, it is most notable for several pair of Bobolink observed here on each breeding bird survey date. On the date with the lowest activity, only two males were observed, but at activity peaks, seven males and four females were observed. Males were observed singing, and defending territories. Thus seven pairs of Bobolink are thought to be nesting here. No incidental nests were found, and as per MNR recommendations, in order to minimize disturbance to the birds, they were not searched for. Following the 2014 field surveys the pasture lands were ploughed resulting in the removal of grassland habitat.

Immediately adjacent to the pastureland, to its southwest, is a small ploughed field where winter wheat was growing during the surveys. One male Bobolink was observed using this field. This is not high quality Bobolink habitat and no others were seen in this area suggesting opportunistic use potentially by a young male Bobolink.

Barn Swallows were also observed at the pasture field, foraging aerially. Six Barn Swallows were seen during the breeding bird surveys. Permission was not pursued to approach or enter the farm buildings, so no surveys for nests or counts were attempted. It is to be presumed however, that the barn, tool shed, and other outbuildings on the property would provide nesting habitat opportunity for this species. It is also possible that suitable structures are available on parts of the study area.

Ploughed and Row-crop Fields

The agricultural fields on the tablelands have been treated together in this instance, due to their generally uniform character and bird species present. All are ploughed row-crop fields with hedgerows separating fields in some locations. The species observed here are broadly of two types; ground-nesting birds which utilize the open habitat present, such as Killdeer, Horned Lark (*Eremophila alpestris*) and Savannah Sparrow; and secondly, shrub/tree nesting birds which forage on the open ground, but utilize the occasional shrub or hedgerow tree for nesting, such as the American Robin, Northern Cardinal and Brown Thrasher. No SARs or rare species were located in these fields with the exception of one field noted below.

Avian Species at Risk

Three species at risk were recorded on the subject lands by Beacon Environmental; Bobolink, Eastern Wood Pewee and Barn Swallow. Both the Barn Swallow and the Bobolink are listed as Threatened nationally (by the Committee on the Status of Endangered Wildlife in Canada [COSEWIC]) and provincially (by the Committee on the Status of Species at Risk in Ontario [COSSARO]), and as mentioned earlier are therefore protected by the provincial Endangered Species Act (ESA), 2007. Both the individual birds and their habitat are protected under the Act. They have been listed as Threatened due to recent population declines. Nevertheless, both species are still quite common and widespread throughout southern Ontario, and primarily use human-created or modified habitats in Ontario.

Eastern Wood Pewee is a federally and provincially listed Special Concern species. It is ranked S4 in Ontario, but is still a common woodland species, especially of deciduous woodlands. It is not protected under the provincial ESA, as it is not listed provincially (by COSSARO) as Threatened or Endangered. This species was observed and heard calling in three woodlots on site from Block B, Block C and Block D. Any change (i.e., SAR designation) in the provincial status of this species will have to be taken into consideration.

Bobolink

The Bobolink is a bird of open grasslands. Specifically, it is an area-sensitive specialist of large open upland meadows, especially older (five to ten year-old) hay fields. An estimated 700,000 Bobolinks occur in southern Ontario south of the Canadian Shield (Cadman et al. 2007).

Several Bobolink, including females, but mostly males, were recorded in June 2013 in the pasture field of the active farm located between Block B and Block C. Eleven (7 males and 4 females) were counted June 07, 2013, four (3 males and female) on June 17, 2013 and five (3 males, 2 females) on July 01, 2013. One Bobolink male was observed to be using the adjacent wheat field as well.

We conclude that seven pair of Bobolink are using this site for breeding, roosting, shelter and feeding and that the pasture field represents habitat for Bobolink, which is protected under the provincial Endangered Species Act (2007). Following the 2014 field surveys the pasture lands were ploughed resulting in the removal of grassland habitat.

Barn Swallow

Barn Swallow is an open land species, which nests primarily in barns and similar buildings and feeds aerially over fields, meadows and bodies of water. It has been listed because it is "has experienced very large declines that began somewhat inexplicably in the mid to late 1980s in Canada" (COSEWIC 2011).

The Barn Swallow is an aerial insectivore which utilizes vertical surfaces with some form of overhang or enclosure for nesting, and these are often found in human structures such as barns. They forage in open grassy fields, and often over water bodies such as ponds or lakes. Historically in eastern North America, the species benefited from human clearing of the forests coupled with the erection of barns, however, like many species of open country habitats, populations in Ontario and other jurisdictions are thought to have declined.

Barn swallows were observed in small groups (one, two or three at a time) on all survey dates in June. They were observed using the pasture field of the active farm and the open fields in the vicinity of Tributary A, west of the isolated woodland (unit 1a). In this area, they were observed to forage along the stream and to a lesser extent adjacent to the stream.

The swallows in this part of the study area may be nesting offsite as no barns or other suitable structures exist any longer in this area. The swallows observed in the pasture field are likely nesting in the barn and other farm outbuildings of the active farm in this part of the study area.

4.9.2.4 Reptiles

Two species of snakes were recorded during spring and summer surveys:

- Eastern Garter Snake (*Thamnophis sirtalis*)
- Northern Red-bellied Snake (*Storeria occipitomaculata*)

Snakes were located under both natural and installed covers throughout May, June and July. None, however, were located at any woodlands or habitats other than the Tributary B ravine forest of Block D and at the southern corner of the woodland associated with Block C (see **Figure 4.9.2**).

In Block C), only one Eastern Garter Snake was located, basking at the forest-field edge at the southwest corner. It was a large adult (est. 60 cm long).

Around the edge of the Tributary Block D forest, 3 Eastern Garter Snakes and a total of 15 Northern Red-bellied Snakes were found during surveys on May 16, May 21, June 07, June 17 and July 01, 2013. One additional snake was observed being carried from Block D in the talons of a flying Red-tailed Hawk on June 17, 2013. It is presumed to have been a Garter Snake, as it was too large for a Red-bellied (estimated to be 50 cm long). Garter Snake is a common food item for large predators such as hawks.

Many of the snakes observed were small, estimated to be less than 15 cm in length and 1-2 years old. A few were adults (20 – 30 cm length for the Red-bellied Snakes, and 25-60 cm length for the Garter Snakes). Both species would benefit from areas of open (i.e., old field meadow) adjacent to the woodlands. This can be a consideration during the development of buffers.

These species are both common and widespread in Ontario. The Red-bellied Snake is seldom seen, however, as it is highly secretive and primarily nocturnal, being mainly active at night. These animals prey on invertebrates, including worms and insect grubs, and especially slugs. These prey are found in the woodland and the adjacent agricultural fields. Red-bellied Snakes generally inhabit well-wooded areas with adjacent open habitat, as they commonly frequent the edges and clearings to hunt and thermoregulate (basking or otherwise controlling body temperature), and venture into adjacent fields, pastures and meadows to hunt. Red-bellied Snakes typically remain within 150-350 m (up to 550 m) of their hibernaculum (subterranean over-wintering site such as a rock crevice, ant colony or deep burrow), which will be reused annually. Credit Valley Conservation notes that they are “Moderately Sensitive” or “Sensitive” to human disturbance, though they are tolerant of urban conditions and can be found in urban/suburban environments (CVC Reptiles and Amphibians of the Credit River Watershed, 2002). The Halton Natural Areas Inventory (2006) lists the status of the Northern Red-bellied Snake as “Common”.

The Eastern Garter Snake is a generalist carnivore in diet and a very adaptable habitat opportunist, being found in a wide variety of wet and dry (upland and lowland), wooded and open habitats, including urban/suburban settings. The Garter Snake is one of the few animals which prey regularly on toads, as they are unaffected by the protective toxins toads secrete. Given the abundance of toads in this area, it is certain that they contribute to the support of the population of Garter Snakes found in the study area.

Credit Valley Conservation notes that Garter Snakes are “Tolerant” of human disturbance, and they are tolerant of urban/suburban conditions (CVC Reptiles and Amphibians of the Credit River Watershed, 2002). The Halton Natural Areas Inventory (2006) lists the status of the Garter Snake as “Abundant”.

The overwintering site (hibernaculum) for these species has not been located to date on this site. Given that the density of snakes found seems to be concentrated in the vicinity of Block D, it is possible that the Tributary B ravine contains a feature which serves as the local snake hibernaculum. Hibernacula are often features which are scattered and rare on the landscape and are thus utilized by multiple species and reused by the same individuals year after year. Each hibernaculum is critical to the local ecosystem and snake population.

4.9.2.5 Odonata

Incidental observations in 2013 of eight Odonate species were made over five survey dates (see **Table 4.9.3** below):

Table 4.9.3 Incidental Odonate species observations from the Study Area, May to July 2013

Species Observed	Scientific Name	Date
Black Saddlebags	*Tramea lacerata*	5/21/2013, 7/1/2013
Common Whitetail	*Plathernis lydia*	5/21/2013, 6/7/2013
Chalk-fronted Corporal	*Ladona julia*	6/10/2013
Ebony Jewelwing	*Calopteryx maculata*	6/10/2013, 7/1/2013
Meadowhawk spp.	*Sympetrum spp.*	6/17/2013, 7/1/2013
12-Spot Skimmer	*Libellula pulchella*	6/17/2013, 7/1/2013
Blue Dasher	*Pachydiplax longipennis*	6/17/2013
Common Green Darner	*Anax junius*	7/1/2013
12-Spot Skimmer	*Libellula pulchella*	7/1/2013
Meadowhawk spp.	*Sympetrum spp.*	7/1/2013

These are all common species in Ontario, and all are listed as Regionally Common in the Halton Natural Areas Inventory (2006).

NHIC records indicate that the Clamp-Tipped Emerald (*Somatochlora tenebrosa*) (S2S3) has been observed in this area historically (pre-1941). This species was not observed during field investigations in 2013. Potential suitable habitat is present onsite for this emerald species. This species requires shady forest streams, swampy or partly dry habitat. This type of habitat is found in the wooded areas primarily of Tributary B.

The Clamp-tipped Emerald is now rare and the record from the 1 km area is historical (over 70 years old). It is not an urban tolerant species and is unlikely to occur again in the future now that the surrounding landscape has urbanised. However, if it did occur again, it would be associated with the watercourse, which is being protected.

Additional formal surveys were completed over three survey dates in 2014 (June 21, July 12 and August 11). These results are provided in **Appendix L-2**. A total of thirty dragonfly and damselfly species were observed from the study area. Twenty-three of these species are ranked as S5, five are S4 and two species are ranked as S2,S3 (Unicorn Clubtail and Swamp Darner). A total of thirty-three butterfly species were observed, which included twenty-four ranked as S5, six as S4, two as SNA, and one species as S2N, S4B (Monarch). The most productive areas in the study area consisted of the pond along Tributary A (Block A, ELC Unit 26 and 91) and in Unit 9c, Block D. Both of these areas are within the NHS.

4.9.2.6 Owl Survey

Background information obtained from the Atlas of Breeding Birds of Ontario (Cadman et al. 2005) indicates that Eastern Screech-Owl (Megascops asio) and Great-horned Owl (Megascops asio) are both known to occur in the general vicinity of the subject lands. Based on these records surveys for owls were completed as part of this study. A total of 5 stations, as identified on **Figure 4.9.2** were surveyed on April 24, 2014 between 8:00pm and 10:40pm. Conditions during the survey were suitable for completing Owl surveys and were as follows:

- Temperature: 10°C;
- Cloud Cover: 100%; and
- Wind Speed: Ranged from 1 to 2 on the Beaufort Wind Scale (approximately 1 to 11 km/h) with occasional gusts to 3 (approximately 12 to 19 km/h).

A single Eastern Screech-Owl responded from within Block D to the broadcasted call at Survey Station 4. No other observations were made during the survey.

4.9.2.7 Winter Wildlife

The mammals of the settled landscapes of southern Ontario are mostly species that have benefited from agricultural expansion and other human activities. Since many of the sensitive species have already been extirpated, the remaining species are generally widespread and common, as were all of the species detected on the subject lands. The following species were recorded during the winter survey or incidentally while on the site for other purposes (summer season):

- White-tailed Deer (*Odocoileus virginianus*)
- Raccoon (*Procyon lotor*)
- Coyote (*Canis latrans*)
- Eastern Chipmunk (*Tamias striatus*)
- Eastern Gray Squirrel (*Sciurus carolinensis*),
- Red Squirrel (*Tamiasciurus hudsonicus*)
- Other small mammal tracks (mouse sp.)

These species are expected to be residents of the site. During the January 30, 2014 winter survey there was an abundance of small mammal tracks (Red Squirrel, Gray Squirrel) along the east side of Block D and particularly within the northeast portion of Block C (ELC unit 6a) with areas of feeding and burrowing in the snow crust observed. Very fresh Coyote tracks found in the mid to lower slopes of the valleyland in Block DD (ELC units 11, 12b) lead to the observation of a Coyote resting in the valley floor adjacent to what appeared to be a den. Despite large snow drifts within the linkage area between Block C and D drifting, intermittent Coyote tracks were observed. Evidence of coyote foraging was observed within Block C as well as one set of tracks leading to Block B.

During the March 13, 2014 survey there were Coyote tracks observed throughout Block B with tracks leading to Block C as well as to the north side of Block A. There were scattered small mammal tracks (Red Squirrel, Gray Squirrel) observed in Block A and B. There were no tracks observed between the isolated woodland at the south end of Block A and the main woodland within this block.

Numerous tracks of small mammals were also recorded. These were not possible to identify to species, however, they are likely to be the *Peromyscus* mice and Meadow Voles *(Microtus pennsylvanicus*). Tracks of White-tailed Deer were seen in only along the north end of Block D. There was no evidence of deer wintering within the study area. While there may be some habitat opportunities within Block D in areas of hemlock and pine cover, the limited tracks suggest that the area is not suitable during winters with greater snow accumulation.

All of the species observed are ranked as S5 (secure) provincially by the province's Natural Heritage Information Centre.

4.9.3 Aquatic Resources

4.9.3.1 Methodology

Aquatic Resources

Aquatic habitat assessments were carried out in April and May 2013. The assessments consisted of a qualitative survey based on visual inspections of the watercourses throughout the subject property. Stream physical conditions were inspected and documented with photography. Data recorded during the assessments included: stream morphology, flow regime, substrates, seepage area, locations of inflows, riparian/instream vegetation cover, and bank condition and potential barriers to fish movement. While completing the habitat assessment, riparian characteristics and disturbances to the natural environment on the site were also documented.

The features were classified according to flow regime, defined as follows (see **Figure 4.9.3**):

Perennial Watercourse – maintains continuous surface flows most years, well defined, low-flow.

Intermittent Watercourse – water flows for several months during the year, typically during the spring and early summer when water table is high, and late fall; these watercourses have a defined high-flow channel with a poorly defined or absent low flow channel.

Ephemeral Watercourse – water flows for a short period of time primarily in response to snow melt (spring freshet) or storm events, typically have no clearly defined high or low-flow channel or sorting of substrate. Frequently occurring as vegetated swales or bare soil rills in agricultural fields where they are often ploughed through.

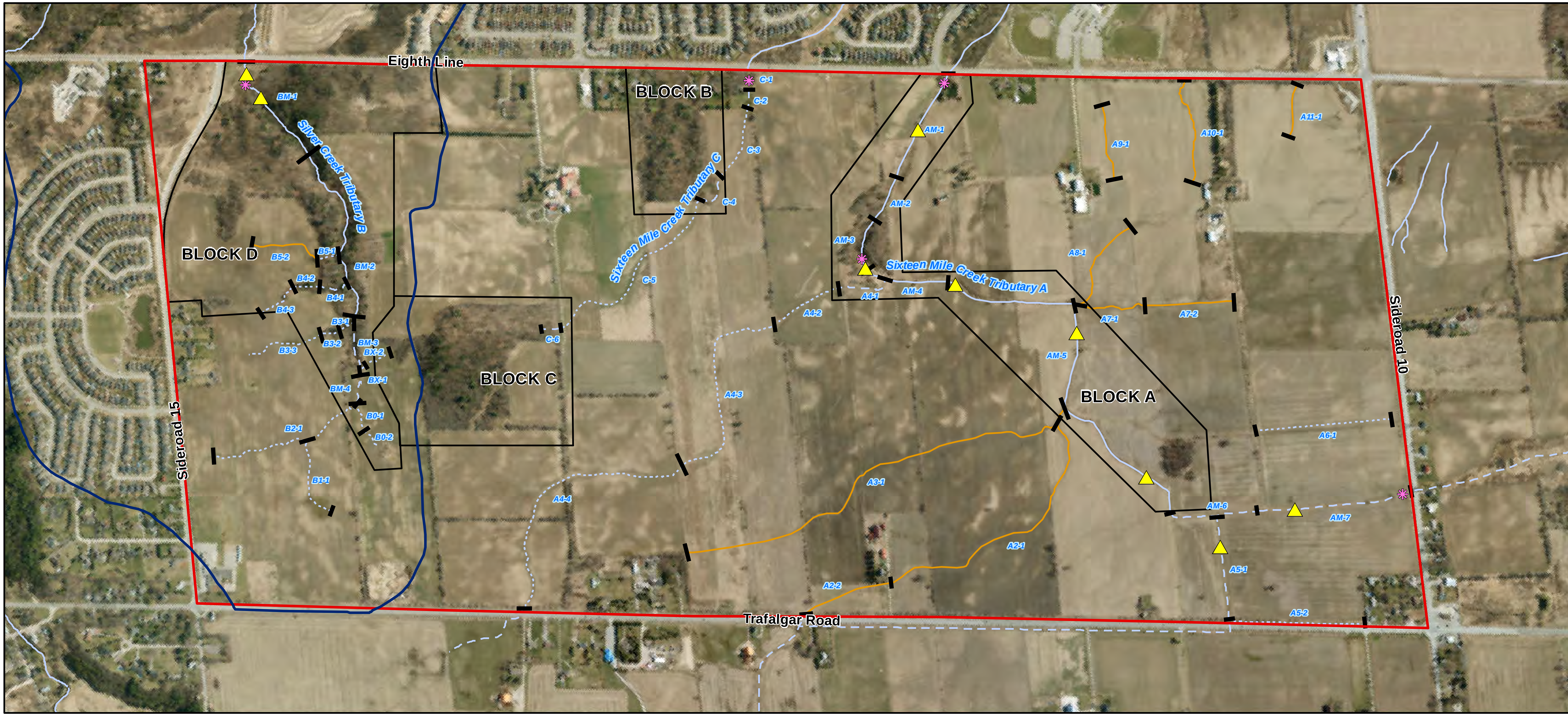
During the investigations the function of headwater features were assessed using the Draft Evaluation, Classification and Management of Headwater Drainage Features Interim Guideline (TRCA and Credit Valley Conservation 2009, Revised 2011). The management recommendations which result from this assessment will be used to assist in determining the treatment of these features as part of the future development of these lands.

The final version of the headwater guideline was approved in July 2013 with minor revisions in January 2014. The original scope of work to assess the HDF's was completed according to the 2009 guidelines. Furthermore, management recommendations were applied according to the 2009 guidelines, however a high level analysis has been completed by applying the 2014 Management Recommendations for comparison. The 2014 Management recommendations provided in **Appendix I** are only tentative results and for the purpose of this study the 2009 results should prevail.

Fish Community Sampling

Site specific fish sampling was completed on July 12, 2013 by Beacon Environmental under Scientific Collectors Permit # 1074215 issued by the MNR. Sampling was carried out using a Haltech backpack electrofishing unit following single pass method outlined in Section 3, Module 1 of OSAP (Stanfield et al 2009). Fish sampling locations are provided on **Figure 4.9.3**. All habitat types with sufficient water were sampled along Tributary A and Tributary B. Tributary C was dry along its entire length in July and sampling could not be undertaken. With respect to rare fish species, the MNR was contacted to provide record information from the Natural Heritage Information Centre (NHIC) database.

Credit Valley Conservation, Conservation Halton, and MNR have previously undertaken fish sampling at multiple locations within the Silver Creek and Sixteen Mile Creek systems, in the proximity of the Southwest Georgetown study area. Fish sampling records were obtained from CVC, Conservation Halton and MNR and used to describe the fish community structure within the Southwest Georgetown study area and to supplement the site specific fish sampling.



Legend

- Study Area
- Block
- Fish and Benthic Sampling Locations
- Water Temperature Monitoring Locations
- Subwatersheds

Flow Regime

- Permanent
- Intermittent
- Ephemeral
- No Flow
- Reach Breaks
- B1-1 Reach Labels

Existing Aquatic Resources and Flow Regime

Figure 4.9.3

SW Georgetown IPP RPP

First Base Solutions Web Mapping Service 2010

UTM Zone 17 N, NAD 83

0 125 250 500 Meters

1:10,000

BEACON ENVIRONMENTAL

Project 213002
August 2014

Benthic Invertebrates and Crayfish

Benthic invertebrate sampling was carried out on June 11, 2013 following the standard methodology set out in the Ontario Benthos Biomonitoring Network (OBBN) (Jones et al. 2004). Benthic invertebrates were collected from stations along Sixteen Mile Creek and Silver Creek using a travelling kick and sweep method. The travelling kick and sweep is typically applied by wading along transects through the habitat of interest, kicking the substrate to dislodge benthos, and collecting dislodged benthos by "sweeping" a hand-held net through the water. Mesh size of the net was 500 µm, which is considered an intermediate size within the common range of net sizes typically used.

Benthic invertebrate sampling locations are provided on **Figure 4.9.3**. Samples preserved were provided to an aquatic entomologist.

During all site investigations in 2013 Beacon Environmental undertook incidental searches for evidence of chimney crayfish. No evidence of chimney crayfish was found.

Stream Temperature Monitoring

To determine the thermal regime of the watercourses within the Southwest Georgetown study area, temperature monitoring was undertaken at various stations along both Sixteen Mile Creek and Silver Creek. Stream temperatures were monitored by AECOM, and Beacon Environmental. The locations of the water temperature recording stations are presented on **Figure 4.9.3.**

Thermal regime was established using the protocols detailed in the Department of Fisheries and Oceans "Method to Determine the Thermal Stability of Southern Ontario Trout Streams" (DFO 1996) and the Stream Thermal Characteristics Classification Methods (Chu et al. 2009). These methods use the maximum daily water temperatures (typically measured between 16:00 and 18:00) plotted against the daily maximum air temperatures. The data set is then plotted to determine the thermal classification of the stream (Cold, Cold-Cool, Cool, Cool-Warm, Warm).

4.9.3.2 Aquatic Habitat Assessment

The Southwest Georgetown study area lies along the subwatershed divide for Sixteen Mile Creek and Silver Creek. The south portion of the study area is situated with the Sixteen Mile Creek watershed and the northern portion of the study area is within the Silver Creek subwatershed (**Figure 4.9.3**). The Sixteen Mile Creek watershed originates along the Niagara Escarpment and flows southward through a mixed landscape of natural, rural and urban land uses prior to entering into Lake Ontario. As part of the Conservation Halton Long Term Monitoring Program the fish community in Sixteen Mile Creek has been sampled and characterized (Conservation Halton 2010). The fish species assemblages ranged from coldwater specialist species to warmwater generalists. This is reflective of the varied habitat conditions and land uses found throughout the watershed. The Silver Creek subwatershed forms part of the larger Credit River watershed. Silver Creek originates along the Niagara Escarpment, near the Town of Erin, and continues southward until its convergence with the Credit River near the Town of Norval. The Silver Creek Subwatershed Report, completed by CVC, indicates that the subwatershed is dominated by coldwater and cool/coldwater habitat conditions with limited records of warmwater fish communities present in areas with habitat limitations (i.e., flow regime) (Credit Valley Conservation 2001).

The following sections provide a qualitative assessment of the function of the aquatic features within the study area as they relate to fish habitat. A quantitative evaluation of the physical parameters of each feature is provided in **Section 4.8.6,** which addresses Fluvial Geomorphology and a photographic log of each reach is provided in **Appendix F**.

Tributary A

Tributary A is part of the Sixteen Mile Creek Subwatershed. It converges with the main branch of East Sixteen Mile Creek just east of Eighth Line.

Main Branch Tributary A

Tributary A enters the subject property through a concrete culvert underneath Side Road 10. The tributary traverses the study area in a northwesterly direction prior to exiting the property via a culvert underneath Eighth Line. Tributary A has been delineated into seven distinct reaches throughout the study area.

Reaches AM-7 and AM-6 are the uppermost reaches of the feature within the study area. Throughout these reaches, there is a defined channel that has been straightened to accommodate agricultural activities. Grasses and cattail were observed growing in sporadic pockets within the channel. There was flow within the reaches during the spring 2013 assessment and during summer 2013 fish sampling standing water was present in AM-6. In AM-7, a pool of standing water at the downstream side of the culvert under Side Road 10 was present. The remainder of AM-7 was dry. Several tile drain outlets were noted along the reaches indicating that the features convey surface flow from the surrounding agricultural lands and form part of the tile drain network for the area.

Reach AM-7 and reach AM-6 support intermittent flows. Twenty Brook Stickleback (*Culaea inconstans*) were captured from reach AM-6 during the summer 2013 sampling. Reach AM-7 was dry on the sampling date and could not be sampled. This reach may provide seasonal direct fish habitat because when flows are present no barriers are present between it and the downstream reaches.

Reaches AM-5 and AM-4 continue through the agricultural field and also have been straightened for agricultural activities. Dense patches of grasses were observed growing within the defined channel and with a narrow strip of grasses along the banks, which separate the reaches from the surrounding agricultural areas. Flow was evident throughout both reaches during the spring and summer 2013 assessments. Tile drain outlets were noted along AM-5 and the upper portions of AM-4.

Reaches AM-5 and AM-4 convey permanent surface flows and tile drainage from the surrounding agricultural lands. During the summer 2013 fish sampling, 17 Brook Stickleback were captured from stations located along AM-5 and AM-4.

Reaches AM-3 and AM-2 are situated within a Dry-Fresh Sugar Maple-White Ash Deciduous Forest community. The channel is well-defined through these reaches and has a more natural channel form, with a riffle, run pool sequence, than the upstream reaches of the tributary. The feature is well shaded by mature trees and the mid portions flow through a defined valley area. Through the upper portions of reach AM-3 and the lower sections of AM-2 grasses were growing within the channel. During the spring and summer 2013 assessments flow was evident throughout both reaches.

Reaches AM-5 conveys intermittent and AM-4 convey permanent surface flows and tile drainage from the surrounding agricultural lands. During the summer 2013 fish sampling, 17 Brook Stickleback were captured from stations located along AM-5 and AM-4.

Reach AM-1 is the most downstream reach of Tributary A within the study area. The reach has a well-defined channel with a riffle pool sequence although it has clearly been historically straightened. The riparian corridor is lined with grasses and meadow species which overhang the channel. Adjacent to Eighth Line, where the tributary exits the property, a pond was observed, but no connection to reach AM-1 was identified. It is unknown if this is a natural pond or if it was dug by the farmer. Flow was present throughout the reach during the spring and summer 2013 assessments.

Reach AM-1 conveys permanent surface flows from upstream reaches and the surrounding meadow area. Four Brook Stickleback and ten young of the year Creek Chub (*Semotilus atromaculatus*) were captured from Reach AM-1.

Branch A2

Branch A2 enters the study area from a culvert underneath Trafalgar Road. The branch is situated within a topographic low point but lacks a defined channel. The upstream portion of the branch (reach A2-2) is a grass meadow with no distinction between the vegetation within the branch and the upland areas. The lower reach (reach A2-1) is actively managed as an agricultural area and is planted throughout with crops. During the spring of 2013, Branch A2 was dry however pockets of moist soils were observed throughout reach A2-1.

Branch A2 does not flow and does not provide fish habitat.

Branch A3

Branch A3 originates from a treed area surrounding a residential property along the east side of Trafalgar Road and within the study area. This branch is situated within a topographic low point but lacks a defined channel. Branch A3 is actively managed as an agricultural area and is planted throughout with crops. During the spring of 2013, the branch was dry however pockets of moist soils were present.

Branch A3 does not flow and does not provide fish habitat.

Branch A4

Like Branch A2, Branch A4 enters the study area through a culvert underneath Trafalgar Road. A defined channel is absent through the majority of its length. It is actively managed as an agricultural area and is planted throughout with crops. During the spring of 2013, the upstream portion of A4 (reaches A4-4, A4-3 and A4-2) were dry, however, moist soils were present. The most downstream reach of A4 (reach A4-1) becomes increasingly defined as it flows through a cultural thicket area. The downstream reach has sorted substrates that are dominated by gravel and cobble overlaid on hard packed clay. No vegetation is growing within the channel but the riparian area is well vegetated with dense grasses which overhang the channel. During the spring 2013 assessment, flow was present within the channel. However, during field visits in the summer of 2013 reach A4-1 was dry.

The upstream portion of Branch A4 is an ephemeral drainage feature which conveys surface flows from the surrounding agricultural lands during the spring freshet and storm events to the main branch of Tributary A. The downstream portion of Branch A4 (A4-1) supports intermittent flow which is conveyed to the main branch of Tributary A. The fish habitat function of the upstream reaches of Branch A4 (A4-4, A4-3 and A4-2) is limited to conveying ephemeral surface flows to the main branch of Tributary A. The downstream reach of A4 (reach A4-1) was dry at the time of the 2013 fish sampling. However, there is the potential for this reach to provide seasonal direct fish habitat as no barrier is present between A4-1 and the main branch of Tributary A.

Branch A5

Branch A5 flows within a roadside ditch as it enters the study area along Trafalgar Road near the corner of Side Road 10. This branch has a defined channel that has been straightened and is located between two active agricultural fields. Along the edge is a narrow band of grasses as well as pockets of dense grasses growing within the channel. During the spring 2013 assessment there was slight flow within the channel and in June and July 2013 there was standing water present.

Within Branch A5, Reach A5-1 is intermittent and Reach A5-2 is ephemeral. It conveys surface flows from the roadside ditch along Trafalgar Road and the surrounding agricultural fields to the downstream reaches of Tributary A. Areas of standing water were sampled for fish in July 2013, however, no fish were captured. There is no barrier to fish access from the main branch of Tributary A, therefore, there is the potential for Branch A5 to provide direct fish habitat during periods of sufficient flows.

Remnant Branches

Branches A6 – A11 are remnants on the landscape. Without exception, these features are heavily altered, do not flow and have a tenuous or no connection to Tributary A. The following **Table 4.9.4** summarizes their characteristics and their functions.

Table 4.9.4 Summary of Remnant Tributary A Branches A6 to A11

Branch	Origin	Channel	Fish Habitat Function	Connection to Tributary A
A6	Culvert beneath Side Road 10	Furrow to FOD and into storm grate	None	None
A7	Hedgerow within agricultural field	Vegetated ditch upstream, ploughed and planted downstream	None	Tenuous
A8	Agricultural field	Rill, ploughed and planted throughout	None	Tenuous
A9	Agricultural field	Rill located within the low point of a steep slope along Eighth Line	None	None
A10	Agricultural field	Tire tracks	None	None
A11	Agricultural field near the corner of Side Road 10 and Eighth Line	No defined channel. Ploughed and planted through.	None	None

Tributary B

Tributary B is part of the Silver Creek subwatershed. It is a headwater tributary and converges with the main branch of Silver Creek just east of Eighth Line. Seven small branches converge with the main branch along its length within the study area.

Main Branch Tributary B

Tributary B originates within the study area within a steep valley feature. Tributary B has been delineated into four distinct reaches. The upper reaches, BM-4, BM-3 and BM-2, are confined to the bottom of the steep valley features. There is a defined channel with sorted substrates. The channel is well shaded by mature trees. Woody debris is present through the channel, however, there is no instream vegetation. Slight flow was present within the lower portion of reach BM-2 and isolated pools of standing water were present throughout BM-3 and BM-4 during the spring 2013 assessment. In July 2013 during the fish sampling event reaches BM-3 and BM-4 were dry with areas of moist substrates and isolated pools were observed in the lower portions of reach BM-2. Reach BM-4 and BM-3 support intermittent flows and Reach BM-2 supports permanent flows.

The lower reach of the main branch of Tributary B (BM-1) is situated within a wide floodplain at the base of the steep valley feature. There is a defined channel through this reach. The riparian corridor is well vegetated with a mix of trees, shrubs and meadow species. Through the lower portion of the reach, iron staining was observed within the channel indicating possible groundwater input. This reach was flowing during the spring 2013 assessment standing water was present in July 2013. Reach BM-1 supports permanent flows.

Branch BX

Branch BX originates within a Willow Mineral Deciduous Swamp located along the edge of an agricultural field and wooded area. The upper reach (BX-2) has a poorly defined channel that traverses an active agricultural field. This reach is actively ploughed and planted with crops. The downstream reach (BX-1) is an eroded gulley within the valley sounding the main branch of Tributary B. During the spring 2013 assessment slight flow was present within the branch, however, during the June 2013 benthic sampling, the branch was dry.

Branch BX conveys ephemeral surface flows from the surrounding agricultural lands and flows from the swamp feature to the upper portion of the main branch of Tributary B. The fish habitat function of Branch BX is limited to the seasonal conveyance of surface flows from the surrounding agricultural field and swamp community to the main branch of Tributary B.

Branch B0

Branch B0 arises from a Willow Mineral Deciduous Swamp located within an agricultural field. There is a slight defined channel through the upper portion (reach B0-2) that becomes increasingly defined as it progresses downstream to Reach B0-1). Branch B0 lacks vegetation and the riparian corridor is actively farmed to the edge. During the spring 2013 assessment there was slight flow within Branch B0, however, during the June 2013 benthic sampling, it was dry.

Branch B0 conveys ephemeral surface flows from the surrounding agricultural lands and flows from the swamp feature to the upper portion of the main branch of Tributary B. The fish habitat function of Branch B0 is limited to the seasonal conveyance of surface flows from the surrounding agricultural field and swamp community to the main branch of Tributary B.

Branches B1, B2 and B3

These branches all originate within an active agricultural field. Feature B1 converges with B2, which connects downstream to the main branch. Feature B3 also connects downstream to the main branch. The downstream reaches (B3-2 and B3-1) are situated within an eroded gulley within the valley surrounding the main branch of Tributary B. All three features lack a defined channel and are present as topographic low points within the agricultural field and are ploughed and planted throughout. During the spring 2013 assessment there were pockets of standing water but no flows were observed.

All three branches convey ephemeral flows in response to the spring freshet and periods of precipitation. Based on the limited flow conditions, lack of defined channel and lack of upstream or downstream connection to direct fish habitat none of these support any type of fish habitat.

Branches B4 and B5

Branch B4 originates at the rear yard of a residential property located along Side Road 15. At one time, it arose north of Side Road 15 but land development has since reduced its length. Branch B5 originates within an active agricultural field. The upper reaches of both of these features lack a defined channel and arise as topographic low points in an agricultural field. Both are actively ploughed and planted with crops. The downstream reaches of these features are situated within an eroded gulley within the valley surrounding the main branch of Tributary B. During the spring 2013 assessment pockets of standing water were present within the upper reaches but the remainder of the feature was dry.

Branches B4 and B5 convey ephemeral surface flows from the surrounding agricultural lands and residential rear yards to the main branch of Tributary B. The fish habitat function of both is limited to flow conveyance of surface flows from the surrounding agricultural field to the main branch of Tributary B.

Tributary C

Tributary C is a headwater tributary of Sixteen Mile Creek. It converges with the main branch of East Sixteen Mile Creek just east of Eighth Line. The tributary arises within the subject area from a tile drain within a Dry-Fresh Sugar Maple-White Ash Deciduous Forest and traverses the study area in a north-easterly direction prior to exiting via a culvert underneath Eighth Line. Through the study are Tributary C has been delineated into six distinct reaches.

Reach C-6 is the upper most reach. It is situated within the Dry-Fresh Sugar Maple-White Ash Deciduous Forest. The reach has a defined channel that is well shaded by mature trees. There is a tile drain which outlets into this reach. During the spring 2013 assessment, only standing water was present. Reach C-6 supports intermittent flows.

Reach C-5 is located within an active agricultural field and is ploughed and planted throughout. This reach is present only as a broad depression without a defined channel. No water was present during the spring 2013 assessment, but moist soils were noted.

The upper portions of reach C-4 is situated along a meadow area and the downstream portion skirt the edge of a cultural thicket. The reach has a defined channel with dense grasses within the channel. There were pockets of standing water present during the spring 2013 assessment. Reach C-4 supports intermittent flows. A site visit conducted on June 16, 2016 confirmed that this reach and all reaches upstream and downstream provide only a periodic flow contribution to fish habitat. Insufficient flow prevents fish movement upstream from lower reaches.

Reach C-3 is located within an active agricultural field and is ploughed and plants throughout. This reach lacks a defined channel and is present as a topographic low point. There was no water present during the spring 2013 assessment, but moist soils were noted. Reach C-3 conveys ephemeral flows.

Reaches C-2 and C-1 are the downstream reaches of Tributary C within the study area. The reaches traverse a manicured lawn which is mowed almost to the edge of the poorly defined feature. There are terrestrial grasses and several cattails throughout the channel. There was standing water present in these reaches during the spring 2013 assessment. Reaches C-2 and C-1 support intermittent flows but are too choked with vegetation to provide fish habitat.

Tributary C provides flow and likely some nutrients to fish habitat downstream.

4.9.3.3 Fisheries

All habitat types with sufficient water were sampled along the main branch of Tributary A and the main branch of Tributary B. Sampling was not carried out on Tributary C due to a lack of water; however a follow-up site visit was conducted in the spring which confirmed absence of fish. **Table 4.9.5** provides a summary of the fish sampling results from July 2013.

Table 4.9.5 Summary of Fish Sampling Results for Tributary A and Tributary B (July 2013)

Common Name	Scientific Name	Locations Captured
Brook Stickleback	*Culaea inconstans*	BM-1 AM-1 AM-3 AM-4 AM-5 AM-6
Creek Chub	*Semotilus atromaculatus*	AM-1

Based on the fish sampling results, the main branch of Tributary A, with the exception of reach AM-7, provides permanent direct fish habitat for warmwater tolerant cyprinid species. Only two species, Brook Stickleback and Creek Chub, were captured. These species are known to be tolerant of degraded conditions and are often found in altered systems where more sensitive species are absent. AM-7 was dry but this reach could support seasonal direct fish habitat as there is no barrier to fish access when sufficient flows are present. Feature A5 was the only contributing feature to the main branch of Tributary A which had sufficient water for fish sampling in July 2013 but no fish were captured. However the reach is well connected to the main branch of Tributary A therefore Feature A5 could provide direct fish habitat during periods of sufficient flows.

Results from the summer 2013 fish sampling confirm that the lower portion of reach BM-1 supports direct fish habitat. At the time of the sampling there were limited flows and only two Brook Stickleback were captured. Based on the flows and the gradient of the channel through the valley feature it is unlikely that the reaches upstream of BM-1 could provide direct fish habitat, however, these reaches support the fish habitat downstream through flow conveyance during the spring freshet.

4.9.3.4 Benthic Invertebrates and Crayfish

Benthic sampling was completed at seven stations along Tributary A and two stations along Tributary B on June 11, 2013.The results of the benthic invertebrate sampling were analyzed using the Hilsenhoff Biotic Index (HBI) which is a standard method of water quality assessment and degree of organic pollution in watercourses using the benthic invertebrate community. Each species has an associated tolerance value and from these tolerance values the HBI is calculated for the community. **Table 4.9.6** provides the HBI values and their associated indications of water quality and organic pollution.

Table 4.9.6 Water Quality and Organic Pollution Levels Based on Hilsenhoff Biotic Index

Biotic Index Value	Water Quality	Degree of Organic Pollution
0.00 – 3.50	Excellent	No apparent organic pollution
3.51 – 4.50	Very Good	Possible slight organic pollution
4.51 – 5.50	Good	Some organic pollution
5.51 – 6.50	Fair	Fairly significant organic pollution
6.51 – 7.50	Fairly Poor	Significant organic pollution
7.51 – 8.50	Poor	Very significant organic pollution
8.51 – 10.0	Very Poor	Severe organic pollution

Table 4.9.7 provides a summary of the benthic invertebrate sampling and Hilsenhoff Biotic Index for the sampling locations on Tributary A and Tributary B within the study area. The complete benthic results and HBI analysis are provided in **Appendix N**.

Table 4.9.7 Hilsenhoff Biotic Index Results Tributary A and Tributary B

Location	HBI	Water Quality	Degree of Organic Pollution
AM-1	7.15	Fairly Poor	Significant organic pollution
AM-3	6.85	Fairly Poor	Significant organic pollution
AM-4	7.20	Fairly Poor	Significant organic pollution
AM-5 Downstream	8.61	Very Poor	Severe organic pollution
AM-5 Upstream	7.56	Poor	Very significant organic pollution
AM-7	7.59	Poor	Very significant organic pollution
A5-1	8.67	Very Poor	Severe organic pollution
BM-1 Downstream	8.41	Poor	Very significant organic pollution
BM-1 Upstream	9.5	Very Poor	Severe organic pollution

Tributary A

A total of 1,184 individuals from 45 taxa were collected from the seven sampling locations along Tributary A. The dominant species throughout the Tributary was *Micropsectra* sp. with 412 individuals present in the samples (**Appendix N**). This midge species is often found in conjunction with reduced water quality and is tolerant of organic pollution (Peckarsky et al 1990). The predominance of this species is reflected in the HBI values for the sampling stations which ranged from 6.85 to 8.85 which indicate fairly poor water quality and significant organic pollution to very poor water quality and sever organic pollution (**Table 4.9.7**).

Tributary B

A total of 252 individuals from 23 taxa were collected from the two sampling locations along Tributary B. The dominant species throughout the Tributary was *Stictochironomus* sp. with 92 individuals present in the samples (**Appendix N**). This midge species is found in conjunction with reduced water quality and is very tolerant of organic pollution (Peckarsky et al 1990). The predominance of this species is reflected in the HBI values for the sampling stations which 8.61 and 9.50 which indicate very poor water quality and severe organic pollution (**Table 4.9.7**).

Overall the results of the benthic invertebrate sampling in Tributary A and Tributary B, reflect an invertebrate community that has been shaped through the anthropogenic land use, mostly agriculture, that surround the watercourses. Benthic invertebrates rely on aquatic habitat for their development and survival hence watercourses impacted by anthropogenic land use characteristically support communities that are tolerant to extreme environmental fluctuations and pollution inputs. These watercourses often have more homogeneous habitat types that lack complexity. This lack of complex habitat results in reduced species richness in the benthic community and higher incidences of tolerant, generalist species. This was reflected in the absence of more tolerant groups such as Trichoptera, Ephemeroptera and Plecoptera.

The Chimney (or Digger) Crayfish (*Fallicambarus fodiens*) is presently ranked in the NHIC database as “G5” – very common; “N4” - apparently secure; and “S4” – apparently secure. It has a Canada General Status Rank of “sensitive” (Canadian Endangered Species Conservation Council 2011), meaning that it “may require special attention or protection to prevent [it] from becoming at risk”. It is not designated as a Species at Risk by MNR; therefore, it is not afforded any specific protection under the Ontario Endangered Species Act. Little is known about the Chimney Crayfish, although it is known to inhabit creek beds, wetlands and ditches as a semi-terrestrial burrower.

No evidence of Chimney Crayfish was observed on the Southwest Georgetown study area through incidental observations of the property on a number of occasions between spring and summer 2013.

Tributary C

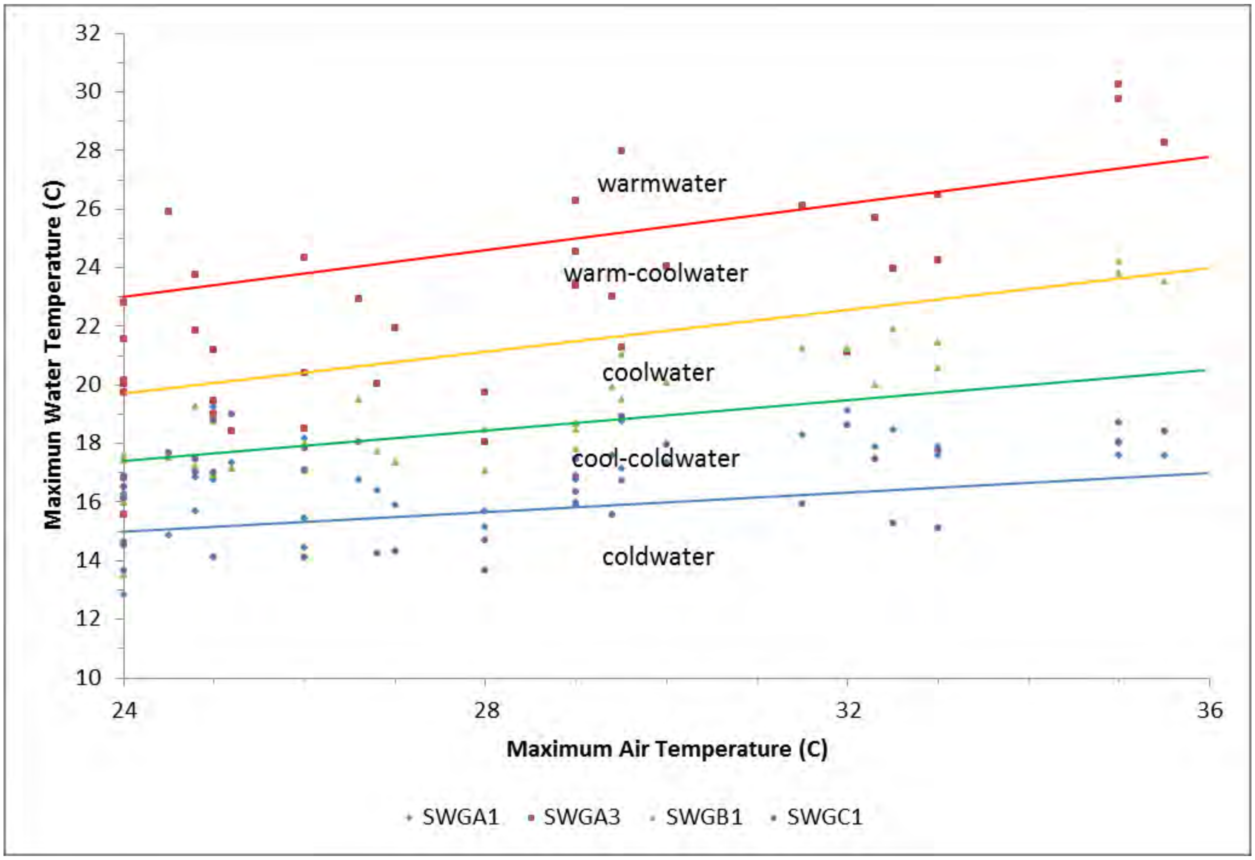
The absence of definition for most of Tributary C in which the feature was ploughed through, precluded the need for benthic invertebrate sampling.

4.9.3.5 Thermal Regime

Following the protocol detailed in the Department of Fisheries and Oceans "Method to Determine the Thermal Stability of Southern Ontario Trout Streams" (Dept. of Fisheries and Oceans, 1996), water temperatures were compared against high maximum afternoon ambient air temperatures to provide an assessment of each watercourse. This protocol determines stable water temperatures which can be used to identify cold, cool and warm water temperature regime. Following the model, coldwater supports average daily maximum summer water temperature around 14^{o}C, cool water 18^{o}C and warm water 23^{o}C or higher. Analysis of the thermal data was further refined by plotting the daily water and air temperature maximums using the thermal classification nomogram as described in Chu et al. (2009). The use of the nomogram allows for the thermal regime to be described using five thermal categories (coldwater, cold-coolwater, coolwater, cool-warmwater and warmwater).

Following the thermal stability model the daily maximum water temperatures indicate that Reach AM-1 supports a cool-coldwater temperature regime, Reach AM-3 supports a warm-coolwater thermal regime, Reach BM-1 supports a coolwater thermal regime and Reach C1 supports a cool-coldwater thermal regime. These temperature data are supported by groundwater data that show input to these features in varying amounts. In this regard, a temperature target for Reach BM-1 of approximately 22 ºC would be sufficient to maintain the existing temperature input to Silver Creek. **Figure 4.9.4** depicts the thermal classification nomogram generated based on the daily maximum air and water temperatures on dates where the maximum air temperature met or exceeded 24ºC between June 01, 2013 and July 21, 2013. Locations of temperature monitoring stations are provided on **Figure 4.9.3**.

Figure 4.9.4 Thermal Classification Nomogram for Tributary A, B and C



4.9.4 Significant Natural Heritage Features

The following review and assessment of significant natural heritage features relating to the secondary plan study area has been provided.

4.9.4.1 Wetlands

The designation of wetlands as provincially significant, is completed through a standardized assessment known as the Ontario Wetland Evaluation System. Evaluated "non-provincially" significant wetlands may be considered locally or regionally significant by planning authorities. The Ontario Ministry of Natural Resources (OMNR) is generally responsible for the evaluation of wetlands, although wetland data information may be provided by other agencies, such as local conservation authorities. The final designation of a wetland as either locally or provincially significant is ultimately the responsibility of the OMNR.

The Hungry Hollow Wetland Complex, a Provincially Significant Wetland (PSW), is located immediately to the north and east of the study and found downstream of the Silver Creek Tributary B (see **Figure 4.9.5**).

Section 115.3 of Halton's ROPA 38 identifies significant wetlands as key features that are part of the Regional Natural Heritage System.

Definitions and criteria provided in ROPA 38 were used to screen and identify significant wetlands for each Block area and included review of the Natural Heritage System Definition & Implementation (2009) report. The following policies from ROPA 38 were used to inform and identify areas that qualify as significant wetland within each of the four Blocks in study area as applicable:

<u>ROPA 38</u>

115.3(6) wetlands other than those considered significant under Section 115.3(1)b).

276.4 SIGNIFICANT means:

276.4(1) in regard to wetlands, an area as defined under Section 276.5 of this Plan;

276.5 SIGNIFICANT WETLANDS means:

276.5(1) for lands within the Niagara Escarpment Plan Area, Provincially Significant Wetlands and wetlands as defined in the Niagara Escarpment Plan that make an important ecological contribution to the Regional Natural Heritage System;

276.5(2) for lands within the Greenbelt Plan Area but outside the Niagara Escarpment Area, Provincially Significant Wetlands and wetlands as defined in the Greenbelt Plan;

276.5(3) for lands within the Regional Natural Heritage System but outside the Greenbelt Plan Area, Provincially Significant Wetlands and wetlands that make an important ecological contribution to the Regional Natural Heritage System; and,

276.5(4) outside the Regional Natural Heritage System, Provincial Significant Wetlands.

The Town of Halton Hills provides the following definitions in their OP:

Regionally Significant Wetland
Means a wetland classified as "Other Wetlands" by the Ontario Ministry of Natural Resources based on the Ontario Wetland Evaluation System 1994 Southern Manual, as amended from time to time.

Significant
Means:
a) in regards to wetlands and areas of natural and scientific interest, an area identified as provincially significant by the Ontario Ministry of Natural Resources using evaluation procedures established by the Province, as amended from time to time;..

There is a limited representation of wetlands found within the secondary plan study area. Wetlands consist of surface water dependant features consisting of a long, narrow riparian meadow marsh wetland (unit 10, MAM2-2) along Tributary A in Block A, two isolated wetlands in the agricultural fields consisting of a small deciduous swamp and meadow marsh (unit 3a, SWD4-1 and unit 2, MAM2) and a riparian and isolated deciduous swamp (unit 3b and c, SWD4-1) in Block D (see **Figure 4.9.1**)

Some wetlands within the study are generally sustained through "perched" surface water conditions resulting from the tighter Halton Till soils. This material is known to hold surface water as infiltration rates are low and contributes to the development of a wetland. The riparian wetlands within the study area are riverine wetland types receiving and attenuating surface water drainage through the watercourses on site.

Given the small size of the individual wetland units, small total area of wetland and lack of rare species that are directly supported by the wetland units, the wetlands, either individually or collectively as a wetland complex, would not be assessed to be Provincially Significant following the *Ontario Wetland Evaluation System.*

4.9.4.2 Habitat of Endangered and Threatened Species

Species at Risk awareness and legislation has increased extensively in recent years. The Ontario Endangered Species Act came into force in June 2008 and the Act is having a significant role in land use activities and planning due to protection of both the species as well as its habitat on all lands (i.e., private and public). Under the *ESA* there are over 200 species in Ontario that are identified as extirpated, endangered, threatened, or of special concern.

The Act prohibits the killing or harming of threatened and endangered species, as well as the destruction of their habitat. For Special Concern species the *Act* does not afford protection to the individual or their habitat.

There are two key protection provisions in the ESA:

- Section 9 describes prohibited activities (i.e., kill, harm, harass, possess, collect, buy and sell) for species listed as extirpated, endangered or threatened on the SARO List.
- Section 10 prohibits the damage of destruction of protected habitat of species listed as extirpated, endangered or threatened on the SARO List.

There are provisions for enforcement and penalties under the ESA that include:

- The Act is binding on everyone including provincial and municipal governments *and* their staff, individuals, corporations, businesses.
- Provisions for appointment of officers, inspections, searches, seizure, forfeiture, stop work orders, and Habitat protection orders.
- The specific requirements of the due diligence defence (sec 39).
- Maximum penalties of $250K for individuals and $1M for corporations and/or imprisonment for up to 1 year for first offence.

It is important to note that the owner of the land as well as the individual or organization carrying out any activities on those lands are both subject to the enforcement and penalty provisions of the ESA should Sections 9 or 10 of the ESA be contravened.

The full requirements of the *Act* for the protection of habitat for all endangered and threatened species listed on the Species at Risk in Ontario List (SARO List) came into effect on June 20, 2013 providing “general habitat” protection for those species that do not have specific “habitat regulation”.

Two species of birds recorded from the study area are listed as SAR species in Ontario; Bobolink (THR) and Barn Swallow (*Hirundo rustica*) (THR). Additionally, one species ranked Special Concern federally was found; Eastern Wood Pewee (*Contopus virens*).

The 2014 PPS states that:

> *2.1.7 Development and site alteration shall not be permitted in habitat of endangered species and threatened species, except in accordance with provincial and federal requirements.*

4.9.4.3 Significant Woodlands

The Natural Heritage Reference Manual (OMNR 2010) provides evaluation criteria for the identification and determination of significant woodlands. Under the *Planning Act*, the Province provides guidelines in identifying significant woodlands, but because such a designation is a relative exercise it is the responsibility of the planning authority (i.e., the local or regional municipality) to complete the identification, evaluation, and designation of these features.

The suggested criteria (OMNR 2010) for identifying significant woodlands are:

a) woodland size (based on the percent forest cover in the planning area or regional landscape, should account for landscape-level physiographic differences);
b) ecological functions (woodland interior, shape and proximity, linkages, water protection, woodland diversity);
c) uncommon woodlands (unique species composition, rare communities, quality, older woodlands); and
d) economic and social values (high economic productivity, social value).

Woodland size is generally viewed as one of the main criteria in the determination of significance and from a landscape-level planning approach can be determined through map-based analysis, unlike some other criteria that may require field confirmation (i.e., presence of rare species). An estimate of the forest cover in Halton Region has placed this number at approximately 20% (Riley and Mohr 1994), with the current cover likely over 20%.

The Natural Heritage Reference Manual (OMNR 2010c) recommends that in planning areas or regional landscapes where forest cover is between 5% to 15%, woodlands 4 ha and larger should be considered for significance. Where forest cover is 15% to 30% it is recommended that woodlands 20 ha in size or greater be considered for significance. Where forest cover is 30% to 60% (such as Simcoe County) it is recommended that woodlands 50 ha in size or greater be considered for significance. These are guidelines and many municipalities, including Halton Region, use different size criteria thresholds.

Section 115.3 of Halton's ROPA 38 identifies significant woodlands as key features that are part of the Regional Natural Heritage System.

Based on information provided in the Region's background study *Natural Heritage System Definition & Implementation* (North-South Environmental 2009), size thresholds of 20 ha were used for the identification of Core Area Woodlands to guide the development of the Region's NHS. Based on this size there are technically no "Core Areas" within the study area as described in the background study.

Definitions and criteria provided in ROPA 38 were used to identify significant woodland for each Block area and included review of the *Natural Heritage System Definition & Implementation* (2009) report. The following policies from ROPA 38 were used to inform and identify areas that qualify as significant woodland within each of the four Blocks in study area as applicable.

ROPA 38

276.4 SIGNIFICANT means:

276.4(4) in regard to woodlands, an area as defined by Section 277 of this Plan;

277. SIGNIFICANT WOODLAND means a Woodland 0.5ha or larger determined through a Watershed Plan, a Sub-watershed Study or a site-specific Environmental Impact Assessment to meet one or more of the four following criteria:

277(1) the Woodland contains forest patches over 99 years old,

277(2) the patch size of the Woodland is 2 ha or larger if it is located in the Urban Area, or 4 ha or larger if it is located outside the Urban Area but below the Escarpment Brow, or 10 ha or larger if it is located outside the Urban Area but above the Escarpment Brow,

277(3) the Woodland has an interior core area of 4 ha or larger, measured 100m from the edge, or

277(4) the Woodland is wholly or partially within 50m of a major creek or certain headwater creek or within 150m of the Escarpment Brow.

*295**.** WOODLAND means land with at least: 1000 trees of any size per ha, or 750 trees over 5 cm in diameter per ha, or 500 trees over 12 cm in diameter per ha, or 250 trees over 20 cm in diameter per ha but does not include an active cultivated fruit or nut orchard, a Christmas tree plantation, a plantation certified by the Region, a tree nursery, or a narrow linear strip of trees that defines a laneway or a boundary between fields. For the purpose of this definition, all measurements of the trees are to be taken at 1.37 m from the ground and trees in regenerating fields must have achieved that height to be counted.*

The definition for significant woodland provided in the Town of Halton Hills OP is the same as above.

Further site analysis for identification of “woodlands” was needed to complete tree stem density counts in young regenerating shrub thicket areas in order to determine if such areas qualified as woodland (i.e., supporting 1000 stems per hectare). This was important in Block C to differentiate between the young successional thicket and the “woodland” component of the Block based on the definitions under Section 295 of ROPA 38. The stem count resulted in the exclusion of the cultural thicket (CUT1, unit 4) along the western corner of Block C as part of the woodland and the inclusion of the cultural woodland (CUW1, unit 5) along the southern corner of Block C as part of the significant woodland and key feature (see **Figure 4.9.1**). Those areas determined to be woodland were then assessed for “significance” based on criteria provided in Section 277.

Based on the foregoing, the following areas of significant woodland have been identified for the study area and represent key features within the NHS as identified through ROPA 38 (**Figure 4.9.1**).

<u>Block A supports:</u>

- two separate areas of significant woodland based on the criteria that both woodlands are > 0.5 ha and within 50 m of a watercourse (southern woodland = unit 1a; northern woodland = units 6b, 6c, 18c and 22);

<u>Block B supports:</u>

- one contiguous significant woodland based on the criteria of a woodland in an Urban Area that is > 2.0 ha (woodland = unit 13, 14a and 14b);

<u>Block C supports:</u>

- on contiguous significant woodland based on the criteria of a woodland in an Urban Area that is > 2.0 ha (woodland = unit 5, 6a and 7); and, Block D supports:

- on contiguous significant woodland based on the criteria of a woodland in an Urban Area that is > 2.0 ha (woodland = unit 1b, 3b, 8a, 8c, 8d,11,12a, 12b, 16a, 17a, 17b, 19, 21).

4.9.4.4 Significant Valleylands

The designation of Significant Valleylands is usually undertaken by the planning authority and/or the relevant Conservation Authority (in this case CH and CVC). Criteria recommended by the Province for significant valleyland designation include prominence as a distinctive landform, extent of naturalness, importance of its ecological functions, restoration potential, and historical and cultural values.

The Town of Halton Hills provides the following definitions in their OP:

> ***Valley or Valleylands***
> *Means a natural area that occurs in a landform depression that has water flowing through or standing for some period of the year and is defined by the primary top of bank. See also **Major Valley/Watercourse** and **Minor Valley/Watercourse.***
>
> ***Major Valley/Watercourse***
> *Means a watercourse and its associated valley system that typically has valley walls 5 metres or greater in height.*
>
> ***Minor Valley/Watercourse***
> *Means a watercourse and its associated valley system or stream corridor that typically has valley walls less than 5 metres in height.*

No formally designated significant valleylands are found in the study area. However, based on the above definitions the valleyland that supports the Silver Creek Tributary B would be considered significant.

4.9.4.5 Significant Wildlife Habitat

The Natural Heritage Policies of the Provincial Policy Statement (Subsection 2.1.5 d) identify four principal components of SWH as described in the Significant Wildlife Habitat Technical Guide (OMNR 2000). These are:

a) Seasonal Concentrations of Animals;
b) Animal Movement Corridors;
c) Rare Vegetation Communities or Specialized Habitats; and
d) Habitats of Species of Conservation Concern.

Significance Wildlife Habitat can be difficult to appropriately determine at the site-specific level. Under the PPS, the planning authorities have the responsibility to identify SWH and to our understanding no municipality has completed comprehensive jurisdiction-wide SWH analysis and mapping, which is also the case for the Town of Halton Hills and Halton Region. The types of SWH that some municipalities have mapped and included in their official plan schedules may include deer wintering area, colonial bird nesting sites and other habitat areas that are typically mapped and provide by the MNR. Peel Region has completed a significant wildlife habitat study with criteria for the identification of candidate SWH (North-South *et al.* 2009), which is the first comprehensive approach by a municipality to address SWH within its planning area.

The Town of Halton Hills provides the following definition in their OP:

> ***Wildlife Habitat***
> *Means areas where plants, animals and other organisms live and find adequate amounts of food, water, shelter and space to sustain their populations. Specific wildlife habitats of concern, may include areas where a species concentrate at a vulnerable point in their annual or life cycle and an area that is important to a migratory or non-migratory species.*

Based on the Province's Significant Wildlife Habitat Technical Guides (OMNR 2000), wildlife habitat is identified as:

> *"areas where plants, animals, and other organisms live, and find adequate amounts of food, water, shelter and space needed to sustain their populations. Specific wildlife habitat of concern may include areas where species concentrate at a vulnerable point in their annual or life cycle; and areas which are important to migratory or non-migratory species."*

Wildlife habitat is considered significant where it is:

> *"ecologically important in terms of features, functions, representation or amount, and contributing to the quality and diversity of an identifiable geographic area or Natural Heritage System".*

The following sections provide an assessment of existing wildlife features and habitats found on the property against the four component parts of SWH listed above under the PPS (OMNR, 2000). It's important to note that this is based on site specific information with background information from adjacent lands and therefore any identified SWH is considered "candidate".

Habitat of Seasonal Concentrations of Animals

This category includes:

- areas where animals occur in relatively high densities for the species at specific periods in their life cycles and/or in particular seasons
- seasonal concentration areas, which tend to be localized and relatively small in relation to the area of habitat used at other times of the year

Some species of animals gather together from geographically wide areas at certain times of year. This could be to hibernate or to bask (i.e., such as snake hibernaculum), over-winter (i.e., deer yards) or to breed (i.e., Bullfrog breeding and nursery areas). Maintenance of the habitat features that result in these concentrations can be critical in sustaining local or sometimes even regional populations of wildlife.

Based on the vegetation community classification, flora and fauna inventory surveys, and wildlife habitat assessments completed for the project, the secondary plan study area does not support vegetation community types, habitat conditions, or features that have been identified to specifically provide for seasonal concentrations of animals. For example, based on two winter wildlife surveys and additional seasonal surveys, the study area does not support any winter deer yards. This is primarily a function of a deciduous dominated forest cover in the wooded areas found within the study area. Large areas of dense conifer cover that hold the snow load to provide winter shelter does not exist.

Based on multi-season observations of raptors and owl surveys, SWH for raptor winter feeding areas would not qualify a SWH. While a Red-tailed Hawk (*Buteo jamaicensis*) was seen regularly during site visits, it appears that there is only one pair found in the study area. One Northern Saw-whet Owl (*Aegolius acadicus*) was heard calling during the owl survey on April 24, 2014. The owl responded to taped calls and was heard from the southeast side of Block D.

For flora, mammals and birds, the seasonal concentration criterion is not met by any habitat features or functions within the study area. However as noted in Section 4.9.2.4 given that there is a high density of snakes in the vicinity of Block D, it is possible that the Tributary B ravine contains a feature(s) which serves as the local snake hibernaculum. Hibernacula are often features which are scattered and rare on the landscape and are thus utilized by multiple species and reused by the same individuals year after year. Each hibernaculum is critical to the local ecosystem and snake population. Based on these factors, the ravine areas of Block D could be considered to support Significant Wildlife Habitat, based on the probable occurrence of snake hibernacula, the exact location(s) are not know at this time.

Rare Vegetation Communities or Specialized Habitats

Rare vegetation communities include:

- areas that contain a provincially rare vegetation community
- areas that contain a vegetation community that is rare within the planning area

Specialized wildlife habitats include:

- areas that support wildlife species that have highly specific habitat requirements
- areas with exceptionally high species diversity or community diversity
- areas that provide habitat that greatly enhances species' survival

Rare vegetation communities apply to the maintenance of biodiversity and of rare plant communities (rather than individual rare species) and may include communities such as alvar, tall-grass prairie or rare forest types. Based on the vegetation community classification for the study area using the ELC and review of the NHIC ranking for rarity, there are no vegetation communities within the secondary plan area that are rare.

Specialized habitat conditions can include those for species of breeding birds that are associated with large blocks of wetland (generally >25 ha) that also include area sensitive habitat. Large forested areas support habitat opportunities for breeding forest birds with area sensitive requirements (i.e., that which is more than 100 m from an edge). Representation of forest interior areas found at least 100 m from the forest edge have limited representation within the study area, with some located in Block C and in the northern portion of Block D. These would not be considered SWH.

There is a complex of vernal pools in Block C along the west and northwest side of the woodland block made up of several small pools (generally 2 to 6 m^2 in size) in an area of approximately 80 x 130 m (see **Figure 4.9.2**). The scattered pools are surrounded by upland mixed forest. The pools are considered to be of relatively high function within the context of the study area suitable depth and longevity depending on factors such as winter snow cover and extent of rain in the spring to maintain suitable water levels for successful development and emergence of amphibians. Designation of this area as *candidate* SWH should be considered.

Habitats of Species of Conservation Concern

This category includes:

- the habitat of species that are rare or substantially declining, or have a high percentage of their global population in Ontario
- special concern species identified under the ESA on the SARO List, which were formally referred to as "vulnerable" in the Significant Wildlife Habitat Technical Guide
- species identified as nationally endangered or threatened by the Committee on the Status of Endangered Wildlife in Canada, which are not protected in regulation under Ontario's ESA

Habitats of endangered and threatened species covered under the ESA are excluded from this category.

This category is potentially complex and includes species that may be locally rare or in decline, but that have not reached the level of rarity that is normally associated with Endangered or Threatened designations. The Significant Wildlife Habitat Technical Guide (OMNR 2000) suggests that the highest priority for protection be provided to habitats of the rarest species (on a scale of global through to local municipality), and that habitats that support large populations of a species of concern should be considered significant. An additional eight criteria under the Species of Concern category are found in Appendix Q (OMNR 2000), with 28 guidelines within these criteria. The determination of SWH under this category (and under other categories) is a comparative process that must extend across the jurisdiction of the planning authority to be considered definitive.

There were ten regional uncommon/rare plants recorded from the study area. All of these species were recorded from either Block C or D and their presence may be indicative of good floristic quality in the associated vegetation communities. For example, Sugar Maple – Beech forest community FOD5-2 in Block D supports four uncommon/rare plant species. However, all of these plants occur as individuals or small groups rather than large representative populations. These species are also not rare or uncommon at the provincial or global level, nor do they have specific designation to our knowledge as "species of conservation concern" by the local or regional planning authorities. It is therefore our opinion that SWH under the category of Species of Conservation Concern would not qualify.

Animal Movement Corridors

This category includes:

- habitats that link two or more wildlife habitats that are critical to the maintenance of a population of a particular species or group of species
- habitats with a key ecological function to enable wildlife to move, with minimum mortality, between areas of significant wildlife habitat or core natural areas

Landscape connectivity (often referred to as "wildlife corridors") has become recognized as an important part of natural heritage planning and a wide range of benefits have been attributed to the maintenance or re-connection of the natural landscape. Corridors allow animals to move between areas of high habitat importance. Conservation of distinct habitat types to protect species is not effective unless the corridors between them are also protected. In the fragmented landscape of southern Ontario, connectivity functions range from low, where major development features (i.e., highways, railways) fragment a pathway, to high, where natural features dominate the landscape and are more or less contiguous.

The study area and immediate adjacent lands are not part of a large regional corridor such as the main branch of the Credit River. Such corridors, which are usually forested, are expected to provide passage and potential movement for many species that are present in the landscape and are often 300 to 500 m and wider, such as many of the major river systems in the Greater Toronto Area.

On a local level, however, both Silver Creek and Sixteen Mile Creek provide a linkage function for the movement of wildlife to varying degrees (see **Figure 4.9.5**). In the order of quality, Tributary B (Silver Creek) and Tributary A (Sixteen Mile Creek) are headwater tributaries and provide connectivity for local fauna and flora. There is a weaker linkage function along Tributary C (Silver Creek) due to the active agricultural field between Block B and Block C. All of these tributaries provide existing ecological linkages from within the study area to adjacent lands to the northeast across Eighth Line (see **Figure 4.9.5**). There are no other existing linkages from the study area to adjacent lands associated with well vegetated areas.

While the identified local level movement corridors provide function within the site, there are no corridors of provincial or regional importance found in the secondary plan area or on adjacent lands to which there is a significant connection.

4.9.4.6 Ecological Linkages

Linkages (or landscape connectivity as discussed above) describe the way in which components of the ecosystem are connected. These linkages may be aquatic, such as stream corridors or connections between groundwater and surface water, or they may be land based such as valleylands, hedgerows, field and tableland woodlots.

In addition to field investigations, topographic mapping and aerial photography were used to identify larger and smaller linkage areas within and surrounding the subject properties. There is currently limited development to hinder movement of some wildlife within the study area as the natural areas are separated by agricultural fields, which some (mid-sized to larger mammals), but not all (amphibians, reptiles and small mammals) species can cross. Lands adjacent to the study area to the west, south and southeast support primarily agriculture and provide some movement opportunities (mid-sized to larger mammals), although natural vegetation cover is lacking. There is significant urbanization to the northwest and northeast of the study area.

Within the study area there is existing linkage between Block C and Block D along the narrow section of willow swamp (unit 3c) and poplar deciduous forest (unit 8e). This linkage provides important local movement opportunities for amphibians and likely the Red-bellied Snakes that have been recorded from each of these blocks. There is also a good linkage function along the Tributary B ravine, which given the length and extent of natural forest cover provides local movement function from the tablelands and forest edges down into and along the ravine.

The remainder of the study area has isolated areas of vegetation and habitat such as the small woodland at the southern end of Tributary A. This deciduous forest (unit 1a) is not directly along Tributary A and is considered isolated. This woodland does, however, represent a node for potential linkage opportunities along Tributary A within the study area and for connectivity along watercourse features to Side Road 10 and Trafalgar Road to adjacent lands outside of the study area.

To improve connectivity of features within the study area linkage opportunities exist along Tributary A between the isolated woodland and the downstream reach of the tributary that is forested (units 6b, 6c and 22). Another linkage opportunity exists to connect Block B and C along Tributary C through the existing agricultural field. This is an opportunity to connect the woodland in Block C to Sixteen Mile Creek.

A wide range of benefits can be attributed to maintaining connectivity at the site-level as well as the local landscape. In the fragmented landscape of southern Ontario, connectivity functions range from low, where major development features (e.g., highways, railways) fragment a pathway, to high, where natural features dominate the landscape and are more or less contiguous. Within the study area the local landscape includes the surrounding natural features.

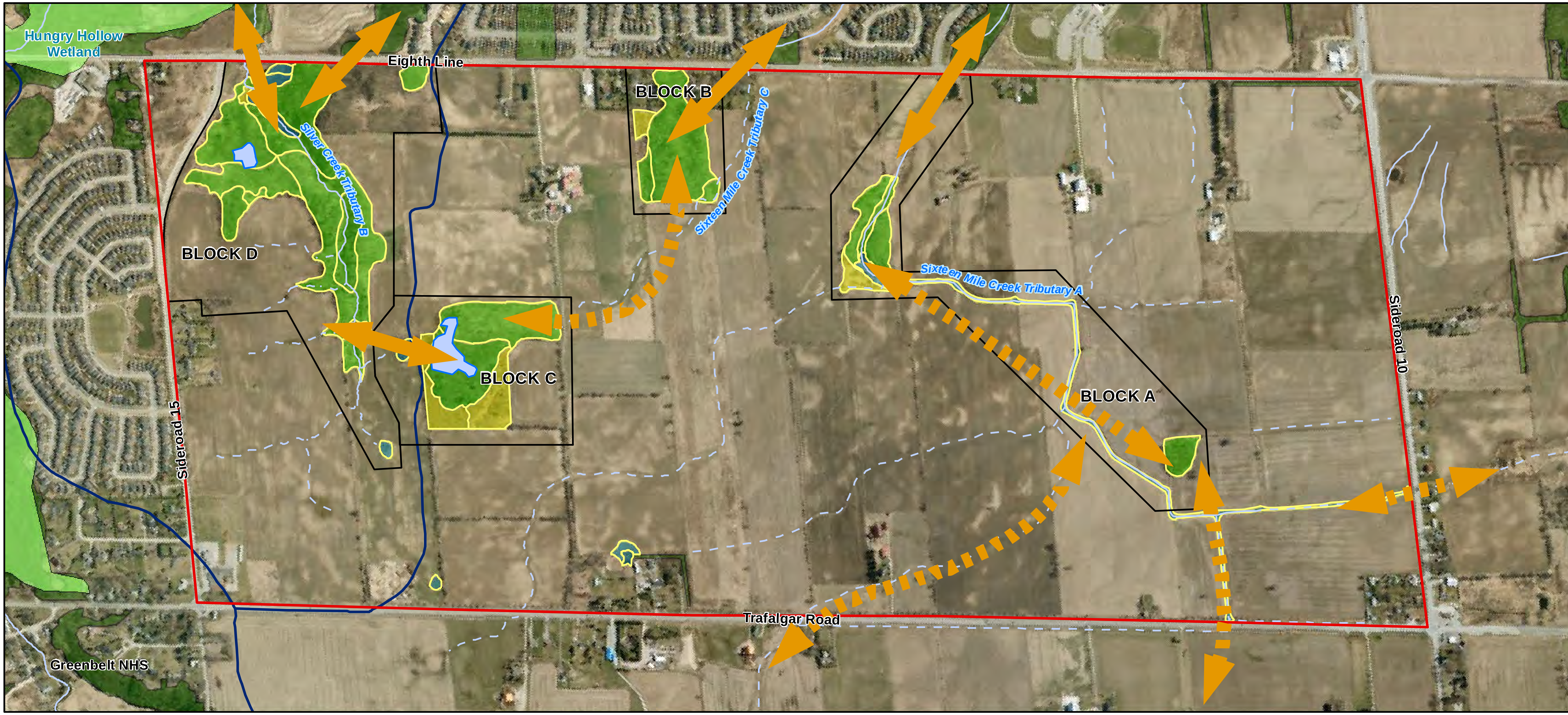
The terminology surrounding landscape connectivity and corridors can be confusing and ambiguous, for a variety of reasons. Linkages or corridors can vary in size from minor connectors such as hedgerows to large features greater than a kilometre wide such as the Oak Ridges Moraine. Identification of connectivity across the landscape is sensitive to the scale at which the analysis is undertaken. Connections can link terrestrial features, aquatic features (i.e., along a tributary) and sometimes both.

There is currently minimal urban development to hinder wildlife movement for some species to the west, south and southeast of the study area (see **Figure 4.9.5**). Developed urban areas to the northwest, north and northeast represent significant barriers to wildlife movement. The level of traffic along Trafalgar Road (which will increase with planned upgrades) and Eighth Line is also a factor in wildlife movement to and from the study area. The adjacent natural heritage corridors along the Silver Creek (Tributary B) into the Hungry Hollow Provincially Significant Wetland and ESA, and along Sixteen Mile Creek (Tributary A and C) into downstream riparian corridors play an important role in providing permeability through these urban areas. The linkage along the creek tributaries also provides good hydrological connection from the study area into downstream features.

The Hungry Hollow Ravine Environmentally Sensitive Area (ESA #37) is approximately 193 ha in size and identified as fulfilling three primary ESA criteria (5, 6, and 11), and three secondary criteria (12, 13 and 14). The ESA includes a Regional Life Science Area of Natural and Scientific Interest (ANSI) and the Hungry Hollow Provincially Significant Wetland (PSW) complex. The ESA is characterized by a deep valley that is fed by many tributary streams of Silver Creek. Features and functions of importance include: native plant communities that are rare in Halton Region; presence of provincially rare flora and fauna; contribution to maintaining surface water quality and quantity; presence of regionally rare plants; high quality representation of native flora and fauna; and, aesthetic and designated viewpoints (Halton Region 2005).

The Hungry Hollow PSW is located to the east of the study area within the Hungry Hollow ESA (see **Figure 4.9.5**). The PSW is a riverine wetland located along Silver Creek from the confluence of Black Creek to the confluence with the Credit River (CVC 2001). It includes a small fen wetland inclusion that is very unique to this area and characterized by fen indicator plants (Slender Sedge, Thin-leaved cotton grass) and deep peat accumulation of over 110 cm (North-South Environmental 2004). A continued linkage to these provincially and regionally designation natural heritage features is to be maintained.

The Greenbelt NHS is located about 250 m the west of the of the study area, west of the Trafalgar Road and Sideroad 15 intersection. There are no identified linkage opportunities along existing natural features to this area.



Existing and Potential Linkage Opportunities	**Figure 4.9.5**
SW Georgetown IPP RPP	
First Base Solutions Web Mapping Service 2010	
UTM Zone 17 N, NAD 83	
0 125 250 500 Meters	1:10,000
BEACON ENVIRONMENTAL	Project 213002 February 2016

4.10 Water Quality

4.10.1 Sixteen Mile Creek Watershed

Water quality was monitored within the study area between June and October of 2013. The field program was designed using grab sampling to capture 6 events at 4 different sites within the study boundary. Sites are illustrated in **Figure 4.10.1** and details of their sampling are included in **Table 4.10.1**. Although the events were scheduled to consist of 3 “wet weather” events (following a minimum of 10mm of rainfall) and 3 “dry weather” events (following a minimum of 72 hours without rain), actual results consisted of 4 wet weather events and 3 dry weather events at all sites excluding SWG-C(01), where only 1 dry weather sample was obtained due to particularly dry conditions. Results are provided in **Appendix M**.

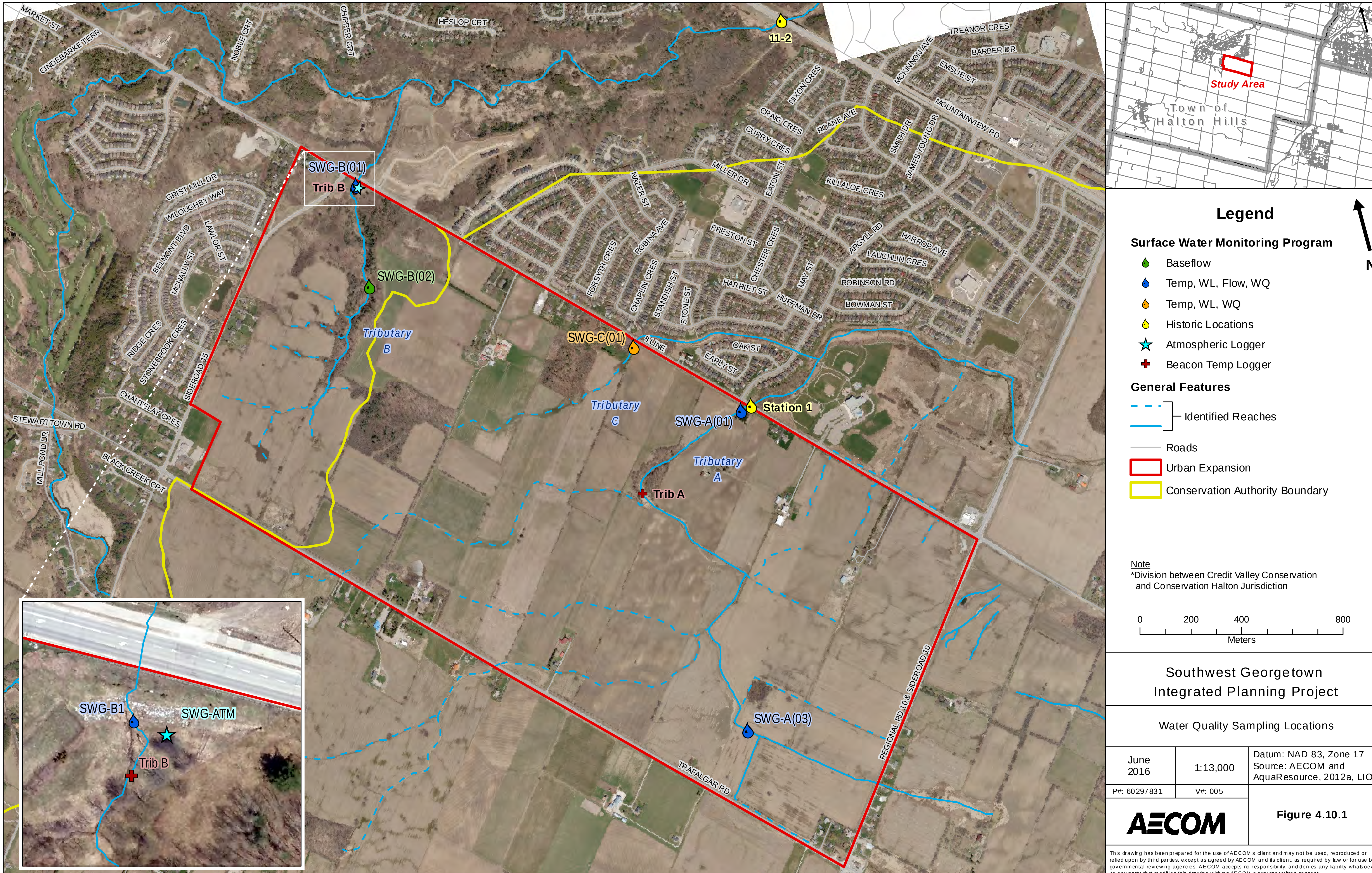
Table 4.10.1 2013 Water Quality Sampling

Site	Location Description	Related Historical Site	2013 Samples		
			Wet	Rainfall	Dry
SWG-A(01)	Tributary A of Sixteen Mile Creek, upstream of the intersection with Eighth Line.	Station 1	July 9 Aug 1 Aug 26 Oct 22	126 mm 14 mm 10 mm 8 mm	June 21 July 17 Sept 18
SWG-A(03)	Tributary A of Sixteen Mile Creek, upstream of site SWG-A(01). Site SWG-A(03) is near the southwest corner of the study area	N/A	July 9 Aug 1 Aug 26 Oct 22	126 mm 14 mm 10 mm 8 mm	June 21 July 17 Sept 18
SWG-B(01)	Tributary B of Silver Creek, upstream of the intersection with Eighth Line.	11-2	July 9 Aug 1 Aug 26 Oct 22	126 mm 14 mm 10 mm 8 mm	June 21 July 17 Sept 18
SWG-C(01)	Tributary C of Sixteen Mile Creek, upstream of the intersection with Eighth Line.	N/A	July 9 Aug 1 Aug 26 Oct 22	126 mm 14 mm 10 mm 8 mm	July 17

Water quality parameters, outlined in **Table 4.10.2**, were sampled for all events specified in **Table 4.10.1**. Each parameter’s corresponding federal, provincial and regional guidelines were identified for the Project and represent the following sources; Provincial Water Quality Objectives (PWQO), Canadian Environmental Quality Guidelines (CCME), Credit Valley Conservation Fisheries Plan (CVCFP) and Conservation Halton Fisheries Plan (CHFP).

Table 4.10.2 Guidelines for all Relevant Water Quality Parameters

Parameter	Standard	Units	Parameter Choice	Standard Choice
Zinc	0.02	mg/L	Heavy metals in runoff can indicate urban/highway runoff or the presence of an industrial discharge.	Interim PWQO
Total Phosphorus	0.03	mg/L	Established to prevent nuisance aquatic growth of algae and plants.	PWQO
pH	6.5 - 8.5		Measure of Alkalinity/Acidity - Impact on Aquatic Life	PWQO
Copper	0.005 for hardness > 20 mg/L and 0.001 for hardness ≤ 20 mg/L	mg/L	Heavy metals in runoff can indicate urban/highway runoff or the presence of an industrial discharge.	Interim PWQO
Chloride	120	mg/L	A component of road salt, it provides a good measure of urbanization and road activity.	CCME
Total Suspended Solids (TSS)	For 24-hour period - max increase of 25 mg/L from background levels For 24-hour to 30 day period -max average increase of 5 mg/L from background levels	mg/L	Removal targets are often set on this parameter for control of urban runoff. TSS is a good surrogate for other water quality parameters that adhere to particulates and can indicate erosion, construction or agricultural activity.	CCME
Temperature	Thermal Classification	°C	Indicator of Aquatic Life - Thermal Classification	CVCFP, CHFP
Dissolved Oxygen	Temperature-dependent: 8 at 0-5°C; 7 at 5-10°C; 6 at 10-20°C; 5 at 20+°C	mg/L	Indicator of Aquatic Life	PWQO
Nitrate-N (NO3-N)	Long-term Exposure (prevents against negative effects) - 3.0 mg/L Short-term Exposure (protects most species against lethality during severe but transient events) – 124 mg/L	mg/L	Stimulates aquatic plant growth, elevated levels are known to be toxic to aquatic biota.	CCME



MARKET ST
CINDEBARKE TERR
NOBLE CRT
CHIPPER CRT
HESLOP CRT
11-2
TREANOR CRES
BARBER DR
MCKINNON AVE
EMSLIE ST
MOUNTAINVIEW RD
CRAIG CRES
NIXON CRES
ROANE AVE
CURRY CRES
SMITH DR
JAMES YOUNG DR
MILLER DR
EATON ST
KILLALOE CRES
NAZER ST
GRIST MILL DR
WILOUGHBY WAY
LAWLOR ST
BELMONT BLVD
MCNALLY ST
ROBINA AVE
PRESTON ST
ARGYLL RD
HARROP AVE
LAUCHLIN CRES
FORSYTH CRES
CHESTER CRES
CHAPLIN CRES
STANDISH ST
STONE ST
HARRIET ST
MAY ST
HUFFMAN DR
ROBINSON RD
BOWMAN ST
RIDGE CRES
STONEBROOK CRES
SIDEROAD 15
CHANTELAY CRES
STEWARTTOWN RD
MILL POND DR
BLACK CREEK CRT
8 LINE
OAK ST
EARLY ST
SWG-B(01)
Trib B
SWG-B(02)
Tributary B
SWG-C(01)
Tributary C
Station 1
SWG-A(01)
Tributary A
Trib A
SWG-A(03)
TRAFALGAR RD
REGIONAL RD 10 & SIDEROAD 10
SWG-B1
SWG-ATM
Trib B
Study Area
Town of Halton Hills
Legend
Surface Water Monitoring Program
Baseflow
Temp, WL, Flow, WQ
Temp, WL, WQ
Historic Locations
Atmospheric Logger
Beacon Temp Logger
General Features
Identified Reaches
Roads
Urban Expansion
Conservation Authority Boundary
N
Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction
0 200 400 800
Meters
Southwest Georgetown Integrated Planning Project
Water Quality Sampling Locations
June 2016
1:13,000
Datum: NAD 83, Zone 17
Source: AECOM and AquaResource, 2012a, LIO
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V#: 005
AECOM
Figure 4.10.1
This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.
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4.10.2 Sampling Results and Interpretation for Sixteen Mile Creek

Historic and Present Sample Locations

For Sixteen Mile Creek, there were no Provincial Water Quality Monitoring Network (PWQMN) stations located within reasonable proximity to the study area to provide a historical comparison. As such, 2013 water quality results will be compared with historical water quality data from the Georgetown South Secondary Plan Implementation Report (Winter Associates,1990). Historical samples were taken between October 1989 and April 1990 at Station 1 (historical), located at the intersection of Sixteen Mile Creek and Eighth Line. Historic sampling has been summarized below, in **Table 4.10.3**.

Table 4.10.3 Historic Sampling at Station 1

Date	Weather	Parameters Sampled
Oct 23, 1989	Sunny high 15°C, low 6°C	Lead, Zinc, Sodium, Total Phosphorus, NH3-N, BOD, TDS, Cl, Fecal Coliform, Total Coliform, Total Plate Count, Fecal Steptococcus
Nov 24, 1989	Cloudy/Sunny high 3°C, low -5°C	Lead, Zinc, Sodium, Total Phosphorus, NH3-N, BOD, TDS, Cl
April 3, 1990	Cloudy high 7°C, low 1°C	Lead, Zinc, Sodium, Total Phosphorus, NH3-N, Cl, Fecal Coliform, Total Coliform, TDS, Dissolved Oxygen, PH, Temperature
April 30, 1990	Sunny high 22°C, low 8°C	Lead, Zinc, Sodium, Total Phosphorus, NH3-N, Cl, Fecal Coliform, Total Coliform, TDS, Dissolved Oxygen, PH, Temperature

Within the proposed urban expansion study area, there are two tributaries of Sixteen Mile Creek. Tributary C drains agricultural land, primarily from the study area, and crosses Eighth Line at sampling site SWG-C(01). Tributary C merges with Tributary A outside of the study boundary. Tributary A drains agricultural land from inside the study area as well as land from outside of the study area. Tributary A is sampled at site SWG-A(03), in the southwest corner of the study area, where it collects drainage from areas across both Trafalgar Road and Side Road 10 (both areas outside of the study area). Tributary A is also sampled at site SWG-A(01), located downstream of site SWG-A(03) and just prior to crossing Eighth Line. Between SWG-A(03) and SWG-A(01), the Tributary merges with several intermittent watercourses.

Site SWG-A(01) is in the same general location as Station 1 (historical), and can be used for historical comparison purposes. Sampling locations and site descriptions are outlined in **Figure 4.10.1** and **Table 4.10.1**, respectively. Guidelines for all parameters are outlined in **Table 4.10.2** and specific parameters will be discussed below.

A complete tabulation of all results of the water quality analyses in 16 Miles Creek is presented in **Table 4.10.4**.for historic samples and in **Table 4.10.5** for 2013 samples.

A review of sampling results identified an anomaly in the wet weather sample at SWG-A(03) on August 26, 2013. This sample was taken from pooled water, and it corresponds to a reported TSS value of 7960 mg/L, an anomaly when compared to the remaining data. It is anticipated that because the water level in the pool was very low, sediment from the pool bottom may have entered the sampling vessel and skewed the results. The sample is not representative of conditions downstream and was removed for all of the following analysis. A reported total phosphorus of 7.87 mg/L was also removed from analysis as being an anomaly from any typical runoff quality.

Table 4.10.4 Historic Water Quality Results for Sixteen Miles Creek

Parameter	23-Oct-89	Nov-89	3-Apr-90	30-Apr-90	Average
Lead (mg/L)	<0.05	<0.05	<0.05	<0.05	<0.05
Zinc (mg/L)	0.01	0.025	0.01	0.04	0.02
Sodium (mg/L)	-	115.5	81.85	69.6	89
Total Phosphorus (mg/L)	0.0505	0.1365	0.0945	0.0455	0.08
NH3-N (mg/L)	0.1	0.09	0.465	0.025	0.17
BOD (mg/L)	0.2	0.35	-	-	0.28
TDS (mg/L)	983	913.5	693	671	815
Cl (mg/L)	245	237	179	144	201
Fecal Coliform (/100ml)	50	-	47.5	9.5	36
Total Coliform (/100ml)	65	-	108.5	15	63
Total Plate Count (/ml)	2500	-	-	-	2500
Fecal Streptococcus (/100ml)	95	-	-	-	95
Oxygen Dissolved (PPM)	-	-	12	8.9	10
PH Value	-	-	7.3	8	7.7
Water Temperature (°C)	-	-	3	18	11

Table 4.10.5 2013 Water Quality Results for Sixteen Miles Creek

Station	Date	Ammonia, Total (as N)	Chloride (Cl)	Copper (Cu)-Total	Nitrate-N (NO3-N)	Nitrite-N (NO2-N)	Total Kjeldahl Nitrogen	Total Nitrogen	Phosphorus, Total, Dissolved	Total Phosphorus	Total Suspended Solids	Zinc (Zn)-Total	Dissolved Oxygen	pH
SWG-A1	6/21	<0.05	140	0.002	10.7	-	-	-	0.0266	0.0511	6.4	0.0054	6.9	7.5
	7/9	0.135	55	0.0141	4.91	<0.5	2.12	7.03	0.12	0.349	34	0.0212	6.8	7.3
	7/17	0.077	72	0.0017	8.41	<0.5	0.67	9.08	0.0468	0.0565	2.4	0.0035	4.3	7.4
	8/1	0.059	50	0.0069	3.47	<0.5	1.42	-	0.193	0.305	36	0.0098	7.9	7.6
	8/26	0.199	58	0.0013	1.55	<0.5	0.86	2.41	0.0131	0.0623	5.6	0.0047		7.2
	9/18	0.191	68	0.0014	1.54	<0.5	0.42	-	<0.03	0.041	10	0.004	1.7	6.9
	10/22	<0.05	74	0.0054	4.29	<0.5	1.38	-	0.118	0.17	113	0.01	9.3	7.9
SWG-A3	7/9	0.428	109	0.0067	2.57	<0.5	1.66	4.23	0.119	0.169	13.6	0.0094	3.7	7.0
	7/17	0.153	313	0.0031	4.65	<0.5	1.11	5.76	0.0052	0.044	32.8	0.0065	3.5	7.2
	8/1	0.085	117	0.0179	0.74	<0.5	1.08	-	0.298	0.503	44	0.0239	10.9	7.4
	8/26	*0.463*	*339*	*0.0752*	*<0.5*	*<0.5*	*8.69*	*8.69*	*0.0444*	*1.71*	*7960*	*0.226*	*5.7*	*7.4*
	9/18	0.053	530	0.0054	<0.5	<0.5	1.65	-	<0.03	0.308	163	0.0302		
	10/22	0.07	100	0.0047	3.76	<0.5	0.96	-	0.106	0.15	16	0.0102	>16	7.1
SWG-C1	7/9	0.06	<10	0.0071	21.8	<0.5		23.3	0.0759	0.159	43.2	0.0079	6.5	7.5
	7/17	0.065	13	0.0028	1.32	<0.5	0.37	1.69	0.0242	0.107	45.6	0.254	6.6	6.9
	8/1	0.052	<10	0.0119	25.8	<0.5	1.89	-	0.153	0.438	126	0.0591		
	8/26	0.061	121	0.0163	0.7	<0.5	2.64	3.34	0.171	0.639	658	0.0398	6.6	6.7
	10/22	0.07	59	0.0064	7.18	<0.5		-	-	*7.87*	90	0.0243	8.3	7.4

Note: all in mg/L, except for pH - : not measured

Chloride

Results from SWG-A(03) and SWG-A(01) were combined to provide a more complete picture of chloride levels in Tributary A. For both wet and dry weather conditions in Tributary A (total of 14 events), the guideline of 120 mg/L was exceeded twice at site SWG-A(03) and once at site SWG-A(01). **Table 4.10.6** provides a summary of all measured chloride concentrations in Sixteen Mile Creek.

Table 4.10.6 Summary of 2013 Chloride Concentrations in Sixteen Mile Creek

	Trib A Dry	Trib A Wet	Trib C Dry	Trib C Wet	Station 1 (historic)
Minimum (mg/L)	68	50	13	59	144
Maximum (mg/L)	530	117	13	59	245
Mean (mg/L)	201	84	13	59	201

The observation that wet weather samples have a lower chloride concentration when compared to dry weather samples indicates that rainwater and its associated surface runoff (storm flow) is not a substantial source of chloride in the catchment area.

Site SWG-A(01) had lower chloride levels for all sampling events when compared to SWG-A(03). This indicates that as water flows across the study area, from SWG-A(03) to SWG-A(01), it is influenced by the intermittent watercourses which presumably contribute flow with considerably lower chloride levels. The drainage area for the intermittent watercourses is primarily agricultural which supports their lower chloride levels (assumes very little road or urbanization contribution to agricultural areas) although sampling has not been done to confirm this.

All wet and dry event results for Tributary C fell within or were at the guideline of 120 mg/L. It should be noted that during 2 of the 3 dry weather events, the Tributary was completely dry and samples were not taken.

Results from the 2013 sampling program at site SWG-A(01) are comparable to those seen historically. It must be noted that all 4 of the Station 1 (historic) events were sampled between the months of October and April, while all of the 2013 sampling occurred between June and October and therefore the effect of seasonal variation cannot be compared within the two data sets.

Total Phosphorus

Using watershed monitoring data from prior to 1996, The Sixteen Mile Creek Watershed Plan (Gore & Storrie Ltd., Ecoplans Ltd., HUSRCT, 1996) reported consistent elevated nutrient (phosphorus) levels within the watershed, specifically in the East Branch of Sixteen Mile Creek. The study site is located in the East Branch of Sixteen Mile Creek and therefore elevated phosphorus levels may be expected.

Results from SWG-A(03) and SWG-A(01) were combined to provide a more complete picture of total phosphorus levels in Tributary A. **Table 4.10.7** provide a summary of phosphorus measurements in Silver Creek. An apparent anomaly of 7.87 mg/L measured in October was removed from analysis.

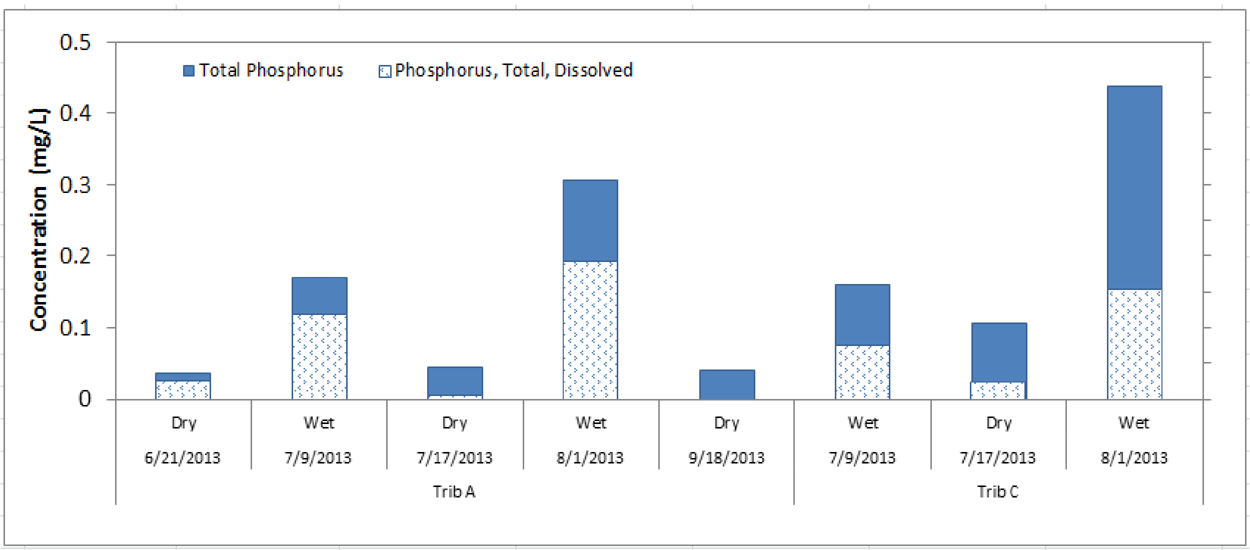
For Tributary C, it should be noted that upon visiting the site during 2 of the 3 dry weather events, the Tributary was completely dry and samples were not taken.

Table 4.10.7 Summary of 2013 Total Phosphorus Concentrations in Sixteen Mile Creek

	Trib A Dry	Trib A Wet	Trib C Dry	Trib C Wet	Station 1 (historic)
Minimum (mg/L)	0.041	0.15	0.11	0.16	0.046
Maximum (mg/L)	0.31	0.50	0.11	0.44	0.137
Mean (mg/L)	0.10	0.27	0.11	0.30	0.082

All 2013 and historic results exceeded the PWQO guideline of 0.03 mg/L demonstrating consistent elevated phosphorus levels within the study area. For both Tributary A and Tributary C, wet weather results are considerably higher than dry weather results. Generally, results which exceed the guideline can be attributed to high nutrient levels in agricultural soils. Comparison of total phosphorus with dissolved phosphorus (**Figure 4.10.2**) shows that under wet weather conditions, up to 70% of phosphorus is dissolved which could be an indication of surface runoff from grassland, forest land or non-erosive soils, as this type of runoff carries little sediment and is generally dominated by dissolved phosphorus. However, phosphorus transport attached to colloidal material may also be a significant portion of total phosphorus where land is overstocked.

Figure 4.10.2 Total and Dissolved Phosphorus in Silver Creek



Total Suspended Solids (TSS)

Results from SWG-A(03) and SWG-A(01) were combined to provide a more complete picture of TSS levels in Tributary A. **Table 4.10.8** provides a summary of the results. Average results for the two tributaries and under different weather conditions are about 40-90 mg/L.

In Tributary C, dry weather samples were collected on 2 of the 3 occasions due to lack of water. The dry weather sample that was collected on July 17, 2013 had a reported value of 45.6 mg/L. When the sample was collected, it was noted that the station was wet but the area upstream was dry. From these observations, it is assumed that flow is intermittent at the site and that the sample is not fully representative of the downstream conditions.

Table 4.10.8 Summary of 2013 TSS Results in Sixteen Mile Creek

	Trib A Dry	Trib A Wet	Trib C Dry	Trib C Wet	Station 1 (historic)
Minimum (mg/L)	2.4	13.6	45.6	43.2	N/A
Maximum (mg/L)	163	113	45.6	126	N/A
Mean (mg/L)	43	43	45.6	86	N/A

Station 1 (historic) did not include TSS sampling and the Sixteen Mile Creek Watershed Plan (Gore & Storrie Ltd., Ecoplans Ltd., HUSRCT, 1996) does not present background TSS levels for the study reach. Other reaches within the Sixteen Mile Creek watershed had mean TSS values ranging from 5 mg/L to 320 mg/L for wet weather events and mean values between <3 mg/L and 4 mg/L for dry weather events (Gore & Storrie Ltd., Ecoplans Ltd., HUSRCT, 1996). More data is required to develop background TSS levels for future comparison at the study site.

Metals

Results from SWG-A(03) and SWG-A(01) were combined to provide a more complete picture of metal levels in Tributary A. As indicated in the above sections, three events were sampled from pooled water at site SWG-A(03) and will be removed from the analysis. Events include; 2 dry weather events (July 17 and September 18, 2013) and one wet weather event (August 26, 2013). Results from the 2013 sampling are shown below, in **Table 4.10.9,** and do not include the pooled water samples.

Table 4.10.9 Summary of 2013 Zinc and Copper Concentrations in Sixteen Mile Creek

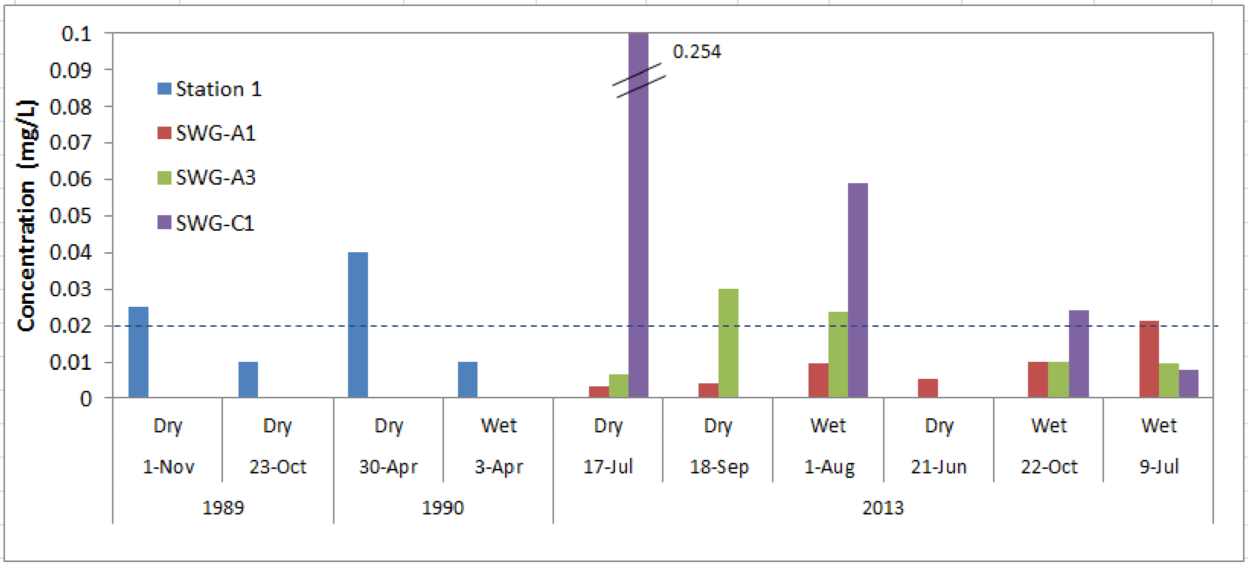
	Zinc					Copper			
	Trib A Dry	Trib A Wet	Trib A Dry	Trib A Wet	Trib A Dry	Trib A Wet	Trib A Dry	Trib A Wet	Trib A Dry
Minimum (mg/L)	0.0035	0.0094	0.25	0.0079	0.01	0.0014	0.0047	0.0028	0.0064
Maximum (mg/L)	0.0302	0.024	0.25	0.059	0.04	0.0054	0.0179	0.0028	0.0119
Mean (mg/L)	0.01	0.014	0.25	0.030	0.02	0.0027	0.0093	0.0028	0.0085

Samples taken during wet weather events generally returned a concentration higher than samples taken during dry events. Copper concentration was within guideline limits for dry events but results exceeded the PWQO guideline during wet weather events. It is difficult to correlate the samples that exceeded the guidelines with specific conditions as they ranged over 3 separate events and all 3 monitoring locations; SWG-A(01), SWG-A(03), and SWG-C(01). No historic data was recorded for copper.

Zinc concentrations in Tributary A exceeded the guideline during one dry event and 2 of 6 samples under wet conditions. In Tributary C, 2 of 3 wet weather samples exceeded the guideline as did the single dry weather sample. Due to limited dry weather data, it is difficult to reliably compare the dry weather results from Tributary C to other events. A comparison of zinc levels between site SWG-A(01) and Station 1 (historic) is shown in **Figure 4.10.3**. The range and variability of observed concentrations are similar between historic data and 2013 results (except for the one dry event in Tributary C).

Copper and zinc could originate from agricultural sources or road runoff. Copper and zinc are used as animal feed additives and can accumulate in soils receiving heavy applications of manure, leading to high concentrations in runoff. Other potential sources of copper include rocks weathering and atmospheric deposition, sewages, runoffs from land, roads and roofs. The proposed baseline monitoring program will provide more data to help identify potential sources of metals in runoff.

Figure 4.10.3 Comparison of Zinc Concentrations in 2013 Samples and Historic Results



Nitrogen Compounds

A portion of ammonia (un-ionized ammonia) is toxic to aquatic life, depending on the temperature and pH of the water. TKN represents the organic nitrogen plus the ammonia. Nitrite and nitrate are nutrients similar to phosphorus and can stimulate plant growth.

Measured ammonia levels were well below the guideline (after conversion to un-ionized for pH and temperature). Results from SWG-A(03) and SWG-A(01) were combined to provide a more complete picture of nitrate levels in Tributary A. As discussed in the sections above, one wet weather sample (August 26) was taken from pooled water and so it was not included in the results summary, outlined in **Table 4.10.10**, or subsequent discussion.

Table 4.10.10 Summary of 2013 Nitrate-N (NO3-N) Results in Sixteen Mile Creek

	Trib A Dry	Trib A Wet	Trib C Dry	Trib C Wet
Minimum (mg/L)	1.54	0.74	1.32	7.2
Maximum (mg/L)	11.8	4.91	1.32	25.8
Mean (mg/L)	7.42	3.29	1.32	18.3

The wet weather sampling results indicate that nitrate levels exceeded the long-term exposure guideline (3.0 mg/L) in 7 out of 11 samples but did not exceed the short-term exposure guideline (124 mg/L) in any samples during 2013. Under dry weather conditions, 3 of 5 samples exceeded the long-term exposure guideline but no samples exceeded the short-term exposure guideline.

Elevated nitrate levels can be an indication of point source contamination such as municipal wastewater, or industrial wastewater, and nonpoint source contamination could be from; agricultural runoff, feedlot discharge, septic beds, urban runoff, lawn fertilizers or storm sewer overflow (CCME, 2012).

Thermal Classification

Water temperature was evaluated as part of the ecological review of conditions and is presented in **Section 4.9.3.5**.

pH

All pH measurements taken in both Tributary A and Tributary C of Sixteen Mile Creek fell within the guideline range. The following, **Table 4.10.11**, provides a summary of the results.

Table 4.10.11 Summary of 2013 pH Results in Sixteen Mile Creek

	Trib A Dry	Trib A Wet	Trib C Dry	Trib C Wet	Station 1 (historic)
Minimum (mg/L)	6.88	7.16	6.79	6.68	7.3
Maximum (mg/L)	7.45	7.9	6.79	7.29	8.0
Mean (mg/L)	7.21	7.74	6.79	6.97	7.65

The minimum, maximum and mean of each 2013 data set is lower than the historic results.

Dissolved Oxygen

Results from SWG-A(03) and SWG-A(01) were combined to provide a more complete picture of Dissolved Oxygen levels in Tributary A. Results from both Tributary A and Tributary C are reported below, in **Table 4.10.12**.

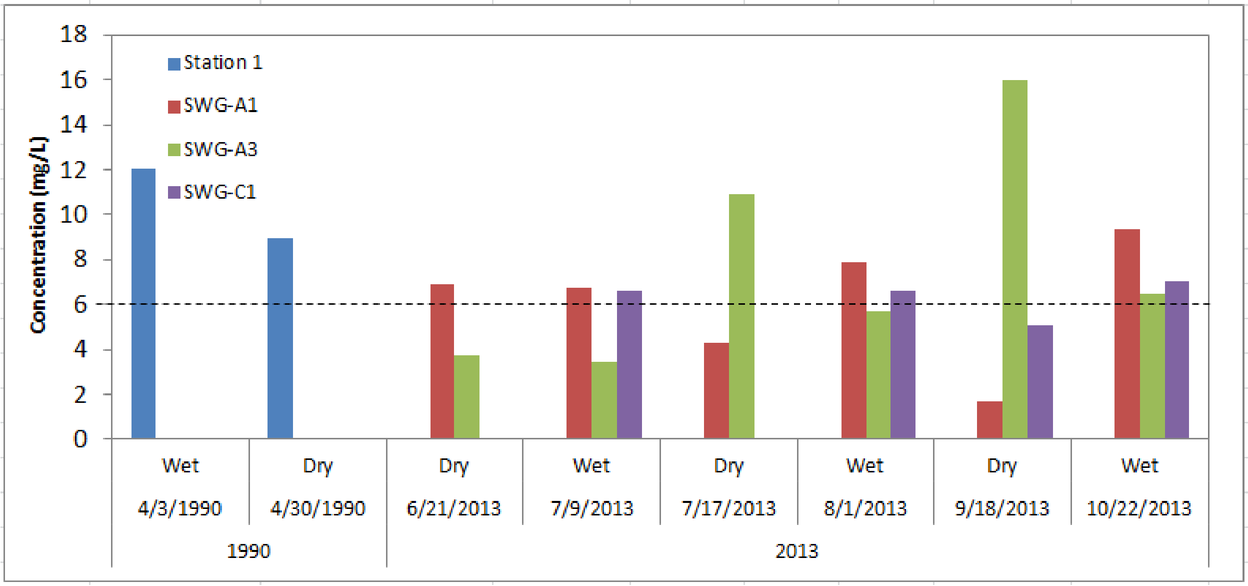
Table 4.10.12 Summary of 2013 Dissolved Oxygen Results in Sixteen Mile Creek

	Trib A Dry	Trib A Wet	Trib C Dry	Trib C Wet	Station 1 (April 1990)
Minimum (mg/L)	1.66	3.46	5.06	6.59	8.9
Maximum (mg/L)	16	9.33	5.06	7.05	12
Mean (mg/L)	7.23	6.6	5.06	6.75	10.45

Water temperature ranged roughly between 10 and 20 °C for the sampling period and therefore the results were compared to an objective of 6 mg/L. There is a similar trend in Tributary A and Tributary C. The dry weather results have a similarly low average when compared to the wet weather results. In Tributary A, half of dry event samples and 2 of 6 wet event samples resulted in dissolved oxygen below the minimum guideline of 6. For Tributary C, the single sample obtained from a dry event was below the guideline minimum (**see Figure 4.10.4**). All samples were taken between 10 am to 2 pm, when oxygen could be produced due to photosynthesis.

Historically, DO has been measured at levels above 9 mg/L. The apparent decline in dissolved oxygen can be the result of increasing nutrient levels entering water. Very low concentrations are correlated with high nutrient levels.

Figure 4.10.4 Dissolved Oxygen in Silver Creek



4.10.3 Sampling Results and Interpretation for Silver Creek

Historic and Present Sample Locations

Historical water quality samples were collected as part of a subwatershed study at site 11-2, located downstream of the 2013 Silver Creek monitoring site, SWG-B(01). The historic site is situated at the intersection of Silver Creek and Mountain View Road, upstream of the Sewage Treatment Plant. Monitoring began at this site in 1979 and is still active. Samples are taken on a monthly basis, on a random date towards the end of each month. Results from the monitoring were compiled in the Silver Creek Subwatershed Study (CVC, Schroeter & Assoc., EWRG, Aquafor Beech Ltd., Jacques Whitford Env. Ltd, 2002) and reviewed for the purpose of this project. Monthly averages of water quality parameters for the entire period are summarized in **Table 4.10.13**. For a complete set of historic data, please reference the Silver Creek Subwatershed Study (CVC, Schroeter & Assoc., EWRG, Aquafor Beech Ltd., Jacques Whitford Env. Ltd, 2002).

Sampling locations are shown in **Figure 4.10.1**. Results of the 2013 water quality analyses are presented in **Table 4.10.14** and discussed below.

Table 4.10.13 Historic Water Quality Results for Silver Creek (Monthly Averages 1979-2012)

Month	Ammonia, Total (as N)	Chloride (Cl)	Copper (Cu)-Total	Nitrate-N (NO3-N)	Nitrite-N (NO2-N)	Total Kjeldahl Nitrogen	Total Phosphorus	Zinc (Zn)-Total	Dissolved Oxygen	pH
Jan	0.106	113	0.003	2.31	0.014	0.63	0.03	0.004	12.5	8.1
Feb	0.117	91	0.002	2.20	0.009	0.64	0.04	0.004	13.0	7.4
Mar	0.066	72	0.002	1.47	0.009	0.78	0.06	0.005	12.7	7.8
Apr	0.043	59	0.002	1.41	0.017	0.44	0.03	0.003	11.3	8.0
May	0.040	73	0.003	1.39	0.013	0.50	0.03	0.003	10.4	8.0
Jun	0.040	84	0.003	1.64	0.030	0.51	0.03	0.003	9.1	7.8
Jul	0.066	99	0.003	1.94	0.023	0.51	0.04	0.003	9.3	7.8
Aug	0.095	99	0.002	2.18	0.023	0.48	0.03	0.003	9.5	7.7
Sep	0.125	94	0.003	1.98	0.021	0.50	0.04	0.004	9.6	7.7
Oct	0.119	95	0.003	2.06	0.022	0.50	0.03	0.003	10.5	7.7
Nov	0.006	82	0.003	1.92	0.005	0.51	0.03	0.004	11.5	7.6
Dec	0.006	84	0.004	2.40	0.006	0.47	0.04	0.012	12.1	7.4
Average	0.074	87	0.001	1.89	0.017	0.54	0.04	0.002	11	8
75^{th} Percentile	0.03	106	0.02	2.39	0.012	0.56	0.034	0.003	12.6	8.1
Maximum	1.8	306	0.01	4.1	0.31	5.25	0.49	0.035	17	9 (min 6)

Note: all in mg/L; Average, 75^{th} percentile and maximum were calculated using individual data points rather than monthly averages.

Table 4.10.14 2013 Water Quality Results for Silver Creek

Date	Ammonia, Total (as N)	Chloride (Cl)	Copper (Cu)-Total	Nitrate-N (NO3-N)	Phosphorus, Total, Dissolved	Total Kjeldahl Nitrogen	Total Nitrogen	Total Phosphorus	Total Suspended Solids	Zinc (Zn)-Total	Dissolved Oxygen	pH
6/21	<0.05	13	0.002	1.63	0.021	-	-	0.036	16.8	0.040	3.5	7.3
7/9	0.121	16	0.005	1.07	0.048	0.74	1.81	0.090	23.2	0.007	7.8	7.4
7/17	0.059	10	0.004	26.9	0.025	0.35	27.3	0.119	26	0.015	5.2	7.4
8/1	0.117	<10	0.029	0.88	0.011	0.81	-	0.171	72.8	0.061	7.8	7.5
8/26	0.102	11	0.004	1.35	0.046	0.77	2.12	0.166	604	0.008	-	7.4
9/18	0.077	13	0.004	0.97	0.036	1.07	-	0.305	212	0.011	3.6	7.7
10/22	0.091	12	0.003	0.69	0.017	0.42	-	0.286	23.2	0.008	7.8	7.8

Note: all in mg/L - : not measured

Chloride

Sampling results for chloride are illustrated below, in **Table 4.10.15**.

Table 4.10.15 Summary of 2013 Chloride Results in Silver Creek at site SWG-B(01)

	Trib B Dry	Trib B Wet
Minimum (mg/L)	10	10
Maximum (mg/L)	13	16
Mean (mg/L)	12	12

The 2013 sampling results indicate chloride concentrations are considerably less than the guideline of 120 mg/L during both wet and dry weather conditions. Dry weather results were within the range of wet weather results and the mean of each is very similar.

The seasonality of the 2013 data should be noted. Sampling was done during the ice free period and therefore does not represent any chloride concentrations caused by the use of road salt during winter months. Review of the data from site 11-2 (historic) indicates that the average chloride concentrations does not vary seasonally, indicating that chloride levels in Silver Creek are not considerably affected by road salt and spring melt events may dilute chloride levels in the stream.

Results from the 2013 monitoring program are considerably lower than historic results from summer and fall sampling (see **Table 4.10.13**). This is believed to be due to the contribution of additional runoff to the historic station.

Total Phosphorus

All 2013 sampling results from site SWG- B(01) exceeded the 0.03 mg/L guideline for total phosphorus. Results are summarized below, in **Table 4.10.16**.

Table 4.10.16 Summary of 2013 Total Phosphorus Results in Silver Creek

	Trib B Dry	Trib B Wet
Minimum (mg/L)	0.036	0.090
Maximum (mg/L)	0.305	0.286
Mean (mg/L)	0.153	0.178

The range of total phosphorus concentration during 2013 wet weather events fits within the range from dry weather sampling. The average wet weather event has a greater total phosphorus concentration than the average dry weather event.

Review of the data from site 11-2 (historic) indicates that the average phosphorus concentrations for the months monitored in the 2013 study are generally lower than the 2013, except for odd years. Average annual concentrations have ranged from 0.01 to 0.15 mg/L with a 75th percentile of 0.046 mg/L. The 2013 results are comparable to the years with the highest phosphorus results (e.g. 2005).

Total Suspended Solids (TSS)

Sampling results are summarized below, in **Table 4.10.17**, indicating averages of about 85 and 180 mg/L for dry and wet weather conditions, respectively. The dry weather average is heavily influenced by a relatively high reading in August (at 600), which is about an order of magnitude higher than other samples. TSS is not measured at the provincial station.

Table 4.10.17 Summary of 2013 TSS Results in Silver Creek

	Trib B Dry	Trib B Wet
Minimum (mg/L)	16.8	23.2
Maximum (mg/L)	212	604
Mean (mg/L)	85	181

Total suspended solid levels appear to be elevated during wet weather events when compared to dry weather events from the same 2013 season. This could be due to increased loading from surface runoff which, in the study area, travels through agricultural areas. TSS in the Tributary is expected to increase after farming activities have disturbed the soil and surface runoff is able to collect more loose particles. Because of the high variability in the sample results, the data from 2013 may not capture the general conditions within Tributary B.

Metals

Sampling results from 2013 have been summarized below, in **Table 4.10.18**.

Table 4.10.18 Summary of 2013 Zinc and Copper Concentrations in Silver Creek

	Zinc		Copper	
	Trib B Dry	Trib B Wet	Trib B Dry	Trib B Wet
Minimum (mg/L)	0.0112	0.0069	0.0015	0.0027
Maximum (mg/L)	0.0399	0.061	0.0039	0.0289
Mean (mg/L)	0.0219	0.0208	0.0030	0.0103

Copper samples did not exceed the PWQO guideline during any dry weather events but did exceed the guideline during 2 of 4 wet weather events. Zinc exceeded its guideline on one of 3 dry weather sampling events as well as one of the 4 wet weather sampling events. Copper concentrations, under wet weather conditions at SWG-B(01), were higher, on average, than dry weather conditions. The opposite is true for Zinc, concentrations were elevated under dry weather conditions although not considerably (elevated by 5% over wet weather conditions).

Historically, copper and zinc samples averaged within guideline limitations. The average zinc concentration (of both wet and dry events) from 2013 is around 8 times the historic value. The average dry weather copper concentration from 2013 is about 3 times the historic value and the average wet weather concentration is about 9 times the historic value (mainly due to the one high sample in August).

Increased metal concentrations in stream water can be caused by an array of sources and scenarios. It can be noted that the wet weather events for both zinc and copper are in range of 8-10 times their historic values. Because the levels increased by a similar magnitude, they could be associated with the same heavy metal source. Naturally, zinc and copper can both be introduced to a watercourse, through runoff that has collected minerals from rocks and soil. Because the historic levels are considerably lower than those observed in 2013 there may be a source of metals either not present historically or not present to the same extent in the full catchment area of the historic site compared to the current site. Although the site has not recently undergone heavy construction or other activities that exposed sub-surface rock and soil it is an active agricultural area. It should be noted that an increase of soils in the creek can elevate both the heavy metals concentration (observed) as well as the TSS levels (observed). Two possible sources of the higher soils seen in Silver Creek when compared to historic data are; agricultural practice change and the resulting exposure of surface area for erosion as well as higher instream erosion (observed during site visits in 2013).

Another possible source is through the use of zinc-containing fertilizers on agricultural land within the study boundary. Although there is no confirmation that zinc-containing fertilizers are being used in the study area, fertilizers are able to impact concentrations in both baseflow (dry weather) and highflow (wet weather). Because the 2013 copper concentrations were considerably more elevated during wet weather events, it can be assumed that rain and storm flow (overland runoff) contribute to the increase.

Monitoring results were limited and without further studies, the specific source of the elevated heavy metal levels cannot be confirmed until the baseline monitoring (as recommended in **Section 6.4.6.6**) is completed.

Nitrogen Compounds

A portion of ammonia (un-ionized ammonia) is toxic to aquatic life, depending on the temperature and pH of the water. TKN represents the organic nitrogen plus the ammonia. Nitrite and nitrate are nutrients similar to phosphorus and can stimulate plant growth. A summary of results from the 2013 monitoring program are illustrated below, in **Table 4.10.19**.

Table 4.10.19 Summary of 2013 Nitrate-N (NO3-N) Results in Silver Creek

	Trib B Dry	Trib B Wet
Minimum (mg/L)	0.97	<0.50
Maximum (mg/L)	26.9	1.07
Mean (mg/L)	9.8	0.79

The water quality results from the subwatershed study and wet weather sampling for this project indicate nitrate levels less than the CCME guideline of 3.0 mg/L. There was one dry weather sample that exceeded the guideline (26.9 mg/L) and was 16.5 times greater than the next greatest value. The 2013 results are comparable with historic measurements.

Table 4.10.20 Historic Nitrate-N (NO3-N) Results in Silver Creek

Site	Season	Mean (mg/L)
11-2 (historic)	Summer, 1980 - 2000	1.8
11-2 (historic)	Fall, 1980 - 2000	2.0
11-2 (historic)	Winter, 1980 - 2000	2.3
11-2 (historic)	Spring, 1980 - 2000	1.5

Thermal Classification

Water temperature was evaluated as part of the review of ecological conditions. See **Section 4.9.3.5**.

pH

All pH measurements taken in Tributary B of Silver Creek fell within the guideline range. The following, **Table 4.10.21**, provides a summary of the results.

Table 4.10.21 Summary of 2013 pH Results in Silver Creek

	Trib B Dry	Trib B Wet
Minimum (mg/L)	7.4	7.35
Maximum (mg/L)	7.68	7.79
Mean (mg/L)	7.54	7.53

Historically, pH has varied between 6 and 9.

Dissolved Oxygen

Results from dissolved oxygen sampling in Tributary B of Silver Creek are reported below, in **Table 4.10.22**.

Table 4.10.22 Summary of 2013 Dissolved Oxygen Results in Silver Creek

	Trib B Dry	Trib B Wet
Minimum (mg/L)	3.64	6.14
Maximum (mg/L)	5.18	7.83
Mean (mg/L)	4.41	7.39

All of the events recorded in Tributary B during 2013 were within the guidelines except for 1 of the 2 dry weather events. The dissolved oxygen levels during wet weather events were higher than during dry weather events. When precipitation increases water levels in the Tributary, the water velocity tends to increase as well. The increase in water velocity causes an increase in water column mixing and therefore the watercourse tends to re-aerate at a faster rate. This could explain the higher wet weather dissolved oxygen concentrations. Both the minimum and the maximum values observed in 2013 were lower than those observed historically, during June and August.

4.10.4 Summary and Conclusions

Water quality was monitored within the study area between June and October of 2013. The field program was designed using grab sampling consisting of four wet weather events and three dry weather events. Water quality results were compared to federal, provincial and regional guidelines identified for the Project for perspective.

Analysis of available historic data and data collected in this study from the Sixteen Mile Creek showed the followings:

Chloride: There were exceedances of the guideline of 120 mg/L in Tributary A but not in Tributary C. Wet weather samples had a lower chloride concentration from dry weather samples, indicating that rainwater and its associated surface runoff (storm flow) was not a substantial source of chloride in the catchment area.

Phosphorus: High levels were observed in both historic and 2013 results and the values were comparable between the two datasets. All 2013 and historic results exceeded the PWQO guideline of 0.03 mg/L demonstrating consistent elevated phosphorus levels within the study area. For both Tributary A and Tributary C, wet weather results were considerably higher than dry weather results. Generally, results which exceed the guideline can be attributed to high nutrient levels in agricultural soils.

TSS: Average results for the two tributaries and under different weather conditions are about 40-90 mg/L. TSS levels in 2013 were higher than they had been historically (in other reaches of the Creek), this could possibly be associated with agricultural practices and increased stream erosion. More data is required to develop background TSS levels for future comparison at the study site.

Copper and zinc: There were a few instance of high metal levels from the 2013 results. Wet weather events generally returned a concentration higher than dry events. Copper concentration was within guideline limits for dry events but results exceeded the PWQO guideline during wet weather events. Zinc concentrations exceeded the guideline in some dry or wet weather events. Copper and zinc could originate from agricultural sources (animal feed) or road runoff. Other potential sources of copper include rocks weathering and atmospheric deposition, sewages, runoffs from land, roads and roofs.

Nitrogen compounds: Measured ammonia levels were well below the guideline (after conversion to un-ionized for pH and temperature). The wet and dry weather results indicated that some nitrate levels exceeded the long-term exposure guideline (3.0 mg/L) but not the short-term exposure guideline (124 mg/L) in any samples during 2013. Elevated nitrate levels can be an indication of point source contamination such as municipal wastewater, or industrial wastewater, and nonpoint source contamination could be from; agricultural runoff, feedlot discharge, septic beds, urban runoff, lawn fertilizers or storm sewer overflow.

pH: all measurements taken in both Tributary A and Tributary C of Sixteen Mile Creek fell within the guideline range.

Dissolved Oxygen: Dry weather results have a lower average than the wet weather results. In Tributary A, half of dry event samples and some wet event samples resulted in dissolved oxygen below the minimum guideline of 6. For Tributary C, the single sample obtained from a dry event was below the guideline minimum . All samples were taken between 10 am to 2 pm, when oxygen could be produced due to photosynthesis. Historically, DO has been measured at levels above 9 mg/L. The apparent decline in dissolved oxygen can be the result of increasing nutrient levels entering water. Very low concentrations are correlated with high nutrient levels.

Analysis of available historic data and data collected in this study from the Silver Creek showed the followings:

Chloride: The 2013 sampling results indicate chloride concentrations are considerably less than the guideline of 120 mg/L during both wet and dry weather conditions. Dry weather results were within the range of wet weather results and the mean of each is very similar. Results from the 2013 monitoring program are considerably lower than historic results from summer and fall sampling. This is believed to be due to the contribution of additional runoff to the historic station.

Total phosphorus: In 2013, the average wet weather event has a greater total phosphorus concentration than the average dry weather event. Historically average phosphorus concentrations have been lower than those in 2013; however, the 2013 results are comparable to the years with the highest phosphorus results (e.g. 2005).

TSS: Sampling results indicated averages of about 85 and 180 mg/L for dry and wet weather conditions, respectively. The dry weather average was heavily influenced by a relatively high reading in August (at 600), which was about an order of magnitude higher than other samples. TSS is not measured at the provincial station. The high TSS could be due to increased loading from surface runoff which, in the study area, travels through agricultural areas.

Copper and zinc: Copper samples did not exceed the PWQO guideline during any dry weather events but did exceed the guideline during some wet weather events. Zinc exceeded its guideline in some dry and wet weather sampling events. Historically, copper and zinc samples averaged within guideline limitations. Increased metal concentrations in stream water can be caused by an array of sources and scenarios. Naturally, zinc and copper can both be introduced to a watercourse, through runoff that has collected minerals from rocks and soil. Monitoring results were limited and without further studies, the specific source of the elevated heavy metal levels cannot be confirmed until the baseline monitoring (as recommended in section 6.4.6.6) is completed

Nitrogen Compounds: The results indicated that nitrate levels were less than the CCME guideline of 3.0 mg/L. There was one dry weather sample that exceeded the guideline (26.9 mg/L), otherwise the 2013 results are comparable with historic measurements.

pH: All pH measurements taken in Tributary B of Silver Creek fell within the guideline range.

Dissolved oxygen: All of the events recorded in Tributary B during 2013 were within the guidelines except for 1 of the 2 dry weather events. The dissolved oxygen levels during wet weather events were higher than during dry weather events, which can be explained by increase in water column mixing. Both the minimum and the maximum values observed in 2013 were lower than those observed historically during June and August.

The results of this program were used to develop a more detailed program to be implemented for pre and post construction conditions (see **Section 5.5** for details).

4.11 Characterization Summary

4.11.1 Introduction and Overview

The preceding sections of this report have provided the background characterization information in support of the development of environmental constraint lands for the Southwest Georgetown study area. These constraint lands will, in turn be used in the Secondary Planning process in developing land use scenarios. Although it provides the information intended to identify constraint lands, it is the first step in a continuing process. The Subwatershed Team will be working with the Secondary Plan team to ensure that land use plans are developed in a manner that meets the Subwatershed Goals and Objectives.

The Characterization process includes both the stream network and terrestrial features. It has been carried out through a process that has integrated the input of all of the disciplines required; aquatic and terrestrial biology, fluvial geomorphology, hydrogeology, hydrology and hydraulics. This integration has been carried out, considering the ecosystem characteristics of the area and linkages to the watershed and surrounding lands. **Appendix I** provides the tables that summarize the overall stream characterization. This has been developed using the integration of the various disciplines noted. The terrestrial features are illustrated in **Figure 4.9.1**. This provides an initial step in the identification of the stream classification, stream corridor constraints and terrestrial constraint lands. This evaluation and identification is developed further in **Section 5** and **6** of this report.

4.11.2 Stream Characterization Process

This section of the report provides a discussion of the classification of the streams under the 2009 CVC/TRCA headwater classification system. This provides the basis for developing the overall classification of streams from a management standpoint (i.e. how the streams should be protected, enhanced and managed under future urban land use). The classification of the streams from a future management approach requires additional analysis and is outlined in **Section 5** of this report. The classification in this section of the report is developed primarily on the field data collected and characterization carried out to date.

Development of many areas within the Greater Toronto Area is spreading northward and westwards, into the headwater areas of the watercourses that are situated within the cities. The effects of land use change on the hydrology and sediment regime of watercourses have been studied and are understood (i.e., flashier flow regime, increased flow volumes and peak flows that require physical adjustments in channel form and result in increased erosion potential). Many watercourses that are situated within urban areas have been adversely affected, resulting in an increased risk to public health and safety and degradation in aquatic habitat. As part of the drainage network, the functional contribution of headwater channels to the health of the downstream watershed is not always clearly defined.

There is a need for a better understanding of headwater drainage features to determine if development will impair the functioning of watersheds. It can be challenging to accurately define the importance of intermittent and ephemeral flow, particularly with regard to fish habitat and the possible contribution of flow and nutrients to downstream reaches. There has historically been a lack of clarity in how headwater drainage features should be assessed and properly managed to protect their ecological function and contributions to watershed health. The implementation of benthic invertebrate sampling for water quality is one method by which the stream health can be tracked.

In 2007, the Toronto and Region Conservation Authority (TRCA) completed a literature review to summarize the state of the science concerning the natural functions of headwater drainage functions. Subsequent to this review, TRCA and Credit Valley Conservation (CVC) developed the Interim Guidelines for the Evaluation, Classification and Management of Headwater Drainage Features (March 2009). These Interim Guidelines were being updated at the initiation of this study, and therefore the Interim Guidelines were used as our framework for assessing the headwater drainage features within the study area.

The Interim Guidelines provide a comparative evaluation tool to review the integrative nature of flow, channel form, and vegetation with regard to fish habitat and hydrologic functions of headwater drainage features, In accordance with these Guidelines, experts in the fields of geomorphology; geology; hydrogeology; fisheries biology and terrestrial ecology, visited the study area in different seasons in order to conduct field-based assessments of: flow; channel form; fish habitat; vegetation assessment; linkages and connectivity. The Guidelines were used where possible, although it was not always possible to conduct field work at the preferred season as recommended in the Interim Guidelines. However, the headwater drainage features within the study area were assessed by different disciplines to ensure information was synthesised into a comprehensive assessment, and background information was used to further improve the level of understanding of these features.

Multiple discipline specific studies were undertaken to gain insight into the study area's physical and biological functions, conditions and processes. The studies were based on a review of background materials, desktop analyses, field investigations and subsequent analyses. Findings from each study, which are outlined in the preceding sections of this report, resulted in a greater understanding of the characteristics and functions of the drainage features. Characterization of the watercourses from geomorphic and aquatic perspectives is presented in Sections 4.8 and 4.9. Results confirmed that the study area is in the headwater subwatershed of Sixteen Mile Creek East Branch (Tributary A and C) and also contains a low order (second) tributary of Silver Creek.

4.11.3 Application of Characterization

Individual assessments were undertaken by a multi-disciplinary team for each of the components identified within the 2009 CVC/TRCA Headwater Drainage Feature: Interim Guideline document (HDFG). Field reconnaissance investigations undertaken for this study were completed throughout the study period which encompassed the time period from April to August, 2013 and will also include data from the Fall 2013.

This section outlines, in brief, the various components of the Headwater Drainage Feature Assessment including the following:

- Flow assessment
- Aquatic Habitat Assessment
- Vegetation/Wetland Assessment and Ecological Linkage
- Hydrological Linkage
- Channel Form
- Channel Conditions
- Habitat Classification

Specific details of the workplan and assessments have already been presented in the preceding sections of **Section 4**. The findings from each discipline specific assessment were summarized into a table (as recommended in the Interim Guidelines) (**Appendix I**). This promotes an integrated understanding of each feature and associated functions and enables potential linkages to be identified both within and across disciplines. Results from the assessments are used to classify the aquatic and riparian habitat of the headwater drainage features. The outcome of the habitat classification informs management recommendations that will protect and mitigate the function of these headwater features within their overall watershed.

Characterization of each tributary and its branches was undertaken at the reach scale. This was intended to reflect spatial variability with respect to channel and habitat functions and characteristics. As noted in **Section 4.8**, drainage features are part of a larger spatial continuum within the drainage network which should be recognized when assessing overall functions and determining a characterization of the channel.

4.11.3.1 Flow Assessment

The flow assessment component of the HDFG includes catchment size, surface flow and groundwater flows. Catchment size was determined for each reach, using GIS analyses.

Observations of surface flow conditions were made by any discipline conducting field investigations in the study area. According to the 2009 (CVC\TRCA) document, observations are required within three specific time frames to enable classification of the flow regime into no flow, ephemeral, intermittent or perennial. The specific classification is outlined in **Table 4.11.1**. A summary of all surface flow observations made during the study period and the resultant classification are summarized in **Appendix H.**

Table 4.11.1 Flow Assessment Classification (CVC\TRCA, 2009)

Assessment Period	Flowing Conditions			
Spring Freshet or Rainfall Events	YES	YES	YES	NO +/-
Late April – May	YES	YES	NO	NO
July – August	YES	NO	NO	NO
Flow Description	Perennial	Intermittent	Ephemeral	Does Not Flow

4.11.3.2 Groundwater Discharge

A hydrogeological study (**Section 4.4** and **Section 4.5**) was completed to assess groundwater conditions within the study area. This included field observations and measurements, supplemented by modeling. Observations of groundwater flow are summarized by reach in **Appendix I**.

4.11.3.3 Aquatic Habitat Assessment

Assessment of aquatic habitat was completed during April and May, 2013 (**Section 4.9.3**). The assessment included a qualitative survey of the watercourses, resulting in documentation of stream morphology, surface flow, substrates, seepage area, locations of inflows, riparian/instream vegetation cover and bank condition. While completing the habitat assessment, riparian characteristics and disturbances to the natural environment on the site were also documented. Results of the aquatic habitat assessment are summarized by reach in **Appendix I**.

4.11.3.4 Vegetation/Wetland Assessment and Ecological Linkage

Field investigations enabling observations of vegetation within the study area were completed monthly from April to July, 2013 (**Section 4.9**). The assessment was intended not only to document conditions along the drainage features, but also within the overall study area. This recognizes terrestrial and natural heritage attributes and functions and their potential connectivity to aquatic functions. Further discussion regarding study area characteristics is in **Section 4.11.4**.

4.11.3.5 Hydrological Linkage

Headwater tributaries are the external links of the drainage network regardless of whether they are continuous or discontinuous features and/or whether they are well, or poorly, defined. In addition to being part of a larger network that receives water and sediment, and conveys these downstream, headwater channels may also be part of a horizontal link across the floodplain or vertically, into the ground and thus encompasses multiple disciplines of study.

Assessment of linkages along each reach was intended to examine the longitudinal (downstream), horizontal (across the floodplain) or vertical (groundwater) directions as ascertained through study observations and findings. Linkages are described below and are specifically identified in **Appendix I**.

Longitudinal Linkage

All water that originates within both the continuous and discontinuous headwater channels contributes to the overall hydrologic and sediment regimes of the watercourse. Headwater channels include the “fingertip” tributaries that are the starting points of the drainage network. The spatial extent of the features may be poorly defined and poorly connected to the drainage network, except during periods of flow in response to precipitation events or seasonal flow regime. Thus, the function of a drainage feature within the overall downstream network will vary in response to the magnitude and duration of precipitation events (i.e., if flows are of sufficient volume and magnitude to result in a continuous drainage feature rather than a discontinuous feature that stores water and contributes to attenuation of the hydrograph), to antecedent soil moisture conditions, and seasonal variations in precipitation (i.e., snow cover).

Specific longitudinal linkages identified for the study area include the following:

- Hydrology: the hydrograph of the channel is determined, in part, by characteristics of the drainage network as indicated by drainage density and bifurcation ratio. Flow attenuation may occur due to temporary storage within the discontinuous features.

- Flow Conveyance: straightened watercourses and those with tile drainage route water and sediment quickly through the channel to the downstream drainage network.

- Sediment: the tributaries that originate or flow through agricultural areas are a source of sediment for the downstream watercourse. The volume of sediment that enters the watercourse is highly affected by agricultural activity (i.e., crop type) and vegetation cover. While some of this sediment is stored in the floodplain, a portion is conveyed through the study area to the main tributary branches. Sediment also originates within the channel corridor, in alluvial channels or heavily modified channels (i.e., main branches of Tributary A and B, and defined reaches along Tributary C).

- Nutrient: nutrients are derived from organic materials along the channel corridor. Along most of the reaches, there is little riparian cover that would provide leaf litter and organic matter, and no debris jams that would increase the retention and nutrient uptake in this feature during most of the year. Nutrient contributions do, however, coincide with the growing season of the agricultural land use (i.e., corn and soybean observed during the 2013 field investigations) and along the wooded sections along each Tributary.

- Aquatic Habitat: in addition to containing aquatic habitat, reaches could provide connectivity to upstream/downstream habitat or include migration routes for species. Seasonal pools may be used by amphibians.

- Wildlife: drainage features may function as a corridor for wildlife passage/migration to naturalized areas (i.e., hedgerows, wooded areas).

Horizontal Linkage

Horizontal links are defined as those that result from an interaction of the drainage features across the floodplain. This can include linkage to terrestrial vegetation units (and nutrient inputs), other drainage features, indirect fish habitat, and/or other wildlife habitat. Specific horizontal links that were assessed for the study area include:

- Hydrology: most of the reaches along the study area tributaries were well connected to their floodplain. Floodplain depressions and surface water pooling were observed in the floodplain with several of these draining into the main branch of Tributary A. In general, surface depressions would provide storage of water (i.e., surface flow and/or from overbank flows) resulting in an attenuation of the downstream hydrograph.

- Sediment: the low-lying floodplain and frequent inundation would result in some sediment deposition and storage on the floodplain.

- Wildlife: The area surrounding the forested patch is highly urbanized with minimal natural vegetation cover. Consequently, this small patch provides little to no direct linkage to other natural areas in the immediate vicinity. Further, no species at risk or significant wildlife habitat were identified in, or adjacent to, the study area.

Vertical Linkage

The vertical link of a drainage feature refers primarily to interactions with groundwater. Typically, a tributary may interact with groundwater through recharge (i.e., water infiltrates into the ground to recharge groundwater supplies) or discharge (groundwater seeps into the creek). Areas of potential groundwater discharge/recharge (observed or measured) were identified during the study. Results are documented in **Section 4.4** and in **Appendix I**.

4.11.3.6 Channel Form and Conditions

Assessment of channel form occurred in conjunction with the geomorphologic field investigation (**Section 4.8**). This resulted in the delineation of reaches in which general physical characteristics of the watercourse were relatively homogeneous. Measurements of channel dimensions were made in the field whereas channel slope was derived from GIS analysis. Observations of general channel form and bed morphology enabled grouping of the watercourse into one of six channel forms (i.e., undefined, poorly defined, defined, alluvial gully, heavily modified). Along alluvial watercourses, relative stability was assessed through application of the Rapid Geomorphic Assessment. All findings regarding channel form and function are summarized in **Appendix I** and in **Section 4.8**.

4.11.4 Linkage to Terrestrial

The distribution and configuration of the vegetation communities that have been characterized (see **Figure 4.9.1**) are closely associated with the network of permanent and intermittent watercourses found within the study area. In a primarily agricultural landscape, such as is found in this case, vegetated areas usually occur on lands of lower agricultural quality such as low-lying poorly drained areas, steeper slopes, drainage ditches, riparian zones, and ravines of larger watercourse systems. Remaining vegetated areas may also include tablelands that are less suitable to agricultural and support mid-aged to mature woodlands.

The vegetation communities within Block A (Tributary A) and Block D (Tributary B) as illustrated on **Figure 4.9.1**, are present in large part due to physical constraints to agricultural use. In Block A, the riparian vegetation ranges from a narrow channelized ditch with low flora diversity (dominated by Reed-canary Grass), to a woodland area where channelization has greatly reduced the active lowland forest/riparian zone function. Based on the characterization of vegetation communities along Tributary A, the flood attenuation and riparian habitat functions that riverine wetlands/lowlands typically provide to stream systems have been greatly reduced along this watercourse. While the existing vegetation along Tributary A contributes to improving water quality, the general narrowness and lack of an active floodplain due to past channelization has reduced the quality of the vegetated riparian zone. Tributary A does provide a linkage to terrestrial features upstream of Trafalgar Road on Reach A.

While there is very active sediment transport, particularly along the lower reaches of Tributary B, the vegetated riparian zone is more functional and intact in Block D (in comparison to Block A), primarily along sub-reaches BM-1 and BM-2. The mid-aged to mature forests found along the steep slopes and smaller inflow ravines provide a critical function to reducing erosion and maintaining water quality within Tributary B. The forest cover also provides shade to the watercourse reducing higher thermal exposure.

Under current conditions Block B and C provide more limited functional contribute to Tributary C in comparison to Blocks A and D and their respective tributaries. This is due to the fact that Tributary C does not flow directly through either Block B or C thereby reducing riparian zone/habitat opportunities. Tributary C flows partially from (in the case of Block C) or along the edge of (Block B) the blocks. The woodlands that form Block B and C therefore have primarily a headwater function, providing attenuation of snow melt and surface runoff that feds into Tributary C.

4.11.5 Stream Characterization Results

Through the stream characterization process, an integrated description and understanding of the drainage features within the study area was been gained as summarized in **Appendix I**. Results of the multi-disciplinary classification forms the basis from which management recommendations regarding the protection and conservation of fish habitat and mitigation for associated hydrological functions are made. In addition to considering site specific implications, the cumulative effects on the drainage network and on terrestrial and natural heritage must also be assessed. The classification and management recommendations presented in this chapter follow the CVC/TRCA (2009) document and also include recommendations based on findings from the studies conducted during this study.

Within the HFDG (CVC\TRCA 2009) document three general management classes were defined. Determination of which management class applies to any reach was accomplished through review of study area findings (**Appendix I**) and internal discussion amongst the multi-disciplinary team. A summary of the management strategy for each class is provided below and defined for each reach in **Appendix I**.

- Protection: attributes and functions of the existing watercourse should be protected and, if applicable, mitigated where necessary. Protection could include realignment of highly altered channels to restore natural form and function. This requires establishment of a channel corridor around the existing feature that is defined with consideration of all setbacks and regulatory limits. This management classification is typical of perennial and natural alluvial watercourses but may also apply to highly altered watercourses that, through natural channel design, could enhance existing channel form, function, and habitat features.

- Conservation: Reaches identified for conservation could be relocated with the intent of maintaining or enhancing the form and function of the channel. Demonstration of ecological form and function in the modified or relocated channels would need to be demonstrated in the EIR stage.

- Mitigation: reaches identified under the mitigation management strategy are those which provide a high level function within the drainage network and its aquatic habitat. These functions relate primarily to nutrient inputs, water conveyance/hydrograph, and sediment movement. The function of these streams can be replicated through incorporating features within development plans such as open grassed swales.

The characterization work provided in this section provides the basis for final stream classification that will be provided in the analysis section of this report (see **Section 5.9**). The additional analysis in the next study phase will take management requirements into consideration as well.

4.12 Southwest Georgetown Preliminary Natural Heritage System

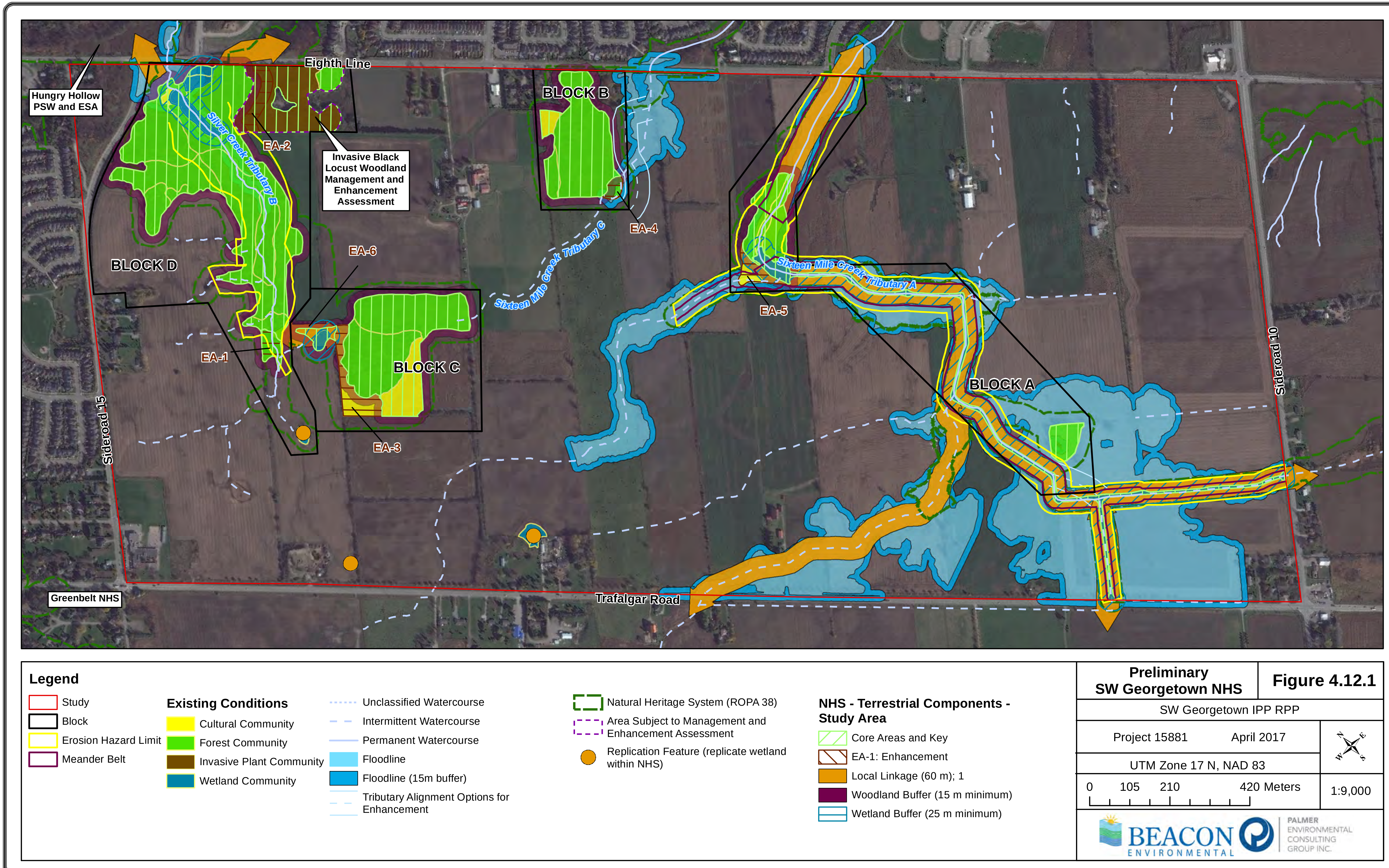
The following provides the review and assessment of the development of the preliminary Natural Heritage System (NHS) for the Southwest Georgetown Secondary Plan area as part of the Subwatershed Study (**Figure 4.12.1**). The steps followed in developing the NHS included the identification of natural heritage features within and adjacent to the study area, screening for core areas and opportunities for enhancing the NHS, and the identification of ecological linkages and buffers. This process includes the refinement (i.e., boundary adjustments, additions and deletions) of the Regional NHS for a site specific verified NHS that is consistent with provincial and municipal environmental policies including ROPA38. The Region's NHS as provided on Map 1G of ROPA38 is overlaid on **Figure 4.12.1** to provide for a comparison to the initial site specific NHS identified through the characterization stage of the Subwatershed Study. This NHS is further refined through the Management Strategy (Section 6.0) and Implementation (Section 7.0) stages of the Subwatershed Study. The methodology and results in developing the NHS are outlined in the following sections.

4.12.1 Overview and Methodology

The NHS was developed through a multi-disciplinary approach taking into account biotic and abiotic components through a functional assessment. The stream characterization system and evaluation of terrestrial features and characteristics have been combined to develop an overall proposed Natural Heritage System (NHS). This approach considers the characterization of terrestrial features, aquatic conditions as well as other stream characteristics. The interrelationship of the terrestrial features, watercourses and linkages both within and outside the secondary plan area and watersheds includes items such as the role that a stream corridor will play as a wildlife linkage between terrestrial features.

The preliminary NHS is based on landscape level and site specific information from background studies, data and the field investigation program completed by Beacon and AECOM over the 2013 and spring 2014 field seasons. The following are the key references used in the development of the NHS:

- Halton Region ROPA 38 – Interim Office Consolidation September 28, 2015 (Halton Region 2009);
- Natural Heritage System Definition & Implementation (North-South Environmental 2009);
- Halton Hills Official Plan as Amended by OPA 10 (Town of Halton Hills 2008);
- Ecological Buffer Guideline Review (Beacon Environmental 2012);
- Silver Creek Subwatershed Study (CVC et al. 2001);
- Conservation Halton Long Term Environmental Monitoring Reports (Conservation Halton 2006 – present);
- Sixteen Mile Creek Watershed Plan (Ecoplans Limited 1996).



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

NHS Components

The terrestrial environment components of the NHS are based on key features (see analysis in **Section 4.9.4**) and other components as identified in Section 115.3 of ROPA 38 with further definitions and interpretation provided in Part VI Definitions of ROPA38 and review of the Natural Heritage System Definition & Implementation (2009) Halton Region background study.

The proposed NHS is based on a systems approach for the protection and enhancement of natural features and functions and is comprised of the following components:

- The following key features (ROPA Section 115.3(1)) have been identified through Southwest Georgetown subwatershed study (see **Section 4.9.4**):
    - significant habitat of endangered and threatened species,
    - significant wetlands,
    - significant woodlands,
    - significant valleylands,
    - significant wildlife habitat,
    - fish habitat

- Enhancement areas to key features, ROPA Section 115.3(2);
- Linkages, ROPA Section 115.3(3);
- Buffers, ROPA Section 115.3(4);
- Floodplains (hazard lands);
- Watercourses, ROPA Section 115.3(5); and,
- “Other” Wetlands, ROPA Section 115.3(6).

In regards to the other constraints identified on **Figure 4.12.1**, the Region Storm Floodlines and associated supporting hydrological requirements have been developed and identified as outlined in the subwatershed study. Floodlines have been included for the streams that have been identified as part of the management plan as open streams. The associated hydrological functions will have to be maintained. Similarly, meander belt widths have been identified for the streams that are recommended open streams. The limits established also take hazard lands limits into account, specifically stable slope setbacks for valleylands, where appropriate.

Site Specific Analysis and Refinement of Regional NHS

The identification and classification of the Natural Environment Existing Conditions are documented in **Section 4.9** of this report, which is based on detailed field investigations completed during 2013 and winter-spring of 2014.

Following the study Terms of Reference (**Appendix A**), the level of site specific analysis is very detailed. Specialized flora and fauna surveys have provided for a comprehensive understanding of the terrestrial ecological features and functions of the study area. Assessment of the watercourses included fish community sampling, benthic sampling and stream temperature monitoring. This information in conjunction with the aquatic habitat assessment provided for the identification of permanent and seasonal fish habitat.

The detailed site level analysis has allowed for further refinement and confirmation of the Regional Natural Heritage System as provided on Map 1G of ROPA38 and Schedule A3 of the Town’s OP.

ROPA38 provides the following policies regarding the boundaries and refinement of the Regional Natural Heritage System:

***116.1** The boundaries of the Regional Natural Heritage System may be refined, with additions, deletions and/or boundary adjustments, through:*

a) a Sub-watershed Study accepted by the Region and undertaken in the context of an Area-Specific Plan;
b) an individual Environmental Impact Assessment accepted by the Region, as required by this Plan; or
c) similar studies based on terms of reference accepted by the Region.

Once approved through an approval process under the Planning Act, these refinements are in effect on the date of such approval

The Region will maintain mapping showing such refinements and incorporate them as part of the Region's statutory review of its Official Plan

***118.** It is the policy of the Region to:*

118(1) Require Local Official Plans and Zoning By-laws to recognize the Regional Natural Heritage as identified in this Plan and include policies and maps to implement policies of this Plan and to incorporate any refinements made thereto through Section 116.1.

118(1.1) Require Local Municipalities, when undertaking the preparation of Area-Specific Plans, Zoning By-law amendments and studies related to development and/or site alteration applications, to protect, through their Official Plans and Zoning By-laws, the Key Features listed in Section 115.3(1) but not mapped on May 1G in accordance with policies of this Plan.

118(2) Apply a systems based approach to implementing the Regional Natural Heritage System by:

a) Prohibiting development and site alteration within significant wetlands, significant coastal wetlands, significant habitat of endangered and threatened species and fish habitat except in accordance with Provincial and Federal legislation or regulations;
b) Not permitting the alteration of any components of the Regional Natural Heritage System unless it has been demonstrated that there will be no negative impacts on the natural features and areas or their ecological functions;
c) Refining the boundaries of the Regional Natural Heritage System in accordance with Section 116.1; and
d) Introducing such refinements at an early stage of the development or site alteration application process and in the broadest available context so that there is greater flexibility to enhance the ecological functions of all components of the system and hence improve the long-term sustainability of the system as a whole.

Key Features within the Greenbelt and Regional Natural Heritage Systems

***139.11** The purpose of the Key Features within the Greenbelt and Regional Natural Heritage Systems, as identified in Sections 115.3(1) and 139.3.3, and shown on Map 1G, is to assist in the implementation of permitted use policies in the Regional Natural Heritage System and the requirement for Environmental Impact Assessments, as well as to assist the Local Municipalities in developing detailed implementation* *policies for the Key Features of the Greenbelt Natural Heritage System in accordance with policies of the Greenbelt Plan and this Plan.*

139.12 There may exist other *Key Features* within the Greenbelt and Regional Natural Heritage System that are not shown on Map 1G, or that may exist in other land use designations, such as the Agricultural Area. Local Municipalities in their official plans shall ensure that these *Key Features* are protected through appropriate *Area-Specific Plans* or studies related to *development* and/or *site alteration* applications in accordance with Section 118.

The assessment and rationale for boundary refinements of the Regional Natural Heritage System completed as part of the Southwest Georgetown Subwatershed Study is consistent with the ROPA38 policies.

4.12.2 NHS Key Features and Other Components

Key Features

Based on the definitions provided in Natural Heritage System Definition & Implementation (NorthSouth Environmental 2009), there are technically no “Core Areas” within the study area as described in the background study. However, within the site level context of the study area there are natural areas that support larger contiguous blocks of woodlands (i.e., Block D), with greater biodiversity and ecological function. Specifically, Block D has core area functions. In comparison, smaller areas such as the isolated woodland at the south end of Block A have limited ecological function but in the case of this woodland it is captured as a key feature based on its size (> 0.5 ha) and proximity to Tributary B (based on ROPA 38 policies, see Section 4.9.4.3). The proposed NHS is therefore comprised of Core Area (with Block D supporting more than one key feature) and key features (see **Figure 4.12.1**).

Definitions and criteria provided in ROPA 38 and review of the Natural Heritage System Definition & Implementation (2009) report were used to identify key features for each Block area. In some cases this required further site analysis, such as tree stem density counts in young regenerating shrub thicket areas in order to determine if such areas qualified as woodland (see **Section 4.9.4.3**). Those areas determined to be woodland were then assessed for “significance” based on criteria provided in Section 277.

The following is a summary of the respective key features that have been identified for the NHS identified for each Block area (see **Section 4.9.4** for analysis of key feature identification).

<u>Block A Key Features:</u>
- significant woodland (both woodlands are > 0.5 ha and within 50 m of a watercourse);
- habitat for threatened or endangered species (Barn Swallow along riparian corridor); and,
- fish habitat.

<u>Block B Key Features:</u>
- significant woodland (woodland in Urban Area that is > 2.0 ha).

<u>Block C Key Features:</u>
- significant woodland (woodland in Urban Area that is > 2.0 ha); and,
- significant wildlife habitat (specialized habitat = vernal pool complex).

<u>Block D Key Features:</u>
- significant woodland (woodland in Urban Area that is > 2.0 ha);
- significant valleyland;
- potential significant wildlife habitat (probable snake hibernaculum in ravine); and,

- fish habitat.

Other Components

The NHS includes other components such as wetlands that are not considered significant and watercourses that are within the regulation limits of the conservation authority (CVC and CH), or provide a linkage to a wetland or significant woodland. These components are inherently captured as part of the key features that have been identified. These components have been identified as features on the landscape but may not necessarily be retained. Rather, replication would be provided that would provide enhanced function to the NHS. For example, there are three small wetlands (< 0.5 ha), one within CVC's watershed and two within CH's watershed (see **Figure 4.12.1**). These features will be replicated and enhanced within the Local Linkage area between Block C and D. Construction of the replication wetland will be within areas of the Local Linkage that are currently agricultural lands.

4.12.3 NHS Enhancement Areas

Enhancement Areas are identified as lands that contribute to the NHS providing supporting functions and opportunities for protecting, restoring, connecting and improving the natural heritage features of the NHS. For example, Enhancement Areas can help maintain wetland hydrology by providing surface drainage function and reduce edge effects of woodlands and habitats.

Based on the inventory and analysis of the subwatershed study, six main Enhancement Areas (EA) have been identified for the secondary plan area for inclusion as part of the proposed NHS (see **Figure 4.12.1**). These provide supporting functions to the key features. Enhancing these areas through management and/or restoration will benefit the NHS through increased habitat diversity, buffering of key features, improved ecosystem function among other improvements.

The following descriptions are provided.

EA-1: Located in Block D at the western end and headwater area of the Tributary B ravine, EA-1 is represented by a cultural thicket community (CUT1, unit 18a) that is dominated by Staghorn Sumac and European Buckthorn. The area is the transition from agricultural field to the forest of Block D/Tributary B. Inclusion of EA-1 as part of the NHS with restoration opportunities will contribute to managing erosion and invasive buckthorn, and increase the extent of the forested ravine.

EA-2: Located in Block D along the northeast end of the Tributary B ravine, EA-2 is represented by a cultural woodland community (CUW1, unit 16a) that is dominated by invasive Black Locust. The area is adjacent to the mature Sugar Maple-Hemlock forest of the Block D ravine and the transition from the non-native cultural woodland to native forest. The exact limit of the EA-2 will be identified and staked through a site survey with the agencies and landowner, followed by an OLS survey. Restoration opportunities include the management of EA-2 to control the Black Locust and enhance native species cover.

EA-3: Located on the western side Block C and into the linkage to Block D, EA-3 is represented by a cultural thicket community (CUT1, unit 4) that consists of hawthorn, buckthorn and apple shrub cover with regenerating Black Walnut and Green Ash. The area is the transition from agricultural field to the forest of Block C and is adjacent to the vernal pool complex. Inclusion of EA-3 as part of the NHS will contribute to maintaining surface drainage to the vernal pools and increase the extent of the forest cover in Block C as the thicket succeeds to forest.

EA-4: Located on the southern corner of Block B, EA-4 is represented by a cultural thicket community (CUT1, unit 18b) that is dominated by sumac with some regenerating Manitoba Maple. The area is the transition from agricultural field to the forest of Block B and is along the Tributary C corridor. Inclusion of EA-4 as part of the NHS will contribute to the riparian function of Tributary C and increase the extent of the forest cover in Block B as the thicket succeeds to forest.

EA-5: Located on along the west side Block A, EA-3 is represented by a cultural thicket community (CUT1, unit 18c) with old field meadow that consist of sparse cover of Ironwood, White Elm, Sugar Maple, buckthorn and apple cover. The area is the transition from agricultural fields to the forest and riparian meadow marsh of Block A. Inclusion of EA-5 as part of the NHS will contribute to the riparian function of Tributary A and increase the extent of the forest cover in Block B as the thicket succeeds to forest.

EA-6: Located between Block C and Block D, EA6 is represented by a small strip of agricultural field that separates the natural areas and is located in NHS linkage area between the two Blocks. Naturalization plantings of these farm lands will enhance the linkage function.

4.12.4 NHS Linkages

The following is a summary of the Linkages that are part of the NHS that builds on the analysis in **Section 4.9.4.6**.

At the local site level, the tributaries of both Silver Creek and Sixteen Mile Creek provide a linkage function for the movement of wildlife to varying degrees. Tributary B (Silver Creek) and Tributary A (Sixteen Mile Creek) are headwater tributaries and provide connectivity for local fauna and flora. There is a weaker linkage function along Tributary C (Silver Creek) due to the active agricultural field between Block B and Block C. These tributaries provide varying levels of linkage functions from within the study area to adjacent lands to the northeast across Eighth Line.

Based on the length of the linkage, types of key features and ecological functions found along the proposed local linkages, a width of 60 m is proposed along Tributary A. Candidate local linkage widths along reaches A2-1 and A2-2 will be determined through the implementation stage. Within this linkage, the protection of the watercourse functions and associated buffers are included, however following current Regional direction in regard to local linkage total widths, the linkage should be a minimum of 60 m as recommended in the Sustainable Halton background study. The meander belt along Tributary A is for the most part also contained within the proposed Local Linkages except in some areas where it extends beyond the 60 m width. The Tributary A Meander Belt also requires a 7.5 m buffer as per Conservation Halton policy requirements and Section C4.3 of the Town's OP for a minor valley/watercourse. Also Conservation Halton setbacks are 15m from the greatest hazard.

The close connection between Block C and D is recognized as a Local Linkage where the components of the NHS are closely linked and provide supporting functions for flora and fauna. For example, breeding amphibians recorded within this area can utilize summer habitat found in Block C and D. Enhancement and restoration within this linkage is identified as particularly beneficial.

4.12.5 NHS Buffers

Definitions provided in ROPA 38 regarding buffers (outside of the Greenbelt) are provided in Section 220.1.1 as described below. There are no minimum size thresholds or recommended buffer widths provided in this definition.

> ***220.1.1*** *BUFFER means an area of land located adjacent to key features or watercourses and usually bordering lands that are subject to development or site alteration. The purpose of the buffer is to protect the features and ecological functions of the Regional Natural Heritage System by mitigating impacts of the proposed development or site alteration. The extent of the buffer and activities that may be permitted within it shall be based on the sensitivity and significance of the*

> *key features and watercourses and their contribution to the long term ecological functions of the Regional Natural Heritage System as determined through a Subwatershed Study, an Environmental Impact Assessment or similar studies that examine a sufficiently large area.*

The proposed development of the NHS buffers for the study area is being based on a variable buffer approach. This approach takes into consideration the natural heritage features and functions to be protected, buffer function, the proposed adjacent land uses, as well as enhancement and mitigation opportunities.

ROPA 38 does not prescribe buffer widths outside of the Greenbelt Plan area. Through background studies, site specific knowledge of the study area and references including the Ecological Buffer Guideline Review (Beacon Environmental 2012), a variable buffer approach is recommended.

This will be subject to further analysis in **Section 7.4.2.2** including confirmation of the types of proposed adjacent land uses.

5. Impact Analysis/Management Requirements

5.1 Introduction/Approach

The characterization of the Southwest Georgetown Subwatershed (Vision Georgetown) is outlined in **Sections 4** of this report. This section of the report provides the analysis of the study area, as well as further characterization of the stream network.

These analyses are based on the field data collected, background information reviewed and hydrologic modelling. The subcatchments are illustrated in **Figure 4.6.1**. This study, particularly the modelling, forms the basis for evaluating subwatershed processes and functions that support and influence subwatershed characteristics, as well as identifying potential impacts of future land use changes.

The process of carrying out the impact analysis included consideration of potential development scenarios. In this case, a development scenario was identified for lands within the study area. This allows for an assessment of the sensitivity of the catchment areas to change. This scenario was modelled, primarily from a hydrologic standpoint, according to surface water, water balance, and the potential impacts on stream conditions. This information was also used in the consideration of terrestrial, wetland, and aquatic conditions and associated management requirements to preserve and enhance environmental conditions. Development of these requirements is outlined in this report. The resulting management strategy is presented in the next chapter.

A comprehensive management strategy consists of multiple elements and under no circumstances can a single element, such as stormwater management (SWM), dominate the entire strategy. A broad range of components are necessary to address all processes that influence watershed conditions. The various components that are considered in the development of a strategy include:

- SWM measures to protect flow regime conditions (baseflow, bankfull flow, and flood flows) and water quality.
- The preservation, restoration, and enhancement of terrestrial features for habitat conditions and to protect hydrologic processes.
- The preservation and enhancement of linkages to ensure that a sustainable natural heritage system is maintained.
- The preservation of topography and surficial geological conditions that contribute to surface water and groundwater flow conditions.
- The identification and preservation of stream corridors for aquatic habitat, hydrologic processes and water quality.
- The identification, preservation and restoration of selected headwater systems that are important to the stream corridor functions (hydrologic, stream geomorphology, hydrogeologic, aquatic, and terrestrial).
- The identification of rehabilitation opportunities to increase the resiliency of the stream system.
- Public ownership of natural hazards.

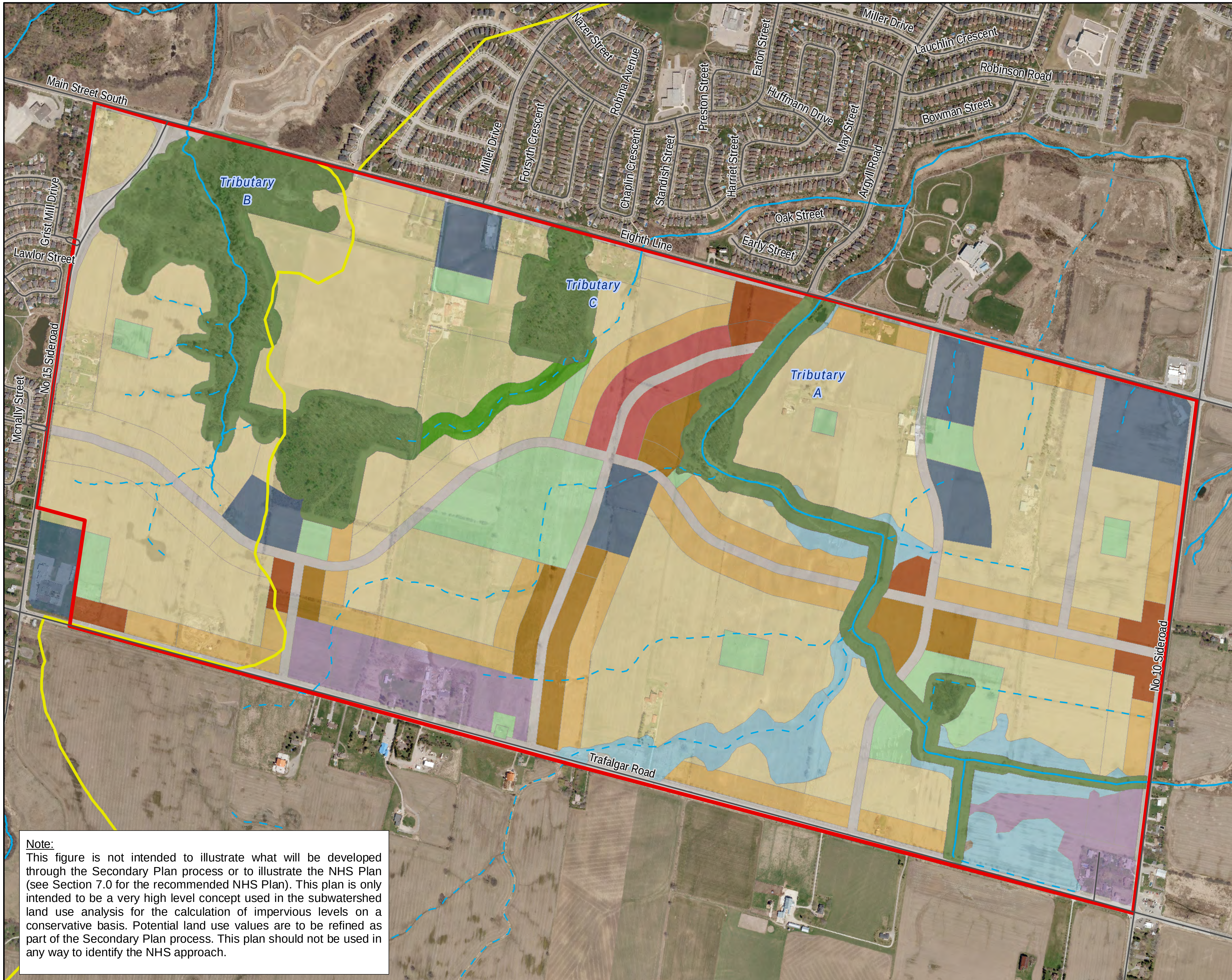
The Characterization Report for this Subwatershed Study provided a review of stream characteristics from the standpoint of the various disciplines involved; aquatic biology, terrestrial biology, fluvial geomorphology, hydrogeology, hydrology and hydraulics (see **Section 4.11.2**). As part of the subwatershed analysis, further consideration was put into the form and function of the streams to develop an approach required for management. This is provided in **Section 5.9**.

5.2 Impact Analysis - Land Use Scenarios

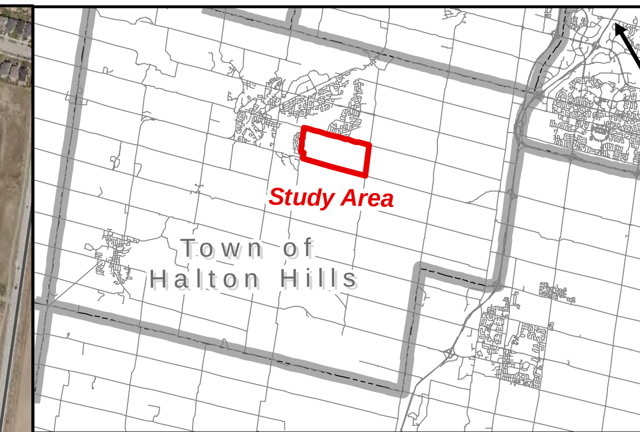
The current land use consists primarily of agricultural. There are some single lot residential buildings on the main roadways, plus a school at the corner of Trafalgar Road and Side Road 15. From a hydrologic response perspective, the existing land use is mostly agricultural, with some wetland and remnant upland habitat.
Future land use changes in the catchment areas will focus on residential and employment land development. The future land use scenario (**Figure 5.2.1**) reflects land use patterns proposed by the Town of Halton Hills and as being developed in the Secondary Plan process.

In each scenario, the significant natural features, including remnant upland habitat, wetlands and stream corridors have been excluded from development for the purposes of analysis.

The potential impacts have been identified and will provide the basis for identification of management requirements for the study area.



Note:
This figure is not intended to illustrate what will be developed through the Secondary Plan process or to illustrate the NHS Plan (see Section 7.0 for the recommended NHS Plan). This plan is only intended to be a very high level concept used in the subwatershed land use analysis for the calculation of impervious levels on a conservative basis. Potential land use values are to be refined as part of the Secondary Plan process. This plan should not be used in any way to identify the NHS approach.



Legend

N

General Features

- Identified Reaches
- Roads
- Study Area
- Conservation Authority Boundary*

Potential Land Use

- Collector Road Rights-of-Way
- Mixed Use - Main Street
- Neighbourhood Commercial
- Institutional
- Regional Floodplain
- High Density Residential
- Environmental Linkage
- Low Density Residential
- Medium Density Residential
- Mixed Use
- Natural Heritage System
- Open Space

Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600
Meters

Southwest Georgetown Integrated Planning Project

Potential Land Use

April 2017	1:10,000	Datum: NAD 83, Zone 17 Source: Chapman and Putnam, 2007. Ontario Geological Survey, MRD 228, LIO
P#: 60297831	V#: 002	

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Figure 5.2.1

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5.3 Management Requirements from Past Studies

Management measures identified in past studies are briefly summarized in the following section of this report.

Sixteen Mile Creek (Sixteen Mile Creek Watershed Plan, Gore & Storrie Limited and Ecoplans Ltd., February 1996)

This study involved a total of nine catchments tributary to Sixteen Mile Creek, for which a number of management criteria/recommendations were established, including:

- Control of peak post development runoff rates to predevelopment levels;
- Quality treatment of all storm runoff prior to discharge to the creek;
- Control of post development runoff to maintain predevelopment flow duration (i.e., runoff hydrograph) characteristics as much as possible, to minimize erosion potential; and
- Maintain existing groundwater recharge rates on an area basis (i.e., maintain existing infiltration rates to maintain base flow characteristics).

Specific recommendations put forth as a result of this study included:

- Minimize imperviousness by clustering of development, utilizing underground parking, minimizing pavement widths, using grassed ditches instead of curb and gutter, and any other innovative architecture or site layouts that can be identified on a site specific basis. Techniques which encourage infiltration should be emphasized, such as roof downspout disconnection, soakaway pits, grassed filter strips, grassed ditches, swales, depressions, collection of runoff in temporary pooling areas within parks and other open spaces;
- Provide on-site storage equivalent to 5mm over the impervious area through roof and parking lot detention, cisterns;
- Maintain water balances, increase groundwater recharge, and reduce peak runoff rates by encouraging runoff dispersal rather than collection and concentration of runoff;
- Minimize the use of storm sewers and maximize overland drainage and dispersal wherever feasible;
- Extend overland drainage for the greatest distance possible via grassed ditches and swales; and
- Minimize deepening of watercourses to accommodate storm sewer outlets.

It was further concluded that in general, Sixteen Mile Creek will be capable of accommodating the anticipated level of urban development within Milton and North Oakville as defined in the Halton Urban Structure Plan. This would be attainable by maintaining or enhancing the current water quality by implementing appropriate SWM measures. This study also determined that the anticipated levels of future development would not require updating of the current regulatory flood lines.

Water quality control as based on the MOECC/MNR Storm Water Management Plan (SWMP) Design Manual (1994) should be adequate, provided the following are taken into account:

- Erosion control should be based on flow duration exceedence characteristics (see Gore & Storrie study);
- Sustenance of base flows should be emphasized based on maintenance of groundwater recharge; and
- Ponds should be designed to minimize their impact on water temperature.

Furthermore, aquifer protection should involve identification of potential contaminant sources, determination of appropriate land uses and monitoring of quality and quantity of groundwater within the watershed. Areas susceptible to groundwater contamination were delineated as part of the Gore & Storrie study.

Recommendations specifically related to agricultural lands included:

- Planting of trees along streams as windbreaks to reduce wind erosion, and to provide riparian habitat and filter buffers along streams;
- Reconstruction of ponds or pond outfalls or construction of pond bypass channels;
- Fencing to limit cattle access to streams and wetlands; and
- Protection/retention of existing wetlands on agricultural property.

A comprehensive monitoring program was recommended including monitoring of the following:

- Streamflow;
- Water quality including dissolved oxygen, temperature, bacteria, nutrients, pesticides, metals, and suspended solids under dry and wet weather conditions;
- Erosion inventory;
- Groundwater base flow and temperature;
- Infiltration rates in various soil types;
- Water levels in existing wells; and
- Water quality from existing wells.

Silver Creek (Silver Creek Subwatershed Study Phase III Implementation Report, Credit Valley Conservation, Schroeter & Associates, Environmental Water Resources Group, Aquafor Beech Limited, Jacques Whitford Environmental Limited and Waterloo Hydrogeologic Inc., July 2003)

In this study, a number of management criteria/recommendations were established, including:

- Flood control management focuses on protecting against flood risk associated with approved land use changes;
- Runoff volume and peak flow rate attenuation will be required on all new development within the Silver Creek subwatershed;
- Managing stable, natural stream corridors is an integral component of protecting, restoring and enhancing aquatic and terrestrial resources, controlling damages to private and public property from floodflow events, and maintaining the conveyance and hydraulic capacity of watercourse and structures;
- Any direct alteration to the adjacent riparian zone or channel due to land use change should be avoided;
- In terms of protecting water quality for aquatic biota, a healthy dissolved oxygen and temperature regime should be maintained, nutrient levels should be below those that could cause excessive plant growth, and increased loadings of suspended solids and toxins, such as metals or ammonia, should be minimized;

The study also determined the recommended management strategy for groundwater, including:

- Manage the groundwater recharge areas to maintain a high quality and quantity of water for a domestic water supply, and to provide the baseflow link for aquatic resources;
- Protect the groundwater recharge and discharge functions;
- Manage the groundwater use, which in this case is water taking; and
- Monitor appropriate indicators, in this case water quality and streamflow quantity, to ensure public health and aquatic resources, are protected.

A comprehensive monitoring program was recommended including monitoring of the following:

- Streamflow;
- Water quality including dissolved oxygen, temperature, bacteria, nutrients, pesticides, metals, and suspended solids under dry and wet weather conditions;
- Erosion inventory;

- Groundwater base flow and temperature;
- Infiltration rates in various soil types;
- Water levels in existing wells; and
- Water quality from existing wells.

In conclusions of the study, the solutions to mitigate the impact of urban development include:

- Preserving land designated as Protection level 1 as “high protection” zones;
- Keeping environmental resources in mind when designing the location and orientation of lots;
- Incorporating stormwater management where appropriate;
- Maintaining the original topography;
- Designing the infrastructure so it mimics current conditions; and
- Designing the servicing and water supply to minimize environmental impacts.

5.4 Surface Water and Groundwater Analysis

This section describes the assessment of potential impacts to the surface water hydrology and hydrogeology as a result of proposed development within the study area.

5.4.1 Development Concept Plan

The current concept plan for future urban development in the Southwest Georgetown study area is illustrated in **Figure 5.2.1**. The proposed layout of collector roads is shown along with land use zoning patterns. The approximate boundaries of protected areas are shown including the regulatory floodplain, environmental linkages, and natural heritage system. It is noted that the boundaries of the regulatory floodplain are provided as guidance for general requirements for the Secondary Plan; the actual future hazard limits are subject to the ultimate channel/floodplain configuration and future management strategy for floodplain storage and conveyance. Any change to the floodline limits would be subject to the appropriate Conservation Authority review and approval. No future development was assumed for the external drainage areas that discharge into Tributary A (i.e., subcatchments A-4a and A-6 as well as portions of subcatchments A-2 and A-5).

Percent impervious values for the proposed development were established in consultation with the agencies, Town, and landowner consultants**.** Percent impervious values were translated into a relationship between surface cover types and are summarized in **Table 5.4.1**. Surface cover types are the same as those described for existing conditions in **Section 4.6.3**. The bottom row shows the overall percentage of impervious cover for each zoning category, calculated as the surface cover array multiplied by the corresponding imperviousness values shown in **Table 4.6.3**.

The majority of the study area is comprised of residential land use zoning, with densities that are consistent with the Town of Halton Hills Official Plan, namely:

- Low Density Residential: 20-25 units/ha, for analysis purposes we used an imperviousness value of 60%;
- Medium Density Residential: 50-65 units/ha (65% imperviousness); and
- High Density Residential: 90-100 units/ha (80% imperviousness).

In addition, the proposed zoning for Mixed Use - Main Street is envisioned to include a higher proportion of residential units on top of street-level commercial properties, featuring more opportunities for shared parking.

Mixed Use zoning will likely have less shared parking opportunities, and consequently larger parking areas per property and higher levels of impervious.

5.4.2 Hydrology

Surface water hydrology parameters were developed for the uncontrolled future land use conditions (without SWM controls) in the same manner as described in **Section 4.6** (refer to **Figure 5.4.1** for the uncontrolled future development catchments). There were no changes to any hydrology parameters for external drainage areas outside of the development area (i.e., subcatchments A-4a as well as portions of subcatchments A-2, A-5 and A-6).

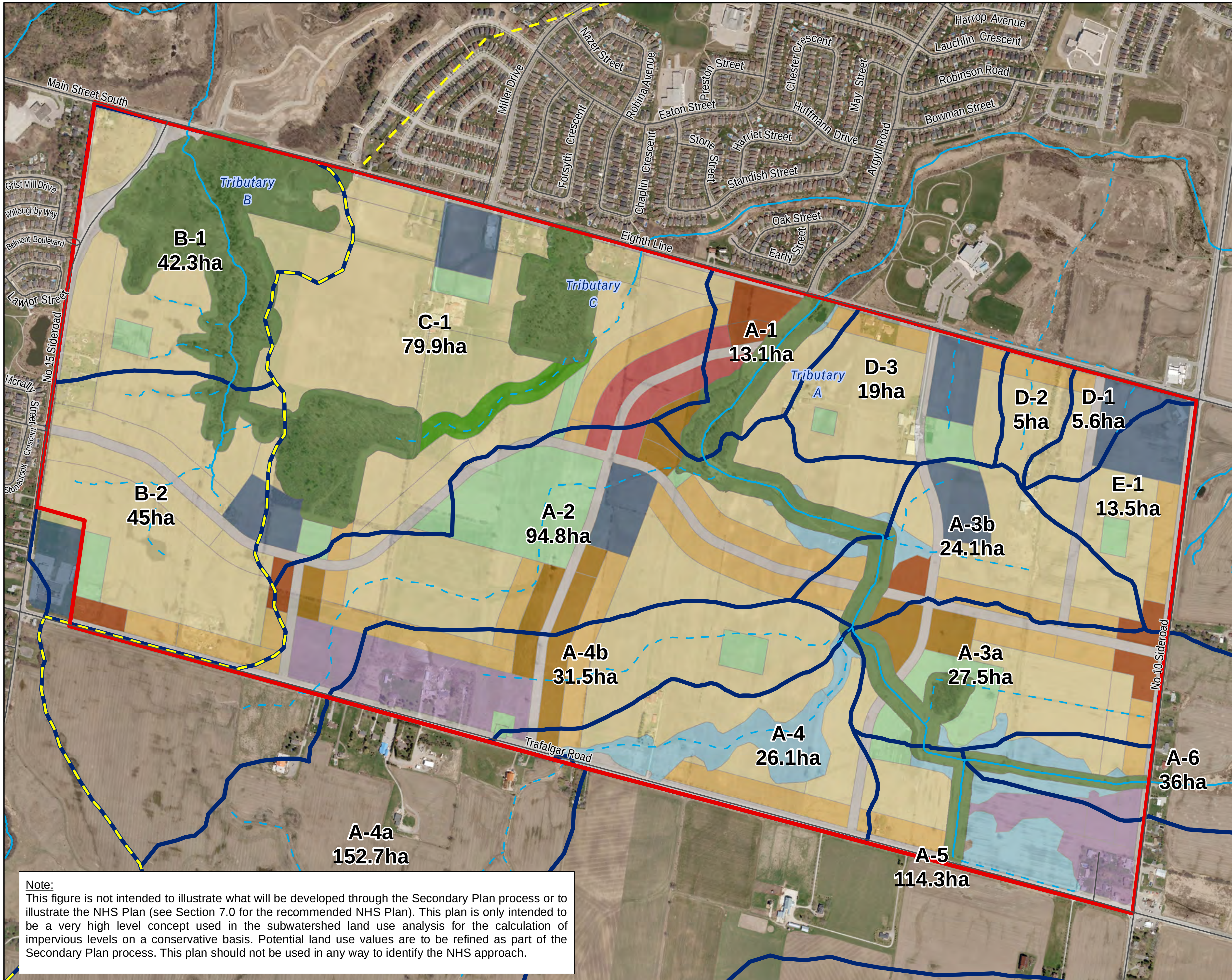
By multiplying the array of surface cover types within each subcatchment by the global hydrology parameters that were listed in **Table 4.6.3**, the resulting area-weighted hydrologic parameters were determined. The average imperviousness of all subcatchments under future land use conditions is 33% (i.e., a sixfold increase compared to existing conditions).

Overland flow parameters were revised to reflect developed areas within each subcatchment, including land re-grading (i.e., standard 2% slope) and reduced flow path lengths that would result from the installation of storm sewer collection systems. Overall, the average slope of overland flow is 2.1% under future land use conditions, a slight increase from 2.0% under existing conditions.

It was assumed that future development did not alter the infiltration characteristics of the underlying soils.

Table 5.4.1 Relationship of Land Use Zoning to Hydrologic Surface Cover

Surface Cover Type	Residential			Non-Residential		Mixed Use		Open / Protected Areas				Utilities
	Low Density Residential	Medium Density Residential	High Density Residential	Neighbour-hood Commercial	Institutional (schools)	Mixed Use - Main Street	Mixed Use	Open Space (public parks)	Regional Floodplain	Environ-mental Linkages	Natural Heritage System	Collector Road Rights-of-Way
Forest								7%	5%	10%	15%	
Meadow	6%	3%			5%			10%	35%	55%	60%	
Farm												
Grass	32%	29%	16%	5%	17%	13%	9%	70%	53%	34%	23%	16%
Bare												
Wetland									2%		1%	
Bedrock												
Gravel												
Roof	36%	42%	50%	45%	45%	44%	45%	0.5%				
Paved	26%	26%	34%	50%	33%	44%	46%	13.0%				84%
Water									5%	1%	1%	
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100.0%**	**100%**	**100%**	**100%**	**100%**
Impervious	**60%**	**65%**	**80%**	**90%**	**75%**	**83%**	**87%**	**15%**	**8%**	**3%**	**4%**	**80%**



Note:
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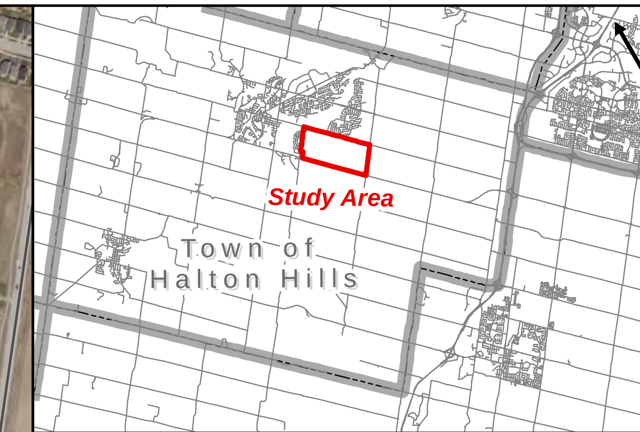

Legend

N

General Features

- Identified Reaches
- Roads
- Study Area
- Conservation Authority Boundary*
- Subcatchment Boundary

Potential Land Use

- Collector Road Rights-of-Way
- Mixed Use - Main Street
- Neighbourhood Commercial
- Institutional
- Regional Floodplain
- High Density Residential
- Environmental Linkage
- Low Density Residential
- Medium Density Residential
- Mixed Use
- Natural Heritage System
- Open Space

Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600
Meters

Southwest Georgetown Integrated Planning Project

Uncontrolled Future Land Use Catchments

March 2017	1:10,000	Datum: NAD 83, Zone 17 Source: Chapman and Putnam, 2007. Ontario Geological Survey, MRD 228, LIO
P#: 60297831	V#: 001	

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Figure 5.4.1

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A summary of the resulting area-weighted hydrologic parameters for uncontrolled future land use conditions are shown in **Table 5.4.2.**

Table 5.4.2 Uncontrolled Stormwater Future Land Use Condition Hydrologic Parameters

Hydrologic Unit Name	Area (ha)	% Imperv-ious	% Routed	% Imperv. Without Storage	Manning's "n"		Dep. Storage (mm)		Slope	Width
					Imperv-ious	Pervious	Imperv-ious	Pervious		
A-1	13.1	45.7	48.7	14.4	0.022	0.238	4.8	10.2	2.9%	1,364
A-2	94.8	40.2	49.6	13.3	0.023	0.232	4.6	9.3	1.9%	7,253
A-3a	27.5	50.9	43.1	15.7	0.021	0.216	4.2	8.7	2.0%	4,582
A-3b	24.1	59.3	36.4	17.1	0.019	0.201	3.8	7.8	2.0%	4,023
A-4	26.1	47.4	45.1	14.9	0.021	0.217	4.2	8.7	2.0%	4,344
A-4a	152.7	5.1	74.5	5.9	0.029	0.300	6.4	12.7	1.0%	5,091
A-4b	31.5	67.4	29.9	18.6	0.018	0.184	3.4	6.8	2.0%	5,257
A-5	114.3	15.8	66.8	7.8	0.027	0.279	5.9	11.7	1.7%	4,424
A-6	36.1	11.4	71.0	7.1	0.028	0.291	6.2	12.6	1.4%	1,513
C-1	79.9	47.3	46.2	15.1	0.021	0.226	4.4	9.3	2.0%	7,254
D-1	5.6	69.1	28.7	18.7	0.018	0.182	3.3	6.7	2.0%	930
D-2	5.0	61.5	34.0	17.9	0.019	0.191	3.5	7.2	2.0%	831
D-3	19.0	59.8	35.5	17.5	0.019	0.195	3.6	7.4	2.0%	3,162
E-1	13.5	65.3	31.4	18.3	0.018	0.187	3.4	7.0	2.0%	2,255
B-1	42.3	31.5	59.8	12.1	0.024	0.264	5.4	11.7	5.0%	2,537
B-2	45.0	58.8	36.6	17.2	0.019	0.200	3.7	7.7	2.0%	5,991

5.4.3 Modelling Assumptions

Without the appropriate stormwater management measures, uncontrolled future development not only impacts surface water hydrology, but many other disciplines as well and these are described elsewhere in this report. Potential impacts include:

- Geomorphology (flows and sediment loads that shape the watercourse and affect bank/bed stability);
- Hydrogeology (baseflows, seepage, and groundwater recharge);
- Water chemistry (sediment circulation, nutrient cycling, temperature regulation); and
- Ecology (aquatic and terrestrial resources) that include fisheries, benthic habitat, wildlife, vegetation, and soils that are affected by in-stream velocities, water levels, inundation periods, and upland soil water content.

This section continues the discussion of water quantity impacts, identifying how proposed development affects the depth, velocity, and rate of surface water flows in the watercourses. Erosive flow impacts are characterized in terms of instream erosion indices for flow duration and exceedance (see **Section 5.4.3.4**).

5.4.3.1 Watercourse Flow Targets

Unit-area peak discharge values for uncontrolled future land use conditions are given in **Table 5.4.3**. For each design storm event, the unitary discharge is shown (i.e., the peak computed flow rate divided by the total contributing area) along with the difference compared to existing land use conditions. The overall unit-area peak discharge values for the four main tributaries are highlighted in bold. The rows at the bottom of the table show the range and average unitary discharge for each design storm event.

The overall impacts of uncontrolled future development on peak discharge flow targets (average for all watercourses) include:

- 2-year return period/24-hour duration: 38 L/s/ha peak flow increase
- 5-year /24-hour: 63 L/s/ha peak flow increase
- 10-year /24-hour: 76 L/s/ha peak flow increase
- 25-year /24-hour: 94 L/s/ha peak flow increase
- 50-year/24-hour: 105 L/s/ha peak flow increase
- 100-year /24-hour: 117 L/s/ha peak flow increase
- Regional storm: 19 L/s/ha peak flow increase

It is intended that development impacts on hydrology will be managed on a watercourse basis, such that proposed stormwater management facilities will limit peak discharges at the outfall of each tributary to existing land use conditions. These values were summarized for all design storm events in **Table 4.6.10**.

Compared to existing land use conditions, the biggest increases in peak discharge are evident in Tributary B. Flow increases for all Tributaries range from approximately 150-4000% for the 2-year event, 80-400% for the 100-year event, and 3-80% for the regional storm. The extremely large increases for the 2-year event are caused by very low runoff volumes in the predevelopment model for catchments B and C.

Table 5.4.3 Uncontrolled Stormwater Future Land Use Conditions - Unit-Area Peak Discharge

		2-yr/24-hr			5-yr/24-hr			10-yr/24-hr			25-yr/24-hr			50-yr/24-hr			100-yr/24-hr			Regional Storm		
Contributing Subcatchments	**Area (ha)**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Δ_{Ex}**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Δ_{Ex}**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Δ_{Ex}**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Δ_{Ex}**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Δ_{Ex}**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Δ_{Ex}**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Δ_{Ex}**
all of Tributary A	**520.3**	**6.1**	**12**	**7**	**13.9**	**27**	**17**	**19.4**	**37**	**21**	**26.4**	**51**	**25**	**32.3**	**62**	**29**	**37.9**	**73**	**32**	**48.1**	**92**	**3**
A-2,3a,3b,4,4a,4b,5,6	507.2	5.9	12	7	13.5	27	17	19.0	37	21	25.7	51	25	31.5	62	29	36.9	73	31	47.3	93	3
A-2	94.8	2.7	28	23	5.9	62	49	9.1	96	78	13.5	143	109	17.5	184	136	21.5	226	165	13.1	138	39
A-3a,3b,4,4a,4b,5,6	412.4	6.3	15	11	9.9	24	14	12.2	29	13	15.2	37	12	17.5	42	10	19.7	48	8	37.9	92	3
A-4,4a,4b,3a,5,6	388.2	5.3	14	9	8.1	21	11	9.9	26	10	12.4	32	7	14.3	37	5	16.1	41	2	35.8	92	3
A-3a,5,6	177.9	2.4	13	11	3.8	21	14	4.8	27	10	6.1	34	4	7.0	39	-2	8.4	47	-6	17.6	99	11
A-4 & A-4a	178.8	2.8	16	14	4.9	27	19	6.3	35	17	7.9	44	15	9.0	51	11	10.2	57	7	15.6	87	2
A-4a	152.7	0.4	2	-4	1.3	9	-5	2.7	18	-1	4.5	29	3	6.0	40	6	7.6	50	9	13.0	85	-9
A-5 & A-6	150.4	1.3	9	2	2.6	18	-2	3.7	24	-6	5.0	34	-12	6.3	42	-18	7.7	51	-23	14.9	99	0
A-5	114.3	1.2	11	3	3.1	27	7	4.7	42	10	7.1	62	15	9.1	80	20	11.1	97	23	12.5	109	7
A-6	36.1	0.4	12	11	1.1	30	22	1.6	44	28	2.3	64	33	3.0	83	39	3.7	102	44	4.1	113	45
all of Tributary B	**87.3**	**5.1**	**58**	**55**	**9.4**	**108**	**99**	**12.6**	**144**	**126**	**16.9**	**194**	**164**	**20.3**	**232**	**191**	**23.8**	**273**	**220**	**10.7**	**123**	**50**
B-2	45.0	4.3	96	93	7.8	174	164	10.2	226	207	13.4	297	266	15.7	348	305	18.1	402	347	6.0	134	51
all of Tributary C	**79.9**	**4.7**	**59**	**46**	**9.0**	**113**	**82**	**12.2**	**153**	**105**	**16.3**	**204**	**134**	**19.6**	**245**	**156**	**22.8**	**285**	**176**	**10.7**	**133**	**17**
all of Tributary D	**29.5**	**4.9**	**165**	**154**	**7.8**	**263**	**235**	**9.3**	**316**	**274**	**11.4**	**386**	**323**	**12.8**	**432**	**352**	**14.3**	**483**	**385**	**4.3**	**145**	**33**
all of Tributary E	**13.5**	**2.4**	**177**	**175**	**3.7**	**276**	**269**	**4.4**	**329**	**313**	**5.4**	**400**	**375**	**6.0**	**446**	**414**	**6.7**	**498**	**458**	**2.0**	**145**	**78**
	Min:		2			9			18			29			37			41			85	
	Avg:		**44**			**77**			**99**			**129**			**152**			**175**			**111**	
	Max:		177			276			329			400			446			498			145	

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Notes:
1. Δ_{Ex} indicates the difference in unit-area peak discharge compared to Existing land use conditions. No value is shown if the peak flowrate is within 10 L/s.

Unit-area total runoff volumes for future land use conditions are given in **Table 5.4.4**. For each design storm event, the unitary volume is shown (i.e., the total runoff volume divided by the total contributing area) along with the difference compared to existing land use conditions. The overall unit-area runoff volumes for the four main tributaries are highlighted in bold. The rows at the bottom of the table show the range and average unitary volume for each design storm event. The storm event rainfall depth can be expressed in the same unitary volume units (i.e., 2-year event rainfall of 55.8 mm = 558 m^3/ha). When the unit-area rainfall is divided into the corresponding unit-area runoff volume, the volumetric runoff coefficients can be calculated as shown at the bottom of the table.

5.4.3.2 Hydraulic Gradeline Analysis

A hydraulic gradeline analysis was conducted, comparing peak computed water surface elevations to the corresponding road centerline elevations as a means of identifying potential road flooding occurrences under uncontrolled future land use conditions. **Table 5.4.5** shows the model results under uncontrolled future land use conditions. For each junction in the study area, the table shows the junction name, location, road overtop elevation, along with the peak computed water surface elevation for each design storm event. The table also shows the difference in peak flood stage compared to existing conditions as well as the road flooding depth for each rainfall event. The number of flooding occurrences for each event is shown in the bottom row.

These values were compared under existing and uncontrolled future land use conditions to determine impacts to road flooding as follows:

- 2-year return period/24-hour duration: 1 new road flooding occurrence, maximum flood depth increase of 0.32 m (0.15 m existing land use, 0.47 m future land use)
- 5-year /24-hour: 1 new road flooding occurrence, 0.17 m flood depth increase (0.40 m existing, 0.57 m future)
- 10-year /24-hour: no new road flooding occurrences, 0.12 m flood depth increase (0.51 m existing, 0.63 m future)
- 25-year /24-hour: no new occurrences, 0.08 m flood depth increase (0.60 m existing, 0.68 m future)
- 50-year/24-hour: 1 new occurrence, 0.05 m flood depth increase (0.67 m existing, 0.72 m future)
- 100-year /24-hour: 1 new occurrence, 0.04 flood depth increase (0.71 m existing, 0.75 m future)
- Regional storm: 1 new occurrence, with no maximum flood depth increase.

5.4.3.3 Culvert Capacity Analysis

The hydraulic performance is indicated by the level of service provided at each road crossing, which reflects the largest design storm event that does not yield any road flooding. The existing and future levels of service are compared in **Table 5.4.6**. The worst hydraulic performance is evident at all three of the internal private roads, which overtop for the 2-year design storm event, as was the case for one of the crossings under existing conditions (Bridge 1000) (**Table 4.7.4**). However, under future conditions, similarly poor levels of service are indicated at the Trafalgar Road culverts in the upper reaches of Tributary A (Reach A4-4 Structure #13).

Another decrease in level of service is indicated at the Eighth Line crossing of Tributary B, in which the existing service level is reduced from the regional storm to a 100-year return period of road flooding. The culverts along Eighth Line show the best hydraulic performance at Tributary A and C, passing the regional storm without overtopping, similar to existing conditions.

Table 5.4.4 Uncontrolled Stormwater Future Land Use Conditions - Unit-Area Runoff Volume

		2-yr/24-hr			5-yr/24-hr			10-yr/24-hr			25-yr/24-hr			50-yr/24-hr			100-yr/24-hr			Regional Storm		
Contributing Subcatchments	**Area (ha)**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Δ_{Ex}**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Δ_{Ex}**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Δ_{Ex}**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Δ_{Ex}**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Δ_{Ex}**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Δ_{Ex}**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Δ_{Ex}**
all of Tributary A	**520.3**	**83,800**	**161**	**95**	**147,000**	**283**	**107**	**198,000**	**381**	**115**	**266,000**	**511**	**123**	**319,000**	**613**	**127**	**372,000**	**715**	**131**	**907,000**	**1,743**	**244**
A-2,3a,3b,4,4a,4b,5,6	507.2	79,800	157	92	141,000	278	105	190,000	375	112	256,000	505	120	307,000	605	122	359,000	708	128	877,000	1,729	241
A-2	94.8	22,900	241	184	36,700	387	213	47,000	496	228	60,500	638	245	70,700	746	252	81,000	854	263	192,000	2,025	506
A-3a,3b,4,4a,4b,5,6	412.4	57,300	139	72	104,000	252	79	143,000	347	85	196,000	475	92	237,000	575	95	278,000	674	97	685,000	1,661	179
A-4,4a,4b,3a,5,6	388.2	48,700	125	62	92,000	237	70	128,000	330	74	177,000	456	80	214,000	551	80	253,000	652	85	626,000	1,613	155
A-3a,5,6	177.9	25,500	143	108	50,000	281	169	68,800	387	202	93,600	526	238	112,000	630	255	131,000	736	276	318,000	1,788	574
A-4 & A-4a	178.8	10,800	60	44	24,800	139	58	38,200	214	66	57,000	319	76	72,600	406	81	88,200	493	87	228,000	1,275	188
A-4a	152.7	2,520	17	-57	12,400	81	-113	22,600	148	-144	37,100	243	-181	49,700	325	-204	62,100	407	-228	166,000	1,087	-489
A-5 & A-6	150.4	16,400	109	45	36,300	241	64	52,100	346	76	73,000	485	93	89,300	594	103	105,000	698	110	252,000	1,676	189
A-5	114.3	11,100	97	-17	25,300	221	-34	36,400	318	-48	50,900	445	-71	62,300	545	-82	73,600	644	-97	182,000	1,592	-281
A-6	36.1	5,320	148	141	10,600	294	265	14,700	408	340	20,100	558	425	24,200	671	477	28,300	785	528	70,500	1,956	1,402
all of Tributary B	87.3	14,400	165	156	24,400	279	238	31,900	365	280	41,700	478	323	49,400	566	346	56,900	652	367	122,000	1,397	713
B-2	45.0	11,600	258	249	17,600	391	334	22,100	491	378	27,800	618	420	32,200	716	443	36,500	811	465	80,900	1,798	872
all of Tributary C	**79.9**	**16,200**	**203**	**67**	**26,500**	**332**	**52**	**34,200**	**428**	**35**	**44,100**	**552**	**13**	**51,800**	**648**	**-2**	**59,300**	**742**	**-23**	**135,000**	**1,689**	**-224**
all of Tributary D	**29.5**	**11,200**	**379**	**244**	**16,000**	**542**	**262**	**19,800**	**670**	**279**	**24,800**	**840**	**299**	**28,300**	**958**	**307**	**31,900**	**1,080**	**311**	**73,600**	**2,492**	**577**
all of Tributary E	**13.5**	**5,310**	**392**	**386**	**7,540**	**557**	**528**	**9,270**	**685**	**617**	**11,600**	**857**	**724**	**13,100**	**968**	**773**	**14,700**	**1,086**	**830**	**34,200**	**2,528**	**1,974**
	Min:		17			81			148			243			325			407			1,087	
	Avg:		**175**			**300**			**399**			**532**			**632**			**734**			**1,753**	
	Max:		392			557			685			857			968			1,086			2,528	
	Available Rainfall:		**558**			**734**			**871**			**1,054**			**1,178**			**1,309**			**2,860**	
	Avg. Runoff Coefficient:		**31%**			**41%**			**46%**			**50%**			**54%**			**56%**			**61%**	

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Notes:
1. Δ_{Ex} indicates the difference in unit-area runoff volume compared to Existing land use conditions. No value is shown if the total volume is within 100 m^3.

Table 5.4.5 Uncontrolled Stormwater Future Land Use Conditions - Hydraulic Gradeline Analysis

			2-yr/24-hr			5-yr/24-hr			10-yr/24-hr			25-yr/24-hr			50-yr/24-hr			100-yr/24-hr			Regional Storm		
Junction Name	Location	Road Overtop Elev. (m)	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road
Tributary A: Reach AM-1, AM-2, and AM-3																							
J0		n/a	231.95	0.33		231.99	0.26		232.00	0.19		232.02	0.13		232.03	0.09		232.04	0.07		232.05	0.05	
J60.29	d/s end of culverts at Bridge 180	n/a	242.60	0.06		242.69	0.11		242.74	0.11		242.80	0.11		242.84	0.11		242.87	0.11		242.95		
J105.06	u/s end of culverts at Bridge 180	244.98	242.97	0.27		243.39	0.49		243.63	0.52		243.90	0.54		244.10	0.56		244.29	0.57		244.96	0.11	
J138.04		n/a	243.23	0.30		243.60	0.45		243.78	0.40		243.99	0.40		244.16	0.45		244.33	0.48		244.97	0.11	
J195.83		n/a	243.66	0.16		243.83	0.21		243.91	0.19		244.04	0.22		244.21	0.33		244.36	0.42		244.98	0.10	
J228.22		n/a	243.79	0.18		244.00	0.25		244.09	0.22		244.19	0.21		244.31	0.26		244.44	0.32		245.00	0.10	
J274.82		n/a	244.33	0.23		244.54	0.26		244.63	0.22		244.73	0.20		244.80	0.21		244.87	0.21		245.13	0.06	
J299.64		n/a	244.49	0.21		244.72	0.28		244.81	0.24		244.91	0.20		244.98	0.20		245.05	0.21		245.24	0.05	
J361.59		n/a	244.89	0.31		245.31	0.50		245.42	0.40		245.54	0.24		245.62	0.27		245.68	0.22		245.80	0.02	
J404.79		n/a	245.23	0.32		245.65	0.50		245.82	0.45		245.96	0.33		246.06	0.31		246.14	0.28		246.27	0.02	
J441.39		n/a	245.40	0.22		245.81	0.47		245.99	0.45		246.15	0.36		246.26	0.34		246.35	0.31		246.50	0.02	
J477.76		n/a	245.80	0.24		246.14	0.41		246.31	0.40		246.47	0.36		246.58	0.34		246.68	0.32		246.83	0.02	
J525.66		n/a	246.13	0.26		246.43	0.36		246.57	0.33		246.74	0.33		246.86	0.34		246.96	0.33		247.13	0.02	
J574.87		n/a	246.44	0.21		246.80	0.42		246.98	0.42		247.11	0.34		247.21	0.29		247.30	0.28		247.45	0.02	
J626.25		n/a	247.20	0.21		247.54	0.40		247.70	0.39		247.82	0.31		247.90	0.26		247.97	0.23		248.09	0.02	
J689.29		n/a	247.90	0.27		248.30	0.46		248.45	0.40		248.60	0.32		248.71	0.32		248.80	0.30		248.96	0.02	
AMA4		n/a	248.00	0.29		248.40	0.47		248.54	0.39		248.70	0.32		248.81	0.32		248.91	0.31		249.07	0.02	
Tributary A: Reach AM-4																							
J726.16		n/a	248.20	0.37		248.47	0.40		248.61	0.31		248.75	0.26		248.86	0.26		248.95	0.25		249.17	0.02	
J741.53		n/a	248.31	0.34		248.52	0.33		248.65	0.26		248.78	0.22		248.89	0.23		248.97	0.22		249.21	0.02	
J784.64		n/a	248.55	0.38		248.67	0.24		248.76	0.17		248.88	0.16		248.97	0.16		249.04	0.15		249.32	0.02	
J810.50		n/a	248.64	0.27		248.77	0.22		248.84	0.16		248.94	0.13		249.03	0.13		249.10	0.12		249.39	0.02	
J837.80		n/a	248.79	0.28		248.91	0.20		248.97	0.14		249.05	0.11		249.12	0.10		249.18	0.08		249.48	0.02	
J869.45	d/s end of culvert at Bridge 1000	n/a	248.86	0.26		248.97	0.19		249.03	0.13		249.11	0.11		249.17	0.09		249.23	0.08		249.52		
J881.13	u/s end of culvert at Bridge 1000	248.85	249.32	0.32	**0.47**	249.42	0.17	**0.57**	249.48	0.12	**0.63**	249.53	0.08	**0.68**	249.57	0.05	**0.72**	249.60	0.04	**0.75**	249.73		**0.88**
J933.10		n/a	249.33	0.32		249.42	0.17		249.48	0.12		249.54	0.09		249.57	0.05		249.60	0.03		249.75		
J961.51		n/a	249.34	0.31		249.44	0.18		249.49	0.12		249.55	0.08		249.59	0.05		249.62	0.03		249.79		
J1009.21		n/a	249.36	0.28		249.46	0.18		249.52	0.13		249.58	0.09		249.62	0.06		249.65	0.03		249.83		
J1058.64		n/a	249.45	0.21		249.55	0.17		249.60	0.12		249.66	0.09		249.70	0.06		249.73	0.04		249.93		
J1097.22		n/a	249.54	0.22		249.62	0.16		249.67	0.12		249.72	0.08		249.76	0.06		249.80	0.04		250.00		
J1146.62		n/a	249.65	0.23		249.75	0.19		249.80	0.14		249.85	0.09		249.89	0.07		249.93	0.05		250.14		
J1215.03		n/a	249.93	0.32		250.04	0.23		250.10	0.16		250.15	0.10		250.17	0.05		250.20	0.04		250.38		
J1233.42		n/a	249.98	0.34		250.10	0.24		250.16	0.17		250.20	0.09		250.23	0.05		250.25	0.03		250.42		
J1251.14		n/a	250.04	0.36		250.15	0.24		250.21	0.15		250.25	0.08		250.28	0.04		250.31	0.03		250.49		
J1312.09		n/a	250.17	0.39		250.33	0.30		250.41	0.19		250.49	0.11		250.54	0.06		250.58	0.03		250.86		
J1328.03		n/a	250.23	0.39		250.39	0.31		250.47	0.19		250.55	0.11		250.60	0.06		250.64	0.03		250.93		
J1362.31		n/a	250.47	0.38		250.61	0.31		250.67	0.14		250.74	0.08		250.79	0.05		250.83	0.02		251.14		
J1400.64		n/a	250.58	0.35		250.70	0.21		250.76	0.13		250.83	0.08		250.88	0.05		250.92	0.02		251.24		
J1429		n/a	250.68	0.29		250.79	0.18		250.84	0.12		250.90	0.07		250.95	0.04		250.99	0.02		251.31		
AMA2		n/a	250.74	0.27		250.84	0.17		250.89	0.12		250.96	0.08		251.00	0.04		251.04	0.02		251.36		
Tributary A: Reach AM-5																							

			2-yr/24-hr			5-yr/24-hr			10-yr/24-hr			25-yr/24-hr			50-yr/24-hr			100-yr/24-hr			Regional Storm		
Junction Name	Location	Road Overtop Elev. (m)	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road
J1482.68		n/a	250.76	0.25		250.85	0.13		250.90	0.07		250.98	0.04		251.05	0.03		251.11	0.03		251.42		
J1516.26	d/s end of culvert at Bridge 150	n/a	250.79	0.18		250.88	0.08		250.99	0.07		251.10	0.05		251.18	0.04		251.25	0.05		251.53	0.02	
J1534.07	u/s end of culvert at Bridge 150	251.15	251.10	0.19		251.34	0.09	**0.19**	251.41	0.04	**0.26**	251.47	0.03	**0.32**	251.51	0.02	**0.36**	251.55	0.03	**0.40**	251.69		**0.54**
J1551.87		n/a	251.10	0.19		251.34	0.08		251.41	0.04		251.48	0.04		251.52	0.03		251.56	0.03		251.70		
J1608.03		n/a	251.11	0.18		251.34	0.08		251.42	0.04		251.48	0.03		251.52	0.03		251.56	0.03		251.71		
J1671.38		n/a	251.12	0.18		251.35	0.09		251.42	0.04		251.48	0.03		251.53	0.03		251.56	0.02		251.71		
J1710.16		n/a	251.18	0.16		251.38	0.07		251.45	0.04		251.51	0.03		251.55	0.03		251.59	0.03		251.74		
J1764.95		n/a	251.30	0.18		251.49	0.08		251.53	0.05		251.56	0.02		251.60	0.03		251.64	0.03		251.76		
J1821.83		n/a	251.39	0.09		251.57	0.05		251.63	0.04		251.68	0.04		251.72	0.04		251.75	0.03		251.85		
J1860.66		n/a	251.43	0.09		251.64	0.07		251.72	0.05		251.79	0.05		251.83	0.04		251.86	0.04		251.94		
J1887.99		n/a	251.46	0.09		251.65	0.07		251.72	0.05		251.79	0.05		251.83	0.04		251.86	0.03		251.95		
AMA5		n/a	251.51	0.09		251.67	0.06		251.73	0.04		251.79	0.04		251.84	0.04		251.87	0.04		251.96		
Tributary A: Reach AM-6 and AM-7																							
J2021.40		n/a	251.52	0.09		251.67	0.05		251.74	0.05		251.80	0.04		251.84	0.04		251.87	0.04		251.96		
J2072.56		n/a	251.53	0.09		251.67	0.05		251.74	0.05		251.80	0.04		251.84	0.04		251.87	0.03		251.96		
J2126.95		n/a	251.60	0.06		251.68	0.04		251.74	0.04		251.80	0.04		251.84	0.04		251.87	0.03		251.96		
J2176.63		n/a	251.67	0.06		251.78	0.03		251.80	0.02		251.83	0.02		251.85	0.03		251.88	0.04		251.97		
J2244.43		n/a	251.77	0.02		251.81			251.83			251.85			251.87	0.02		251.90	0.03		251.98		
J2254.97		n/a	251.84	0.03		251.93	0.03		251.98	0.04		252.04	0.05		252.16	0.13		252.18	0.03		252.18		
J2299.97		n/a	252.15	0.03		252.24	0.04		252.26	0.02		252.30	0.03		252.32	0.03		252.34	0.03		252.34		
J2340.31		n/a	252.52	0.04		252.56	0.02		252.59	0.03		252.62	0.03		252.65	0.04		252.67	0.03		252.68		
J2362.75		n/a	252.67	0.04		252.75	0.03		252.80	0.04		252.83	0.03		252.86	0.03		252.89	0.04		252.90		
J2401.07		n/a	252.79	0.05		252.90	0.04		252.96	0.05		253.00	0.04		253.03	0.04		253.05	0.03		253.07	0.02	
J2433.86		n/a	252.95	0.04		253.05	0.03		253.10	0.04		253.15	0.04		253.18	0.04		253.21	0.04		253.22		
J2450.6		n/a	253.12	0.02		253.19	0.03		253.23	0.04		253.27	0.04		253.30	0.04		253.33	0.04		253.34		
J2479.5	d/s end of culvert at Structure #10	n/a	253.24	0.03		253.33	0.04		253.38	0.04		253.44	0.05		253.48	0.05		253.52	0.06		253.54	0.02	
J2509.5	u/s end of culvert at Structure #10	254.90	253.66	0.09		253.96	0.15		254.20	0.21		254.80	0.54		254.93	0.24	**0.03**	254.98	0.09	**0.08**	255.00	0.02	**0.10**
J2524		n/a	253.75	0.02		253.97	0.14		254.21	0.21		254.80	0.54		254.93	0.24		254.98	0.08		255.01	0.03	
Tributary A: Reach A2-1 and A2-2																							
J22268.08		n/a	250.74	0.16		250.84	0.17		250.90	0.12		250.96	0.08		251.01	0.05		251.04			251.37	0.02	
J222110.7		n/a	251.17	0.10		251.22	0.08		251.24	0.04		251.27			251.29			251.32			251.44		
J222181.0		n/a	251.45	0.20		251.52	0.13		251.55	0.05		251.60	0.02		251.63			251.67	-0.02		251.83		
J222256.8		n/a	251.79	0.08		251.85	0.10		251.88	0.05		251.93	0.02		251.96			252.00			252.15		
J222345.5		n/a	251.93	0.10		252.00	0.11		252.04	0.07		252.07			252.09			252.11			252.23		
J222411.2		n/a	252.34	0.11		252.41	0.12		252.44	0.06		252.48	0.03		252.50			252.52			252.61		
J222445.0		n/a	252.52	0.11		252.58	0.09		252.62	0.06		252.65	0.03		252.68			252.70			252.82		
J222503.2		n/a	252.74	0.19		252.82	0.14		252.87	0.08		252.91	0.03		252.94			252.97	-0.02		253.12		
J222581.8		n/a	252.95	0.11		253.00	0.09		253.02	0.05		253.05	0.03		253.07	0.02		253.08			253.17		
J222652.7		n/a	253.38	0.08		253.41	0.06		253.43	0.04		253.44	0.02		253.45			253.46			253.50		
J222721.4		n/a	253.63			253.74			253.81			253.87			253.91			253.94			254.01		
J222740	d/s end of culvert at Bridge 2400	n/a	253.74			253.91			254.02			254.06			254.09			254.12			254.18		
J222795.9	u/s end of culvert at Bridge 2400	254.41	254.26			254.57		**0.16**	254.61		**0.20**	254.65		**0.24**	254.67		**0.26**	254.69		**0.28**	254.74		**0.33**
J222831.9		n/a	254.26			254.57			254.62			254.65			254.68			254.70			254.76		
J222880.7		n/a	254.32			254.57			254.62			254.67			254.70			254.73			254.82		

			2-yr/24-hr			5-yr/24-hr			10-yr/24-hr			25-yr/24-hr			50-yr/24-hr			100-yr/24-hr			Regional Storm		
Junction Name	Location	Road Overtop Elev. (m)	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road
J222914.5		n/a	254.74			254.84			254.93			255.01			255.06			255.10			255.22		
J222968.0	d/s end of culvert at Bridge 2530	n/a	254.84			254.93			255.01			255.08			255.14			255.18			255.31		
J223004.5	u/s end of culvert at Bridge 2530	256.99	256.16			257.08		**0.09**	257.14		**0.15**	257.18		**0.19**	257.20		**0.21**	257.21		**0.22**	257.27		**0.28**
J223038.1		n/a	256.17			257.08			257.14			257.18			257.20			257.22			257.28		
J223116.5		n/a	256.21			257.08			257.15			257.20			257.24			257.27			257.39		
J223199.9		n/a	256.84			257.09			257.18			257.25			257.30			257.35			257.51		
Tributary A: Reach A4-1, A4-2, A4-3, and A4-4																							
J44414.18		n/a	248.62	0.16		248.84	0.33		249.03	0.43		249.14	0.44		249.19	0.40		249.24	0.39		249.15	0.09	
J44452.82		n/a	248.89	0.18		249.10	0.31		249.25	0.37		249.37	0.40		249.45	0.40		249.52	0.41		249.38	0.10	
J44495.83		n/a	249.53	0.12		249.65	0.18		249.73	0.21		249.81	0.23		249.87	0.25		249.93	0.27		249.82	0.07	
J444130.4		n/a	250.13	0.16		250.26	0.22		250.32	0.21		250.39	0.20		250.44	0.21		250.49	0.22		250.40	0.06	
J444160.3		n/a	250.28	0.08		250.38	0.15		250.45	0.18		250.53	0.21		250.58	0.22		250.63	0.24		250.53	0.06	
J444198.8		n/a	250.52	0.15		250.71	0.29		250.80	0.30		250.89	0.30		250.96	0.30		251.02	0.30		250.90	0.08	
J444266.6		n/a	250.85	0.09		250.97	0.16		251.04	0.20		251.11	0.21		251.16	0.22		251.21	0.24		251.12	0.07	
J444328.7		n/a	251.31	0.06		251.36	0.09		251.40	0.09		251.44	0.11		251.47	0.13		251.50	0.14		251.44	0.04	
J444380.8		n/a	251.64	0.10		251.68	0.10		251.73	0.10		251.78	0.12		251.82	0.16		251.86	0.18		251.79	0.05	
J444460.7		n/a	252.23	0.21		252.37	0.28		252.43	0.22		252.47	0.17		252.50	0.16		252.54	0.17		252.47	0.04	
J444521.1		n/a	252.50	0.08		252.59	0.14		252.64	0.15		252.70	0.17		252.75	0.19		252.78	0.19		252.70	0.05	
J444543.8		n/a	252.72	0.09		252.82	0.16		252.88	0.17		252.94	0.18		252.98	0.18		253.02	0.20		252.94	0.05	
J444594.6		n/a	253.29	0.18		253.49	0.31		253.61	0.34		253.72	0.35		253.81	0.37		253.88	0.39		253.73	0.11	
J444655.7		n/a	253.66	0.15		253.81	0.25		253.90	0.26		253.98	0.26		254.05	0.28		254.11	0.30		253.99	0.08	
J444726.7		n/a	253.82	0.07		253.92	0.14		253.98	0.17		254.07	0.21		254.13	0.24		254.20	0.28		254.07	0.08	
J444793.7		n/a	254.27	0.08		254.34	0.12		254.38	0.12		254.42	0.12		254.46	0.14		254.49	0.15		254.41	0.03	
J444867.4		n/a	254.72	0.09		254.81	0.15		254.86	0.16		254.92	0.17		254.96	0.18		255.01	0.20		254.92	0.05	
J444936.3		n/a	255.40	0.07		255.49	0.14		255.53	0.14		255.57	0.14		255.61	0.15		255.64	0.15		255.57	0.04	
J4441008		n/a	255.87	0.09		255.98	0.17		256.04	0.19		256.10	0.19		256.15	0.20		256.19	0.21		256.10	0.05	
J4441090		n/a	256.48	0.13		256.60	0.22		256.66	0.20		256.73	0.20		256.79	0.22		256.84	0.24		256.73	0.06	
J4441201		n/a	257.92	0.11		258.04	0.19		258.10	0.19		258.16	0.19		258.21	0.20		258.26	0.22		258.16	0.06	
J4441280		n/a	258.35	0.12		258.46	0.19		258.52	0.19		258.58	0.19		258.62	0.19		258.66	0.19		258.58	0.05	
J4441342		n/a	258.86	0.14		259.00	0.23		259.07	0.23		259.15	0.24		259.20	0.24		259.25	0.25		259.14	0.06	
J4441419		n/a	259.41	0.15		259.57	0.26		259.66	0.27		259.76	0.28		259.83	0.30		259.89	0.32		259.75	0.08	
J4441488		n/a	259.90	0.10		260.04	0.21		260.13	0.25		260.22	0.27		260.29	0.29		260.35	0.31		260.21	0.08	
J4441559		n/a	260.44	0.18		260.64	0.32		260.76	0.35		260.88	0.37		260.97	0.38		261.06	0.42		260.87	0.10	
J4441588	d/s end of culvert at Structure #13	n/a	260.72	0.09		260.81	0.15		260.87	0.16		260.94	0.18		261.03	0.24		261.11	0.30		260.94	0.07	
J4441640	u/s end of culvert at Structure #13	262.15	262.37	0.75	**0.22**	262.50	0.37	**0.35**	262.57	0.23	**0.42**	262.63	0.20	**0.48**	262.67	0.20	**0.52**	262.71	0.21	**0.56**	262.63	0.06	**0.48**
J4441665		n/a	262.37	0.74		262.50	0.37		262.57	0.23		262.63	0.20		262.68	0.21		262.71	0.21		262.63	0.06	
J4441750		n/a	262.37	0.56		262.51	0.38		262.57	0.22		262.64	0.21		262.69	0.22		262.73	0.22		262.64	0.06	
Tributary A: Reach A5-1																							
J555272.5		n/a	251.72	0.02		251.81	0.04		251.85	0.03		251.90	0.04		251.94	0.04		251.97	0.04		252.04		
J555210.0		n/a	251.68	0.03		251.77	0.03		251.81	0.03		251.86	0.04		251.89	0.04		251.91	0.03		252.01		
J555130.6		n/a	251.66	0.04		251.75	0.03		251.78	0.02		251.82	0.03		251.85	0.03		251.88	0.04		251.99		
J55560.97		n/a	251.54	0.07		251.67	0.06		251.73	0.04		251.80	0.05		251.84	0.04		251.87	0.04		251.97		
Tributary B																							
J0		n/a	231.95	0.33		231.99	0.26		232.00	0.19		232.02	0.13		232.03	0.09		232.04	0.07		232.05	0.05	

			2-yr/24-hr			5-yr/24-hr			10-yr/24-hr			25-yr/24-hr			50-yr/24-hr			100-yr/24-hr			Regional Storm		
Junction Name	Location	Road Overtop Elev. (m)	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road	Peak Stage (m)	Δ_{Ex}	Depth Above Road
J1	d/s end of culvert at Bridge 1.5	n/a	233.15	0.25		233.17	0.18		233.18	0.13		233.19	0.08		233.20	0.05		233.21	0.05		233.22	0.04	
J2	u/s end of culvert at Bridge 1.5	239.05	235.96	1.53		236.92	2.25		237.45	2.52		238.06	2.77		238.54	2.77		238.93	2.58		239.14	1.87	**0.09**
J3		n/a	236.12	0.25		236.91	0.96		237.45	1.45		238.06	2.01		238.54	2.45		238.93	2.58		239.13	1.86	
J4		n/a	238.77	0.18		238.85	0.22		238.89	0.22		238.94	0.23		238.98	0.24		239.02	0.25		239.14	0.35	
J5		n/a	241.08	0.35		241.22	0.41		241.29	0.40		241.38	0.41		241.44	0.41		241.49	0.41		241.25	0.14	
J6		n/a	242.31	0.51		242.47	0.54		242.55	0.55		242.64	0.56		242.70	0.57		242.76	0.58		242.40	0.15	
J7		n/a	245.00	0.34		245.12	0.41		245.17	0.41		245.24	0.42		245.29	0.43		245.33	0.43		245.07	0.12	
Tributary C																							
J900	d/s end of culvert at Bridge 950	n/a	247.20	0.25		247.26	0.19		247.28	0.15		247.30	0.12		247.31	0.10		247.31	0.08		247.31	0.02	
J1000	u/s end of culvert at Bridge 950	249.78	247.91	0.83		248.51	1.14		248.80	1.26		249.09	1.35		249.31	1.37		249.38	1.23		249.38	0.46	
J1100		n/a	248.38	0.16		248.51	0.23		248.80	0.49		249.09	0.75		249.31	0.95		249.38	1.00		249.38	0.46	
J1115		n/a	248.88	0.21		248.96	0.21		249.01	0.22		249.10	0.27		249.31	0.45		249.39	0.51		249.38	0.43	
J1150		n/a	249.88	0.28		249.98	0.28		250.03	0.28		250.10	0.30		250.14	0.30		250.18	0.31		250.01	0.08	
J1200		n/a	251.55	0.13		251.62	0.16		251.65	0.17		251.69	0.18		251.71	0.18		251.74	0.19		251.63	0.05	
Road Flooding Occurrences:					2			5			5			5			6			6			7

Filename: SWGeorgetown_Uncontrolled_XXyr_43.inp/rpt

Notes:
1. All values are rounded to the nearest 10 mm.
2. Δ_{Ex} indicates the difference in peak flood stage compared to Existing land use conditions. No value is shown if the peak stage is within 12.5 mm.
3. Depth Above Road indicates the depth (m) that the peak flood stage rises above the road centerline elevation or top of ground at a culvert crossing.

Table 5.4.6 Level of Service Comparison - Existing vs. Uncontrolled Stormwater Future Land Use Conditions

Location	Description	Structure Name	Service Level Provided	
			Existing	Future
Tributary A				
Eighth Line	twin 2.42m × 3.78m concrete box culverts	Bridge 180	Regional	Regional
private road	0.95m × 1.50m concrete box culvert	Bridge 1000	<2-yr	<2-yr
private road	1.40m Ø concrete round culvert	Bridge 150	2-yr	2-yr
10th Side Rd.	1.18m Ø concrete round culvert	Structure #10	100-yr	25-yr
private road	0.70m Ø concrete round culvert	Bridge 2400	2-yr	2-yr
Trafalgar Rd.	0.77m Ø PVC round culvert	Bridge 2530	2-yr	2-yr
Trafalgar Rd.	0.92m Ø corrugated steel round culvert	Structure #13	Not applicable [1]	Not applicable [1]
Tributary B				
Eighth Line	1.40m Ø corrugated steel round culvert	Bridge 1.5	Regional	100-yr
Tributary C				
Eighth Line	1.43m × 2.02m corrugated steel box culvert	Bridge 950	Regional	Regional

1. The model for uncontrolled Flows at Structure #13 includes downstream catchment areas. Capacity of culvert due to actual catchment area is assessed under proposed condition modeling in Section 6.3.5.

Table 5.4.7 compares the peak computed flowrates for the various design storm events to the culvert capacity. For each culvert, the full-flow capacity is shown along with the peak flow under uncontrolled future land use conditions, the difference compared to existing conditions, and the capacity ratio (percentage of the peak computed flowrate compared to the full-flow capacity). Occurrences that exceed 85 percent of the culvert capacity are highlighted in red.

These values were compared under existing and future land use conditions to determine culvert capacity impacts as follows:

- 2-year return period/24-hour duration: 3 new capacity violations, maximum flow increase of 4.9 m^3/s
- 5-year /24-hour: 4 new capacity violations, 8.9 m^3/s maximum flow increase
- 10-year /24-hour: 1 new capacity violation, 10.9 m^3/s maximum flow increase
- 25-year /24-hour: 2 new capacity violations, 13.3 m^3/s maximum flow increase
- 50-year/24-hour: 2 new capacity violations, 15.1 m^3/s maximum flow increase
- 100-year /24-hour: : 1 new capacity violation, 17.0 m^3/s maximum flow increase
- Regional storm: : 1 new capacity violation, 3.7 m^3/s maximum flow increase

The analyses described above characterize flood hazards based on the maximum depth of flooding (hydraulic gradeline analysis) or the maximum rate of flow through the culverts at each road crossing. A better indication of flooding hazard potential is provided by assessing the combination of depth and velocity of flow over the road. Like other regulatory agencies across North America, Ontario Conservation Authorities consider flood risk envelopes for pedestrian stability and safe vehicular access under road flooding conditions.

Table 5.4.7 Uncontrolled Stormwater Future Land Use Conditions - Flow and Culvert Capacity Analysis

			2-yr/24-hr			5-yr/24-hr			10-yr/24-hr			25-yr/24-hr			50-yr/24-hr			100-yr/24-hr			Regional Storm		
Upstream Node	**Structure, Location**	**Full-Flow Capacity (m^3/s)**	**Peak Flow (m^3/s)**	**Δ_{Ex}**	**Q_p/Q_{full}**	**Peak Flow (m^3/s)**	**Δ_{Ex}**	**Q_p/Q_{full}**	**Peak Flow (m^3/s)**	**Δ_{Ex}**	**Q_p/Q_{full}**	**Peak Flow (m^3/s)**	**Δ_{Ex}**	**Q_p/Q_{full}**	**Peak Flow (m^3/s)**	**Δ_{Ex}**	**Q_p/Q_{full}**	**Peak Flow (m^3/s)**	**Δ_{Ex}**	**Q_p/Q_{full}**	**Peak Flow (m^3/s)**	**Δ_{Ex}**	**Q_p/Q_{full}**
Tributary A																							
J105.06	Bridge 180, Eighth Line	66.8	6.0	3.68	9%	13.8	8.94	21%	19.2	10.87	29%	25.9	12.73	39%	31.4	14.22	47%	36.3	14.88	54%	47.6	1.39	71%
J881.13	Bridge 1000, private road	5.17	5.6	3.81	109%	9.0	5.07	173%	11.2	4.69	217%	14.1	4.07	273%	16.5	3.38	320%	18.8	2.52	363%	37.7	0.96	730%
J1534.07	Bridge 150, private road	2.5	1.5	0.46	62%	2.7	0.64	108%	3.8	0.71	152%	5.3	0.80	211%	6.6	0.92	263%	8.0	1.12	321%	17.3	0.94	694%
J2509.5	Structure #10, 10th Side Rd.	2.64	0.4	0.15	17%	1.1	0.32	40%	1.6	0.46	61%	2.3	0.60	87%	3.0	0.85	113%	3.7	1.00	139%	4.1	0.40	154%
J222795.9	Bridge 2400, private road	0.3	0.3		102%	1.0		336%	2.4		808%	4.2		1408%	5.9		1962%	7.5		2496%	13.0		4338%
J223004.5	Bridge 2530, Trafalgar Road	0.42	0.4		83%	1.3		316%	2.7		650%	4.5		1068%	6.0		1440%	7.6		1806%	13.0		3100%
J4441640	Structure #13, Trafalgar Road	0.98	2.7	2.15	274%	5.9	4.68	600%	9.1	7.35	931%	13.5	10.31	1381%	17.5	12.87	1781%	21.5	15.65	2190%	13.1	3.74	1338%
Tributary B																							
J2	Bridge 1.5, Eighth Line	10.5	5.0	4.87	47%	9.2	8.62	88%	12.1	10.67	115%	14.7	11.99	140%	15.7	11.85	150%	17.0	11.96	162%	7.8	2.62	75%
Tributary C																							
J1000	Bridge 950, Eighth Line	1.39	4.4	4.30	319%	8.7	7.89	626%	11.8	10.27	848%	15.8	13.30	1138%	18.6	15.13	1338%	21.4	17.01	1540%	8.7	2.39	623%

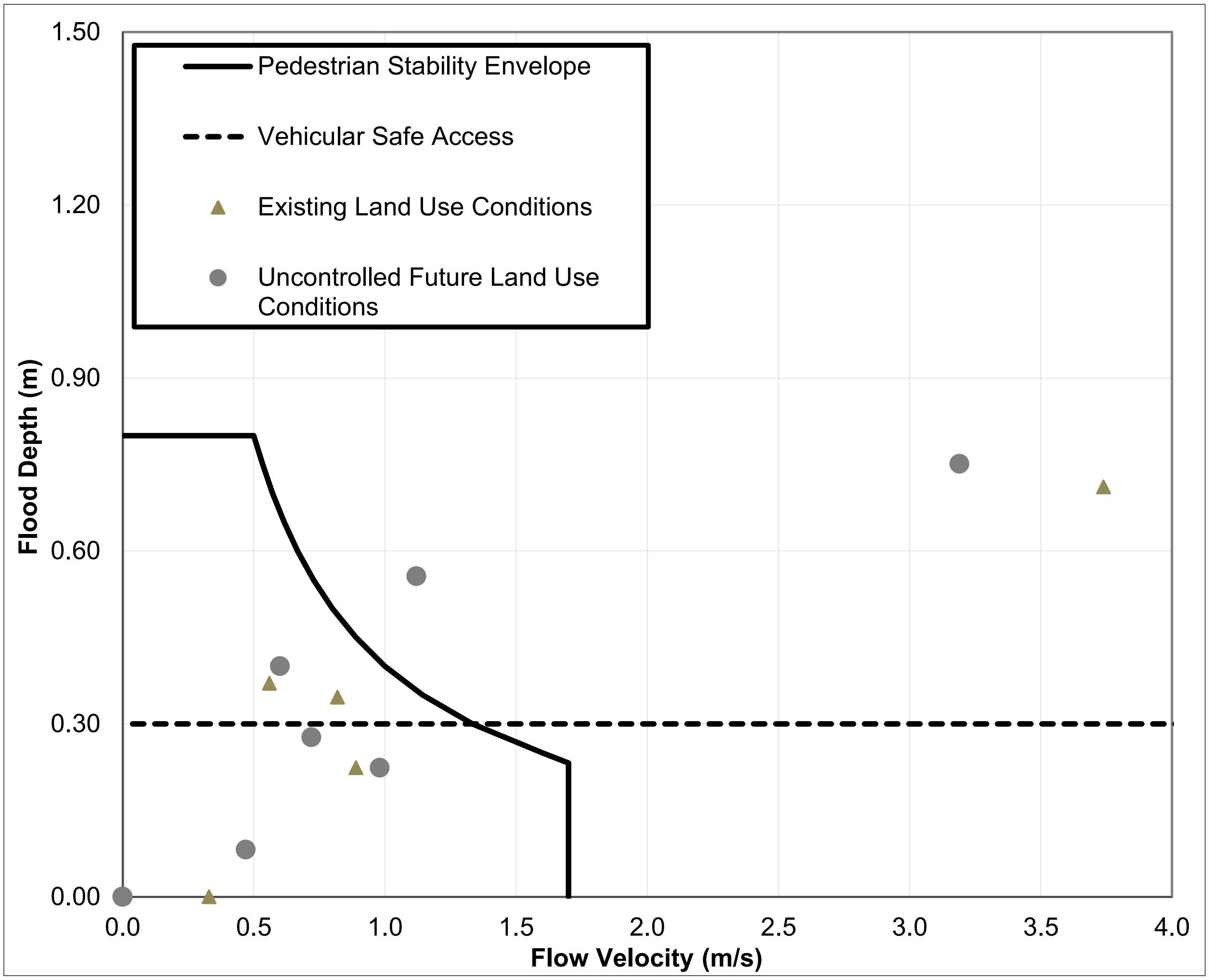
Filename: SWGeorgetown_Uncontrolled_XXyr_43.inp/rpt

Notes:
1. Culvert full-flow capacity based on Manning's equation.
2. Peak computed flowrates that exceed 85% capacity are highlighted.

Figure 5.4.2 shows the peak computed depth and flow velocities for all road flooding occurrences during the 100-year design storm event under existing (plotted with triangle markers) and uncontrolled future land use conditions (circle markers). The vehicular safe access envelope characterizes a depth of floodwaters that do not exceed 0.3 m for all velocities up to 3.0 m/s. The pedestrian stability envelope describes the following limitations:

- Peak velocity of floodwaters does not exceed 1.7 m/s;
- Peak depth of floodwaters does not exceed 0.8 m; and
- The product of Velocity × Depth does not exceed 0.4 m^2/s.

Figure 5.4.2 Road Flooding Impacts (100-Year Design Storm Event)



Exceedances of these envelopes are indicated at the following locations under existing land use conditions:

- Tributary A, Reach AM-4 (Bridge 1000, private internal road): peak depth = 0.71 m, peak velocity = 3.7 m/s

The following exceedances indicate road flooding impacts under future land use conditions:

- Tributary A, Reach AM-4 (Bridge 1000, private internal road): peak depth = 0.75 m, peak velocity = 3.2 m/s

- Tributary A, Reach A4-4 (Trafalgar Road, Structure #13): peak depth = 0.56 m, peak velocity = 1.1 m/s

The overall impacts of proposed development on runoff volume (average for all watercourses) are smaller in magnitude than the peak flow impacts described above, but display a similar trend of diminishing impact as the event return period increases. The comparison of future unitary runoff volumes to existing conditions indicates the following:

- 2-year return period/24-hour duration: 20% runoff volume increase
- 5-year /24-hour: 18% runoff volume increase
- 10-year /24-hour: 17% runoff volume increase
- 25-year /24-hour: 15% runoff volume increase
- 50-year/24-hour: 14% runoff volume increase
- 100-year /24-hour: 13% runoff volume increase
- Regional storm: 12% runoff volume increase

5.4.3.4 Erosion Threshold Analysis

The future development model was applied to the long-term rainfall dataset and cumulative erosion indices were computed at each of the detailed geomorphological field data collection sites. A comparison of existing and future land use condition (no SWM Control) erosion indices is provided in **Table 5.4.8**. Refer to **Section 4.6.9** for the erosion index methodology.

Table 5.4.8 Erosion Index Comparison - Existing vs. Uncontrolled Stormwater Future Land Use

	Tributary A Reach AM3 J477.76	**Tributary B Reach BD1 J1**	**Tributary C Reach C2 J1100**
Existing Development	47	4	32
Future Development (No SWM Controls)	212	132	832

Cumulative erosion indices increase significantly if no SWM erosion controls are implemented. Increases in high flow frequency, duration, and magnitude could cause the existing reaches to become unstable and lead to significant morphological adjustment. Post development cumulative erosion indices should match existing conditions, unless more stringent control is required. The recommended SWM strategy will aim to maintain existing erosion indices through SWM facility erosion control volumes and LID measures.

5.4.4 Hydrogeology and Water Balance

The hydrogeologic water balance assessment modelling was completed by Matrix Solutions Inc., under contract to AECOM. The work completed by Matrix is documented in a Memorandum included as **Appendix O**. The following sections are largely a summary of the contents of this memorandum.

The hydrogeologic water balance modelling was completed by refining an existing three-dimensional groundwater flow model that was developed for the Region of Halton as part of the Halton Hills Tier 3 Water Budget and Local Area Risk Assessment (Tier 3 Assessment) (AECOM and AquaResource, 2014a). The Tier 3 Model domain covers the Town of Halton Hills including the communities of Georgetown and Acton, and extends into the 16 Mile Creek watershed; however, the assessment discussed herein only considered the area local to the Study Area.

5.4.4.1 Water Budget Components

The circulation and movement of water between the atmosphere, surface waterbodies and the land surface is called the hydrologic cycle. Water that falls to the ground as precipitation (P) either runs off (R) to a surface waterbody, evapotranspires (ET, a combination of evaporation from ground surface and waterbodies and transpiration by plants) or infiltrates (I) into the ground. The water that infiltrates moves either vertically down to the water table as recharge or flows horizontally in the unsaturated zone, eventually discharging as interflow to the nearest surface water feature. The rate at which water infiltrates into the ground is controlled by factors such as the permeability and porosity of the earth materials, topography, ground cover, and the size and timing of precipitation events. Soils such as sands and gravels are generally more permeable, enabling water that falls on these soils to infiltrate relatively easily. Fine grained soils, such as those typically at ground surface in the Southwest Georgetown Study Area, are considered to be less permeable, resulting in little infiltration and a predominance of evapotranspiration and runoff. **Figure 2.1.1** shows a schematic of the hydrologic cycle.

When long-term averages of P, R, ET, and I are used, there is no net change in groundwater storage (S). On a short-term basis, however, there is a potential for changes in S. This analysis was completed on an average annual basis and therefore the S term was not evaluated.

The annual water budget can be stated as:

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

In the following sections, the methodology used to evaluate each component of the water budget in the Tier 3 Model is detailed. This text is largely taken from the model development and calibration report (AECOM and AquaResource, 2014b). Also included are the results of the water balance assessment, which considered potential changes to the water budget components resulting from the proposed development in the Study Area.

The surface water (hydrology) component of the model uses the MIKE SHE model to simulate the major hydrologic processes and provide an estimate of groundwater recharge over the area of interest. The analysis completed for this study did not involve modifications to the MIKE SHE component of the model; therefore, site specific values of precipitation, evapotranspiration and runoff are not available as output from the Tier 3 Model. Estimates for the Study Area, based on the regional output from the model, are included in the following sections, where possible.

Precipitation

The Tier 3 Model utilizes Environment Canada climate stations from the MNR-infilled climate data set (Land Information Ontario, 2008) within or near the model domain to characterise the climate of the Study Area. The specific climate stations used to build the data set are listed in **Table 5.4.9**. This data set was subsequently infilled to address data gaps and errors, and includes data from 1950 to 2005. Based on this data input, a precipitation estimate of 880 mm/a is derived for the Study Area (AECOM and AquaResource, 2014a).

Table 5.4.9 Selected Climate Stations

AES ID	Station Name	Latitude	Longitude	Elevation (m)
6142400	Fergus Shand Dam	43.73	-80.33	418
6143090	Guelph Turfgrass CS	43.55	-80.22	325
6150916	Brampton MOECC	43.67	-79.7	183
6152695	Georgetown WWTP	43.64	-79.88	221
6153410	Heart Lake	43.73	-79.78	259
6153552	Hornby Trafalgar	43.53	-79.73	183
6155187	Milton Kelso	43.5	-79.95	244

Evapotranspiration

In order to evaluate evapotranspiration, a vegetation map was used as input to the Tier 3 Model to describe the spatial distribution of vegetation in the watershed (AECOM and AquaResource, 2014b). Evapotranspiration was approximated using a two-layer water balance model that considers interception, ponding and evapotranspiration. Actual evapotranspiration was computed considering vegetation parameters and specifying a potential evapotranspiration rate. In the MIKE SHE model, the leaf area index defines canopy interception of precipitation, and the rooting depth defines the depth to which plants may draw moisture from the subsurface for transpiration. MIKE SHE attempts to meet the potential evapotranspiration rate through consideration of water availability in the various phases of the hydrologic cycle in the following order:

- Accumulated Snow (if present, through evaporation or sublimation);
- Canopy Interception (through evaporation);
- Ponded Water (through evaporation);
- Unsaturated Zone (through transpiration); and
- Saturated Zone (through transpiration).

Once all water content in a storage element is evaporated, no further evaporation occurs from that storage element until it is replenished by a precipitation event, overland runoff or though groundwater flow.

Infiltration and Recharge

One-dimensional (vertical) unsaturated flow is considered within MIKE SHE using a two-layer water balance approach. This considers an upper layer of the unsaturated zone that extends from the ground surface to the top of the capillary fringe and a lower layer that extends from the evapotranspiration extinction depth (the maximum root depth + capillary fringe thickness) to the water table. In areas where the water table is above the evapotranspiration extinction depth, there is only one layer (maximum root depth + capillary fringe) (AECOM and AquaResource, 2014b).

Water that is accessible for evapotranspiration is defined by the amount of soil-water content contained within the rooting zone. The soils of the unsaturated zone are described with a spatial distribution, based on surficial geology, and are characterized by a hydraulic conductivity parameter, soil-water parameters (wilting point, field capacity, saturation point) and suction head. Infiltration to the unsaturated zone is calculated using the Green and Ampt method. Limiting factors for infiltration are the soil hydraulic conductivity and the suction head. Soil-water content of the unsaturated zone is maintained on a mass balance basis. When the soil-water content of the unsaturated zone exceeds field capacity, water drains to the saturated zone (recharge). When soil-water content is below field capacity, recharge ceases with further reductions in soil-water content only occurring through evapotranspiration.

The Green and Ampt infiltration equation modifies the infiltration rate to account for changes in soil moisture, and when net precipitation falls at a rate faster than the infiltration rate, overland runoff is generated (AECOM and AquaResource, 2014b).

The pre-development rechargee component of the water budget was estimated at 1,317 m^3/d for the Study Area. This includes 1,298 m^3/d surficial recharge and 19 m^3/d recharge from streams. Groundwater recharge from streams is simulated to naturally occur at locations where a downward hydraulic gradient is present.

Runoff

Topography of the subwatershed is characterized in the Tier 3 Model by a 5 and 10 m digital elevation model (DEM). Overland flow is simulated though a diffusive wave approximation of the St. Venant equations (Chin, 2006). Numerically, this method is implemented through a two-dimensional finite difference method. Additional overland considerations include (AECOM and AquaResource, 2014b):

- Spatially variable surface roughness, characterized through a Manning's number;
- Spatially variable depression storage, characterized by a depth of storage; and
- Spatially variable imperviousness, characterized by the fraction of flow immediately directed to river systems.

Although a site specific runoff value was not reported in this exercise, it is a factor in estimating the recharge value, as a majority of the runoff volume is not available to infiltrate the subsurface.

Groundwater Discharge

Groundwater discharge occurs at locations where the water table intercepts the ground surface, in the presence of an upward hydraulic gradient. Examples of typical groundwater discharge areas are lakes, creeks and wetlands. The field characterization of the Study Area completed by AECOM showed that portions of Tributaries A and B were perennial, while Tributary C is not perennial within the Study Area. Therefore, Tributary A (below AM-6) was modelled as a constant-flowing feature. Tributary B was observed to have low flow (below the field equipment measurement capabilities) to dry conditions. Therefore, this feature was evaluated to receive groundwater support, where the water table is at or near the ground surface but significant groundwater discharge does not occur. Based on this conceptualization, the Tier 3 Model estimates that 181 m^3/d of groundwater discharge occurs in the Study Area to Tributaries A and B.

5.4.5 Groundwater Potential Impacts and Management Needs

The potential hydrogeologic impacts associated with the proposed development were assessed by evaluating impacts to the following hydrologic parameters:

(1) Groundwater Recharge: a permanent decrease in groundwater recharge could result from increasing the impervious surface cover in the Study Area. This was evaluated by estimating the post-development change in recharge to the groundwater system.
(2) Groundwater Discharge: a reduction in recharge, as described in (1), could result in a reduction in discharge to surface water features and wetlands in the Study Area, or further downgradient.
(3) Groundwater flow out of the Study Area: the volume of groundwater leaving the groundwater system below the Study Area (i.e. flow off-site through the overburden) was evaluated to assess whether potential impacts to downgradient receptors could occur. Given the proximity to the Cedarvale municipal wells, these were the focus of the downgradient impact assessment.

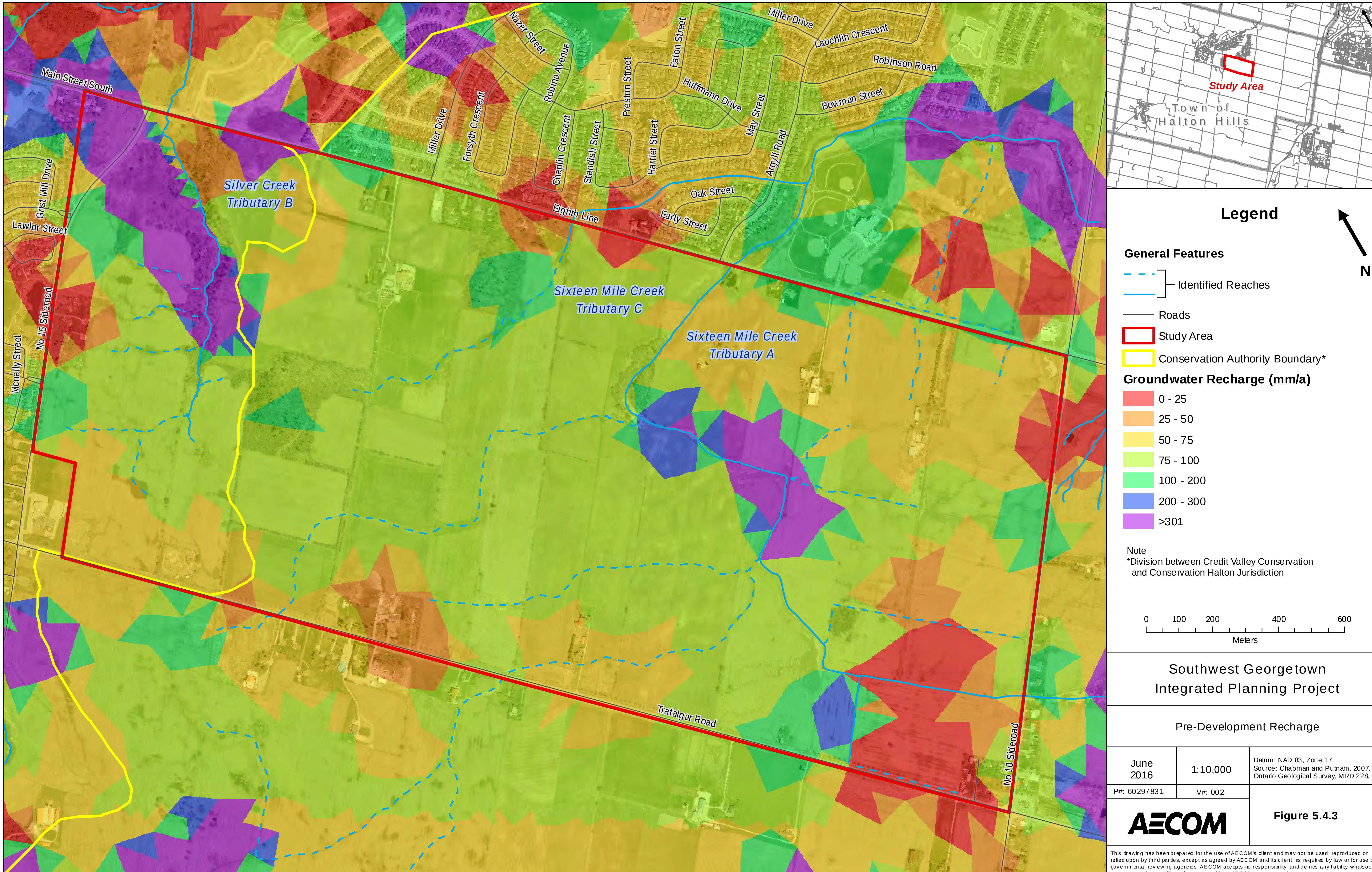
(4) Groundwater Levels: the groundwater levels in the vicinity of on-site surface water features and at the Cedarvale wells were evaluated to assess the related potential impacts.

The pre-development baseline conditions were established in the Tier 3 Model as described in **Section 5.4.4**. The post-development conditions were then established using the development scenario shown in **Figure 5.2.1**. The potential change to the quantity of groundwater recharge that occurs in the Study Area is linked to changes in the ground surface cover as the Study Area is developed. When the native soils are replaced with other materials and/or covered with impervious materials, the total area that is available for subsurface infiltration correspondingly decreases and may result in impacts to vegetation and aquatic features. The post-development increase in impervious surface cover was represented in the model by assigning a % impervious surface value to each land use shown in **Figure 5.2.1**. The % impervious surface values used are included in **Table 5.4.10**.

Table 5.4.10 Post-Development Land Uses and Estimated % Impervious Surface

LAND USE	Description	Suggested Impervious-ness
LOW	Low Density Residential (30 units/ha)	60%
MED	Medium Density Residential (65 units/ha)	65%
HIGH	High Density Residential (100 units/ha)	80%
CC	Neighbourhood Commercial	90%
INSTITUTIONAL	Institutional (schools)	75%
MSC	Mixed Use - Main Street (75% commercial / 25% residential)	83%
MU	Mixed Use (80% commercial / 20% residential)	87%
PROPOSED OS	Open Space (public parks)	15%
CEMETERY	Existing Public Cemetery (with proposed buffer)	4%
FLOODLINE	Regional Floodplain (to be determined)	8%
LINKAGE	Environmental Linkages (to be determined)	3%
NHS	Natural Heritage System (to be determined)	4%
Road Rights-of-Way	Proposed Collector Roads	80%

The incorporation of impervious ground surface into the Study Area redirects some precipitation as runoff where it would have previously infiltrated into the ground and contributed to groundwater recharge. The estimated pre- and post-development recharge rates, and distribution across the Study Area, are shown in **Figure 5.4.3** and **Figure 5.4.4.** The overall reduction in recharge rates corresponds to an estimated reduction in surficial groundwater recharge volume from 1,298 to 774 m^3/d (**Table 5.4.11**). Groundwater recharge is also simulated to occur in the Study Area as surface water leakage. An increase in estimated runoff from the site results in additional surface water conveyance in the tributaries and larger downward hydraulic gradients, where downward gradients presently exist. This would result in an estimated increase in the stream leakage component of groundwater recharge from 19 to 59 m^3/d (**Table 5.4.11**). Overall, the estimated net reduction in groundwater recharge is 484 m^3/d.



Legend

N

General Features

- Identified Reaches
- Roads
- Study Area
- Conservation Authority Boundary*

Groundwater Recharge (mm/a)

- 0 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 200
- 200 - 300
- >301

Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600
Meters

Southwest Georgetown Integrated Planning Project

Pre-Development Recharge

June 2016	1:10,000	Datum: NAD 83, Zone 17 Source: Chapman and Putnam, 2007. Ontario Geological Survey, MRD 228, LIO
P#: 60297831	V#: 002	

AECOM

Figure 5.4.3

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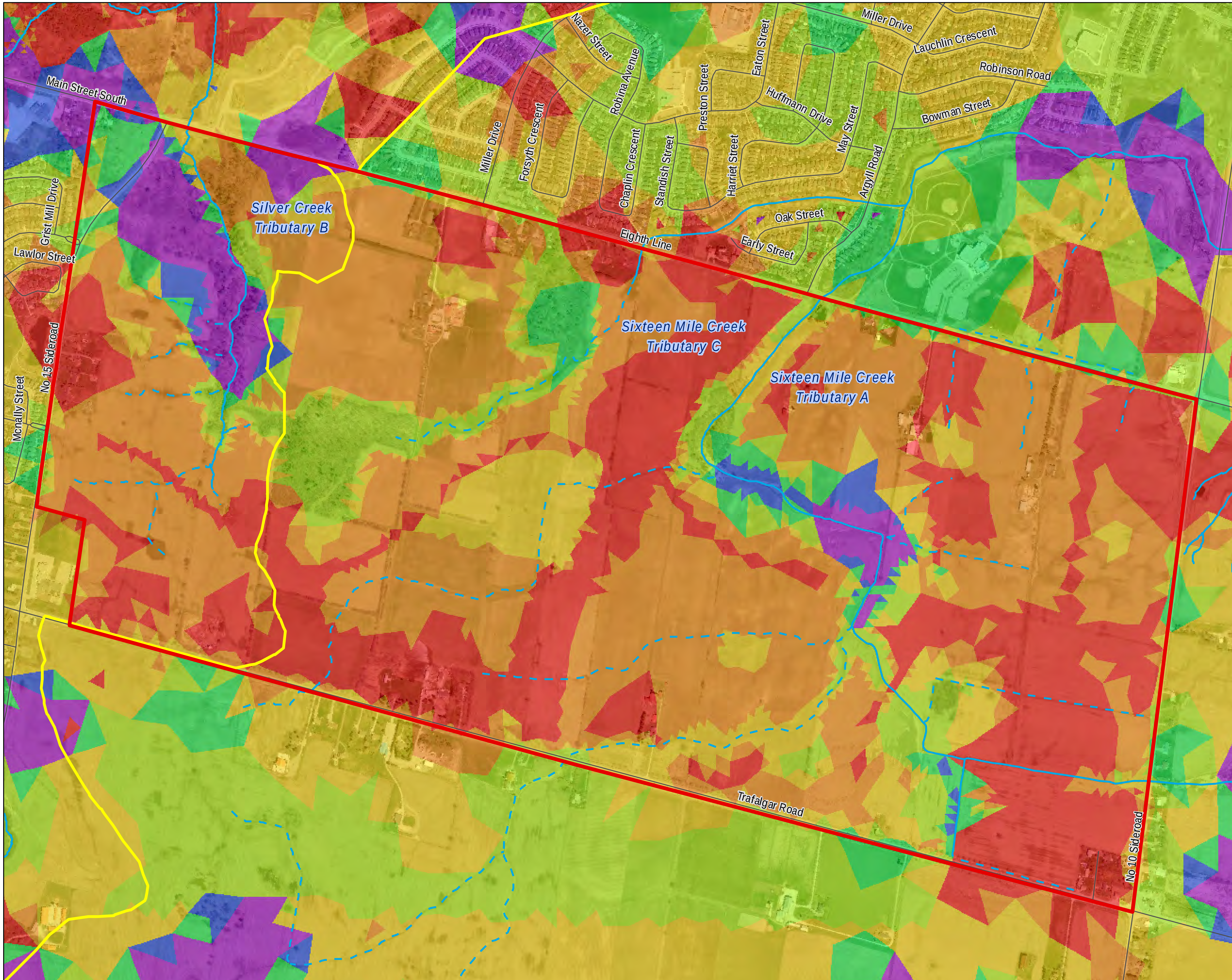

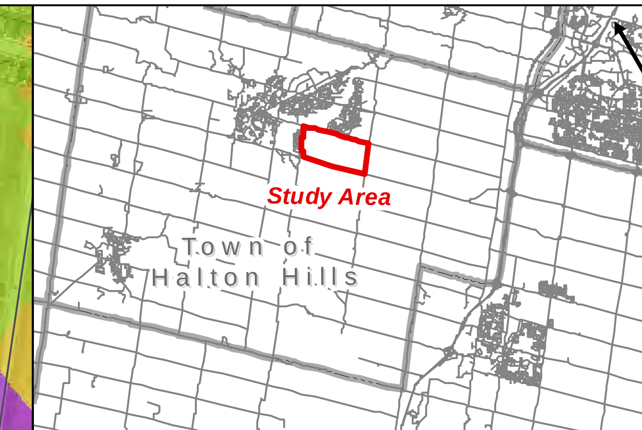

Legend

N

General Features

Identified Reaches

Roads

Study Area

Conservation Authority Boundary*

Groundwater Recharge (mm/a)

- 0 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 200
- 200 - 300
- >301

Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600
Meters

Southwest Georgetown Integrated Planning Project

Post-Development Recharge

June 2016	1:10,000	Datum: NAD 83, Zone 17 Source: Chapman and Putnam, 2007. Ontario Geological Survey, MRD 228, LIO
P#: 60297831	V#: 002	

AECOM

Figure 5.4.4

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Table 5.4.11 Groundwater Water Budget Components Pre- and Post-Development

	Pre-Development (m^3/d)	Post-Development (m^3/d)
Surficial Recharge	1,298	774
Recharge from Streams	19	59
Groundwater Flow In	2,896	3,055
Discharge to Streams	181	73
Groundwater Flow Out	4,032	3,815
Imbalance	0	0

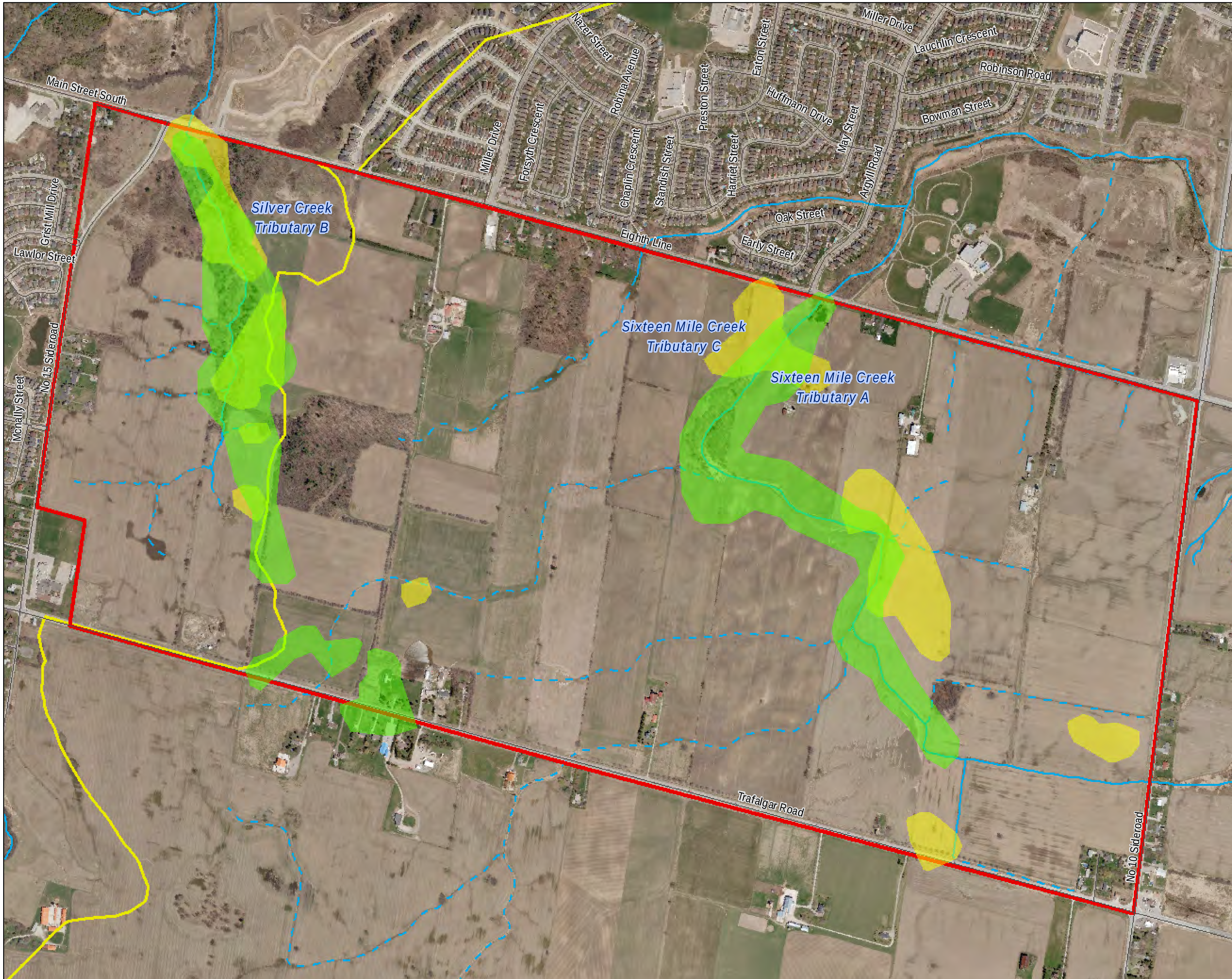
A reduction in groundwater recharge can result in related impacts (2), (3) and (4) discussed at the front of this section. With respect to impacts to groundwater discharge, the estimated reduction in potential discharge to the tributaries on site is 108 m^3/d. The site characterization work showed that Tributaries A and B support aquatic habitat and the groundwater inputs to these features contribute to stream health. Similarly, any wetlands that receive input from groundwater may be impacted over the long term by a decrease in groundwater input. Therefore, the simulated reduction in groundwater recharge is undesirable. A method called particle tracking was used to roughly delineate the ground surface area where a portion of the precipitation received will eventually discharge to a tributary on site (**Figure 5.4.5** and **Figure 5.4.6**). This analysis indicates that the contributing area is likely a relatively narrow band that surrounds these features (Tributary A and B). Groundwater recharge occurring outside of these areas is simulated to flow off-site without contributing to the tributaries.

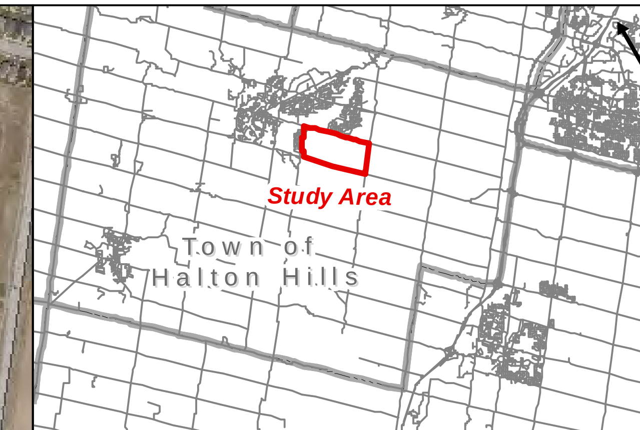
The contributing area analysis also considered potential contribution to Silver Creek, which is a large off-site surface water feature known to receive significant groundwater discharge. A series of smaller, disconnected polygons on **Figure 5.4.5** delineate the area simulated to contribute flow to Silver Creek, in the form of groundwater discharge.

If the % impervious surface values shown in **Table 5.4.10** are realized at the lands contained within the contributing area polygons, it could result in baseflows in Tributary A of 0.1 L/s, compared to a pre-development simulated value of 1.7 L/s. Baseflow reductions of a certain magnitude can impact fish communities and fish habitat by creating isolated pools, by reducing flow to spawning areas and potentially compromising egg survival. The simulated reduction in groundwater discharge to Silver Creek was 1.4 L/s. This result indicates that a substantial majority of groundwater discharge to the evaluated segment of Silver Creek (**Appendix O**) is not originating in the Study Area. As a result, the estimated reduction in groundwater recharge over the Study Area is assessed as having little potential impact on this creek.

Relative to Silver Creek, Tributary A is a small, low flow feature that is more sensitive to a potential baseflow reduction. In order to mitigate the potential reduction in baseflow predicted by the model, the lands within the contributing area polygons should be addressed. It is recommended that Low Impact Development measures be employed to minimize the potential reduction in groundwater recharge/discharge. Given the low permeability soils over much of the study area, in particular around Tributary A, mitigating the potential reduction to infiltration in these areas will be difficult; however, LID options are available and should be considered (TRCA, 2013). Opportunities for infiltration are site specific, requiring more detailed studies on individual land parcels to identify and take advantage of infiltration opportunities.

The land around Tributary B is more likely to provide opportunities for mitigation. A baseflow reduction was not specifically estimated for this feature due to the field observations of low to no flow. However, it is recognized that this tributary likely receives some level of groundwater support and the riparian vegetation may rely on a high water table. Therefore, it is recommended that the contributing areas delineated for Tributary B are also the focus of mitigation.





Legend

N

General Features

Identified Reaches

Roads

Study Area

Contributing Area within Study Area

Tributary A/B

Silver Creek

Conservation Authority Boundary*

Note

*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600

Meters

Southwest Georgetown Integrated Planning Project

Stream Baseflow Contributing Areas

June 2016	1:10,000	Datum: NAD 83, Zone 17 Source: Chapman and Putnam, 2007. Ontario Geological Survey, MRD 228, LIO
P#: 60297831	V#: 002	

AECOM

Figure 5.4.5

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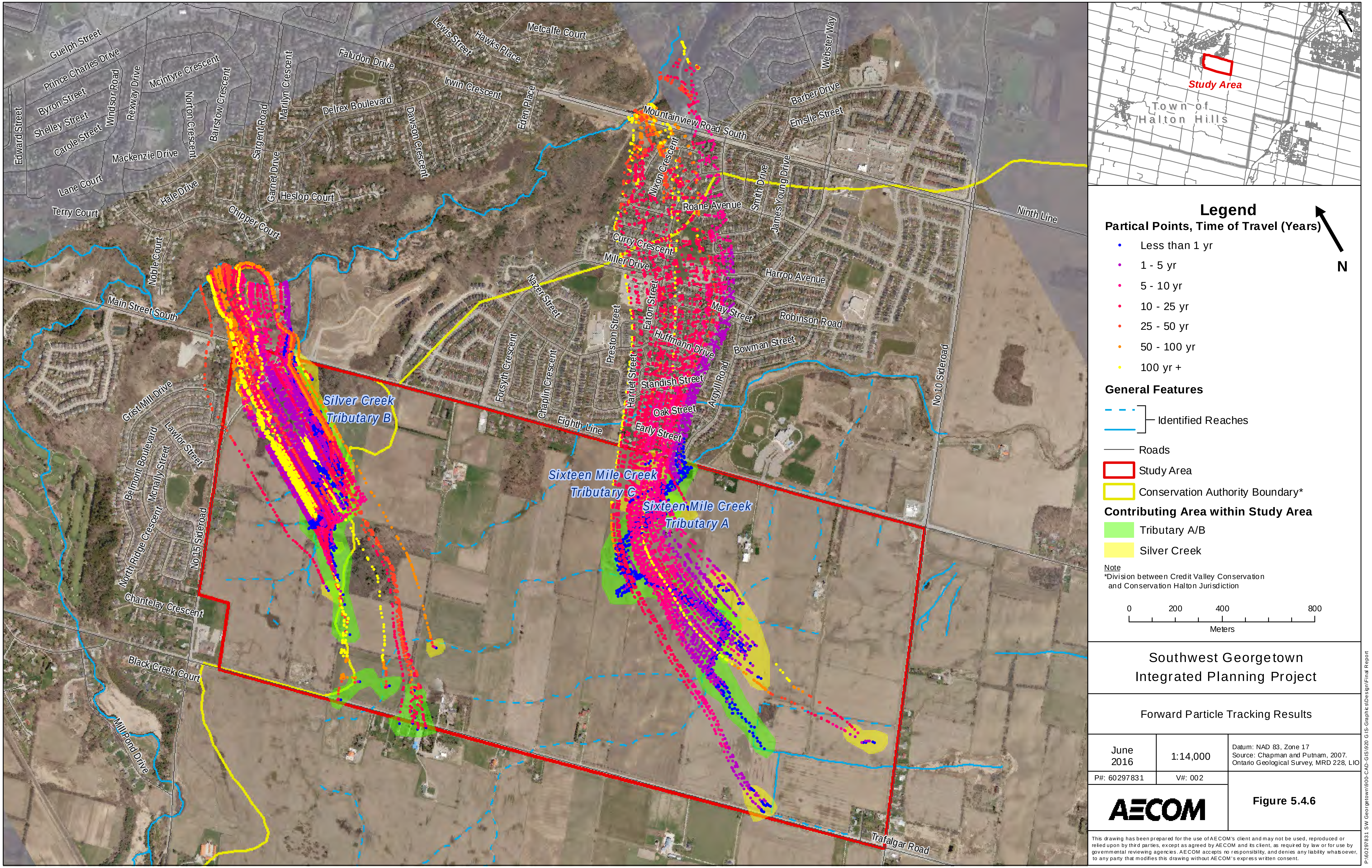

Guelph Street
Prince Charles Drive
Byron Street
Shelley Street
Carole Street
Edward Street
Windsor Road
Rexway Drive
Mcintyre Crescent
Norton Crescent
Bairstow Crescent
Mackenzie Drive
Lane Court
Terry Court
Hale Drive
Chipper Court
Sargent Road
Garnet Drive
Marilyn Crescent
Heslop Court
Faludon Drive
Delrex Boulevard
Dawson Crescent
Lewis Street
Hawks Place
Metcalfe Court
Irwin Crescent
Eden Place
Mountainview Road South
Webster Way
Barber Drive
Emslie Street
Nixon Crescent
Roane Avenue
Smith Drive
James Young Drive
Curry Crescent
Miller Drive
Nazer Street
Harrop Avenue
Eaton Street
May Street
Robinson Road
Huffmann Drive
Bowman Street
Preston Street
Standish Street
Harriet Street
Argyll Road
Oak Street
Early Street
Forsyth Crescent
Chaplin Crescent
Eighth Line
Ninth Line
No 10 Sideroad
Noble Court
Main Street South
Grist Mill Drive
Laylor Street
Belmont Boulevard
Mcnally Street
North Ridge Crescent
No 15 Sideroad
Chantelay Crescent
Black Creek Court
Mill Pond Drive
Trafalgar Road
Silver Creek Tributary B
Sixteen Mile Creek Tributary C
Sixteen Mile Creek Tributary A
Study Area
Town of Halton Hills
Legend
Partical Points, Time of Travel (Years)
Less than 1 yr
1 - 5 yr
5 - 10 yr
10 - 25 yr
25 - 50 yr
50 - 100 yr
100 yr +
General Features
Identified Reaches
Roads
Study Area
Conservation Authority Boundary*
Contributing Area within Study Area
Tributary A/B
Silver Creek
Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction
0 200 400 800
Meters
N
Southwest Georgetown Integrated Planning Project
Forward Particle Tracking Results
June 2016
1:14,000
Datum: NAD 83, Zone 17
Source: Chapman and Putnam, 2007. Ontario Geological Survey, MRD 228, LIO
P#: 60297831
V#: 002
AECOM
Figure 5.4.6
This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.
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The volume of groundwater flowing off-site through the overburden was also evaluated to decrease by 257 m^3/d under post-development conditions. The change in down gradient groundwater water table elevation was evaluated to determine if this reduction represents a potential impact to the Cedarvale municipal wells. The water table elevation at the location of these wells was simulated to decline approximately 2.5 cm. This value is close to the numerical error associated with the model, indicating virtually no simulated effect to the municipal wells.

5.5 Analysis of Water Quality Impacts

Urban land uses generate residual and waste material from a range of individual and group activities. Each type of land use has unique characteristics that result in the generation of pollutants and runoff volume. Density or intensity of the land use and percent imperviousness also play a part.

Pollution Sources in Urban Areas

- Vehicular traffic accounts for much of the build-up of contaminants on road surfaces. Wear from tires, brake and clutch linings, engine oil and lubricant drippings, combustion products and corrosion, all account for build up of sediment particles, metals, and oils and grease. Wear on road surfaces also provides sediment and petroleum derivatives from asphalt.
- Lawn and garden maintenance in all types of land uses including residential, industrial, institutional, parks, and road and utility right-of-way accounts for additions of organic material from grass clippings, garden litter, and fallen leaves. Fertilizers, herbicides, pesticides can all contribute to pollutant loads in runoff.
- Air pollution fallout of suspended solids accounts for build-up of sediments contaminated from traffic, industrial sources, and wind erosion of soils.
- Municipal maintenance activities including road repair and general maintenance (road surface treatment, salting, and dust control).
- Industrial and commercial activities can lead to contamination of runoff from loading and unloading areas, raw material and by-product storage, vehicle maintenance, and spills of petroleum products.
- Illegal connections of sanitary services to storm sewers can cause contamination with organic wastes, nutrients, and bacteria.
- Illegal disposal of household hazardous wastes can introduce waste oil and a multitude of toxic materials to storm sewers.
- Transportation spills from accidents can occur on heavily traveled arterial streets.
- Construction activity can introduce heavy loads of sediment from direct runoff, construction vehicles and wind-eroded sediment.
- Pet feces and litter introduce organic contamination, nutrients and bacteria.
- Runoff from residential driveways and parking areas can contain driveway sealants, oil, salt, and car care products.
- Urban areas usually have an increased impervious surface area which leads to heat island effect. Stormwater runoff from urban areas will have a higher temperature which will impact the overall temperature of water courses.

Pollutant Impacts

The receiving water quality impacts of municipal discharges vary depending upon the quality and quantity of the wastewater and the assimilative capacity of the receiving waterbody. Control measures implemented in newer developments mitigate or prevent many of these impacts. Potential water quality concerns resulting from stormwater include:

- Bacteria from fecal material in pet and wildlife litter and sanitary wastes from illegal connections causing increased levels E.coli in water courses.
- Nutrient enrichment, from nitrogen and phosphorous compounds, which can lead to nuisance growths of algae in the receiving waterbody;
- Deposits of contaminated sediments, which can lead to degradation of benthic (bottom-dwelling) organisms and restrictions on dredging;
- Toxicity from ammonia, metals, and organic compounds present in the runoff and overflows and potential human endocrine disruption from pesticides;
- Oxygen depletion potential (‘oxygen demand’ or BOD) of the wastewater from biodegradable organic material, which can lead to oxygen deprivation of the organisms in the receiving waterbody;
- Temperature changes due to an influx of water warmed by the ‘heat island’ effect of roads and buildings;
- Aesthetic impacts from floatable matter and sediments (*i.e.,* litter, grass clippings, sanitary items, soil erosion, etc.); and
- Contamination of groundwater with soluble organic chemicals, metals, nitrates and salt.

5.5.1 Water Quality Background

Section 4.10 describes the water quality in the watersheds with existing land uses. Water samples were taken at various locations shown in **Figure 4.10.1**. The results are summarized. A detailed baseline (and post-construction) water quality monitoring is recommended in **Section 7.5.6.3** to provide a better picture of the background conditions.

Generally, water quality results so far shows some metals and total phosphorus exceeding the Provincial Water Quality Objectives (PWQO). Nitrates exceed guideline levels being considered by Environment Canada for protection of aquatic life. A Canadian water quality guideline for the protection of aquatic life was adopted in 2003 for nitrates. TSS exceed guidelines set by the Canadian Council of Ministries of the Environment. Ontario Government policies outlined below give some guidance on the approach to be followed concerning water quality and developments.

- *The Ministry of Environment Water Management Policies, Guidelines and Provincial Water Quality Objectives* (MOECC, 2003) outlines the approach to be taken regarding water quality. For surface water quality, the goal is to ensure that the surface waters of the Province are of a quality which is satisfactory for aquatic life and recreation. The PWQO are a set of narrative and numerical criteria designed for the protection of aquatic life and recreation in and on the water. In assessing water quality conditions, a comparison can be made between the water quality and the PWQO. One of the following two cases would apply:

  - Policy 1: In areas which have water quality better than the PWQO, water quality shall be maintained at or above the objective.
  - Policy 2: In areas where water quality presently does not meet the PWQO, water quality shall not be further degraded and all practical measures shall be undertaken to upgrade the water quality to the objectives.

- *Stormwater Management Practices Planning and Design Manual* (MOECC, 2003). This document has guided SWM practice and design since an earlier version was released in 1994. The key provision of sizing SWM systems based on achieving levels of protection for protection of aquatic life based on sedimentation of total suspended solids (TSS) is being retained in the updated versions. Once a level of protection target is established for a watershed, the design requirements are clear, with choices provided to select alternative methods for meeting the objectives. The three levels are:

- Enhanced, with 80% long-term suspended solids (SS) removal;
- Normal, with 70% long-term SS removal; and
- Basic, with 60% long-term SS removal.

Although TSS is considered a pollutant, in that excessive amounts can affect critical life stage activities of resident fish, there is no PWQO for this parameter. However, many of the contaminants found in urban runoff, such as heavy metals, petroleum hydrocarbons, PAHs (polynuclear aromatic hydrocarbons) are associated with TSS. This is the basis for using TSS as a surrogate parameter for control in the Ministry of the Environment (MOECC) SWM manual. Given technological advancements in the stormwater management industry, it is recommended to consider a variety of LID approaches to achieve or possibly exceed the targets identified in the 2003 MOECC Manual. For example, some recent studies (TRIECA 2014: Water Sensitive Urban Design Performance Monitoring) have a demonstrated achievement of removal efficiencies in excess of 80% when lot level evapotranspiration and infiltration and re-use measures are implemented.

Other contaminants in urban drainage will be included in the management plan are as follows:

- Nitrate: This soluble nutrient is not removed with TSS. It is anticipated that the existing amounts observed are likely from discharges from septic tank systems to the groundwater that appear in baseflow, or from fertilizer applications running off agricultural lands. It is expected that with urbanization and the installation of sanitary services, septic tank systems will be removed. As the land use changes to urban, the agricultural fertilizer applications will stop. Best Management Practices (BMP) for reducing fertilizer use in the urban area will be recommended as part of the management plan; and
- Chloride: These are present as part of the background from the mineral soils, the underlying bedrock and from the application of road salt. With urbanization and the addition of more roads and parking lots, additional applications can be expected. Chloride is soluble and is not removed by SWM ponds.

Environment Canada declared road salt toxic by adding road salt to the Priority Substances List of the *Canadian Environmental Protection Act* (1999). Road salts are used in Canada as de-icing and anti-icing chemicals for winter road maintenance, with some use as summer dust suppressants.

The Canadian Council of Ministers of the Environment developed water quality guidelines for the protection of aquatic life. There are two guidelines for freshwater chloride concentration. 640 mg/l is the short term (acute) concentration and the 120 mg/l is the long term (chronic) concentration.

5.5.2 Water Quality Loading Model

A spreadsheet model was developed for this study to estimate loads of pollutants derived from runoff in Southwest Georgetown, originally applied to the City of Kingston (TSH *et al.,* 2003). The model takes land uses and estimates runoff co-efficients for each land use which, along with an estimate of annual rainfall, gives a runoff volume for each area. An event mean concentration (EMC) for each land use is applied to the runoff to obtain an annual loading rate for two parameters, Total Suspended Solids (TSS) and Total Phosphorus (TP). The significance of these parameters is discussed below:

- TSS is used as the basis for SWM facilities design in the *Storm Water Management Planning and Design Manual*, with the Levels of Protection for fisheries made equivalent to specific performance for long-term TSS removal; and
- Phosphorus is an ideal parameter to consider cumulative impacts of development on the watershed, both because of its impact on stimulating excessive algal growth causing reduced dissolved oxygen and impaired aesthetics.

The loadings can then be reduced by control measures and a revised overall pollutant load calculated for all the management areas. The quantitative review of the loadings derived from changes in land use and implementation of control measures can provide input to planning decisions on development and control measures.

Other substances of potential concern including nitrate, chloride and metals (e.g. Cu, AL, Zn and Fe) were assessed qualitatively. Appropriate mitigation measures are discussed in **Section 6.3.5.4**.

5.5.3 Land Use

Land uses for each management area were derived from Geographical Information System (GIS) data provided by the Town of Halton Hills. The existing land use designations are provided in **Table 5.5.1**, and future land use in **Table 5.5.2**. The subwatersheds, or unit areas are illustrated in **Figure 4.6.1**.

Table 5.5.1 Existing Land Use

Unit Name	Area (Ha) by Surface Cover Type			
	Wetland	Agriculture	Industrial/Commercial	Total
A-1	0.05	12.9	0.18	13.14
A-2	0.00	93.7	1.15	94.83
A-3a	0.00	27.3	0.15	27.49
A-3b	0.00	24.1	0.05	24.14
A-4	0.00	24.1	1.97	26.07
A-4a	2.56	147.0	3.19	152.72
A-4b	0.00	30.3	1.20	31.54
A-5	0.28	106.3	7.76	114.34
A-6	0.16	35.0	0.88	36.05
B-1	0.00	40.7	1.65	42.31
B-2	0.00	43.4	1.58	44.99
C-1	0.00	77.3	2.64	79.93
D-1	0.00	5.5	0.11	5.58
D-2	0.00	4.9	0.10	4.99
D-3	0.00	18.4	0.58	18.97
E-1	0.00	13.0	0.52	13.53

Table 5.5.2 Future Land Use

Land Use	A-1	A-2	A-3a	A-3b	A-4	A-4a	A-4b	A-5	A-6	B-1	B-2	C-1	D-1	D-2	D-3	E-1
Commercial	2.1	0.5	1.5	1.1	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.2	0.0	0.0	0.0	0.4
Main St. Commercial	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0
ROW	0.1	0.9	0.7	0.9	7.9	0.0	0.1	5.1	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Institutional	0.0	2.8	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	3.7	4.3	2.1	0.0	2.9	3.5
Mixed Use	0.6	4.6	2.7	0.4	0.3	0.0	2.3	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
High Density Residential	0.5	10.7	3.6	3.6	3.4	0.0	4.2	1.3	0.5	0.0	3.0	3.2	0.3	1.1	1.6	1.9
Medium Density Residential	2.7	22.7	8.2	11.1	10.8	0.0	13.9	3.1	1.7	16.8	30.0	42.3	2.2	3.8	11.3	5.5
Low Density Residential	5.3	4.4	4.0	2.0	0.2	0.0	0.1	2.0	1.9	21.7	2.8	16.7	0.0	0.0	0.0	0.0
NHS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0
Linkages	0.0	2.9	0.0	0.0	0.1	0.0	7.7	5.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open Space	0.0	9.7	3.7	0.2	0.1	0.0	1.5	0.6	0.0	0.8	1.3	3.1	0.0	0.0	1.8	0.7
Floodline Concept	0.8	6.7	3.0	2.2	3.4	0.0	1.9	1.8	0.3	2.9	3.1	3.0	0.9	0.1	1.4	1.4
Outside of Study Area	0.0	28.0	0.0	0.0	0.0	152.6	0.0	94.6	28.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**13.1**	**94.8**	**27.5**	**24.1**	**26.1**	**152.7**	**31.5**	**114.3**	**36.0**	**42.3**	**45.0**	**79.9**	**5.6**	**5.0**	**19.0**	**13.5**

Note: Sub Catchments A-2, A-4a, A-5 & A-6 are either partially or completely outside of the study area
28.3 ha of land cover were dropped from catchment A2 as this area is outside of study area.

5.5.4 Runoff and Water Quality

The estimates of runoff coefficients and the EMCs for TSS and TP for each land use are presented in **Table 5.5.3**. TSS values range from 10 mg/L to 150 mg/L, with TP levels two orders of magnitude less ranging from 0.12 to 0.36 mg/L. The total annual rainfall for Southwest Georgetown used in the model is 877mm based on Climate Normals from the Environment Canada Gauge at WWTP

Table 5.5.3 Pollutant Loadings

Land Use Classification	% Impervious	Runoff Coefficient	Pervious Area %	Runoff Coefficient	Combined Runoff Coefficient	Event Mean Concentration	
						TSS (mg/L)	Total Phosphorus (mg/L)
Commercial	90.00	0.95	10.00	0.25	0.880	91.00	0.36
Main St. Commercial	83.00	0.95	10.00	0.25	0.880	91.00	0.36
ROW	80.00	0.95	20.00	0.30	0.820	91.00	0.36
Institutional	75.00	0.95	25.00	0.30	0.788	70.00	0.30
Mixed Use	87.00	0.95	13.00	0.30	0.853	70.00	0.30
High Density Residential	80.00	0.95	20.00	0.30	0.820	91.00	0.36
Medium Density Residential	65.00	0.95	35.00	0.30	0.723	91.00	0.36
Low Density Residential	60.00	0.95	40.00	0.30	0.690	91.00	0.36

NHS	4.00	0.95	96.00	0.15	0.182	70.00	0.20
Linkages	3.00	0.95	97.00	0.15	0.174	70.00	0.20
Open Space	15.00	0.95	85.00	0.28	0.376	70.00	0.20
Floodline Concept	8.00	0.95	92.00	0.10	0.168	10.00	0.12

Source: http://www.halton.ca/ppw/PlanningRoads/Transp/RoadSalt/default.htm
Rainfall amounts were obtained from Environment Canada Gauge at Georgetown WWTP

5.5.5 Control Measures

Three types of control measures can be applied in the model:

- A source control BMP such as street sweeping, catch basin cleaning or fertilizer use reductions. This is applied as a reduction in the EMC on a land use basis;
- Infiltration measures, such as ex-filtration systems in the conveyance system, bioinfiltration or end-of-pipe measures. This is applied as a reduction in runoff flow volume with an equivalent reduction in loading; and
- End-of-pipe water quality control measures, such as wet ponds, dry ponds, wetlands, or oil-grit separators (OGS). These are applied as a reduction in loading related to the efficiency of the measure for that parameter. Where multiple facilities service a land use type in a management area, an area-weighted efficiency is calculated.

All measures can be applied to only a portion of the land use area. In this study, only end-of-pipe measures have been evaluated in the scenarios described below. Other control measures can be assessed in further applications of the model.

Efficiencies of the end-of-pipe measures are given in **Table 5.5.4**.

Table 5.5.4 Control Measure Efficiencies

LEVEL	TOTAL SUSPENDED SOLID REMOVAL %	TOTAL PHOSPHORUS REMOVAL %
Enhanced Treatment	80	65
Normal Treatment	70	57
Basic Treatment	60	50
Dry Pond	40	20
OGS	60	30

Source: Toronto Wet Weather Flow Management Master Plan (July, 2003)

5.5.6 Loading Scenarios

The loading scenarios modelled consist of “Base Scenario - Existing Land Uses Development” and “Future Development Uncontrolled”.

This shows the change in land use is affected by increasing runoff volumes, TSS and TP loadings indicated in **Table 5.5.5.** Note that runoff volume increases from about 31% of rainfall to an average of 60% as a result of increased imperviousness of roadways, parking lots, and roof surfaces. The TSS load and TP loads increase by 51% and 143% respectively, due to the increase in runoff and the change in concentration of the runoff.

Chloride loading to receiving water may increase as a result of urban development and salt application. Chloride concentrations commonly increase with increasing salt application, and decreasing streamflow as less dilution is provided at low flows. Chloride loading will be higher during the de-icing season, but the non-de-icing season will also have loading from salt infiltrating into the shallow groundwater system thereby serving as a reservoir of salt which slowly discharges into streams as baseflow.

Nitrate loading may be quantified through the development of a nitrate budget accounting for removal in upper soil layers and input from other sources including nitrogen input from the atmosphere, as well as nitrate in groundwater. Increased urban development will also alter the nitrogen cycle and biogeochemistry at the subwatershed scale. Given the multiple parameters affecting the nitrate budget, loading may increase or decrease as a result of urban development in an otherwise agricultural setting.

Loading of metals (e.g. Cu, AL, Zn and Fe) to the streams may increase as a result of urban development. This potential increase will result in elevated water column and sediment concentrations. The magnitude of the increase depends on the specific land use and activities. In an urban setting metals discharged to surface water are mainly attributed to non-point sources.

Table 5.5.5 Base Scenario - Existing Conditions

Management Area	A-1	A-2	A-3a	A-3b	A-4	A-4a	A-4b	A-5	A-6	B-1	B-2	C-1	D-1	D-2	D-3	E-1
Total Runoff Volume 1000 m^3	34.8	250.9	71.9	62.8	76.6	406.1	87.2	331.5	97.2	117.2	123.8	219.2	15.0	13.4	51.8	37.5
Runoff percent of Precip	30.2	30.2	29.8	29.6	33.5	30.3	31.5	33.0	30.7	31.6	31.4	31.3	30.6	30.6	31.1	31.6
Runoff as mm	265	265	262	260	294	266	277	290	270	277	275	274	268	268	273	277
TSS Load - tonnes/yr	3.4	24.8	7.2	6.3	7.2	39.7	8.5	31.4	9.5	11.4	12.0	21.4	1.5	1.3	5.1	3.6
TP Load - tonnes/yr	0.01	0.05	0.01	0.01	0.02	0.08	0.02	0.07	0.02	0.02	0.03	0.05	0.00	0.00	0.01	0.01

The following scenarios are provided for comparison purposes. Loadings and runoff volume are estimated in **Table 5.5.6**.

Table 5.5.6 Future Scenario - Development with Uncontrolled Stormwater

Management Area	A-1	A-2	A-3a	A-3b	A-4	A-4a	A-4b	A-5	A-6	B-1	B-2	C-1	D-1	D-2	D-3	E-1
Total Runoff Volume 1000 m^3	83	433	156	149	158	406	156	365	121	245	271	473	32	32	111	81
Runoff percent of Precip	72	52	65	70	69	30	56	36	38	66	69	68	66	73	67	68
% Increase over Base	139	73	117	137	107	0	79	10	25	109	119	116	116	139	115	117
Runoff as mm over each area	632	457	568	616	607	266	494	319	336	580	603	592	580	641	587	600
TSS Load -	7.4	38.2	13.2	12.8	13.9	39.7	13.3	33.9	11.5	21.9	23.7	41.7	2.5	2.9	9.4	6.7

Management Area	A-1	A-2	A-3a	A-3b	A-4	A-4a	A-4b	A-5	A-6	B-1	B-2	C-1	D-1	D-2	D-3	E-1
tonnes/yr																
% Increase over Base	114	54	84	104	93	0	57	8	21	93	97	95	72	120	87	83
TP Load - tonnes/yr	0.03	0.13	0.05	0.05	0.06	0.08	0.05	0.09	0.03	0.09	0.09	0.17	0.01	0.01	0.04	0.03
314	316	163	258	308	232	0	183	25	58	252	264	261	241	317	248	242

5.6 Stream Morphology

A fluvial geomorphic assessment of the watercourses within the study area was performed to assess any potential impacts or effects from proposed development on the stream systems within the study area. The drainage network within the study area includes predominantly headwater channels from both the Silver Creek and the East Branch of Sixteen Mile Creek subwatersheds. The assessment included calculating drainage densities, conducting Rapid Stream Assessments (RGA), reach delineation and characterization, and calculating meander belt width for each reach. This information was then used to identify sections of stream that were representative of conditions within the study area and derive erosion thresholds for the reaches. Based on the integration of all of this information, a constraint matrix was derived. The enhancement potential for each reach was also identified.

5.6.1 Headwater Function/Evaluation

Stream Classification

Each of the tributary channels that form part of the drainage network in the catchments was classified using rapid stream assessments. The aim of the assessments is to identify the local geomorphological form and function of the watercourse and evaluate the current conditions. As reported in **Section 4.8.4** in the Characterization Report, these assessments provide a relative indication of stream health and stability, in addition to identifying the active geomorphic processes affecting each channel. This, in turn, offers insight into the sensitivity of a channel to changes in land use and flow regime.

To facilitate the recording of information, and assessment of channel conditions along each tributary and each branch, reaches were defined. Reaches can be defined as lengths of channel that display similar physical characteristics and have a setting that remains nearly constant along their length. Thus, in a reach, the controlling and modifying influences on the channel are similar, and are reflected in similar geomorphological form, function and processes within the reach. Stream reaches were delineated by key factors that include hydrology, channel gradient, geology, valley setting, sinuosity, and riparian vegetation. Refer to **Section 4.8.3** in the Characterization Report for additional information regarding stream reaches. Reach sensitivities of each system are addressed further in the threshold analysis discussion (**Section 5.6.2**).

An Overall Geomorphology Classification has been assigned to reaches within the Southwest Georgetown study area (**Appendix I**). High Geomorphic Classifications were given to reaches that comprise a defined channel with well-developed channel morphology and/or well-defined valley. These reaches possess both geomorphological form and function and are high-quality streams that could not be re-located and replicated in a post-development scenario. Medium Geomorphic Reaches have a defined channel and may or may not have well-defined morphology, but contribute to maintain geomorphic function and have the potential to be rehabilitated. Low Geomorphic Reaches are first order streams that lack a defined bed and banks but perform a geomorphic function through the conveyance of flow and sediment. These were based on the data gathered to characterize the Headwater Drainage Features (**Appendix I**), which were qualified through stream walks and RGA observations.

Reaches within the sub-watershed present good opportunities for stream enhancement as some reaches are heavily modified, and degraded. However, through completing this assessment process, several reaches were easily identified as being more sensitive and providing more physical functions to the overall channel system. The ultimate result was a categorization of each reach into an overall geomorphic rating, which can then be adapted and applied to the management strategy with respect to the amount of protection required.

Drainage Densities

The Southwest Georgetown Subwatershed is predominantly headwater channels from both the Silver Creek and the East Branch of Sixteen Mile Creek Subwatersheds. These headwater areas include numerous low-order channels which can easily be altered by land use changes such as urbanization. Stream order classification for the mapped study area watercourses was completed and revealed that 60% of the drainage features are first order channels and 26% are second order channels. This finding confirms that the study is a headwater region of the Silver Creek and Sixteen Mile Creek watersheds. The calculation of drainage densities is useful in evaluating basin functions and provides an opportunity to assess the cumulative effects of land use change on low-order tributaries. Drainage densities were calculated for the sub-catchments within the study area (**Table 5.6.1**).

Drainage density, defined as the total length of all channels in the drainage basin divided by the total area of the drainage basin, provides information on how well or how poorly a watershed is drained by the stream channels. Controlling factors of drainage density can be grouped as direct and indirect. Climate and geology provide a direct control while indirect factors include (but are not limited to) basin area, shape and relief.

As seen in **Table 5.6.1**, drainage densities for Tributaries A and B are larger than the drainage density for Tributary C (refer to **Figure 4.6.1**). The drainage density of Tributaries A and B are generally larger than those reported elsewhere within the Credit River watershed and Greater Toronto Area but lower than those in the Huttonville Creek and Springbrook watershed which are situated in proximity to Georgetown (**Table 5.6.2**).

Table 5.6.1 Drainage Densities for Southwest Georgetown Subwatershed

Watercourse	Drainage Area (km^2)	Stream Length (km)	Drainage Density (km/km^2)
Sixteen Mile Creek Watershed	3.40	8.93	2.63
Tributary A	2.17	7.64	3.52
Tributary C	0.80	0.97	1.21
Other Tributaries	0.43	0.61	1.42
Silver Creek Tributary B	0.87	2.66	3.06

Table 5.6.2 Southwest Georgetown Subwatershed Drainage Density Comparison

Watershed	Drainage Density (km/km^2)
Sixteen Mile Creek	2.63
Tributary A	3.52
Tributary C	1.21
Silver Creek Tributary B	3.06
Southwest Georgetown Study area	2.72
Data Reported in Other Studies	

Watershed	Drainage Density (km/km^2)
Credit River: Subwatershed 19 (Monora and Mill Creek- headwaters) (CVC, 2009)	1.34
Credit River: Subwatershed 19 (Monora and Mill Creek- headwaters) including all zero order features (CVC, 2009)	1.63
Credit River: Subwatershed 17 (Shaw's Creek – many headwater channels) (CVC, 2006)	1.84
Credit River: Subwatersehd 16 (Caledon Creek) (CVC, 1997)	1.33
Credit River: Subwatershed 13 (East Credit)	1.92
Credit River: Subwatershed 7 Huttonville Creek (TSH *et al.*., 2004)	4.17
Credit River: Subwatershed 8a Springbrook Creek (TSH *et al.*., 2004)	4.23
Carruther's Creek (TRCA, 2000a)	2.08
Duffins Creek (TRCA, 2000b)	1.5

Results from this study have revealed that several branches and reaches within the drainage network are undefined or poorly defined and were characterized as conveying "no flow". These features may become extensions of the drainage network when the infiltration capacity of the soils is exceeded. Thus, although the nearly 50% of the drainage network that was classified as "undefined" or "poorly defined" and which was typically associated with a "no flow" or "ephemeral" flow regime may appear to be insignificant, they become relevant components of the drainage network during those precipitation events which produce abundant runoff).

The relatively high drainage density, in comparison to other Credit Valley watersheds, suggests that the study area is well drained by surface channels due to the underlying geology. This indicates that water is drained relatively quickly from the landscape and routed to the receiving channel. In addition to the drainage network, review of the topography revealed shallow depressions in the fields, which contained standing water during rainfall events. Further, although swales and defined channels are assumed to be the only conduits of water to a drainage network, field observations confirmed that there are multiple unmapped areas of surface water conveyance to the reaches (i.e., overland flow). Human alterations, such as the creation of tile drains, can also influence the drainage density rate as drains are thought to reduce the length of time over which subsurface inputs to the stream occurs. Tile drains identified during fieldwork discharge directly into the heavily modified and alluvial reaches, as well as the roadside ditches, therefore promoting faster drainage by conveying water away from fields to these reaches. Tile drains were also identified in undefined channels where standing water was present after a rainfall event and then routed to defined channels.

To develop the drainage density targets for the SWG subwatershed the following steps were carried out. Drainage density targets were calculated for Tributary A and C combined and separately for Tributary B within the SWG study area:

- Sub-catchments were defined and the sub-drainage area (km^2) was calculated.
- The total stream length was also determined for each sub-catchment based on the OBM's and defined channels identified in the field.
- The drainage area and total stream length were used to calculate drainage density, and for each sub-catchment an average and standard deviation was calculated.
- A target drainage density for each sub-catchment was calculated by subtracting the drainage density by 1 standard deviation. The standard deviation is used to prevent the drainage density from being reduced to values outside of the observed natural distribution of drainage densities within the particular sub-catchment.
- If the target density resulted in a value less than the minimum allowed (average regional drainage density (1.96 km/km^2 for Tributaries A and C; 3.05 km/km^2 for Tributary B) minus 1 standard deviation (1.18 for Tributaries A and C; 0.04 for Tributary B) then the target drainage density was defaulted to the minimum

allowed (average drainage density minus 1 standard deviation (0.78 km/km^2 for Tributaries A and C; 3.01km/km^2 for Tributary B)).

The Target Drainage Densities were compared to the proposed Management Strategy drainage densities which are based on the medium and high constraint streams as determined in the proposed management strategy (blue and red streams), as discussed in **Section 5.9** and illustrated in **Figure 5.9.1**. Those sub-catchments that meet or exceeded the minimum density target were identified and their “surplus stream length” was calculated. If the sub-catchment did not met the minimum density target, than a ‘deficit stream length’ was calculated for the sub-catchment. This was determined by subtracting the stream length required to meet the density target by the total stream length based on the proposed management strategy. Tributaries A and C exceed the required drainage density. The overall surplus of stream length for Tributaries A and C combined is 3.33 km km, but Tributary B short by 0.02 km.

Meander Belt Widths

The meander belt is defined as the area that a meandering watercourse currently occupies or is expected to occupy in the future. This includes natural planform evolution, and both cross-valley and downvalley migration. Protecting the meander belt area from encroachment within an urban development context serves the dual purposes of enabling continuity of natural channel processes and of protecting public and private property and structures from erosion. Meander belt widths were estimated for reaches that exhibit a defined channel and contain perennial or intermittent flows with downstream connectivity and are determined for unconfined systems within the study area. An unconfined system is where the watercourse is not located within a valley corridor with discernable slopes, but relatively flat to gently rolling plains and is not confined by valley walls (MNR, 2002).

The TRCA empirical relation was considered applicable to the Tributary A main branch, (Reaches AM-1 to AM-6) with the exception of Reach AM-3 which is confined and lower reaches of branch A4 only (Reaches A4-1 and A4- 2). Refer to **Section 4.8.7.1** in the Characterization Report for further details on determination of the meander belt width. Results of the meander belt analyses are presented in **Table 5.6.3**. These meander belts may be over-estimates of the actual meander belt and thus should be reviewed during detailed land use planning.

Table 5.6.3 Meander Belt Widths for Reaches East of Southwest Georgetown

Reach ID	Meander Belt Width (m)
AM-7	29
AM-6	42
AM-5	60
AM-4	65
AM-2	76
AM-1	71
A4-2	23
A4-1	36
A5-1	21

Meander belt width assessment was not considered applicable to the following reaches for the reasons stated below:

- **Branch A2 and upper reaches of A4 (A4-4 and A4-3)** since there is no defined channel along these reaches and therefore no channel dimensions on which to base even an empirical meander belt width.

Channel alterations to these reaches, such as adjustments to channel geometry or ultimate flow, which may occur during the design stage will require the meander belt width to be calculated.

- **Tributary B** – Slope stability analysis is the appropriate tool to define erosion risk for this tributary in a defined, deep valley
- **Tributary C - Reaches C-6, C-4 and C-2** are short localized sections in woodlots and a grassy lawn areas alternating with undefined/poorly defined reaches that are currently cultivated. There is therefore only ephemeral through flow along the length of this tributary. The use of meander belt width (a measure of erosion risk) is therefore not considered applicable in this case. If channel geometry or ultimate flow is altered within these reaches during the design stage then a meander belt width will need to be calculated.

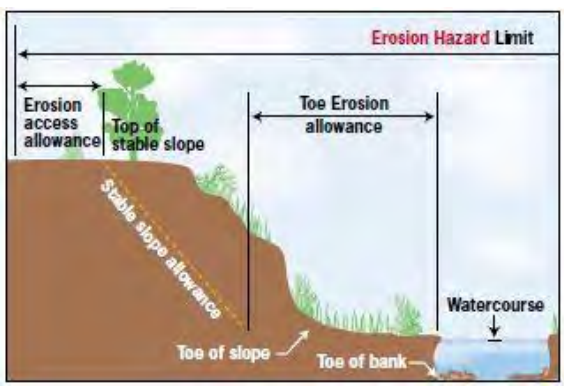
Confined Systems

Reach AM3 and Tributary B are both located within defined valleys and are confined by the valley walls. The empirical approach adopted for other reaches is not appropriate for confined reaches, for which slope stability must also be taken into account. Given this, the most appropriate method of estimating the erosion hazard width is based on the Credit Valley Conservation Slope Stability Definition and Determination Guideline (2014) and the Ontario Ministry of Natural Resources (MNR) Technical Guide, River and Stream Systems: Erosion Hazard Limits (2002).

Confined systems include three (3) components (**Figure 5.6.1**):

1. A toe erosion allowance, which is based on material at channel bank or bank full, as well as bank condition;
2. Stable slope allowance which is recommended as a 3 (horizontal) to 1 (vertical) slope; and
3. The erosion hazard allowance.

Figure 5.6.1 Criteria of erosion hazard limit within a confined valley system when toe of valley slope is located less than 15 m from watercourse (MNR, 2002).



Reach AM3 along Tributary A meanders through a defined valley within which the valley walls are between approximately 2 m and 3.5 m high. The channel is therefore considered to be confined, with alternate valley wall contact on the left and right bank within the reach. **Section 4.8.7.2** in the Characterization Report describes how the erosion hazard width is calculated for this reach using the CVC Guidelines (2014) and the MNR Technical Guide (2002).

Based on Figure 4a of the CVC's Guidelines (2014), a value of 8m has been applied to the Toe Erosion Allowance at the toe of the slope and a value of 6m has been applied to the erosion hazard allowance for Reach AM3. The location of the slope toe from the watercourse varies throughout the reach with the channel meandering from one side of the valley to the other. The described approach is therefore conservative in applying a constant toe erosion allowance. The width of the valley also varies along the reach. Where the field measurements were taken, the valley floor was approximately 40 m wide, giving a total erosion hazard width across the stream corridor of 100.91 m. Tributary B flows through a relatively narrow and deep (up to 25 m high) valley. **Section 4.8.7.3** in the Characterization Report describes how the erosion hazard width is calculated for this reach. The erosion hazard was defined according to the requirements outlined within the MNR (2002) Technical Guide and the CVC (2014) guidelines. A geotechnical investigation of the study area was completed to inform the erosion hazard assessment. The geotechnical report and analytical results are in **Appendix J** of the Characterization Report. The total setback from top-of-bank typically ranges from 25 to 50 m at Tributary B. It is recommended that the top-of-bank be surveyed in the field in order to allow detailed mapping of the setback on a plan.

5.6.2 Channel Thresholds

Erosion control is an integral component of stormwater management, which aims to ensure that post-development stormwater flows are controlled and released in such a manner that existing channel erosion or aggradation is not exacerbated by land use change. In natural systems creeks regularly see flows that entrain and transport sediment; this is part of the natural process that maintains creek form. However, issues arise when changes in the watershed's hydrology results in an increase in the frequency or period of erosive events, or a cumulative increase in the quantity of flow that can entrain and transport sediment (CVC, 2010).

The collection of detailed geomorphological field data enables the calculation of erosion thresholds representative of specific reaches, which relate to the point at which sustained flows will theoretically start to entrain and transport bed or bank sediments within the reach. Associated critical discharge values are calculated based on channel geometry and bed / bank substrate.

5.6.2.1 Site Selection

Detailed geomorphological field data was collected for three tributaries within the Southwest Georgetown subwatershed in August 2014. The data was processed and analyzed to determine flows that would lead to reach-averaged entrainment of bed and bank material.

Following the Credit Valley Conservation Authority (CVC) Erosion Threshold Guidelines (2010), study sites were chosen based on the following criteria:

- Sensitive to changes in hydrology
- Location of reaches that will not be physically altered as part of the development and can therefore be monitored as part of the post-development monitoring program.
- Limits of measurable downstream impact (i.e. location of confluences, presence of downstream pre-existing or recent development and associated SWM ponds)
- Suitability for erosion threshold analysis – requires a defined channel with identifiable bankfull dimensions in order to gather geomorphic data.

Reaches have already been defined and characterised for the tributaries present within the Southwest Georgetown Subwatershed study area as presented in the Characterization Report (AECOM, 2013) within **Section 4.8.4**. At least one reach for erosion threshold analysis needs to be selected for each of the three tributary systems represented within the study area (see **Figure 5.6.2**). Field reconnaissance was completed downstream of Eighth Line to identify potential erosion threshold sites. It was determined that that both Tributary A and Tributary C did not have a defined channel form downstream of the Eighth Line (mostly marsh) and as such were not suitable for erosion threshold analyses. The following sections draw on this information in order to identify the ideal location for the erosion threshold analysis along Tributaries A, B and C. Reaches A9-1, A10-1 and A11-1 were not included due to the fact that they have limited channel dimension and therefore do not fit the protocols for the erosion threshold analysis. If changes to channel form and/or discharge rates occur within these reaches, then future work will need to be conducted to establish an erosion control.

5.6.2.2 Tributary A (Tributary to East Branch Sixteen Mile Creek)

The main branch of Tributary A is classified as “Heavily Modified” with the exception of Reaches AM2 and AM3, which are classified as “Alluvial”. These reaches have also been modified but have since recovered some degree of natural fluvial geomorphological form and function. RGA survey of these two reaches indicates that they are both “Transitional and Stressed” with similar RGA scores of 0.31 (AM2) and 0.35 (AM3). Both reaches are also identified as “High Constraint” under the proposed Stream Classification, and therefore are proposed to remain on the landscape as they are. Reach AM3 was used as an erosion threshold site, as the slightly more “erosion-sensitive” site of the two.

5.6.2.3 Tributary C (Tributary to East Branch Sixteen Mile Creek)

Tributary C is mostly classified as either “Undefined” or “Poorly Defined” along its length within the study area, apart from short, isolated lengths within woodlots that are more defined. Even in these more defined sections, the channel remains very small with bankfull widths ranging between 0.49 and 0.96m and bankfull depths ranging between 0.06 and 0.12m. Due to the lack of definition, RGA survey was not undertaken for reaches along Tributary C.

In order to identify a more appropriate (and potentially more sensitive) erosion threshold site, representative of potential impacts on Tributary C, geomorphological field reconnaissance occurred in the downstream reach between Eighth Line and the confluence with Tributary A. From aerial photography it is not clear whether this channel has been modified as part of residential development. Field reconnaissance completed by walking along this section of the watercourse identified that this reach was not defined, and therefore Reach C2 was determined to be the most “Defined” reach along Tributary C and was used for the analysis. Tributary C has no “High Constraint” reaches under the proposed Stream Classification, but Reach C-1 is identified as a “Special Medium”

5.6.2.4 East Branch Sixteen Mile Creek (Downstream of Tributaries A and C)

Reach delimitation and field reconnaissance occurred at the section of East Branch of Sixteen Mile Creek immediately downstream of the confluence of Tributaries A and C as an erosion threshold site on this section may have been appropriate to take account of cumulative impacts downstream of Tributaries A and C. Examination of aerial photography noted that residential development was recently constructed between 2004 and 2006 upstream of 10th Side Road along the left bank of the creek, including an associated stormwater management (SWM) pond downstream of Danby Road that appears to outlet to the creek. A potential erosion threshold site was considered upstream of this outlet to avoid representation of channel conditions that may potentially be impacted by the recent development, rather than naturally sensitive to erosion. However, the channel is a low-gradient marshland downstream of the confluence (i.e. no defined channel), which was inappropriate for erosion threshold analysis.

5.6.2.5 Tributary B (Tributary to Silver Creek)

Tributary B differs in character, both in comparison to the tributaries of East Branch Sixteen Mile Creek and along its length, as a result of differences in channel gradient. Both of the downstream reaches, BM-2 and BM-1, are in adjustment and sensitive to changes in flow regime. However, the nature of the channel along these two reaches (significantly aggrading environment, dry channel occupying the whole valley floor and interacting with valley wall in many places, significant LWD control, splitting of the channel into two within BM-1) would likely limit the application of erosion threshold analysis.

Detailed geomorphic data and erosion threshold analysis has already been recently undertaken for the reach downstream of Eighth Line and upstream of the confluence with Silver Creek (Parish Geomorphic, 2011). The location of the previously used detailed field site is upstream of the apparent location an associated SWM pond (based on available aerial photography), and therefore suitable for use as an erosion threshold site to represent Tributary B. RGA survey undertaken as part of the previous study identified the channel as being highly unstable (RGA score of 0.59). Aggradation and widening were noted as the dominant modes of adjustment; however, evidence of planform adjustment and degradation (incision) were also observed (Parish Geomorphic, 2011). This reach (referred to hereafter as BD1) therefore appears potentially even more sensitive than the upstream reaches of Tributary B within the SW Georgetown study area. Although it would have been beneficial to establish a monitoring site within a defined section of either reach BM-2 or BM-1, an erosion threshold site to represent Tributary B was located downstream of Eighth Line near a site as for which previous analyses were undertaken.

The site used for the previous erosion threshold analysis (Parish, 2011) was identified in the field. However, there were numerous leaning trees that posed a health and safety hazard. The erosion threshold site was moved downstream to a safer site that displayed similar geomorphic characteristics to the site used for the previous erosion threshold analysis. The chosen site was still upstream of the SWM pond. As this site is located outside of the study boundaries, no Stream Classification has been applied.

5.6.2.6 Geomorphological Conditions

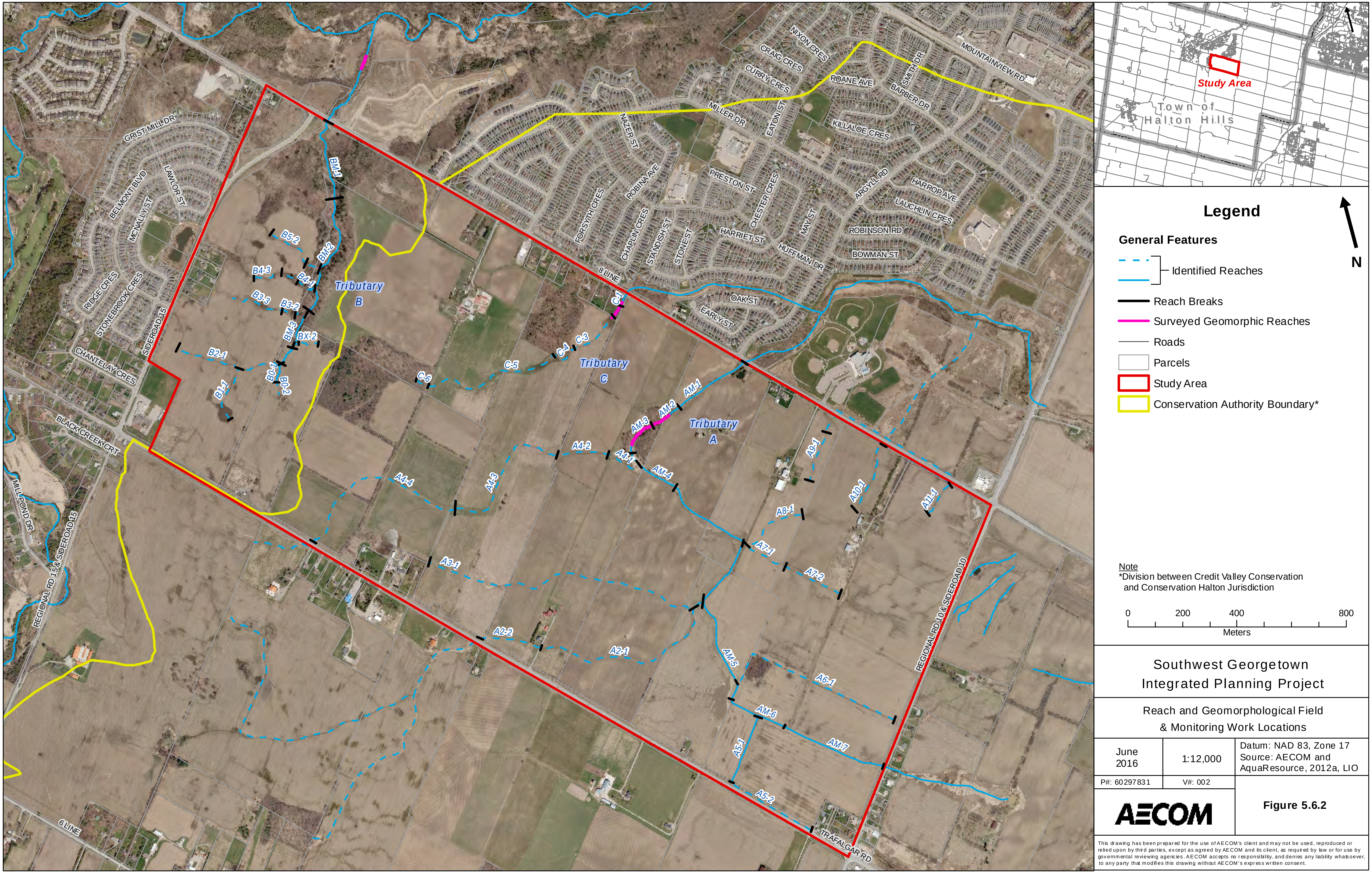
Upon site selection, field data collection took place in August 2014 according to the CVC's guidelines (CVC, 2010). Based on 10 surveyed cross sections at each site reach-averaged morphological measurements were gathered.

Cross sectional attributes were determined based on the results of the topographical survey. AM3 has the largest cross-sectional area of the three reaches and most cross-sections had one steep and one gradually sloping bank. BD1 was narrow and deep (lowest bankfull width:depth ratio) and had steep banks relative to the other reaches. C2 had very shallow sloping banks resulting in the largest bankfull width:depth ratio. Cross section measurements are summarized in **Table 5.6.4**.

Substrate composition was determined using Wolman pebble counts taken at each cross-section within AM3 and BD1 using a step-toe procedure. Due to a lack of unconsolidated sediment, multiple grab samples were taken at each cross-section with C2 and the relative percentage of sand, silt, and clay was estimated. The reach-averaged substrate distribution summary statistics are summarized in **Table 5.6.4.**

5.6.2.7 Hydraulic Assessment

Upon establishing the cross-sectional dimensions and substrate composition at each cross-section, a hydraulic assessment was conducted to determine reach-averaged hydraulic at bankfull conditions. In order to determine the bankfull hydraulics, hydraulic roughness and the energy gradient were established. The energy gradient was determined using the bankfull elevation for each surveyed reach. An estimated Manning's 'n' value was also determined for each site based on field indicators and compared to published tables of Manning's 'n' values (Chow, 1959). The reach-averaged bankfull hydraulics was determined for each reach upon establishing estimates of the bankfull energy gradient and hydraulic roughness. The bankfull hydraulic conditions are summarized in **Table 5.6.4**. As to be expected, AM3 had the largest bankfull discharge. The largest shear stresses were found in BD1 due to its steep gradient and narrow and deep cross-sectional form.



Legend

General Features

- Identified Reaches
- Reach Breaks
- Surveyed Geomorphic Reaches
- Roads
- Parcels
- Study Area
- Conservation Authority Boundary*

N

Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 200 400 800
Meters

Southwest Georgetown Integrated Planning Project

Reach and Geomorphological Field & Monitoring Work Locations

June 2016	1:12,000	Datum: NAD 83, Zone 17 Source: AECOM and AquaResource, 2012a, LIO
P#: 60297831	V#: 002	

AECOM

Figure 5.6.2

P:\60297831 SW Georgetown\900-CAD-GIS\920 GIS-Graphics\Design\Final Report

5.6.2.8 Erosion Threshold

Once the cross-sectional form, substrate composition, and bank materials at each cross-section were established, empirical relations were utilized to determine the flow conditions at which theoretically the substrate and bank materials would be entrained. The three different reaches under consideration are morphologically and hydraulically different from one another. These differences have resulted in the application of three different critical entrainment methodologies.

There are many commonly used empirical formulae for determining when critical hydraulic conditions are met for sediment entrainment. All of the formulae have strengths and limitations stemming from the different data sets that were used to develop the equations. In total, nine (9) empirical formulas were used to calculate an erosion threshold value. From the results, one formula was chosen, based on its appropriateness for the given reach, to represent the erosion threshold value for that reach. The three reaches examined were morphologically quite different. Below is a brief summary of the environmental setting observed at each of the three reaches during the field investigations:

- AM3 was within a mature deciduous forest. The banks are mostly bare and there was LWD observed within the channel. The channel has defined pool-riffle morphology and a sinuous planform. The channel is confined by valley walls on both sides of the channel.
- The riparian vegetation at BD1 was a mixture of grasses, herbaceous plants, and trees (both young and mature deciduous). The banks were well vegetated with grasses and the vegetation extended into the wetted channel. As well, there was LWD observed within the channel. The reach is unconfined, has a sinuous planform, and displays poorly defined pool-riffle morphology.
- C2 is flanked by a maintained lawn along both banks and the grasses extend into the channel. The substrate is exposed surficial cohesive soil. The flow regime is intermittent. There were no flow obstructions within the channel (i.e. no LWD). The channel is unconfined, displays poorly defined pool-riffle morphology, and has low sinuosity.

AM3

The substrate at AM3 is mostly gravel with coarse sand filling the voids in between larger particles and infilling some pools. The Komar (1987) empirical formula was used for this reach due to the substrate conditions along the bed since it was developed for gravel systems. Komar (1987) presented an empirical equation that relates entrainment of a given particle size (D) to a mean critical velocity ($\overline{U}_c$):

$$\overline{U}_c = 57D^{0.46}$$

$\overline{U}_c$ has units of cm/s and D has units of cm for this particular form of the equation. The equation was developed using data from gravel bed rivers and thus it is appropriate for AM3. The median grain size (D_{50}) was used for the entrainment analysis.

BD1

The substrate at BD1 is a comprised of a relatively uniform coarse sand layer overlying a gravel subsurface layer. Neill (1967) empirical formula was developed for coarse substrate conditions and presented an empirical equation that relates entrainment of D to $\overline{U}_c$:

$$\overline{U}_c = \sqrt{\frac{2.5D^{0.8}g\varsigma}{d_b^{-0.2}}}$$

where d_b is bankfull depth, g is the acceleration due to gravity (9.81 m/s^2), and ς is the submerged specific gravity (1.65). $\overline{U}_c$ has units of m/s and D has units of m for this particular form of the equation. The equation was developed using data from uniform sand bed rivers and thus it is appropriate for AM3. The median grain size (D_{50}) was used for the entrainment analysis.

C2

The majority of the empirical critical entrainment formulae are developed for non-cohesive beds. The substrate at C2 is cohesive soil. The soil type and firmness underlying the in-channel grasses was assessed at each cross-section. The clay content and firmness were compared to the permissible unit tractive forces for cohesive materials as presented by the Chow (1959). Critical conditions at C2 will occur when the shear stress on the bed exceeds the permissible tractive forces.

5.6.2.9 Results

The hydraulic conditions at which entrainment would theoretically occur was determined for each cross-section as per the three methodologies described above. The critical hydraulic conditions were averaged over the 10 cross-sections analysed for each reach and are presented in **Table 5.6.4**. Also reported are the measured/modelled bankfull hydraulic conditions. Critical hydraulic conditions occur below bankfull flow for all three reaches. The values represent hydraulic conditions above base flow but well below bankfull.

5.6.2.10 Bank Material Thresholds

The permissible tractive forces were determined for the observed bank material and firmness at each cross-section. Bank material composition at each cross-section were mostly homogenous (i.e. one dominant stratification unit) and the bank composition did not significantly differ between the left and right banks. The permissible tractive forces were compared to the shear stresses on both the left and the right bank for each iteration. For our purposes, critical conditions occurred when the shear stress on just one of the banks exceeded the permissible tractive force, which is a conservative approach. The critical hydraulic conditions were averaged over the 10 cross-sections at each reach. Critical hydraulic conditions for bank material entrainment occur below bankfull conditions for all three reaches. The critical discharge for the bank material is higher than the bed material because the shear stress is greater on the bed than the banks and the bed material is often non-cohesive (i.e. more readily entrained). The critical discharge and critical velocity is present in **Table 5.6.4.**

Table 5.6.4 Southwest Georgetown Subwatershed Erosion Threshold Values

PARAMETER	AM3	BD1	C2
Drainage Area (km^2)	5.09	1.2	0.60
Average Bankfull Width (m)	6.46	2.45	1.30
Average Bankfull Depth (m)	0.37	0.32	0.07
Bankfull Gradient (m/m)	0.005	0.012	0.012
Bed Material (D50)	10.55	3.42	Clay
Bed Material (D84)	28.36	8.06	0.19
Manning's n	0.035	0.05	0.02
Average Bankfull Velocity (m/s)	0.97	0.91	0.30
Average Bankfull Discharge (m^3/s)	2.82	0.90	0.03
Critical Discharge (m^3/s)	0.49	0.17	0.01

PARAMETER	AM3	BD1	C2
Critical Maximum Depth (m)	0.23	0.17	0.07
Critical Average Depth (m)	0.17	0.12	0.05
Critical Maximum Velocity (m/s)	0.70	0.62	0.32
Critical Average Velocity (m/s)	0.55	0.48	0.27
Critical Average Shear Stress (N/m2)	7.36	11.77	4.71
Critical Maximum Shear Stress (N/m2)	11.28	20.01	8.24
Bank Critical Discharge (m^3/s)	0.75	0.22	0.02
Bank Critical Maximum Velocity (m/s)	0.89	0.92	0.40
Bank Critical Average Velocity (m/s)	0.70	0.72	0.32
Method	Komar (1987)	Neil (1967)	Chow (1959)

5.6.2.11 Field Verification

Reach-averaged hydraulic conditions were determined during field reconnaissance to help verify the results of the erosion threshold analysis. The wetted widths and average depths were determined by comparing the cross-section profiles to the observed water elevations. Velocity was determined from the local bed gradient (as determined from the thalweg survey) and the field estimate of Manning's 'n'. Discharge is a product of wetted width, average depth, and velocity. Results were averaged for all 10 cross-sections at AM3 and BD1. At C2 hydraulic conditions were reported as the average of the 5 cross-sections that contained water (i.e. 5 cross-sections were dry during field reconnaissance). The results are presented in **Table 5.6.5**.

Table 5.6.5 Hydraulic Conditions during Field Reconnaissance

Reach	AM3	BD1	C2[1]
Wetted Width (m)	2.56	1.11	0.67
Average Depth (m)	0.07	0.12	0.03
Average Velocity (m/s)	0.28	0.33	Standing water
Discharge (m^3/s)	0.05	0.04	0.00
Entrainment?	No	Yes – fine material	No

1 – based on the average of five cross-sections that contained water

Substrate entrainment was not observed at AM3 and C2 as hydraulic conditions were below critical values. The entrainment of fine material (silt and fine sand) was observed locally at BD1. The average depth (0.12 m) on the day of the field reconnaissance slightly exceeded the critical average depth (0.10 m).

5.7 Terrestrial Resources

This analysis of terrestrial resources includes review of significant natural heritage features as characterized in **Section 4.9**. The analysis therefore includes wetland and upland vegetation features, habitat of endangered and threatened species, special concern species, significant woodlands and valleylands, significant wildlife habitat and ecological linkages. These features have been identified through background review, field inventory and detailed analysis and characterization provided in **Section 4.9**. The analysis is consistent with the applicable environmental policies for the study area.

As part of the identification of potential impacts to terrestrial resources and associated constraints, **Section 5.7.1** provides a functional analysis of the identified natural heritage features for each of the Block Areas (A to D). This allows for a subsequent site level impact assessment.

From the characterization of natural heritage features including significant features in **Section 4.9** and completion of the functional analysis, identification of terrestrial constraints are presented in **Section 5.7.3**. The specific relationship and functional contributions of terrestrial features to the stream reaches within the study area is discussed in **Section 5.7.4**.

Section 5.7.5 provides an analysis of potential impacts to terrestrial features and functions within the NHS.

5.7.1 Functional Analysis of Terrestrial Natural Heritage Features

Through a functional analysis the identification of management needs and objectives for the natural heritage feature components of the NHS (i.e., flora and fauna, key habitats, linkage) can be completed. This has been done for each Block Area to understand their functional requirements. Management of the NHS components is completed at the species, feature and site specific-level. This provides for an understanding of the ecosystem processes for a systems based management approach to sustaining the NHS.

Part of Riparian/Drainage System

The relationship between habitat patches and surface/groundwater resources is frequently noted in natural heritage system evaluations. Vegetative cover associated with drainage courses, upland vegetation in proximity to wetlands, and natural cover influences on groundwater resources have been studied by a number of researchers. The relationship of vegetative cover on fluvial processes, erosion, and aquatic habitats is discussed elsewhere in this report. The role of wetlands in terms of hydrology is also an important component of the NHS.

All of the Block Areas are associated with drainage courses (based on stream reaches delineated as part of the aquatic/fluvial geomorphology assessment). Block A is associated with Tributary A, Blocks B and C are associated with Tributary C, and Blocks D (and the northwest part of Block C) are associated with Tributary B. The vegetation communities all contribute to the headwater functions of these watercourses.

Groundwater relationships and potential impacts to vegetation as a result of changes to the groundwater regime are discussed in **Sections 5.4.4** and **5.4.5** of this report.

Number of Native Plants and Wildlife and Presence of Rare Species

The number of native plant species and wildlife, as well as presence of rare/uncommon species, is often used as an indicator of habitat diversity. This is generally a simple tally of native plant species as well as birds, mammals, reptiles, amphibians and other taxa. The abundance of non-native species is also used as an indicator of disturbance.

Number of Vegetation Types and Relative Area

This factor focuses on the diversity of vegetation types and presence/relative abundance of mature types (based on ELC definitions). The types and extent of vegetation communities within each Block Area are shown on the existing vegetation communities figure (**Figure 4.9.1**). The terrestrial wetland vegetation communities and respective ecosystems and ELC units are described as part of the functional analysis.

Character of Surrounding Habitats/Land Uses

As expected in this highly agricultural landscape, all of the units are surrounded by active agricultural lands and roadways with a few residential homes.

ELC as a Tool for Management

Characterization of the landscape through ELC can be used for an understanding of the ecosystems (e.g., terrestrial, wetland and aquatic) within the study area and their biotic and abiotic attributes and functions. All of the vegetation communities within the study area have been classified to the Ecosite or Vegetation Type levels (Lee *et al.* 1998). Ecosite classification provides local landscape and site level understanding of characteristics such soil texture, moisture regime, drainage, vegetation structure and species composition. Vegetation Type classification provides further understanding of percent vegetation cover, layering, dominant and co-dominant species association, and more detailed species composition including potential occurrence of plant species of conservation concern. This information can be used to assess potential impacts and sensitivities to vegetation communities, flora, wildlife habitat and features. Management requirements can be identified in order to maintain features and functions.

The Ecological Land Classification (ELC) system is a nested classification that groups *Vegetation Types* (e.g., FOD5-2: Dry – Fresh Sugar Maple – Beech Deciduous Forest) into *Ecosites* (e.g., FOD5: Dry – Fresh Sugar Maple Deciduous Forest) with common soil and generalized vegetation characteristics. *Ecosites* are generally grouped into *Community Series* (e.g., FOD: Deciduous Forest) by type of plant form or landform (e.g., deciduous forest), which in turn are grouped at the *Community Class* (e.g., FO: Forest) level according to more inclusive categories of plant form or landform such as forest or rock barren.

The vegetation communities and associated features, functions and terrestrial components are assessed in the following sections for Block A, B, C and D.

Block A

This block includes terrestrial and wetland features associated with Tributary A, which originates at the south-east corner of the plan area by a small isolated woodland and extends north and east to Eighth Line (**Figure 4.9.1**). The block includes a central woodland (1.93 ha) that consisting of Units 6b, 6c and 22.

Block A – Vegetation Communities and Flora

Field investigations identified eight different vegetation communities (e.g., FOD7, MAM2-2) consisting of deciduous forest, old field, cultural thicket and woodland, meadow marsh and a dug pond. The upland and wetland vegetation community boundaries are illustrated in **Figure 4.9.1** with detailed vegetation community descriptions provided in **Section 4.9.1.2**.

Block Area A includes the following upland and wetland vegetation communities, which have been divided into the respective ecosystems and ELC units:

<u>Terrestrial System</u>

Forest (FO)

- Unit 1a: Fresh-Moist Lowland Deciduous Forest (FOD7)
- Units 6b and 6c: Dry-Fresh Sugar Maple-White Ash Deciduous Forest (FOD5-8)
- Unit 22: Fresh-Moist Sugar Maple Deciduous Forest (FOD6)

- Unit 24: Fresh-Moist Lowland Deciduous Forest (FOD7)

There is a total of 2.66 ha of non-contiguous deciduous forest cover within Block A which consists of a small, circular community, Unit 1a (0.67 ha), linear forests along Tributary A consisting of Units 6b, 6c and 22 (1.91 ha) and a small woodland, Unit 24 (0.06 ha), surrounding the dug pond. Forest Units 6b, 6c and 22 provide the greatest functional contribution to Tributary A by providing shade and thermal cooling, some flow attenuation during high flow events (although the channel is deeply incised and eroding) and nutrient and sediment uptake of sheet flow from the adjacent agricultural lands. The separation of Unit 1a from the tributary by active agriculture and its small size (0.67 ha) limits functional contribution to the watercourse. The proximity does provide an enhancement opportunity for reconnection of forest and watercourse.

Cultural (CU)

- Units 9h and 9i: Dry-Moist Old Field Meadow (CUM1-1)
- Unit 18c: Cultural Thicket (CUT1)
- Unit 23a: Cultural Woodland (CUW1)

Of the two old field meadows Unit 9h is the largest (0.75 ha) and provides functional contribution to Tributary A through some flow attenuation from riparian vegetation, and nutrient and sediment uptake of sheet flow from the adjacent agricultural lands. The cultural thicket Unit 18c (0.47 ha) supports an inflow reach (A4-1) to Tributary A providing riparian vegetation, and nutrient and sediment uptake of sheet flow from the adjacent agricultural lands. Cultural Units 9i and 23a are both very small (0.1 ha) and provide some corridor function in combination with adjacent vegetation communities.

<u>Wetland System</u>

Marsh (MA)

- Unit 10: Reed Canary Grass Mineral Meadow Marsh (MAM2-2)

Open Aquatic (OAO)

- Unit 26: Open Water Aquatic (OAO)

The meadow marsh Unit 10 (2.19 ha) is an important riparian wetland that is found along approximately 2 km of Tributary A providing flood attenuation, and nutrient and sediment uptake functions to the watercourse. The wetland also supports the functions of an intermittent stream with direct seasonal fish habitat. The species composition is dominated by Reed-canary Grass and is lacking in species richness, and vegetation layering and structure with very limited shrub and tree cover. This represents an enhancement and restoration opportunity. Unit 26 is a small (0.09 ha) dug pond that is not surficial connected to by stream flow to Tributary A. It provides some corridor function in combination with adjacent vegetation communities.

<u>Flora</u>

There were no rare or uncommon plants recorded from Block A which is likely due to the smaller vegetation community patches and higher degree of past disturbance compared to the other Block Areas. While invasive species have not been identified as a specific issue in this Block, there are opportunities for enhancing floristic quality and diversity.

Block A – Wildlife

Amphibians

Two species of amphibians (American Toad and Green Frog) were recorded from Block A (see **Figure 4.9.2**). Toads were heard calling along the riparian meadow marsh (Unit 10) indicating the riverine wetland has wildlife habitat functions. Although not heard, Green Frogs were seen along the watercourse and the dug pond may provide breeding habitat for this species. Presence of these species along the watercourse is also indicative of the wildlife movement function along Tributary A.

Birds

Twenty-one species of birds were recorded from this Block. While the forest cover along Tributary A is restricted in size and has no forest interior habitat, Units 6b, 6c and 22 provide habitat opportunities for species such as Northern Flicker, White-breasted Nuthatch, Red-eyed Vireo and Great Crested Flycatcher. The proximity to forests in Blocks B, C and D may contribute to the presence of these general forest bird species. The presence of species such as Common Yellowthroat and Spotted Sandpiper suggest that the riparian area is providing some wetland habitat opportunities associated with Tributary A. These existing wildlife habitats represent opportunities for enhancements for breeding bird communities currently using the area. Two SAR, Wood Thrush and Barn Swallow were observed and are discussed in subsequent sections.

Reptiles

Despite the presence of seven snake cover objects (see **Figure 4.9.2**) throughout Block A, there were no reptiles observed. While in time with continued monitoring, common species such as Eastern Garter Snake could be observed due to the presence of food sources (e.g., toads) and some habitat availability, the relatively small habitat patch size, and fragmented character that may increase predation are among factors that limit habitat opportunities for reptiles.

Other Wildlife

Observations from the winter wildlife survey identified no tracks to or within the isolated woodland at the south end of the Block A (Unit 1a). There were also no small mammal tracks (e.g., Red Squirrel or Gray Squirrel) within the woodland indicating limited winter wildlife habitat likely due to the lack of suitable cover and shelter given the small size and exposed structure (i.e., limited vegetation layering and absence of conifer species) of the forest community. A coyote was observed potentially denning in the central forest area (Unit 6b) in April 2013. Small mammal tracks were recorded from the central forest area during the winter wildlife surveys as well as Coyote tracks in the direction from Block B to A. While the amount of observed winter wildlife activity was lowest in Block A it appears to provide peripheral habitat opportunities to the other Block Areas.

Block A – Significant Natural Heritage Features

Wetlands

An assessment of wetland significance is provided in **Section 4.9.4.1** and following definitions and criteria provided in associated environmental policies including ROPA 38 and the Town's OP.

Based on this analysis the meadow marsh wetland (Unit 10, MAM2-2) would qualify as significant under ROPA 38 as the feature supports important ecological contributions to the NHS consisting of approximately 2 km of riparian wetland, an intermittent stream with direct seasonal fish habitat, provides flood attenuation, and nutrient and sediment uptake. The dug pond (off-line from the watercourse) aquatic community (Unit 26 - OAO) provides some habitat diversity including potential breeding amphibian habitat (although no calls heard during surveys). Based on factors such as the small size and anthropogenic origin of the feature, it would not qualify as significant.

Habitat of Endangered and Threatened Species and Special Concern Species

No endangered species have been identified from Block A. One threatened species, Barn Swallow, was observed and likely utilizes the meadow marsh as overhead foraging habitat. Interestingly a Wood Thrush, Special Concern provincially, was recorded from the central forest, although the habitat size is smaller than typically required. This species is discussed further in subsequent sections.

Any site specific application within the secondary plan area will be required to demonstrate conformity to the Provincial ESA and further surveys for SAR will be needed. As part of the EIR and/or EIS stages and assessment of potential species at risk, consultation with the MNRF may be necessary to obtain the most current survey protocol for a given species.

Significant Woodlands

Significant woodlands for Block A are shown on **Figure 4.9.1** and consist of the central forest which includes Units 6b, 6c and 22 that are directly along Tributary A. This woodland provides functions such as shade and thermal cooling to the intermittent stream and qualifies as significant (ROPA38) as it is > 0.5 ha and within 50 m of a watercourse. The isolated 0.67 ha woodland at the south (Unit 1a) qualifies as significant and although not directly along Tributary it is within 50 m of a watercourse.

Significant Valleylands

There are no formally designated significant valleylands associated with Block A. Based on definitions under the Town's OP, portions of Tributary A (an upper reach of Sixteen Mile Creek) would at a minimum qualify as a Minor Valley/Watercourse. This is defined as "…*a watercourse and its associated valley system of stream corridor that typically has valley walls less than 5 metres in height".* Related meander belt and erosion hazard limits are address in **Section 5.6**.

Significant Wildlife Habitat

An assessment of significant wildlife habitat within the study area was completed in Section 4.9.4.5 and includes a screening of the four component parts of SWH, specifically, 1) habitat of season concentrations of animals, 2) rare vegetation communities or specialized habitats, 3) habitats of species of conservation concern, and 4) animal movement corridors (OMNR 2010). Based on the assessment no areas of SWH were identified from Block A including no specialized habitat (e.g., no area-sensitive breeding bird habitat) or habitat of species of conservation concern (e.g., no populations of rare flora or fauna identified). While observations of amphibians moving along Tributary A were observed in the spring-summer and mammals during winter surveys, the limited number of species and level of activity would not qualify the corridor as SWH under the category of animal movement corridors.

Ecological Linkages

While SWH for animal corridors is not found within Block A, it is recognized that there is a local level of linkage opportunity (e.g., reconnecting the isolated areas of vegetation and habitat such as the small woodland at the southern end of Tributary A to the central woodland) and function of overall connectivity along the watercourse from Side Road 10 and Trafalgar Road to adjacent lands outside of the study area downstream of Eighth Line.

Block B

This block includes terrestrial features associated with a 4.9 ha rectangular shaped woodland (including cultural woodland communities) with a portion of Tributary C along the southern corner of the Block (**Figure 4.9.1**).

Block B – Vegetation Communities and Flora

Field investigations identified four different vegetation communities (e.g., FOD6-5, CUM1-1) consisting of deciduous forest, old field, cultural thicket and woodland. The upland vegetation community boundaries are illustrated in **Figure 4.9.1** with detailed vegetation community descriptions provided in **Section 4.9.1.2**. There are no wetland communities in Block B.

This block is located on the east side of the secondary plan area along Eighth Line and includes the following upland vegetation communities, which have been divided into the respective ecosystems and ELC units:

<u>Terrestrial System</u>

Forest (FO)
- Unit 13: Fresh-Moist Sugar Maple-Hardwood Deciduous Forest (FOD6-5)

Unit 13 is comprised of a deciduous forest (3.9 ha) that forms the primary vegetation community within Block B. The soil moisture regime is fresh to moist in this woodland with indicative species such as White Elm and pockets of Red Ash in lower depressional areas found along the northwest side of the unit. There was substantial damage to trees in the central part of the woodland from the December 2013 ice storm resulting in leaning and broken tree trunks and branches. Management such as pruning and limbing should be considered. The shape of the woodland and overall total area of close to 4.5 ha when including the contiguous cultural woodland communities (Units 14a and 14b) provides increased wildlife habitat opportunities for breeding forest birds. There is however no forest interior habitat (i.e., greater than 100 m from the edge). Connection and functional contribution to Tributary C is limited to the southern corner.

Cultural (CU)
- Unit 9g: Dry-Moist Old Field Meadow (CUM1-1)
- Unit 18b: Cultural Thicket (CUT1)
- Unit 14a and 14b: Black Walnut Cultural Woodland (CUW1)

The cultural communities associate with Block B are around the perimeter of Unit 13 and are disturbance based areas where there has been encroachment into the deciduous forest and subsequent regeneration of vegetation. These communities are at various stages of succession with Units 14a and 14b having higher soil moisture, supporting over 50% tree covering and functionally contributing to the forest community (e.g., buffering and increased tree cover). Unit 18b is a semi-open thicket that is succeeding to cultural woodland and is directly adjacent to Tributary C. While dominantly an upland community, the small old field meadow (Unit 9g) has a higher soil moisture regime and supports some facultative wetland plants. It is a location where breeding amphibians were heard calling during surveys.

Flora

There were no rare or uncommon plants recorded from Block B. While past disturbance to the woodland is primarily around the perimeter of the unit, invasive species have not been identified as a specific issue in this Block. The woodland supports good representation of woodland flora including an abundance of Yellow Trout Lily, White Trillium, Running Strawberry Bush, three species of violets and Zig-zag Goldenrod.

Block B – Wildlife

Amphibians

Two species of amphibians (Spring Peeper and American Toad) were recorded from Block B (see **Figure 4.9.2**). Both species were heard calling from the fresh-moist old field meadow on the west side of the Block. While American Toads can utilize lower quality aquatic habitat, the presence of Spring Peepers indicates greater habitat opportunity for consideration in enhancement. Direct proximity to summer forest habitat within Unit 13 for this species contributes to the overall function of Block B with improved breeding habitat. To the south of the Block, five American Toads were heard calling over two surveys from standing water along Tributary C on the edge of the agricultural field. This represents a habitat enhancement opportunity for the Tributary C riparian area.

Birds

Twenty-two species of breeding birds were recorded from the Block B area including representation of forest species that can be associated with smaller wooded areas with some disturbance and varying canopy closure. With the lower edge-to-interior ratio of Block B due to its rectangular shape, species such as Hairy Woodpecker, Downy Woodpecker, Eastern Wood Pewee, Wood Thrush and Red-eyed Vireo were recorded during surveys. This representation of forest species, including two SAR (Eastern Wood Pewee and Wood Thrush), is indicative of functional habitat values of a small to mid-sized woodland in a near urban landscape. Enhancement and management is required to maintain the breeding bird community.

Reptiles

Despite the presence of four snake cover objects (see **Figure 4.9.2**) around the perimeter of Block B, there were no reptiles observed. It is possible that with continued monitoring species such as Eastern Garter Snake and potentially Red-bellied Snake could be found in Block B due to the presence of food sources, suitable habitat and proximity to Block C where a garter snake was observed. Enhancing a linkage between Block B and C as well as other habitat enhancements within Block B are management tasks that may contribute to habitat opportunities for reptiles.

Other Wildlife

Winter wildlife surveys in January 2014 identified one set of Coyote tracks leading to Block B from Block C. During the March 2014 survey there were Coyote tracks (two individuals estimated) observed throughout Block B with tracks leading to Block C as well as to the north side of Block A. Numerous tracks of small mammals (mice, voles) were also recorded. These observations indicate suitable winter foraging and some shelter habitat opportunities for Coyote and other winter mammals. Block B is part of the local habitat range for Coyote which includes Block C and D. Under the current agricultural uses on adjacent lands movement of mammals is relatively permeable. A general “greenway” along Tributary C is proposed which provides for a connection between Block B and C. The purpose of the greenway is to provide an open space that permits accessory uses such as surface water infiltration, a trail and landscaping plantings that would support recreational uses. This may benefit general wildlife movement between Block B and C in an urbanized landscape.

Block B – Significant Natural Heritage Features

Wetlands

While there are elements or small "inclusions" of wetland features within Block B, there are no wetland vegetation communities following the ELC methodology (Lee *et al.* 1998). Wetland inclusions are found on the northwest side of the Block in Units 14b and 9g and features include shallow depression with seasonal standing water and wetland facultative plants. Breeding amphibian habitat opportunities are also found in this area.

Based on an analysis of wetland significance following definitions and criteria provided in ROPA 38 and the Town's OP, these features would not qualify as significant. Nevertheless, the features and habitat attributes are recognized as part of the ecological function of Block B.

Habitat of Endangered and Threatened Species and Special Concern Species

No endangered or threatened species have been identified from Block B. Any site specific application within the secondary plan area will be required to demonstrate conformity to the Provincial ESA and further surveys for SAR will be needed. As part of the EIR and/or EIS stages and assessment of potential species at risk, consultation with the MNRF may be necessary to obtain the most current survey protocol for a given species.

Two Special Concern birds were detected in Block B consisting of one record of Eastern Wood-Pewee (*Contopus virens*) and one record of Wood Thrush (*Hylocichla mustelina*). Both species were listed in Ontario by the Committee on the Status of Species at Risk in Ontario (COSSARO) in April 2014.

The Eastern Wood-Pewee was designated as special concern nationally by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in November 2012. Despite being one of eastern North America's most common and widespread songbirds, this aerial insectivore has experienced ongoing population declines over the past 40 years in both Canada and the U. S. On the breeding grounds Eastern Wood-Pewee occurs in open mixed and deciduous woodlands, as well as in forest edge and forest clearings.

Wood Thrush was designated as threatened in Canada by COSEWIC in November 2012. The primary factors contributing to its status include habitat fragmentation and degradation, as well as high rates of nest predation and cowbird parasitism on the breeding grounds (COSEWIC 2012b). In Canada, Wood Thrush is typically found in moist, mature and undisturbed deciduous and mixed woodlands.

The lower edge-to-interior ratio of Block B due to the rectangular shape likely contributes to the utilization of Block B as habitat by these species. This function needs to be maintained.

Significant Woodlands

Significant woodlands for Block B are shown on **Figure 4.9.1** and consist of the majority of the Block including both deciduous forest and cultural woodland ELC communities (Unit 13, 14a and 14b). This woodland has been identified to provide wildlife habitat functions for forest breeding birds, winter wildlife habitat and to a limited degree for amphibians (breeding and summer habitat opportunities). There is a localized functional contribution to Tributary C along the south side of the Block. The woodland qualifies as significant (ROPA38) as it is > 2.0 ha and within an Urban Area.

Significant Valleylands

There are no formally designated significant valleylands associated with Block B and there are no other features (including Tributary C) that would qualify as valleyland under definitions in ROPA 38 or the Town's OP.

Significant Wildlife Habitat

An assessment of significant wildlife habitat within the study area was completed in **Section 4.9.4.5** and includes a screening of the four component parts of SWH (OMNR 2010). Based on the assessment no areas of SWH were identified from Block B including no habitat of species of conservation concern (e.g., no populations of rare flora or fauna identified) or animal movement corridors that would qualify as SWH. While observations of winter wildlife moving between Block B and C was observed, the extent of activity would not qualify as SWH under the category of animal movement corridors.

Ecological Linkages

While SWH for animal corridors has not been found associated with Block B, a local level importance of wildlife movement is recognized between Block B and C that represents a linkage enhancement opportunity (e.g., reconnecting areas of significant woodland with complementary habitat functions) for wildlife between subwatersheds (Silver Creek to the north and Sixteen Mile Creek to the south).

Block C

This Block includes terrestrial features associated with a 6.7 ha woodland (Units 6a, 7 and 5, which includes a cultural woodland), an adjacent cultural thicket (1.0 ha), and isolated swamp and surrounding woodland (0.36 ha), see **Figure 4.9.1**. The upper headwater reach of Tributary C originates in Block C.

Block C – Vegetation Communities and Flora

Field investigations identified six different vegetation communities (e.g., FOD5-8, SWD4-1) consisting of mixed and deciduous forest, cultural thicket and woodland, and deciduous swamp. The upland and wetland vegetation community boundaries are illustrated in **Figure 4.9.1** with detailed vegetation community descriptions provided in **Section 4.9.1.2**.

Block C is situated within the east-central portion of the secondary plan area and includes the following upland and wetland vegetation communities, which have been divided into the respective systems and ELC units:

Terrestrial System

Forest (FO)

- Unit 6a: Dry-Fresh Sugar Maple-White Ash Deciduous Forest (FOD5-8).
- Unit 7: Fresh-Moist White Pine-Hardwood Mixed Forest (FOM9-1)
- Unit 8e: Fresh-Moist Poplar Deciduous Forest (FOD8-1)

Unit 6a and 7 form the mid-aged to mature component of the forest, with Unit 6a dominated by Sugar Maples and co-dominant species of White Ash, American Basswood and American Beech, with good representation of native woodland flora. Unit 7 represents one of the few natural, mixed forest communities within the study area (the other is found in Block D). This mixed forest unit required more detailed land classification and analysis (e.g., soil augering, micro-mapping) due to the complex micro-topography, mixed representation of tree species composition and small wetland "inclusions". The moisture regime is fresh to moist in this unit with small representative areas dominated by Red Ash. Unit 7 supports amphibian breeding vernal pools which are discussed further in subsequent sections. The tall White Pine and some hardwood canopy trees provide micro-habitat opportunities for species such as Red-tailed Hawk which have been observed utilizing Block C.

Unit 8e is a small early successional wooded area surrounding the deciduous swamp (Unit 3c) and provides functional contribution to both the swamp (e.g., some nutrient and sediment uptake from sheet flow from the adjacent agricultural lands) and as part of the local linkage between Block C and D.

Cultural (CU)

- Unit 4: Hawthorn Cultural Thicket (CUT1)
- Unit 5: Deciduous Cultural Woodland (CUW1)

The cultural communities associate with Block C are found along the northwest (Unit 4) and southwest (Unit 5) perimeter of the forest community. The cultural thicket Unit 4 is recovering from past disturbance that may have included cattle grazing resulting in areas of dense regeneration of mature shrubs including European Buckthorn and hawthorn species. There is limiting herbaceous cover or tree sapling regeneration in the ground layer which is reflected in the observed low plant diversity. The condition of Unit 4 represents an active management and enhancement opportunity (e.g., removal of buckthorn and sapling under-planting) for increasing the area of contiguous woodland. Unit 5 is in the late successional stage of a cultural woodland with percent tree cover changing to greater than 60%. Disturbances found in this community appear to include past installation of an agricultural drain along the north side of the community boundary. It addition to physical disturbance of the vegetation this has likely contributed to changes in the drainage and hydrology of the surrounding area.

<u>Wetland System</u>

Swamp (SW)

- Unit 3c: Willow Mineral Deciduous Swamp (SWD4-1)

This swamp supports a pool of standing water where breeding amphibians have been recorded that persists through the spring and into early summer depending on rainfall. Although there is no direct surficial connection in the form of a channel, there is outflow toward Tributary B from the pool during high surface water events. This creates a hydrological link between Block C and D across the subwatershed boundary and is an important attribute in the management of Block C.

Thistle, Bebb's Sedge, Curly Dock, and Reed Canary Grass. Broad-leaved and Narrow-leaved Cattail are scattered throughout. It appears that this feature may be periodically ploughed. The shallow marsh (MAS2-1) is dominated by Broad-leaved and Narrow-leaved Cattail, with occurrences of Beggar's Tick, Bebb's Sedge, Panicled Aster, and Bittersweet Nightshade.

To the west of Block D there is a small wetland (Unit 21b and 27) behind a residence along Trafalgar Road. This is wetland area is < 0.5 ha, isolated and surrounded by agricultural fields. During very wet years there is some potential for Unit 27 to provide habitat for amphibians. Given the location of the wetland is isolated from other habitat areas the feature has limited ecological function. This feature will be part of the replication wetland proposed within the linkage between Block C and D.

Flora

There were 123 species of vascular plants recorded from the vegetation communities within the general Block C area. Four uncommon plants were recorded that consisted of the following species and locations:

- Pubescent Sedge (Unit 7);
- Blunt Broom Sedge (Unit 3c and 5);
- Cleavers (Unit 5); and,
- Arrow-leaved Aster (Unit 4).

Arrow-leaved Aster have a Coefficient of Conservatism (CC-value) of 6, while the remaining uncommon species have CC-values of 6 or less. Plant species with CC-values of 6 and under are more tolerant of disturbances, to varying degrees. Plant species with CC-values of 7 or 8 (no rare/uncommon species recorded) are considered to be associated with vegetation communities that are in an advanced successional stage, and are therefore tolerant of only minor disturbances.

Past disturbance to vegetation communities in Block C are most evident in Unit 4 and Unit 5 where representation of invasive species is mostly European Buckthorn (particularly in Unit 4 and edge of Unit 7). Buckthorn is co-dominant in the shrub layer in many areas. Unit 6a has some evidence from selective logging and a partial gravel access route, the woodland supports good representation of woodland flora.

Block C – Wildlife

Amphibians

A total of four species of amphibians (Spring Peeper, American Toad, Wood Frog and Gray Treefrog) were recorded from Block C (see **Figure 4.9.2**). All four species were utilizing a complex of vernal pools in an area of approximately 80 x 130 m in size in Unit 7. While the numbers of individuals recorded were not high (6+ Wood Frogs, 1 Spring Peepers, 3 American Toads, 1 Gray Treefrog), the species richness is an important representation of amphibians within the study area. The deciduous swamp Unit 3c supports a pool that may be permanent in high precipitation years and supports at least three species of amphibians that were heard calling during night surveys and with tadpole observations during the day. This is an important habitat patch connection between Block C and D, with foraging and shelter opportunities for a range of species aiding in successful movement. Enhancement along this linkage will provide further buffering of the wetland and amphibian habitat and increase the function of the connection.

Birds

Twenty-two species of breeding birds were recorded from Block C represented by a forest breeding bird community. While the presence of species such as Red-bellied Woodpecker, White-breasted Nuthatch and Black-and-white Warbler may be due to the proximity of the woodland to the large forest in Block D, this is indicative of functioning forest bird habitat. The observation of Common Yellowthroat by the deciduous swamp (Unit 3c) shows some representation of wetland bird species. One Eastern Wood Pewee, a Special Concern species, was also recorded.

Reptiles

There were nine snake cover objects (see **Figure 4.9.2**) established throughout the perimeter of Block C, resulting in the observation of one Eastern Garter Snake (one of four from the study area) from the south-west corner of Unit 5. The survey results indicate that while there were many Red-bellied Snakes found in Block D, including in close proximity to Block C (i.e., from snake covers sc32, sc35, sc36 and sc37), none were recorded from Block C. This may be a result of factors such as linkage function, limited habitat (e.g., insufficient semi-open edge habitat) or predation. As Red-bellied Snakes typically remain within 150-350 m (up to 550 m) of their hibernaculum, the absence of this habitat feature that is critical to the snakes life cycle, could be the key factor. Enhancing the linkage between Block C and D as well as other habitat enhancements (e.g., potential hibernaculum construction) within Block C are management tasks that may contribute to habitat opportunities for reptiles.

Other Wildlife

Winter wildlife surveys in January 2014 identified an abundance of small mammal tracks (Red Squirrel, Gray Squirrel) in the northeast portion of Block C (Unit 6a) with areas of feeding and burrowing in the snow crust observed. There were tracks from Coyotes demonstrating active foraging in areas of mice/vole tracks. Coyote tracks from Block C to both Blocks B and D were observed although the extent of tracks was difficult to determine due to snow drifting. The mixed forest Unit 7 with coniferous tree cover from White Pine and areas of dense shrub cover contribute to opportunities for shelter during the winter.

Block C – Significant Natural Heritage Features

Wetlands

A small pocket of Willow swamp (Unit 3c) is located within Block C. This swamp supports a pool of standing water where breeding amphibians have been recorded. In addition the wetland is located in an area that provides for linkage opportunities to Block D. The identified functions of this wetland do meet the ROPA 38 criteria for significant wetland, which requires that a wetland make an important ecological contribution to the Regional Natural Heritage System.

Habitat of Endangered and Threatened Species and Special Concern Species

No endangered or threatened species have been identified from Block C. Any site specific application within the secondary plan area will be required to demonstrate conformity to the Provincial ESA and further surveys for SAR will be needed. As part of the EIR and/or EIS stages and assessment of potential species at risk, consultation with the MNRF may be necessary to obtain the most current survey protocol for a given species.

One Special Concern species, Eastern Wood-Pewee, was detected in Block C, which on the breeding grounds occurs in open mixed and deciduous woodlands, as well as in forest edge and forest clearings.

Significant Woodlands

Significant woodlands for Block C are shown on **Figure 4.9.1** and consist of the majority of the Block including both deciduous forest and cultural woodland ELC communities (Unit 6a, 7 and 5). This woodland has been identified to provide wildlife habitat functions for forest breeding birds, winter wildlife habitat and breeding and summer habitat opportunities for amphibians of importance at the study area level. The community provides headwater drainage to Tributary C with the channel becoming evident in Unit 6 (with sustained flow observed in April 2013) as well as seasonal overland flow contributions from Unit 5. The woodland qualifies as significant (ROPA38) as it is > 2.0 ha and within an Urban Area, as well as within 50 m of a watercourse. There is technically a small area of forest interior (i.e., areas found at least 100 m from the forest edge) within Block C, which has limited functional contribution to area-sensitive species although Black-and-white Warbler was present in the forest. The presence of decaying logs and standing snags greatly enriches the forest and contributes to providing habitat for a range of wildlife, including amphibians.

Significant Valleylands

There are no formally designated significant valleylands associated with Block B and there are no other features (including Tributary C) that would qualify as valleyland under definitions in ROPA 38 or the Town's OP.

Significant Wildlife Habitat

An assessment of significant wildlife habitat within the study area was completed in **Section 4.9.4.5** and includes a screening of the four component parts of SWH (OMNR 2010). Based on the assessment, *candidate* SWH has been identified for the component of specialized habitat for the complex of vernal pools along the west and northwest side of the woodland (**Figure 4.9.2**). The seasonal pools (generally 2 to 6 m^2 in size) are surrounded by upland mixed forest providing suitable summer habitat. The pools had good structure, with emergent grass and forb vegetation, shrub and tree stems within and along the perimeter as well as downed woody debris contributing to overall habitat function. Although no salamander species have been observed at this location to date, the habitat may be suitable for these animals.

The seasonal pools are considered to be of relatively high function for anurans within the context of the study area and therefore the recommended designation as SWH. The suitable depth and longevity depends on factors such as winter snow cover and extent of rain in the spring to maintain suitable water levels for successful development and emergence of amphibians. The habitat function will therefore varying from year to year depending on conditions. The contributing water through sheet flow from the adjacent lands, potentially including lands outside of the NHS, is an important consideration in maintaining these features. Completion of a feature based water balance and identification of potential enhancement opportunities will be part of the management.

Ecological Linkages

While SWH for animal corridors has not been found associated with Block C, a local level importance of wildlife movement is recognized between Block C and D (as discussed in preceding Sections). This is represented by an existing linkage function as well as an enhancement opportunity (e.g., reconnecting areas of significant woodland with complementary habitat functions) for wildlife moving between subwatersheds for the headwaters of Silver Creek (Block D) and Sixteen Mile Creek (Block C).

Block D

This block includes terrestrial features associated with an 18.5 ha woodland (Units 1b, 3a, 3b, 8a, 8c, 8d, 11, 12a, 12b, 16a, 16b, 17a, and 17b, which includes cultural woodland and deciduous swamp), adjacent old field meadow, cultural thicket and barren/disturbed lands, as well as riparian wetland (**Figure 4.9.1**). The upper headwater reach of Tributary B originates in Block D.

Block D – Vegetation Communities and Flora

Field investigations identified 13 different vegetation communities (e.g., FOD7, MAM2-10) consisting of mixed and deciduous forest, old field, cultural thicket and woodland, deciduous swamp and marsh. The upland and wetland vegetation community boundaries are illustrated in **Figure 4.9.1** with detailed vegetation community descriptions provided in **Section 4.9.1.2**.

Block D is situated within the northern portion of the secondary plan area and includes the following upland and wetland vegetation communities, which have been divided into the respective ecosystems and ELC units:

Terrestrial System

Forest (FO)

- Unit 1b: Fresh-Moist Lowland Deciduous Forest (FOD7)
- Unit 8a, 8b, 8c, and 8d: Fresh-Moist Poplar Deciduous Forest (FOD8-1)
- Unit 11: Dry-Fresh Sugar Maple-Beach Deciduous Forest (FOD5-2)
- Unit 12a and 12b: Fresh-Moist Sugar Maple-Hemlock Mixed Forest (FOM6-1)
- Unit 15 Dry-Fresh White Pine Mixed Forest (FOM2)
- Unit 17a and 17b: Dry-Fresh White Ash deciduous Forest (FOD4-2)
- Unit 19: Dry-Fresh Deciduous Forest (FOD4)

Unit 11, 12a and 12b form a high quality, mature forest communities along the slopes and top of bank of the Tributary B valleyland. Many large, mature trees including some old growth trees are found in these communities. These are highly functional vegetation communities providing slope stability and erosion control, habitat for forest plants and wildlife, sediment and nutrient uptake, and micro-habitats such as localized seepage areas and large canopy trees. Disturbance in these units is limited to walking trails and localized erosion typically associated with the side ravines where agricultural drainage enters the valleyland.

Early to intermediate-aged successional forest communities are found along the tablelands adjacent to the valleyland and some side slopes, and includes Units 1b, 8a, 8c, 17a, 17b, and 19. These vegetation communities provide buffering function to the main valleyland and supporting habitat to the breeding bird community (e.g., contributing to some forest interior). Disturbance in more recent decades, followed by natural regeneration has resulted in the tableland woodland.

Cultural (CU)

- Unit 9a, 9b, 9c, 9d, 9e: Dry-Moist Old Field Meadow (CUM1-1)
- Unit 18a: Cultural Thicket (CUT1)
- Unit 16a and 16b: Black Locust Cultural Woodland (CUW1)

There are several cultural communities found along the perimeter of Block D (mostly small old field meadows) that are associated with localized disturbance from anthropogenic activities and/or natural processes such as erosion where flow from the agricultural fields enters the side ravines. Refuse has been dumped in some of the ravines. There is substantial erosion and incising of Tributary B at the south end of the Block where the primary watercourse enters into the valleyland. A cultural thicket (Unit 18) is found in this location and has been identified as an enhancement area opportunity.

Unit 16 is a large, primarily cultural woodland (i.e., < 60% tree cover) along Eighth Line comprised almost exclusively of young to mid-aged Black Locust trees (non-native species) which have regenerated on disturbed lands from past aggregate extraction. Ground flora is dominated by Smooth Brome Grass and other old field species. Black Locust is a highly invasive tree (weediness index = -3) and is part of the transition of tree cover from previously disturbed tablelands to the adjacent mature Sugar Maple-Hemlock forest of the valleyland. While the cultural woodland provides supporting functions to the native valleyland forest, further analysis has been completed to determine the feasibility of a management and enhancement plan to allow for encroachment into this community with an overall benefit to the Block D woodland.

Wetland System

Swamp (SW)

- Unit 3a and 3b: Willow Mineral Deciduous Swamp (SWD4-1)

Marsh (MA)

- Unit 21: Forb Mineral Meadow Marsh (MAM2-10)

There is limited representation of wetland in Block D, all of which are less than or approximately 0.5 ha. This includes Unit 3a (0.11 ha), which is an isolated feature surrounded by active agriculture, and Unit 3b (0.45 ha), which is riparian swamp along the lower reach of Tributary B. While Unit 3a does support calling amphibians, there appears to be limited to no success in tadpole emergence as there were no vernal pools. This is considered a replication feature that will be added to the NHS to provide for functional breeding amphibian habitat. The replication of this wetland, as well as two small additional wetlands in CH's watershed, will be construction within existing agricultural lands in the Local Linkage between Block C and D. As a riverine wetland, Unit 3b provides functional contribution to Tributary B by providing shade and thermal cooling, flow attenuation, nutrient and sediment uptake and breeding amphibian habitat.

The riparian meadow marsh along the lower reach of Tributary B provides similar functions as Unit 3b. Evidence of localized seepage was observed in Unit 3b and 21.

Other

- Unit 20: Barren

Unit 20 is a small remnant area of disturbed lands from the historic aggregate extraction activity throughout Unit 16a. It is an area with exposed mineral soils where regeneration of vegetation has not occurred.

Flora

There were 159 species of vascular plants recorded from the vegetation communities within Block D representing the most diverse Block within the study area due to the large size of contiguous forest cover. Five rare/uncommon plants were recorded that consisted of the following species and locations:

- Pubescent Sedge (Unit 7);
- Blue Cohosh (Unit 11, 19);
- Squirrel-corn (Unit 11);
- Dutchmen's Breeches (Unit 11); and,
- Pale Jewel-weed (Unit 11, 1b/8c).

Blue Cohosh and Dutchman's Breeches have a Coefficient of Conservatism (CC-value) of 6, while Pubescent Sedge has a CC-values of 5. Plant species with CC-values of 6 and under are more tolerant of disturbances, to varying degrees. Squirrel-corn and Pale Jewel-weed have CC-values of 7. Plant species with CC-values of 7 or 8 are considered to be associated with vegetation communities that are in an advanced successional stage, and are therefore tolerant of only minor disturbances. While not listed as rare/uncommon, Broad-leaved Toothwort (*Cardamine diphylla*), Broad-leaved Sedge (*Carex platyphylla*) and Wild Leek (*Allium tricoccum*) were recorded from Block D and are of note as they have CC-values of 7, providing indication of the floristic quality of the forest.

Past disturbance to vegetation communities in Block D is localized (i.e., not throughout) and found in several locations along the perimeter of the valleyland within notable areas including Unit 18a (requires restoration/enhancement) and the small old field meadows (Unit 9 series) often found along the side ravines. Representation of invasive species has not been identified as a specific issue in the central and northwestern part of the Block. The primary invasive species issue for Block D is the Black Locust woodland (Unit 16a and 16b). Invasive species may having varying levels of impact to biological communities depending on the existing conditions of an ecosystem when the species is introduced, such as level of existing disturbance in a community. When invasive species successfully out-compete native species and become increasingly established, the native species composition and abundance can decline resulting in degradation of the community. This can have a cascading effect on the ecosystem. This can also represents a threat to adjacent native vegetation communities. Invasive species control and management of Unit 16a/16b is an important objective for the study area.

Block D – Wildlife

<u>Amphibians</u>

A total of four species of amphibians (Spring Peeper, American Toad, Green Frog and Gray Treefrog) were recorded from Block D (see **Figure 4.9.2**). Two of the three identified breeding amphibian habitats (BA1a and BA2) are located outside of the valleyland forest Block. BA1 is the one area in the valleyland and is found in the riparian wetlands (Units 3b and 21). During the 2013 BA1 was represented by two species (American Toad and Green Frog).

BA1a is comprised of two survey areas, with amphibians calling from only standing water in the ploughed field (no calls from Unit 8b), see **Figure 4.9.2**. The pool had dried up in subsequent visits and no activity was detected. Pools in agricultural fields such as this were observed to support the majority of the American Toads in the study area, as this species is well adapted to exploiting ephemeral pools where the tadpoles develop quickly and leave the pool. The high snow cover on the landscape in the spring of 2013 likely contributed to amphibian activity in the fields, which may be limited or absent in years with drier spring conditions. Enhancement opportunities to replace this habitat function in the NHS, buffer areas and potentially within the regional flood limits are a management objective.

A small chorus of American Toads (6+), three Spring Peepers and five Grey Treefrogs were recorded from BA2 over the course of the surveys. The Unit 3a wetland is characterized as a “perched” wetland due to fine textured soils where local drainage accumulates. There were no pools observed within Unit 3a to provide suitable habitat for amphibian breeding and tadpole development found in this area. This suggests that this is a low quality habitat patch that may function act as a “habitat sink”.

<u>Birds</u>

Thirty-one species of breeding birds were recorded from Block D, which is the highest species richness for the study area. Additionally, the abundance of individual species was also relatively high for some species (e.g., 3 Northern Flickers, 6 Red-eyed Vireos, 4 Indigo Buntings and 3 Baltimore Orioles). Another species of note is the Pileated Woodpecker, which is an area-sensitive bird typically requiring larger forest habitat with mature mixed and deciduous composition. While it was not confirmed whether the woodpecker was nesting in Block D, it is an indication of the function of the community for forest birds. One Eastern Wood Pewee, a Special Concern species, was also recorded. Interestingly there were no recordings of Wood Thrush (Special Concern) which was recorded from other blocks, although there is suitable habitat.

Reptiles

There were 18 snake cover objects (see **Figure 4.9.2**) established throughout the perimeter of Block D, resulting in the observation of 15 Northern Red-bellied Snakes during multiple surveys in May, June and July. Three Eastern Garter Snakes were also recorded. The observations were mostly of young, smaller snakes with some larger adults also recorded. These observations are further indication of the habitat function of the forest block.
Red-bellied Snakes typically inhabit well-wooded areas with adjacent open habitat, where they hunt and thermoregulate. The semi-open edge areas such as the old field vegetation communities (Units 9a, 9b, 9c, 9d, 9e) provide this habitat function and likely contribute to the numbers observed. It is therefore important that as part of the edge management and buffer restoration design, elements of open habitat are maintained.

Other Wildlife

Winter wildlife surveys in January 2014 identified an abundance of small mammal tracks (Red Squirrel, Gray Squirrel) along the east side of Block D. Coyote tracks in the mid to lower slopes of the valleyland lead to the observation of a Coyote adjacent to what appeared to be a den. As discussed in preceding sections, track observations confirmed that coyotes as well as small mammals move from Block D to C along the existing linkage.

Only a few White-tailed Deer tracks were observed in Block D during the January 2014 survey and there was no evidence of deer wintering. The limited tracks and no observations of bedding or other activity suggest that the area is not suitable for deer winter habitat.

Block D – Significant Natural Heritage Features

Wetlands

Based on an analysis of wetland significance following definitions and criteria provided in ROPA 38 and the Town’s OP, the riparian marsh (Unit 21) and swamp (Unit 3b) wetlands would qualify as significant under ROPA 38. The wetland features provide an important ecological contribution to the NHS including riparian functions to an intermittent stream with contributing fish habitat, flood attenuation and nutrient and sediment uptake, habitat for breeding amphibians, and seepage areas. Wetland Unit 3a is small and isolated and would not qualify although this is considered a replication feature to be replicated in the NHS.

Habitat of Endangered and Threatened Species and Special Concern Species

No endangered or threatened species have been identified from Block D. Any site specific application within the secondary plan area will be required to demonstrate conformity to the Provincial ESA and further surveys for SAR will be needed. As part of the EIR and/or EIS stages and assessment of potential species at risk, consultation with the MNRF may be necessary to obtain the most current survey protocol for a given species.

One Special Concern species, Eastern Wood-Pewee, was detected in Block D. There are also habitat opportunities for Wood Thrush which has been observed from other locations in the study area.

Significant Woodlands

Significant woodlands for Block D are shown on **Figure 4.9.1** and consist of the majority of the Block including both deciduous forest and cultural woodland ELC communities (Unit 1b, 8a, 8c, 8d, 11, 12a, 12b, 17a, 17b, 19 and 16a/16b). While the Black Locust cultural woodland Units 16a and 16b are technically considered part of the significant woodland (contiguous with the main forest block), a management and enhancement assessment has been completed to allow for encroachment into this community.

Black Locust is a highly invasive tree with a weediness index of -3 based on the *Floristic Quality Assessment for Southern Ontario* (Oldham *et al.* 1995). Invasive species may have varying levels of impact to biological communities depending on the existing conditions of an ecosystem, such as the level of existing disturbance. When invasive species successfully out-compete native species and become increasingly established, the native species composition and abundance can decline resulting in degradation of the community. This can have a cascading effect on the ecosystem. This can also represent a threat to adjacent native vegetation communities. Invasive species control and management of Unit 16a has therefore been identified in the Subwatershed Study as an important objective for the study area.

The Block D woodland has been identified to provide wildlife habitat functions for forest breeding birds, winter wildlife habitat and breeding and summer habitat for amphibians. The woodland contributes to the headwater drainage to Tributary B with nutrient and sediment uptake function provided to sheet flow and ravine inflows from the adjacent agricultural lands. There are erosion issues at some inflow locations that represent opportunities for restoration/enhancement.

There is some forest interior habitat within Block D, which contributes to the breeding bird community for observed species such as Pileated Woodpecker, White-breasted Nuthatch, Black-and-white Warbler and American Redstart.

<u>Significant Valleylands</u>

Based on criteria recommended by the Province for significant valleyland designation, including prominence as a distinctive landform, extent of naturalness, importance of its ecological functions, restoration potential, and Town OP definitions, the Tributary B valleyland would qualify as significant.

<u>Significant Wildlife Habitat</u>

An assessment of significant wildlife habitat within the study area was completed in Section 4.9.4.5 and includes a screening of the four component parts of SWH. Based on the high number of Red-bellied Snakes and the fact that they typically remain within 150-350 m (up to 550 m) of their hibernaculum, it very possible that the Tributary B ravine contains a feature(s) which serves as the local snake hibernaculum. Therefore Tributary B could be considered to support Significant Wildlife Habitat, based on the probable occurrence of snake hibernacula, the exact location(s) are not know at this time.

<u>Ecological Linkages</u>

While SWH for animal corridors has not been found associated with Block D, there is a linkage function along the Tributary B ravine. Given the length and extent of natural forest cover the corridor provides local wildlife movement opportunities from the tablelands and forest edges down into and along the ravine as observed during the winter wildlife surveys. Additionally a local level importance of wildlife movement is recognized between Block C and D (as discussed in preceding Sections), which represents an enhancement opportunity for wildlife moving between subwatersheds for the headwaters of Silver Creek and Sixteen Mile Creek.

5.7.2 Block D Woodland Management and Enhancement Assessment

Through a comprehensive ecological restoration approach, the removal of Black Locust trees from Unit 16a could occur with no long-term negative effects, impacts, or loss of the significant woodland features and functions of Block

D as discussed further in this study. The objective is also to provide an overall enhancement to Block D through a well-designed management and reforestation plan (see **Section 6.3.3.6**).

In completing the woodland management and enhancement assessment, the features and functions of Block D as a whole were reviewed. At a site-specific level the existing and contributing features and functions of the Black Locust Unit 16a woodland were identified. This included understanding what areas within Unit 16a provide the most ecological support to the native forest and valleyland component of Block D and retaining these features and functions.

Block D Features and Functions

Through the Subwatershed Study the following significant features and functions have been identified for Block D:

- **Significant Natural Heritage Features**: significant woodland, wetlands of significant, significant valleyland, significant wildlife habitat (Red-bellied Snake) and habitat of special concern species.
- **Linkage**: local linkage between Block C and D and linkage function along Tributary B valleyland.
- **Wildlife**: presence of one species at risk, Eastern Wood-Pewee (*Contopus virens*), Special Concern.

Black Locust Cultural Woodland Features and Functions

The Black Locust cultural woodland does not support wetlands, significant valleylands or any identified habitat of special concern species. The cultural woodland provides some linkage function to other woodland areas on the north side of Eighth Line and may provide some supporting habitat functions (although not direct habitat), such as habitat buffering, for the Eastern Wood-Pewee.

The ecological features and functions of the Black Locust cultural woodland have been identified to consist of:

- cultural woodland community contiguous with the native forest of Block D that provides edge effect buffering of the native forest;
- marginal contribution to forest areas that are > 100 m from the forest edge; and,
- habitat opportunities for common species of breeding birds based on 2014 surveys [i.e., American Goldfinch (*Spinus tristis*), Song Sparrow (*Melospiza melodia*), Chipping Sparrow (*Spizella passerina*), Cedar Waxwing (*Bombycilla cedrorum*), Red-eyed Vireo (*Vireo olivaceus*), Eastern Kingbird (*Tyrannus tyrannus*), Indigo Bunting (*Passerina cyanea*), Black-and-White Warbler (*Mniotilta vari*) and Northern Flicker (*Colaptes auratus*)].

While there is some representation of forest birds, such as Red-eyed Vireo and Black-and-White Warbler, the majority of birds are generalists of semi-open and open habitats. The presence of forest species is likely attributed to the proximity of the larger native forest community.

As the Black Locust cultural woodland does provide some supporting functions to the native valleyland forest, these identified functions need to be maintained, replaced and wherever possible enhanced through the management plan.

Removal and Management of Invasive Black Locust Trees

Non-native Invasive Species

A non-native or introduced plant is considered a species that has arrived and become established in a new geographical range, such as a species arriving to North America and/or Canada through European settlement, which was not part of the native flora pre-settlement. An invasive species (plant, animal, fish, etc.) is typically an introduced species to a region that has a tendency to spread to an extent that it can cause damage to the environment, human health, and potentially the economy (e.g., agriculture, forestry). Black Locust is a non-native tree to Canada that originates from central-eastern United States and has expanded through human distribution throughout North American and the world. Some non-native plants may become invasive and spread widely in forests and other vegetation communities outcompeting our native plants.

Weediness Index

The Floristic Quality Assessment (FQA) for Southern Ontario is a method for an objective numerical comparison of two or more vegetated areas or vegetation types (Oldham et al. 1995). Through the FQA method most non-native plants/weeds found in Ontario are assigned a value between -1 and -3, known as the Weediness Index (WI). Plants with a value of -1 are considered to have little to no impact to natural vegetation communities, as they are not invasive. Introduced plants that can become invasive and problematic are assigned a value of -3. Black Locust has a WI of -3 and is there for considered to have high potential to spread and have negative effects to existing and regenerating vegetation areas.

Allelopathy (Biological Effects of Black Locust)

During the site walk with the agencies (CVC, CH, Halton Region) it was observed and discussed how little regeneration of native trees and shrubs were present even in the areas of long-established mature Black Locust cover directly adjacent to the native forest, as well as in the younger regenerating areas. Halton Region staff raised the potential of Black Locust having allelopathic potential, which was further reviewed by the study team. Allelopathy refers to the potential harmful effects of one plant on another plant from the release of biochemicals, known as allelochemicals. This can occur from leaves or roots or other parts through leaching into the soil or volatilization among other processes. Allelopathy can have negative effects on plant ecology, including occurrence of other species, plant succession, dominance and diversity.

Research indicates that several allelochemicals have been identified and characterized from the leaf tissue and potentially stems of Black Locust. Robinetin, a crystalline flavone, is produced by Black Locust and when found in large amounts has been documented to the cause the suppression of the root and shoot growth of other plants. The presence of these substances may contribute to allelopathic effects and invasion of this species into new habitats (primarily disturbed or semi-natural). With respect to the Black Locust woodland this means that based on the conditions observed it appears that the dominance of Black Locust trees in Unit 16 is preventing the regeneration of other tree species through an allelopathic effect. The expected ecological succession of a young woodland to a mid-age woodland with typical changes in tree species composition has been impeded in this area.

Black Locust Best Management Practices

A recent publication (Warne 2016) by the Ontario Invasive Plant Council and Environment and Climate Change Canada provides comprehensive Best Management Practices (BMPs) for the effective control of this species. The document reflects the current provincial and federal legislation relating to the impacts and management activities of invasive species, discusses the pathways of spread and distribution of Black Locust in Ontario, the ecological impacts, control and disposal measures, and restoration.

(http://www.ontarioinvasiveplants.ca/wp-content/uploads/2016/06/Black_Locust_BMP.pdf). The following provides some of the background information for this species, and recommended approaches for management and control:

- Black Locust is a pioneer species and can survive in many ecosystems and soil types with the ability to colonize disturbed or damaged ecosystems.
- Black Locust will aggressively invade native ecosystems including oak, beech-maple and aspen forests, and prairie and savanna communities where dense colonies can form that out shade native plants and decrease plant diversity. It can invade dry and nutrient poor sites including lowlands, wetlands and riparian areas.
- The tree has an average lifespan of 80 to 90 years and can produce large quantities of viable seed very early (within 6 years) and can propagate via suckering (vegetative reproduction), which are characteristics that contribute to the invasiveness of this species.
- Prolific seed production has been reported with up to ~74,000 seeds/hectare that can be dispersed by strong winds, animals and humans (e.g., transport by construction equipment, planting). The strong seed coats allow for viability for many decades with general germination success rates of 68%.
- The colonization and dominance of Black Locust results in vegetation communities with low diversity and effects species composition. This is a particular threat for a number of Species at Risk plants and animals found in habitats that can be invaded by Black Locust.
- It is difficult to control with a single technique and is therefore important to control the infestation before it becomes established or expands.
- In areas with established Black Locust, physical control such as cutting will result in suckering from the stumps and further colonization making it difficult and costly to fully eradicate. Removal of the full rooting system is needed to prevent suckering and spread.
- A well planned integrated pest management plan (IPM) is recommended for successful control that includes a long term strategy for the control and eradication of priority areas such as large and productive infestations, joint efforts, replanting and monitoring.

<u>Effects to Block D Forest and Future Buffers</u>

As Black Locust is a shade intolerant species (i.e., does not regenerate well under canopy shade) it does not represent a substantial, direct threat to the interior component of the native Block D forest. However, there is still a threat to the Block D forest from the Black Locust woodland. For example, in existing semi-open areas or where there may be disturbance such as wind throw that opens up the canopy in localized areas, Black Locust can become established as there is a large seed source present. There is existing evidence of this in vegetation Unit 18 at the south end of Block D where Tributary B enters the valleyland. This area is a semi-open shrub thicket that has some Black Locust represent that likely came from the Black Locust woodland Unit 16.

The main threat to Block D is to the woodland edge and buffer areas where the establishment of Black Locust will compete with native tree and shrub regeneration. Black Locust will have a direct, negative effect on the outward succession and expansion of native woodland cover into the buffer lands as is currently evident in the area of proposed removal. Once agricultural practices stop along the forest edge, woody vegetation will start to become established in the adjacent lands (i.e., forest edge/ buffer). The source of this regeneration will be from the trees along the edge and surrounding areas, including from the Black Locust woodland. As this species can grow to the stage of seed production relatively quickly, it will increasingly become a threat along the woodland edge as it expands (Warne 2016).

Targeted Removal of Black Locust Trees

As part of the assessment, lower functioning areas were identified in the central and east side of Unit 16a (see **Section 6.3.3.6**). These areas consist mostly of < 60% canopy closure (representative of a cultural woodland), support younger trees and a high degree of anthropogenic disturbance (trails, paint ball targets). The most westerly portion of Unit 16a supports larger, mid-aged Black Locust trees with a closed canopy that is contiguous with the native forest tree canopy. This area provides greater functional value to Block D based on the features and functions identified in **Section 6.3.3.6**. The western area will therefore be retained over the short to medium term, contained and managed for transition to native forest.

The existing Block D forested area including the Black Locust cultural woodland (Unit 16a) and the poplar woodland Unit 8d is about 18.7 ha. Unit 16a and Unit 8d are 3.8 ha and represents 20% of the Block D forest. Based on the desktop and field assessment it is recommended that approximately 2.47 ha (65%) be removed, which is approximately the area of past aggregate extraction. This can only be completed through a management and enhancement plan where the overall function of the Block D forest is maintained and enhanced. Based on the functional value of the west side of Unit 16a, approximately 1.33 ha that runs parallel to the native woodland will be retained. The exact limit of Black Locust removal as recommended in this assessment will be identified and staked through a site survey with the agencies and landowner, followed by an OLS survey.

5.7.3 Identification of Terrestrial Natural Heritage Feature Constraints

Based on the characteristics of the existing terrestrial and wetland vegetation communities, natural heritage features and species found within these areas (see discussion above) a number of significant feature and functions were identified. It is recommended that constraints be identified based on the following:

- ***Significant wetlands*** as identified through the features/functions analysis and applicable environmental policies (definitions and criteria). This includes the riparian meadow marsh (Unit 10) along Tributary A (Block A), the deciduous swamp (Unit 3c) in the linkage between Block C and D, the riparian deciduous swamp (Unit 3b) and meadow marsh (Unit 21) along Tributary B (Block D).
- ***Habitat of Endangered and Threatened Species*** pursuant to the provincial *Endangered Species Act* which includes habitat for Bobolink (pasture land between Block B and C, which since the 2014 field surveys has been ploughed and removed), and habitat for Barn Swallow (foraging habitat along Tributary A).
- ***Habitat for Special Concern Species*** identified through breeding bird surveys in 2013 consisting of woodlands for Eastern Wood Pewee (Unit 13 in Block B; Units 6a and 7 in Block; and, Units 11, 12a, 12b, 1b, 8a, 8c, 17a, 17b, and 19); and, woodlands for Wood Thrush (Units 6b, 6c and 22 in Block A and Unit 13 in Block B).
- ***Significant Woodlands*** as identified through the features/functions analysis and applicable environmental policies (definitions and criteria) and shown on **Figure 4.9.1**. This includes Unit 1a in Bock A, Units 6b, 6c and 22 in Block A; Units 13, 14a and 14b in Block B; Units 6a, 7 and 5 in Block C; and, Units 11, 12a, 12b, 1b, 8a, 8c, 8d, 16a, 16b, 17a, 17b, and 19 in Block D.
- ***Significant Valleylands*** as identified through the features/functions analysis and applicable environmental policies (definitions and criteria). This includes a Minor Valley/Watercourse in Block A and significant valleyland in Block D.
- ***Significant Wildlife Habitat*** as identified through the features/functions analysis and applicable environmental policies (definitions and criteria) and shown on **Figure 4.9.2**. This includes specialized habitat for breeding amphibians (vernal pool complex) in Unit 7 of Block C. There is also a potential for the Block D to support snake hibernaculum – however the location(s) are not known at this time.

- ***Ecological Linkages*** as identified through the features/functions analysis and applicable environmental policies (definitions and criteria) and shown on **Figure 4.12.1**. This includes the local linkage corridor along Tributary A (Block A); local linkage corridor between Block C and D; and, local linkage corridor along Tributary B (Block D) from Unit 18a to Unit 9c, including side ravines along the valleyland.
- ***Core Areas and Key Features*** of the NHS as identified through the features/functions analysis and applicable environmental policies (definitions and criteria) and illustrated on **Figure 4.12.1**.
- ***Enhancement Areas*** as identified through the features/functions analysis and applicable environmental policies (definitions and criteria) and shown on **Figure 4.12.1**. This includes EA-1 and EA-2 (Block D), EA-3 (Block C), EA-4 (Block B), EA-5 (Block A) and EA6 (between Block D and C).
- ***Buffers*** as identified through the features/functions analysis and applicable environmental policies (definitions and criteria) and shown on **Figure 4.12.1**. This consists of a minimum 10 m buffer for the isolated woodland (0.67 ha) Unit 1a in Block A, and a minimum 15 m buffer for all other Core Area woodlands of the NHS.

Sections 4.9 discusses all of the natural heritage features identified as terrestrial constraints through the characterization process.

5.7.4 Terrestrial Relationship with Stream Reaches

As part of the evaluation and classification of stream reaches, terrestrial conditions were considered. This included the determination of the role of the terrestrial characteristics in stream function. For example, if a linear wetland exists along the stream, it will impact on aquatic habitat, maintenance of base flows and nutrient supply. Similarly, a well vegetated stream corridor assists in protecting water quality, providing nutrients to aquatic resources and detaining flows during flood events. Specific terrestrial feature and functional contributions to Tributary A, B and C are discussed in **Section 5.7.1**.

Terrestrial conditions along the streams are summarized in **Appendix I** and are used in **Section 5.9** of this report in the overall stream classification.

5.7.5 Potential Terrestrial Impacts

Generally any discussion of potential impact to natural features can be divided into the following:

- Direct impacts - Associated with disruption or displacement caused by the actual proposed “footprint” of the undertaking, including land use change from farming to urban; and
- Indirect impacts - Associated with changes in site conditions such as drainage.

Typical indirect impacts can relate to:

- Site drainage and water balance within wetlands and watercourses;
- Sediment and erosion; and
- Impacts to wildlife movement corridors.

The scientific literature contains abundant research on forest interior habitats and associated impacts of forest fragmentation as well as edge effects. For the purposes of this report, the key findings of this research have been distilled and salient points are provided. A number of helpful general references and literature reviews are available, (*e.g.,* the 2000 document prepared by the MNR entitled: *Significant Wildlife Habitat Technical Guide*. This document was prepared in support of the Provincial Policy Statement and provides guidelines for the identification and evaluation of significant wildlife habitats including forest interior and corridor habitats, amongst others).

The key findings of this huge volume of research are as follows.

Individual habitat patches (especially forested stands) are affected by their surroundings. At the edge of forested stands wind and sunlight result in drier conditions compared to the sheltered interior of the forest. As well, the edges are more accessible to predators and invasive plant species.

The extent that edge effects extend into the forest stand vary depending on a number of factors including the character of the existing forest edge, extent of buffering as well as the nature of the edge effect in question. Forest interior functions have been variously stated to be found at varying distances from the forest edge. A number of documents have recommended that forest interior habitats can be found 100, 200, or 300 m from the edge. The amount of actual interior habitat is also an important factor.

Fragmentation of habitats (especially forest stands) can result from creation of gaps that not only increase the amount of edge, but also result in smaller potential isolated remnant habitats.

In some instances, it has been found that gaps as large as 100m are readily traversed by species (*e.g.,* birds) while gaps as small as 20m may affect habitat continuity. The nature of the discontinuity is also a factor, ranging from the relatively benign affects of intervening natural habitats to more impacts associated with human-dominated uses. Taking advantage of opportunities to create linkages can reduce this discontinuity such as the potential linkage along Tributary C that will connect Blocks B and C.

In some cases forested habitats surround open pockets of habitat (*e.g.,* marshes and clearings). The forest edges bordering these open habitats are often intact and create a stable edge. As this is an interior natural “edge”, the extent of influence on forest interior habitats is anticipated to be less than edge effects associated with a cultural edge.

Beyond the habitat impacts which result from land use changes around natural habitats, the use of the lands around the outside of forested habitats, including development and roadways, can have an impact on neighbouring habitats due to noise, light and movement impacts. Introduction of exotic species as well as feral domestic pets can also impact neighbouring natural areas. The introduction of human-dominated land uses within a forested habitat can not only have footprint impacts (resulting in loss of habitat), as well as indirect impacts arising from noise, light, movement (as well as erosion and pollution depending on the use).

Research has found that despite controls to the extent of the footprint of facilities within woodlands (*i.e.,* controlling vegetation and soil disruption), that indirect impacts arise from the actual use of the facility by humans (and their pets). This involves the generation of potential noise and light impacts. Some wildlife can become habituated to these types of impacts after exposure, however when these are associated with movements or are sudden and loud, habituation is less likely to occur. A number of species of conservation concern are sensitive to these types of impacts and will not tolerate them. Other impacts such as dust and fumes may occur depending on the use. Setbacks and/or buffers are required to protect the function of remnant natural habitats.

Induced impacts are associated with impacts after the development is constructed such as subsequent demand on the resources created by increased habitation/use of the area and vicinity.

Induced impacts are described as those that are not directly related to the construction or operation of the facilities in question, but rather arise as a result of the use of natural areas as a result of the development. The simplest example is increased use of a natural area by residents. Once development is completed, subsequent use of the retained natural areas by residents is sometimes difficult to control. Another potential impact is increased mortality of fauna as a result of collisions with cars on a new road network can increase impacts on local populations.

Education of residents with respect to the values and implications of the neighbouring natural areas is one tool that can be used. A system of authorized trails can be used to focus use onto properly constructed, laid out and maintained trails. A system of signage educating residents and other users of the lands to the natural values of the area may also be used.

Cumulative impacts are associated with the spatial and temporal implications of a specific proposal in conjunction with other undertakings in the area.

In order to evaluate the potential for cumulative impacts, it is necessary to look beyond the boundaries of the specific site to the lands that currently drain to the site as well as lands that are downstream. The Subwatershed Study provides a good basis for the analysis of potential cumulative impacts. Cumulative impacts as they relate to development may arise as a result of the following:

- Spatial Crowding - Occurs when more than one proposal will occur in close proximity to others, such that there is potential for relatively minor impacts from each undertaking to add up (or combine) since they overlap;
- Temporal crowding - This can occur when phases of a development or different developments overlap in time;
- Spatial Lags - occur in cases where potential impacts are not found for some distance from the proposed undertaking.
- Temporal Lags - Cumulative impacts that arise from temporal lags are those that occur after time has elapsed between the source of the impact and the possible effect. An example of this is when compounds released change to some more problematic compound after some time of exposure to the environment.
- Shared Impact Linkages - These are similar to spatial and temporal crowding, but focus on cases where more than one development, that may not actually overlap in time or space, affects the same component of the ecosystem. An example of this is when one land use change affects the breeding grounds of a species, while a second development affects the over-wintering habitat of the same species. Potential impacts to metapopulations of species can be considered a possible source of cumulative impacts.

5.8 Aquatic Resources

5.8.1 Approach

During subwatershed planning it is useful to categorize aquatic habitats such that the relative importance of the habitat and the relative sensitivity to development can be determined. This helps to guide the management decisions surrounding a particular habitat. For the purpose of this study, a combination of systems was used to characterize aquatic habitats including; Ontario Stream Assessment Protocol(OSAP) (Stanfield et al 2007) and the Evaluation, Classification and Management of Headwater Drainage Features Guidelines (HDFA) (CVC & TRCA 2009). Consideration was also given to the 2013 (finalized in 2014) Evaluation Classification and Management of Headwater Drainage Features. These evaluations, coupled with team knowledge and detailed field surveys were used to develop the stream characterization as summarized in **Section 4.11.5** of the Analysis Report. Utilizing the characterization, a method has been designed by the study team for classifying aquatic features within the study area and will be used to provide direction to the management strategy for the features.

For each reach, an assessment was completed to determine if the particular reach was of high, medium or low significance to the overall contribution to the quality of aquatic habitat within the system. OSAP criteria including stream morphology and fish community were applied to reaches with well defined features and fish habitat. For less defined reaches criteria from the HDFA were applied to determine significance. Details on the rationale are provided in **Section 5.9**. The aquatic assessment was one component in the overall reach management recommendations. Each discipline considered the function and quality of the reaches using relevant criteria. The disciplines included hydrology, water quality, stream morphology and terrestrial resources. The results of the overall management classification assessment and the rationale for the final recommendation are provided in **Section 5.9**.

The aquatic features within the study area constitute the headwaters of Silver Creek and Sixteen Mile Creek resulting in a broad distribution of habitat classifications. Reaches that exhibited permanent flow and that supported fish communities were assigned a ranking of High. High ranking reaches were identified throughout the majority of Tributary A (Sixteen Mile Creek) as well as the downstream reaches of Tributary B (Silver Creek). These high ranking reaches also exhibited coolwater or coldwater thermal regimes. Medium reaches were often transitional reaches that linked low ranking and high ranking aquatic habitats and provide a significant contribution to downstream reaches. Several of the lower branches of Tributary B were included in this designation. Or the reaches support seasonal fish habitat and were assigned a medium ranking. These reaches included AM-6, AM-7 and A5-1. The remainder of the reaches, and this designation captures the majority, were classified as Low ranking. These reaches were poorly defined, were unable to support direct or indirect fish habitat and would not provide a significant contribution to the system. Low ranked reaches were typically provided ephemeral flow regime and lacked complex habitat features.

5.8.2 Identification of Aquatic Constraints

Several locations that support aquatic habitat functions are considered constraints within the study area. Development scenarios for the study area will recognize these limitations and incorporate appropriate provisions for the protection of aquatic habitats.

The area in the vicinity of the confluence of Reach A4-1 and Reach AM-3 has been identified as a potential groundwater discharge location. This area of discharge likely contributes flows to downstream reaches of Tributary A either seasonally or perennially. Reach AM-3 constitutes the transition point at which the influence of groundwater lessens and the thermal regime moves from a cool-coldwater regime to a warm-coolwater thermal regime. The majority of Reach AM-3 likely exhibits a cool-coldwater regime since in addition to groundwater input, the reach is well shaded which results in effective temperature moderation. As the watercourse emerges from the wooded area and transitions into Reach AM-2, the groundwater influence is reduced and the watercourse is more exposed to temperature impacts. The downstream end of Reach AM-3 and into Reach AM-2 is likely the transition point for cool-coldwater to a warm-coolwater thermal regime.

Indicators of groundwater discharge were noted along reaches B-1, B-2, and B-3 and the potential for groundwater flows was inferred. The preservation/enhancement of the wooded areas surrounding theses reaches will assist in protecting the groundwater discharge function within these reaches.

Insufficient flow is present in Tributary C to provide any direct fish habitat. Reaches C-1, C-3 and C-5 are poorly defined channels. Reaches C-2, C-4 and C-6 are reasonably well defined. Flow and nutrients would be provided to reaches downstream of Eighth Line.

Riparian vegetation provides benefits to the aquatic system and reduces erosion potential by binding soils within the root masses and creating more stable banks. Riparian vegetation also assists in maintaining the thermal benefits from the groundwater discharge by maintaining stream shading. Maintenance of current flow conditions must also be considered.

Overall, generally no development or site alteration is permitted within a watercourse. Crossings of watercourses may be permitted provided appropriate studies are completed (e.g. Environmental Impact Study) to address environmental impacts and the necessary permits are obtained from the conservation authority and/or MNRF. The majority of watercourses within the study area support direct and indirect fish habitat. Ponds are generally not considered fish habitat, even if they support fish unless they have an inlet or outlet to a watercourse. The pond located adjacent to Reach AM-1 is an example of an isolated feature. It may support a fish community but has not connected with Tributary A. Where a watercourse provides fish habitat, development setbacks of 15 m or 30 m are required for warmwater and cool/coldwater fisheries respectively. Where watercourses are associated with a floodplain, valleyland and/or the natural heritage system, additional development setbacks may also apply.

5.8.3 Potential Aquatic Impacts

Direct or indirect fish habitat has been identified in the majority of the main tributaries within the study area. The preferred development scenario will involve works to occur within or adjacent to the watercourse and would include works such as road crossings, servicing, stormwater management and a variety of land use possibilities including: low, medium and high density residential, major commercial, schools and public parks. Land use changes have the potential to cause impacts and are often cumulative and, if not accounted for and mitigated, can result in detrimental impacts to aquatic systems. For example, land use changes have the potential to create increases in peak flow conditions through landscape hardening and unsuccessful stormwater management techniques. Flashy flow conditions negatively affect aquatic habitats through increase erosion potential which degrades habitat quality, increases sedimentation within the system and stresses fish and aquatic organisms. All measures to avoid and mitigate impacts to the extent possible will be considered.

The following activities have been identified as having the potential to have a direct or indirect impact on the aquatic habitat. Grading, servicing and development of the study area will occur adjacent to the watercourses Appropriate setbacks have been recommended for the watercourses as described in **Section 5.8.2** to protect the form and function of each watercourse. However, potential impacts may still occur to the watercourse based on the proposed activity and these are outlined below:

Development

- Creation of impervious surfaces that will increase overall runoff volumes and decrease infiltration within the catchment areas of features.
- Decreases to infiltration can reduce base flow contributions to these watercourses and impact fish communities and habitat through reduced flow and elevated temperatures.
- Increased runoff and flows to the valleylands and downstream drainage features can result in erosion and flooding.
- Large flow fluctuations are probable without mitigation and also cause erosion and destabilization of the watercourse which further compromises fish habitat.

Grading

- Increase in erosion along stream banks and valleys and increased sedimentation into the watercourse from the removal of vegetation has the potential to impact fish habitat by compromising spawning, rearing and feeding processes. .

- Change in land drainage patterns, which may alter surface water inputs to watercourses impacting flows and water temperature;
- Change in land drainage patterns, which may increase erosion along streambanks and valley walls from surface water runoff;
- Change in habitat structure and cover from the removal of vegetation

Servicing

- Decrease in baseflow to watercourse from dewatering for service installation, causing increase in stream temperatures and reduced flows, potentially impacting movement of sediments and nutrients, connectivity to downstream reaches, habitat conditions (pools, water depth), dissolved oxygen and access to overhanging vegetation.
- Installation of underground services has the potential to alter groundwater flows and pathways, which may reduce baseflow contribution to watercourses, resulting in thermal impacts and altered baseflows; and
- Installation of underground services may require dewatering of groundwater which may result in reduced baseflow contributions and increase flows at discharge location

Stormwater Management

Multiple stormwater management (SWM) facilities will be required as part of the development of the study area. Stormwater runoff captured by the proposed stormwater infrastructure could affect water quality and stream stability in Sixteen Mile Creek and Silver Creek if released without quality and quantity control. In addition, thermal impacts are probable without mitigation such as bottom draws for releasing cooler water. There is also potential for increased erosion of the receiving waterbody at the discharge location. Excessive erosion of stream banks and down cutting of watercourses can also be caused by the introduction of stormwater from urban landscapes which can be harmful to the aquatic ecological environment including aquatic biota. Impacts to water quality in the receiving waterbody may include increased TSS, turbidity, nutrients, metals, thermal impacts and low dissolved oxygen inputs and will subsequently compromise fish habitat. If SWM facilities function optimally, many of these potential impacts can be mitigated; however the facilities themselves may cause impacts to fish habitat. These could include:

- Post-development, re-direction of surface water to SWM facility instead of natural infiltration may alter hydraulic regime.
- Potential interruption to groundwater flow from SWM facility liners which would impact base flow.
- Redirection of surface water contribution to one discharge point instead of across the capture area, which may reduce flow to reaches upstream of the discharge location that previously received this flow.

Watercourse Crossings

Several road crossings are proposed and it is anticipated that service crossings will be required. This may result in potential impacts including:

- Restricted flows and impact to fish passage based on the type and size of crossing structure.
- Reduced light penetration from the crossing structure resulting in decrease in amount and quality of riparian vegetation.
- Disruption of groundwater flow/upwelling into watercourse from installation of watermain and crossing structure resulting in baseflow reduction.
- Release of sediment into watercourse causing elevated TSS and turbidity in downstream reaches can affect fish by causing elevated stress levels, reduced feeding, loss of suitable spawning substrates, covering eggs and gill abrasion from the suspended particles.

- Removal of riparian vegetation may increase stream temperatures, removal of over-hanging vegetation and cover may impact feeding and refuge areas.

Watercourse crossings with closed bottoms can cause the following impacts to aquatic ecological environments:
- Reduced interaction of groundwater and surface water.
- Create potential for barriers to fish passage to form over time.
- Reduced potential to support aquatic macro invertebrate communities in substrates within culverts due to barrier between groundwater table and substrates inside the culvert.

In addition, open bottom watercourse crossings with abutments constructed too close to watercourses can:

- Cause a temporary interruption to groundwater inputs to watercourses where the abutments involve the construction of large holes in the ground in close proximity to the watercourse.
- Cause long-term harm to in-stream aquatic habitat if the edge of the watercourse meanders into the straight, hardened wall that is the inside of the culvert.

Undersized culverts can also impact watercourses in the following ways:
- Impair natural channel functions.
- Cause backwatering on the upstream side of a culvert.
- Cause scouring and erosion on the downstream side of a culvert.
- Necessitate the lining of the culvert with oversized substrate which may not be consistent with the natural substrates in the channel and could create a physical barrier to fish passage.
- Could lead to water flowing predominantly under the substrates in the culvert rather than over them, which would be a hydraulic barrier to fish passage.

Low Risk Crossings

Where a crossing has been identified as low risk, Conservation Halton requires a minimum of 1.5 metres of cover between the invert of the creek and the top of the utility pipe/casing.

A crossing will be considered low risk where generally all of the following are present:

- There are no signs of active erosion
- There are no proposed changes in upstream land use or any proposed change in land use will be supported by best/current stormwater management practices
- The gradient is low (generally less than 1.5% but preferably less)
- Small drainage area (generally less than 150 ha)
- Low erosive substrates (e.g., silty clay tills)
- Crossing is relatively small diameter (generally equal or less than 300 mm if trenchless technology being utilized; 600 mm or less if open cut)

The presence of an existing or proposed culvert overtop of the utility crossing should be taken into consideration and may allow for designation of a crossing as low risk even if one or more of the above criteria cannot be met. There may also be other situations where one or more of the above are not met but where it is appropriate to deem the crossing as low risk based on the site's specific conditions.

Medium Risk Crossings

Crossings other than those deemed low or high risk are considered to be medium risk. A minimum cover of 2.5 or 3.0 m (to be confirmed during detailed design or FSS stage) must be provided at these crossings unless supported by a detailed geotechnical assessment (including hydrogeological component) and 100-year scour analysis.

High Risk Crossings

High Risk crossings are those proposed in sensitive areas (e.g., Redside Dace habitat, Main Bronte/Sixteen/Grindstone Creek, etc.). In these areas, a detailed geotechnical assessment (including hydrogeological component) as well as a 100-year scour analysis must be undertaken to determine the appropriate amount of cover.

5.9 Stream Corridor Functions and Stream Classification for Management

General

Riparian corridor systems (along streams) are a key element of a management strategy to preserve (and provide for enhancement of) form and function within a subwatershed. Riparian lands are typically the most fertile and productive part of the landscape in both primary production and ecosystem characteristics. These corridors often have better quality soils and typically retain moisture over a longer period.

There is a complex interaction between riparian land and the stream that it is adjacent to. Riparian land will “buffer” the streams against sediment and nutrient wasting of adjacent lands, it will be a source of food to aquatic organisms through insects and other matter that falls from trees and shrubs. Similarly, aquatic organisms are food to wildlife that lives in the riparian vegetation. The shading effects of vegetation will reduce temperatures or prevent temperatures from rising in the stream, protecting aquatic life.

The role of a riparian system can be summarized as:

- Trapping sediments, nutrients and other contaminants that are in streamflow during high flow stages;
- Reducing the rates of erosion and providing bank stability;
- Controlling nuisance aquatic plants (*i.e.,* algae) by reducing nutrient levels,
- Providing stream shading which is very important for temperature moderation
- Helping to ensure healthy stream ecosystems;
- Providing a source of food and habitat for stream animals;
- Providing an important location for conservation and movement of wildlife (*i.e.,* corridors, linkages);
- Providing recreation and delivering an aesthetically pleasing landscape.

It is therefore important to identify the riparian corridor systems that exist assess their function from an overall subwatershed perspective and develop a management strategy to protect and enhance. As a result, identifying the riparian corridors that need to be preserved and enhanced are a key element of the management strategy, and just as important as the terrestrial features that have been identified (discussed in **Section 5.7**).

The riparian stream and riparian corridor system developed for this study area is based on the current stream conditions and, in particular, aquatic habitat provided. In addition connectivity with terrestrial features and upstream and downstream aquatic conditions is taken into account.

Identification and Classification of Riparian Corridors

In identifying and classifying the riparian corridor system both the overall form that exists (characteristics) and function of the corridor must be considered. To include the underlying philosophy of subwatershed planning, to protect and enhance environmental conditions, the overall potential of a corridor that may currently be degraded must be considered. For example, a stream that has been altered, but provides a potential linkage function between two terrestrial units, or can provide a role in protecting downstream receiving system must be considered for its potential role in meeting the management objectives.

As indicated in the introductory section, the role of riparian corridors are as complex as they are important. Their characteristics and functions however can be evaluated through the analysis carried in this phase of the Subwatershed Study.

The stream characterization outlined in **Section 4.11.5** of the Analysis Report provides an overview and characterization based upon the 2009 CVC/TRCA headwater classification system (CVC/TRCA 2009). In addition, consideration was given to the more recent version of this document (CVC/TRCA 2014). This process of analysis provides a method of reviewing the classification of the stream reaches with some direction on how they should be managed. This was used as a basis for classifying the stream system in the study area. However, additional items were included to further analyse and develop a management approach for the headwater streams that are specific to this study area including:

- Conservation Halton has a policy of requiring the consideration of retaining the floodplain on all watercourses, regardless of the upstream drainage area.
- Some of the lands within the study area are extremely flat, resulting in a very significant floodplain. The management approach for this floodplain needs to be considered in the overall management of the stream corridors.
- The existence of a temporary berm (created through roadside ditch maintenance along Trafalgar Road) has resulted in an impact on the characteristics and function of Tributaries A2 and A5. This needs to be considered in the development of a management approach.
- There are terrestrial features including Block C, Block B and Block A (see **Figure 4.9.1**) that provide a connectivity function, as well as the potential for the enhancement of terrestrial linkages that needs to be taken into consideration. These linkages could extend beyond this Block into areas south and west that may be developed in the future. Establishing the need for linkage onto adjacent lands as development in these areas occurs will follow from the linkages established as part of this subwatershed study.
- The smaller branches along the main branch off of Tributary B, are for the most part, exhibiting incision. This needs to be considered in their classification for management.
- Evaluation, considering conditions both before and after filling.
- The impact of the modifier was considered in the classification.
- Evaluation of modified features included an assessment of upstream and downstream reaches of the feature, including historical conditions as well.

It should be noted that it is Conservation Halton’s practice to ensure maintenance of the eliminated function of flood storage and flood conveyance within the associated downstream riparian corridor to remain on the landscape. Conservation Halton regulates the floodplain hazard associated with watercourses having drainage areas greater than or equal to 50 ha, but also recognizes and regulates flood hazards associated with watercourses with smaller drainage areas. Working through a variety of subwatershed studies, Conservation Halton staff has found that drainage areas larger than 50 ha have generally been required to be maintained as open features on the landscape to maintain:

- Balanced, incremental flood storage,
- Conveyance of flow within an open system,
- Sediment transfer,
- Drainage density, and
- Water balance.

Occasionally, features with smaller drainage areas have been required to be maintained on the landscape as regulated features to achieve the above objectives.

Conservation Halton supports the holistic review of systems in determining whether or not features need to be maintained on the landscape, however they require that this review confirm that any proposed modification to the watershed ensure:

- Conveyance and existing floodplain storage is replicated on an incremental basis for all regulated features, also flood storage is to be maintained for all systems with drainage areas >50 ha that are proposed to be removed,
- Sufficient replication of upstream channel functions are maintained to ensure a ‘stable’ natural channel regime within the proposed open channel blocks,
- Existing water balance is maintained, and
- The development limit is maintained outside of all natural hazards, including the regulated floodplain and erosion hazard.

Where systems are required to remain open on the landscape, maintenance of incremental floodplain storage and designated regulated floodplain will be required, regardless of the size of the upstream drainage area.

Each of the factors listed above are specific to this study and need to be taken into consideration in the development of a management approach for the stream corridors. The factors require considering the headwater classification used in **Section 4.11.5** and developing the further through analysis of the functions of the stream corridors involved on a subwatershed basis and identify the management required to continue this function.

It is important to recognize that, although the headwater classification guidelines were applied as the first step in classifying and ranking the stream corridors (see **Section 4.11**), the classification protocol is for headwater streams. In the analysis, in this section of the report, that classification is expanded to recognize that some of these streams are main tributaries, such as the main branches of Tributary A and B. The characteristics and functions of these are considered in a different way, such as the connectivity to the smaller tributaries, existence of a valley feature, and linkage to adjacent terrestrial features etc.

This additional analysis was carried out considering the aquatic, terrestrial, fluvial geomorphology, and hydrologic/hydraulic functions of the stream reaches. Conservation Halton staff had specific concerns regarding the role and functions related to Tributaries A and C. As a result, this assessment was also carried out in a workshop type format with Conservation Halton technical staff on two occasions to discuss and develop a consensus on the approach. The consensus developed in these workshops is provided in **Appendix P**.

In classifying the streams for management, the analysis included the considerations in each of:

- hydrologic, hydraulic and hydrogeologic perspective (**Section 5.4**);
- water quality perspective (**Section 5.5**);
- stream morphology perspective (see **Section 5.6**);
- terrestrial resources perspective (see **Section 5.7**); and
- aquatic resources (i.e. fishery) perspective (see **Section 5.8**)

From a hydrogeologic perspective, **Section 5.4** above considers the stream connection to the groundwater system in supporting baseflow discharge and its role in supporting aquatic life. This section describes the hydrologic/ hydraulic analysis of selected stream reaches carried out for delineation of the floodplain, to assess the hydrologic role of the stream corridors. In addition, a water quality control function is considered and presented.

5.9.1 Hydraulic Stream Characterization

The hydraulic analysis included the development of floodlines along selected watercourse reaches. Watercourses were selected based upon the watercourse definition and overall drainage area. A 50 ha limit was a factor used in the selection of the watercourse reach for developing floodlines, but was not the sole determinant.

The design flows for the hydraulic model were provided by hydrologic modelling (see **Section 5.4**). The resulting floodlines for Regional storm event was plotted on Topographic mapping provided by the Town of Halton Hills, sourced from J.F. Sabourin and Associates Inc. (2015). The floodlines are suitable for the purpose of the subwatershed study and meet the specifications for the regulatory floodlines for use as a regulatory limit.

The calculated floodlines were used in the assessment of flood potential as well as use in the assessment of the hydrologic role of the stream corridors (see **Section 5.4.3**).

Stream Geomorphology and Streambank Erosion

The hydraulic analysis provided information on stage – discharge – velocity for the streams along the reaches modelled. The information was incorporated into the geomorphologic consideration of erosion potential stream geomorphology is discussed in **Section 5.6**.

Hydrologic Stream Functions

Stream reaches were evaluated based upon their function with respect to hydrologic process. This included their ability to accommodate stormwater runoff, connection to other features with a hydrologic role (*e.g.*, wetlands, storage areas), and function as a headwater stream. The characterization was combined with other physical stream characteristics (*i.e.*, environmental, geomorphologic, and hydrogeologic processes) to provide an overall riparian corridor characterization.

Role in Providing Storage

One of the key functional roles considered in this evaluation is the attenuation of flows, or storage provided. Natural stream corridors with a well-defined riparian system provide a role in flow attenuation. This attenuation slows water during overbank flow conditions (*i.e.*, greater than 1:1.5 – 1:2 year events). This leads to reduced peak flow rates and reduced erosion rates. If the riparian system is well vegetated, the storage of flows will also act to remove pollutants.

The evaluation of this storage function was based upon the hydraulic analysis results as well as review of air photos/topographic information and field reconnaissance. The hydraulic modelling provided the data necessary to compare the storage by each reach.

Water Quality Improvements

The ability for a stream corridor to provide ability to provide a water quality control function was another factor considered in the evaluation process. Water quality improvement is provided through the existence of a well developed buffer system and vegetated riparian system. To provide good ability to improve water quality, the buffer would contain a mix of trees and low growing vegetation (*e.g.*, grasses, shrubs). This will assist in both buffering the stream from adjacent lands and removing pollutants during high flow stages.

5.9.2 Stream Classification and Management Requirements

In developing the overall classification and management requirements for the watercourse system, the characterization developed in **Appendix I** was used as a basis. This was coupled with information developed through the analysis to develop the final classification and management approach.

The overall rating, including rating for management is included in **Table 5.9.1**. As the rating for each watercourse was developed, it was determined that differences for the overall rating and what was required for management became evident. This was primarily a result of the fact that some watercourse reaches, although in a degraded state, are important to the overall subwatershed characteristics and functions (including connectivity) and would require improvements as part of the management plan.

In developing the overall classification and requirements for management in **Table 5.9.1**, each stream reach was evaluated by the relevant disciplines including; aquatic conditions including water quality, terrestrial resources including linkages, stream morphology and flooding/conveyance including hydrogeology. The watercourses were ranked on an individual basis and then an overall rating was developed through an integration of the input by each discipline. The integration was carried out in a workshop type format to discuss each reach in turn, develop the net ranking as well as identify any management requirements specific to each reach.

Table 5.9.1 Net Rating and Management Rating

Watercourse ID	Fisheries/Water Quality	Terrestrial Resources/Linkage	Stream Morphology	Flooding/Conveyance	Net Rating	Management Rating
AM-1	HIGH	HIGH	HIGH	MEDIUM	HIGH	HIGH
AM-2	HIGH	HIGH	HIGH	MEDIUM	HIGH	HIGH
AM-3	HIGH	HIGH	HIGH	MEDIUM	HIGH	HIGH
AM-4	HIGH	HIGH	HIGH	MEDIUM	HIGH	HIGH - REHAB
AM-5	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH - REHAB
AM-6	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM
AM-7	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM
A2-1	LOW	LOW	LOW	MEDIUM	LOW	MEDIUM
A2-2	LOW	LOW	LOW	MEDIUM	LOW	MEDIUM
A4-1	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM
A4-2	LOW	LOW	MEDIUM	MEDIUM	LOW	POTENTIAL MEDIUM
A4-3	LOW	LOW	LOW	MEDIUM	LOW	LOW
A4-4	LOW	LOW	LOW	MEDIUM	LOW	OMIT
A5-1	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM
A5-2	LOW	LOW	MEDIUM	LOW	LOW	OMIT
BM-1	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
BM-2	HIGH	HIGH	HIGH	MEDIUM	HIGH	HIGH
BM-3	MEDIUM	HIGH	HIGH	LOW	HIGH	HIGH
BM-4	MEDIUM	LOW	MEDIUM	LOW	LOW	MEDIUM
BX-1	LOW	LOW	MEDIUM	LOW	LOW	MEDIUM
BX-2	LOW	LOW	LOW	LOW	LOW	LOW
B0-1	LOW	LOW	MEDIUM	LOW	LOW	LOW
B0-2	LOW	LOW	LOW	LOW	LOW	LOW
B1-1	LOW	LOW	LOW	LOW	LOW	LOW
B2-1	LOW	LOW	LOW	LOW	LOW	LOW
B3-1	LOW	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM
B3-2	LOW	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM
B3-3	LOW	LOW	LOW	LOW	LOW	LOW
B4-1	LOW	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM
B4-2	LOW	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM
B4-3	LOW	LOW	LOW	LOW	LOW	LOW
B5-1	LOW	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM
B5-2	LOW	LOW	MEDIUM	LOW	LOW	OMIT
C-1	LOW	MEDIUM	LOW	LOW	LOW	SPECIAL MEDIUM
C-2	LOW	MEDIUM	MEDIUM	LOW	LOW	SPECIAL MEDIUM
C-3	LOW	LOW	LOW	LOW	LOW	POTENTIAL MEDIUM
C-4	LOW	MEDIUM	MEDIUM	LOW	LOW	SPECIAL MEDIUM
C-5	LOW	MEDIUM	LOW	LOW	LOW	LOW
C-6	LOW	MEDIUM	MEDIUM	LOW	LOW	SPECIAL MEDIUM

Note: The Management Ranking has introduced some special categories (i.e. High-Rehab). The meaning of, and need for these are discussed in Table 5.9.2.

The stream ratings and classification for management are illustrated in **Figure 5.9.1**.

As noted in **Table 5.9.1**, the stream reach is rated as either low, medium or high, depending upon the characteristics. The specific considerations given in each discipline include:

Fisheries/Water Quality

High Rating
- If fish are present, or it is judged that habitat is suitable for fish on a perennial basis or for the majority of the year.
- If water temperature is sufficient to provide a source of cool water to a cool or coldwater reach.

Medium Rating
- Reach is judged to provide seasonal fish habitat and a significant flow and nutrient contribution to downstream reaches. Typically a contributing stream.

Low Rating
- Does not provide direct or indirect habitat and does not provide significant contribution.
- Flow regime is typically ephemeral.

Terrestrial Resources/Linkage

High Rating
- Reach has a good quality terrestrial riparian system along the watercourse.
- Reach provides a good linkage to a significant terrestrial resource upstream.

Medium Rating
- Riparian corridor exists but not judged to provide a good quality habitat.
- Provides a linkage to upstream terrestrial resources, but not good quality.

Low Rating
- Reach does not have an identifiable riparian corridor from a terrestrial standpoint.
- No identification function from the standpoint of a linkage to upstream terrestrial resources.

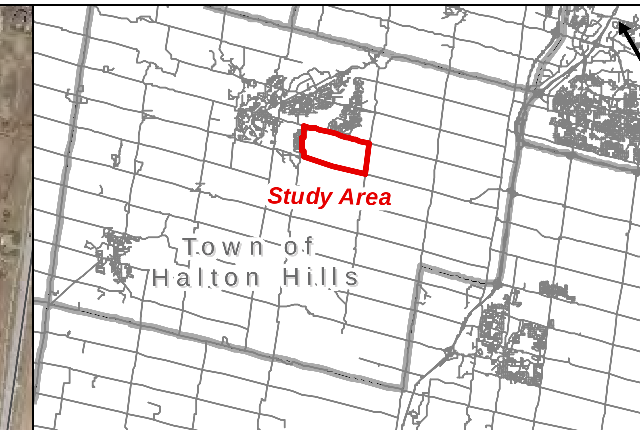
Stream Morphology

High Rating
- Reach has defined bed and bank (either stable or in transition), or it is judged that the watercourse provides the function of a “natural” watercourse including sediment transport.
- In addition, the function provided from a stream morphologic standpoint is site specific and relocation would result in a negative impact.

Medium Rating
- Reach either provides the functions and for the form of a natural watercourse or would if allowed to transition.
- In addition, that this function is not site specific and could be relocated.

Low Rating

- Stream has no bed and bank definition and if in agricultural lands is typically worked the same as table land.



Legend

N

Watercourse Characterization

- Low
- Medium
- High
- High-Rehabilitation Needed
- Enhance In Current Location
- Potential Medium

General Features

- Intermittent Watercourses
- Permanent Watercourses
- Roads
- Study Area
- Conservation Authority Boundary*

Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600
Meters

Southwest Georgetown Integrated Planning Project

Watercourse Characterization for Management

June 2016	1:10,000	Datum: NAD 83, Zone 17 Source: Chapman and Putnam, 2007. Ontario Geological Survey, MRD 228, LIO
P#: 60297831	V#: 005	

AECOM

Figure 5.9.1

Map location: P:\60297831 SW Georgetown\900-CAD-GIS\920 GIS-Graphics\Design\Groundwater Report Figures

Floodplain/Conveyance

The rankings for floodplain and conveyance are not as prescriptive as with the other categories, however, the approach used to provide a relative comparative ranking is outlined as follows:

- The reaches were rated from a floodplain standpoint based upon the relative flood storage provided (normalized, based upon drainage area and reach length). This provides a comparison of the relative storage volume and similarly flood attenuation provided. The comparison was strictly numerical with the highest third being ranked high.
- Floodlines are evaluated to the 50 ha drainage limit.
- Reaches with an observed baseflow discharge location or measured baseflow increase (related to groundwater discharge) are given a high ranking.
- Reaches that are judged to provide a significant hydrologic linkage to upstream reaches and that function should be maintained are assigned a higher rating.

The net ratings were generally developed based upon the following protocol:

- Two or more high ratings resulted in an overall high ranking.
- Three or more medium ratings resulted in an overall medium rating.
- Two medium and a high rating would result in an overall medium rating.

The ratings however, were not totally prescriptive. Judgement was used to develop an overall rating based upon the relative importance of characteristics and function.

The final column on **Table 5.9.1** provides a management rating. This was developed to reflect the fact that, although a reach was exhibiting certain characteristics and functions that resulted in a specific ranking, it did not reflect the potential enhancement that could be achieved to meet the overall watershed goal to protect and enhance watershed function. It was judged that, with some reaches, an enhancement could be provided that would improve the overall watershed resiliency to watershed change and further protect either terrestrial on aquatic features. These are highlighted in **Table 5.9.2** which explains the decision process being the reach ratings in **Figure 5.9.1**.

In the ranking developed for the stream reaches the following definitions apply for evaluation and management.

High Ranking

Provides an important function to the subwatershed and the conditions are comparatively high level.

- Aquatic habitat will be high quality with a diverse fish community.
- Streams provide good definition and typically will have a riparian corridor system (but may be impacted by adjacent land use).
- May or may not be part of a terrestrial feature.
- May have contributing baseflow or interflow function that is dependent upon the location of the watercourse.
- Will have a floodplain where storage function needs to be maintained.

From a management perspective watercourse will need to remain in its current location and rehabilitation may be required to protect and enhance its current function.

Medium Ranking

Provides a function to the subwatershed as an open watercourse that should be maintained.

- Floodplain storage to be maintained (greater than 50 ha of drainage).
- Provides good drainage connectivity to upstream drainage area.
- Provides seasonal or complex contributing habitat, but will be generally degraded, requiring enhancement.
- May have riparian or adjacent terrestrial habitat but will likely be degraded.
- Stream definition will be good (bed and bank) but likely impacted by past or on-going land use activities.
- Displays groundwater discharge potential.

From a management perspective, the reach should be preserved but enhanced as a natural channel with a riparian system and floodplain storage facilities preserved in accordance with Conservation Authority policies. During restoration, watercourse can be relocated however, riparian corridor length should be maintained.

If relocated, the following must be demonstrated:

- Maintain conveyance and existing floodplain storage on a balanced incremental basis for all design storm events.
- Replicate channel functions to ensure a ‘stable’ natural channel regime within the proposed open channel blocks through recreation of an appropriate geomorphic natural channel morphology consistent with anticipated drainage, gradient and sediment transport regimes.
- Maintain existing water balance.

Low Rating

The watercourse has an overall low function.

- Little or no definition from a fluvial geomorphologic standpoint.
- No contribution to fish habitat, ephemeral flow regime.
- No terrestrial amenities.
- Minimal riparian preservation.
- No significant linkage to upstream drainage provided.
- No observed or potential groundwater discharge.

From a management perspective the reach would primarily be required to maintain drainage density and would provide a source of sediment and organics to downstream reaches that are being maintained.

Table 5.9.2 Development of Overall Stream Classification Net Rating and Management Rating

Watercourse Reach	Management Rating	Reasoning Behind Rating
AM-1, AM-2, AM-3	High	These watercourse reaches are in reasonably good condition from an environmental perspective and provide fish habitat. These reaches are ranked as cool water based upon the temperature monitoring carried out. There is a suspected local, seasonal groundwater discharge point approximately midway along tributary AM-3 that would need to be considered further during development design and protected as needed. The riparian condition is somewhat degraded on AM-1 and AM-2 and would benefit from enhancement. There is an off-line pond adjacent to AM-1 that provides minimal connection to the watercourse and it is judged that it can be removed. The management approach should target enhancement of the riparian system to protect water quality, provide cooler water temperatures and a terrestrial linkage. The stream morphology monitoring location used to set the erosion threshold target for Tributary A is in this reach.
AM-4, AM-5	High - Rehab	These reaches are in transition. It appears that, in the past, that they were enlarged to a trapezoidal shape, and straightened, for agricultural drainage purposes. The reaches have been recovering, from fluvial geomorphologic standpoint, in that a meandering low flow channel has formed in the bottom of the trapezoidal channel. In addition, bank vegetation is establishing including grasses and some brush. Flows in the channel have been observed as intermittent and the channel transitions from a cool water stream downstream to warm water upstream. Fish have been observed in the channel during spring months. Given the channel characteristics and functions it should be preserved as a natural functioning watercourse but requires rehabilitation. The performance criteria to be followed for the reach modifications are provided in **Appendix V**. The relocation of these reaches may be possible as long as the functional characteristics of the stream corridor are protected and/or enhanced. This should include maintaining the current corridor length as well as the fluvial, fish habitat, floodplain, and hydrogeological conditions and functions. From a hydrogeological perspective, this function have been discussed in **Sections 5.4.4, 6.3.4, 7.4.4,** and illustrated in **Figures 5.4.5**, **5.4.6**. If relocation is being considered, relocation of a minor extent is preferred to facilitate the replication of current conditions and functions. As part of rehabilitation works, the 90° bend at the transition from AM-4 to AM-5 should be modified to an appropriate curvature radius consistent with channel morphology requirements. There is potential to enhance the connection to a small terrestrial feature at the upstream end (1a in Block A, see **Figure 4.9.1**). The cross-section for AM-4 and AM-5 should be designed in a manner which is conducive to a diversity of locally native and common riparian plantings that can be successfully established and grow in a succession of vegetative community types in a self-sustaining manner.
AM-6, AM-7, A5-1	Medium	All three of these reaches (including AM-5) provide a fairly high flooding and conveyance function, primarily through the relatively high floodplain storage, as compared to other tributaries. This is a result of the flat table lands adjacent to the reaches and topographic construction along AM-5 which raises flood levels locally. From a conveyance standpoint, reaches A5-1 and AM-7 provide an outlet for lands upstream of Trafalgar Road and Number 10 Side Road respectively. Under current conditions, there is a diversion of normal flows from the upper limit of A2-2, along Trafalgar Road to A5-1. This is only temporary in nature, however, and for purposes of this study, the normal flow pattern to tributaries A2-2 and A5-1 are used for analysis.

Watercourse Reach	Management Rating	Reasoning Behind Rating
		Both river morphology and aquatic characteristics for these reaches are ranked as medium, primarily due to the poor physical form of the channel, and that the channel provides intermittent habitat and a contributing function to downstream fisheries. Overall the channel is given a medium rating for overall condition and management. It is judged that these reaches should be maintained as open natural watercourses, but rehabilitated. Relocation is possible, but overall riparian length should be maintained. The drainage area to reach A5-1 is approximately 103 ha. As a result, floodplain storage characteristics are to be maintained as per Conversation Halton policies. The performance criteria to be followed for the reach modifications are provided in **Appendix V**.
A2-1, A2-2	Medium	The drainage to tributary A2, is significant (170.2 ha), see **Figure 4.6.1**), however the low flows have been diverted to the road side ditch on the east side of Trafalgar Road which, in turn, conveys the flows to reach A5-1. This diversion is judged to be temporary, since it has been created by a mound of earth blocking the top of reach A2-2, most likely created inadvertently through ditch cleaning maintenance. If a significant runoff event occurred the earth mound would likely be breached and wash out. For the purpose of this analysis, it is assumed that the earth mound and related diversion does not exist. The net ranking for reach A2-1 and A2-2 was determined to be low as a result of the following: • The watercourse definition is poor, however it is judged that this is a result of the temporary flow diversion. The tributary upstream of Trafalgar Road has a well defined bed and bank and, if continued through reach A2-1 and A2-2, would likely be ranked as a medium stream. • There are no signs of fish or contributing habitat resulting in a low ranking. • There are terrestrial linkages to the tributary upstream of Trafalgar Road, however this is primarily to a minimal riparian corridor along the watercourse, resulting in a low ranking as well. However, due to conditions upstream of Trafalgar Road, on this tributary, it is recommended that this tributary be managed with a medium ranking as a result of the following: • There is an opportunity to connect with the watercourse upstream of Trafalger Road after the blockage is removed. The tributary upstream of Trafalgar Road has better definition with a narrow, vegetated riparian system, providing for a potential ecological linkage to downstream reaches. • Under the Headwater Classification Guidelines applied to these tributaries, the overall rating is to take upstream conditions into account when classifying reaches. • The drainage area upstream of Trafalgar Road is significant. As a result, through Conservation Halton policies, the floodplain must be maintained. As a result of the requirement to maintain the floodplain and the tributary linking to a well defined watercourse with a riparian corridor upstream of Trafalgar Road, it is judged that the watercourse be managed as a medium ranking. Through this, it is recommended reach A2-1 and A2-2 be rehabilitated or relocated as a natural watercourse with the floodplain function preserved. The performance criteria to be followed for the reach modifications are provided in **Appendix V**.

Watercourse Reach	Management Rating	Reasoning Behind Rating
A4-1, A4-2, A4-3	A4-1: Medium A4-2: Potential Medium A4-3: Low	The overall drainage area to the A4 tributary is approximately 107 ha. As a result, the floodplain function is to be preserved under the current Conservation Halton policy. The reach rankings were based upon the following: • Reach A4-1 was found to have good definition and fluvial geomorphologic functions resulting in a high ranking. • Similarly a contributing aquatic habitat function, good riparian corridor and linkage to the terrestrial amenities provided by Block A (**Figure 4.9.1**) led to a medium ranking for terrestrial and aquatic. • The geomorphologic definition, terrestrial and aquatic amenities dissipate within reach A4-2 and A4-3. • The flooding and conveyance functions for A4-1, A4-2 and A4-3 are ranked as medium as a result of linkage to upstream drainage, although floodplain storage is relatively low. From a management standpoint, it is recommended that A4-1 and A4-2 be managed as a medium stream, primarily due to the need to preserve floodplain storage function. The management of A4-1 as a medium stream (natural channel with a riparian corridor and floodplain) is required as a result of current conditions and functions. Management of A4-2 and as a potential medium stream provides enhancement to this portion of the subwatershed. A portion of the floodplain for A4-3 will need to be maintained in accordance with Conservation Halton Policy, however the stream does not need to be managed as an natural watercourse.
BM-1, BM-2, BM-3	High	These tributaries are in a well defined valley and exhibit similar conditions and functions: • Each reach is well defined from a fluvial geomorphologic standpoint and is situated within an established valley system with a good riparian corridor on each side. • The valley and watercourse are incised with some downcutting occurring, except at reach BM-1, which has deposition occurring. This is primarily a result of the culvert and road embankment at Eighth Line. • Aquatic habitat is provided throughout with fish observed in BM-1. BM-2 likely provides seasonal fish habitat and BM-3 appears to be contributing habitat as a result of in-stream barriers and stream slope. • Floodplain is confirmed to the valley system and needs to be preserved. The management requirements for all these reaches are ranked as high. The watercourse is to be preserved in its current location. Rehabilitation is not required as a result of the quality of vegetation in the terrestrial feature in the valley system.
BM-4, B4-1, B4-2, B5-1, B3-1, B3-2, BX-1	Medium	Each of these reaches is connected directly to the main tributary B, located with the valley system. Their form and function are primarily a result of the valley feature and main tributary characteristics: • Each reach is within the defined valley, both from a topographical and adjacent vegetation standpoint. • They are similar to the main branch, in that they are in an incised valley, although not as deep as the main valley. Since they are incised, hazard setbacks are required. • They are ranked lower from a fisheries standpoint than the main branch in that they do

Watercourse Reach	Management Rating	Reasoning Behind Rating
		not provide direct habitat, but would be contributing flow and nutrients to the main branch. • Drainage in each is less than 50 ha and, as such, floodplain storage preservation is not required, however, they provide a conveyance function in connecting the table lands adjacent to the valley to the main tributary. From a management perspective, each tributary needs to be maintained and the environmental and conveyance functions preserved an enhanced. There may be potential for relocation, but it is somewhat limited due to the valley feature. Relocation is only feasible where the tributary is not incised within the valley.
B1-1, B2-1, B0-1, B0-2, BX-2	Low	These features are of low value, with their main function providing conveyance from the table land to the valley system and simple contributing fish habitat. They will be required to meet the drainage density target for tributary B and provide the function of sediment and organic source to the valley system. It is recommended that they be managed as greenway type drainage courses either as grassed waterways or roadside ditches.
C-1, C-2, C-3, C-4, C-5, C-6	Special Medium C3: Potential Medium C-5:Low	This is the second tributary in the study area that is within the Sixteen Mile Creek watershed, conveying flows across Eighth Line. It joins tributary A approximately 500 m downstream of Eighth Line and then crosses Side Road 10. The rating varies along its length as a result of varying conditions: • Reaches C-1, C-3 and C-5 area all poorly defined channels from a fluvial geomorphologic standpoint, with no defined bed and bank. • No fish habitat is present and no fish recorded for the reaches. These are connected to a well-defined water course downstream of Eighth Line that does provide fish habitat. • There are no terrestrial or riparian conditions along the reaches, except for reach C-2, C-4 and C-6. In this case the reach passes through well defined terrestrial features and in the case of C-2 and C-4 the reach is a defined watercourse with bed and bank and good morphological characteristics. From a management perspective, C-2, C-4 and C-6 have a special classification as red and blue. Since these reaches are defined and are part of a terrestrial feature, it is recommended that they be preserved and kept in their current location. There is an opportunity to enhance them. In addition, it is recommended that reach C-3 be enhanced and potentially be relocated so that it is adjacent to the woodlot in Block B (see **Figure 4.9.1**). It should be rehabilitated as a natural channel with a riparian corridor. It is recommended that reach C-5 be managed “as a “green corridor”. This is not intended to be the same as a green stream, but to provide two functions: • It should provide a drainage link between C6 and C4. This could be in the form of either an open swale or closed pipe. However, if a pipe, it is recommended that it could provide an infiltration role as well. • There should be a green corridor linking the terrestrial features (Blocks B and C). A minimum width of 15m is recommended, but this could be a multiple use corridor, including trails or utilities. It should include landscape plantings as well to provide for general wildlife passage.

Note: This information has been developed with the understanding that the maintenance berm at the top end of A2-2 will be removed as part of future work.

5.10 Opportunities, Constraints, Management Needs

5.10.1 Introduction

Future urban land use in the Southwest Subwatershed presents challenges and opportunities for maintaining and enhancing ecological functions. Appropriate management measures must be applied to mitigate the following potential impacts:

- Flood and erosion potential;
- Water quality impacts to receiving system;
- Reduced groundwater infiltration to the aquifer system;
- Potential quality impact to municipal well supply;
- Reduced baseflow to the creek system;
- Stress to fishery resources ;
- Impacts to wildlife habitat; and
- Impacts to woodlands and wetlands (changes in species and health of vegetation due to changes in groundwater, and edge impacts).

The stressors and potential impacts to the study area and the watersheds (upstream and downstream) are summarized in **Table 5.10.1** including the constraints to both management and future land use change, the management opportunities that exist, and the considerations that need to be given to developing a management strategy as a result are summarized.

The considerations for management can be divided into three main areas:

- Riparian Corridor System
- Terrestrial Natural Heritage System
- Stormwater Management

5.10.2 Riparian Corridor System

The form and function of the riparian corridors (and streams) have been evaluated on a reach basis in the following sections.

Hydrogeology and Water Balance - Section 5.4

- To consider the stream correction to the groundwater system in supporting baseflow discharge and its role in supporting aquatic life.

Hydrology, Hydraulics, Water Quality - Section 5.4, 5.5

- The role of the stream corridors from a hydraulic perspective in providing flow augmentation, and the potential to improve water quality.

Stream Morphology - Section 5.6

- The condition of the stream from a geomorphologic standpoint and associated erosion process as well as the overall quality as a stream corridor (including aquatic habitat structure).

Table 5.10.1 Stressors, Constraints, Opportunities and Management Needs

	CHARACTERISTICS AND STRESSORS	CONSTRAINTS	OPPORTUNITIES	MANAGEMENT IMPLICATIONS
1	• The watercourses have been impacted upon by past land use activities. Many of the reaches have been straightened and there is an overall lack of good riparian vegetation. Regardless many of the reaches that have been straightened in the past are transitioning to a more natural form.	• Agricultural activities have encroached upon the watercourses over much of the reaches, resulting in impacts to water quality and aquatic habitat. An improved riparian corridor would require additional width for an appropriate buffer	• The riparian classification system has been developed identifying the requirements to protect and enhance the watercourse network. When adopted, aquatic and terrestrial habitat conditions will be improved to provide the required resiliency for proposed adjacent future urban land use. • Opportunities to enhance the form and function of headwater drainage features within the study area exist given the extent of surface area present, which are draining to conveyance features that have been degraded by past land uses • All of the channels in the A and C tributaries have an existing slope which is greater than 0.5% with the exception of C-2 and A5-1. This presents an excellent opportunity to introduce natural channel design into the systems (where appropriate) and to still retain enough slope to allow for proper water flow and sediment transport with reduced risk of overgrowth of vegetation within newly constructed channels. For this opportunity to be realized, it will be important that erosion thresholds are set in a way that allows a balance between aggradation and degradation of the bed and banks of the watercourses.	• A management approach is required that will incorporate the required riparian corridor system for the stream network into the urban plans
2	• Tributary B is located within an incised valley system and is actively downcutting. It is judged, that if this process continues, it will result in the valley system extending further upstream. • The valley wall system requires setback considerations from a hazard land standpoint.	• The valley lands result in a defined feature which requires consideration from a hazard land standpoint. Stable slope setback requirements will set a constraint limit to adjacent land use. • Future land use changes could potentially impact on the valley incision process. A SWM approach will be needed to retain the current valley form.	• There is an opportunity to divert flows in combination with SWM, including LID to reduce erosion forces within Tributary B and thereby reduce the incision process.	• The SWM plan will need to address current incision of the valley wall and provide an approach to reduce this to an acceptable level. • Appropriate setback limits will be required to meet hazard policies for stable valley wall slope.
3	• There are good quality terrestrial features within the study area that provide quality habitat and require protection under current policies. There have been some impacts from past land use activities that can be mitigated through management.	• The terrestrial features will provide a constraint to future land use. In addition, a buffer system will be required outside the current physical boundaries for protection of these features. • Consideration need to be given to some enhancement as well, to provide for connectivity between the features, and protect current functions.	• There are enhancement opportunities for connectivity between Blocks C and D to preserve existing terrestrial habitat corridors. • The proposed riparian corridor system for the stream network provides opportunities to enhance connectivity within the study area and from a watershed perspective	• The buffer system developed as part of the management strategy will need to provide the appropriate protection of the terrestrial system characteristics and functions. • Consideration needs to be given to enhancement opportunities, to provide increased resiliency as well as an appropriate buffer system
4	• Upstream and downstream watershed conditions influence the management requirements within the study area. • The upstream reach to Tributary A2 has a good stream definition and riparian system (although encroached upon by current land use activities). • The downstream watercourses for all tributaries (A, B and C) provide fish habitat and (although somewhat degraded in general) a good riparian system. These conditions require protection through the management strategy	• The degradation of the stream system, through past and current activities require the development of an enhanced riparian drainage network that with protect upstream and downstream conditions and provide the necessary connectivity. • Terrestrial and aquatic connectivity to watershed conditions outside the study area will require the development of a corridor system within the land use plan	• The current riparian corridor that has been identified through the stream classification system has taken into account the require connectivity outside the watershed.	• The management strategy needs to consider the protection of upstream and downstream conditions through the identification of the required corridors. • The SWM plan, including LID will need to provide the appropriate quantity, quality and erosion conditions to protect the receiving system.

	CHARACTERISTICS AND STRESSORS	CONSTRAINTS	OPPORTUNITIES	MANAGEMENT IMPLICATIONS
5	• The change to urban land use will result in the potential impact to flow response characteristics with related impacts to flood, erosion potential, water quality, and related water quality impacts	• Appropriate flood protection policies will impact on the future land use pattern through the need for the appropriate protection of the watercourse system and floodplain characteristics. Road crossings over watercourses will need to provide the appropriate capacity and flood protection. • The required SWM and LID will need to be incorporated into future land use patterns. • The stream and riparian corridor will require enhancement to provide appropriate protection of the receiving watercourse.	• The steam riparian corridor identified will provide the appropriate network to accommodate flood protection policies, as well as meet the stream morphology needs and environmental protection requirements. • SWM and LID can be developed to ensure that flood, erosion and potential water quality impacts will be mitigated appropriately.	• The management strategy will need to provide the appropriate protection for flood erosion and water quality protection.
6	• Groundwater considerations will be needed from a water balance standpoint as well as the protection of municipal wells. A wellhead protection strategy has been developed with the potential zone of impact delineated in the vicinity of Tributary B	• Land use and SWM considerations will need to address the potential impact in the Tributary B area	• Land use designations, SWM and LID can be developed to provide protection. Salt management requirements will likely be required in the wellhead protection zone.	• The management plan will need to address the requirements for the well head protection zone. • The SWM plan will need to address water balance and provide infiltration targets, as appropriate.
7	• Groundwater considerations will also be needed from a water balance perspective for maintenance of natural features. In particular Tributaries A and B will need groundwater contributions maintained in order to preserve their cool water thermal regime.	• Land use and SWM considerations will need to address the potential impact in Tributaries A and B.	• Land use designations, SWM and LID can be developed to preserve thermal regimes of Tributaries A and B.	• Groundwater conditions and water balance targets will need to address the preservation of thermal regimes.

Terrestrial Resources - Section 5.7

- The terrestrial resource conditions as they affect stream corridor functions.

Aquatic Resources - Section 5.8

- The condition and role of a corridor to support a healthy aquatic system (habitat).

All of these factors are being used in developing an overall ranking of the streams by constraint and are outlined in **Management Strategy - Section 5.9**.

5.10.3 Terrestrial Natural Heritage System

Current approaches to the conservation and management of terrestrial and wetland resources focus on the need to consider the diversity of features, the connections between them and the ecosystem processes and functions. This approach considers a system approach that extends beyond identification of isolated features or habitats. The conservation of terrestrial and wetland resources must consider:

- Protection of the feature itself;
- Identification of a suitable buffer; and
- Management recommendations for lands beyond the buffer that may influence the feature (e.g., servicing, SWM, and grading, hydrological contributions to features/habitats).

The requirement for the study area is the protection of the key features and their ecological functions. This includes all components of the NHS (i.e., Key Features, Linkages, Enhancement Areas, Buffers).

Section 5.7 includes an assessment of the Block Areas and habitat units within the plan area through a functional analysis, ecosystem indicators, and applicable environmental policy definitions and criteria. This allows for the identification of significance at the feature-level.

Section 6.0 of this report provides a discussion of feature-level management, buffers and land use considerations from the perspective of conserving and maintain the features and functions of the terrestrial and wetland resources consistent with the project Terms of Reference.

5.10.4 Stormwater Management

Increased impervious area through future development and urbanization impacts may affect water resources in several different ways. The increase in impervious area often results in increased downstream flooding due to increased runoff volumes and peak flows, increased erosion and geomorphic changes, and degradation of aquatic habitat due to poor water quality. Therefore, water quantity control, erosion and baseflow control, and water quality control for stormwater runoff need to be taken into consideration.

Water Quantity Control

The analysis section has indicated that runoff values (volume and peak runoff) will increase with development, significantly unless managed. The increase in peak flows will, in turn, increase water levels and associated flood potential in receiving watercourses. To mitigate these impacts, stormwater management facilities will need to be addressed in the management strategy for controlling post development runoff volumes and peak flows to match predevelopment conditions.

Erosion and Baseflow Control

Detailed fluvial geomorphological assessments were performed on the stream systems within the area and erosion thresholds were established for the most sensitive reach. The continuous modeling completed for uncontrolled future development indicated significant increases in duration and frequency of erosive flows. To provide the appropriate level of protection, the recommended SWM approach will dictate the required erosion control measures in order to meet pre to post erosion exceedances.

Water Quality Control

The aquatic sensitivity of the receiving watercourse will dictate the level of protection that the SWM facility must provide.

The recommended SWM approach will be addressed in **Section 6.0 - Management Strategy**.

6. Management Strategy

6.1 Introduction

The management strategy is developed to provide guidance for the future management of the Vision Georgetown (Southwest Georgetown Subwatershed) and specifically to meet the goals and objectives within the context of future land use and other activities within the watersheds. The guidance provided, reflects the goals and objectives set for the area and the characteristics of the watershed.

Initially, the characterization (**Section 4.0**) of the watershed was carried out in such a way as to identify current conditions related to the goals and objectives (for example, characteristics of the natural environment including both terrestrial and aquatic, stream conditions, water quality, and hydrogeology) established for the area. The analysis (**Section 5.0**) of the watershed (including potential impacts related to land use change) focused on how the subwatershed functions. Also examined were processes as they relate to the goals and objectives. The subsequent steps involved in developing a management plan are presented in this section of the report and are as follows.

Section 6.1 Provides an overview of the approach to developing a management strategy and the factors associated with the Southwest Georgetown Subwatershed that led to the development of the management strategy.

Section 6.2 Provides a summary of issues (from the characterization and analysis portions of the Subwatershed Study) related to the goals and objectives that have led to the development of the strategy (*e.g.,* Is management intervention needed?) and outlines what targets are needed to meet the specific objectives.

Section 6.3 Provides a detailed discussion of all of the management elements by component, how they have been selected, and why they are needed.

Section 6.4 Presents the monitoring strategy which will enable the evaluation of the management strategy for effectiveness.

6.1.1 What is a Management Strategy?

Many management strategy approaches are based on the “carrying capacity” of the subwatershed as well as the goals and objectives set for the particular watershed. The application of the concept of carrying capacity requires an understanding of the limits of an ecosystem’s ability to support various life forms and land use activities. In any watershed, the existing habitats are generally operating at carrying capacity under the existing pressures of the human matrix within which they lie. As human activities/pressures increase, the carrying capacity of the habitats is reduced. The concept of carrying capacity is generally translated in watershed management into identifying a threshold beyond which the reduction in carrying capacity is not acceptable. In many traditional watershed studies this threshold is based on the survival of key indicator species or habitat types, usually rare species or sensitive habitats that are also protected by policies and regulations. Human activities are then managed in a way that does not exceed these natural limits. The ecosystem approach used in this watershed study used the concepts of carrying capacity and ecosystem health in evaluating land use scenarios and watershed management options. However, instead of focusing the identification of threshold(s) on significant species and/or habitats, the approach was to consider the current biodiversity of the system. In a subwatershed with a balanced carrying capacity, the land uses must be managed through specialized land use policies and stormwater management (SWM) techniques.

Using the public input obtained during the study, it was concluded that the watershed residents are concerned about existing conditions and potential changes to the watersheds in the future. Residents do not want to see conditions worsen and are encouraged about the potential to improve and enhance existing, particularly environmental, conditions.

The management strategy must recognize that human activities will continue, and that land use activities and changes are also a part of society's requirements. Watershed residents and landowners indicated that the strategy must incorporate environment, economics, and society. It is therefore, important that the management strategy is based on the premise that future changes do not exceed the present carrying capacity and that feasible and practical rehabilitation measures are used to enhance conditions and manage expected changes. These enhancements should result in improved resiliency of the system and overall health of the watershed.

The scope of a management strategy must be broad enough to include all of the technical and administrative tools that are involved in land use and resource management measures. The scope of the strategy includes:

- Land Use Management Measures – That guide land use in a manner that recognizes the natural environment which includes terrestrial resources, wildlife, wildlife habitat, ecological linkages and associated environmental corridors, stream and riparian corridors, and the subwatershed processes that influence these resources;
- SWM Measures – To preserve or enhance hydrologic functions/flow conditions related to surface water and groundwater flows and water quality;
- Terrestrial and Wetland Resource Management – To protect and enhance terrestrial and wetland resources;
- Riparian Corridor Management Plans – To protect and enhance riparian systems;
- Rehabilitation and Remediation Plans – For environmental (terrestrial and aquatic) features to increase the resiliency of the catchments and stream system;
- Monitoring Plan – Must be practical and focused to measure the environmental health of the catchments and to track the effectiveness of the watershed management strategy (**Section 6.4**); and
- Implementation Plan – That describes how the strategy is to be put into place. Based on the mandates of the various agencies and stakeholders, identify the specific roles and responsibilities for each group (**Section 7.0**)

6.2 Goals, objectives, management requirements

A subwatershed management strategy was developed on the basis of the goals and objectives for the Southwest Georgetown Subwatershed which was discussed in **Section 1.0**. These objectives were used to guide the overall characterization of the catchments, the analysis carried out and the development of this management strategy. In addition, the strategy also reflects the input by the community through the Official Plan, public meetings, and concerns reflected by input through the Secondary Planning process. In this way the strategy that has been developed shows consideration for the three cornerstones of subwatershed planning: environmental objectives, social concerns, and economic considerations.

For Vision Georgetown, the following steps led to the development of this management strategy:

- Goals and objectives were established resulting in the identification of the key subwatershed components or areas to be considered;
- Concerns and issues were identified;
- The information collected was analyzed, resulting in the development of a series of targets related to specific goals and objectives;

- The targets were used to develop a management approach and strategy. By setting targets within the strategy, the effectiveness of the approach and strategy can be monitored and evaluated; and
- The management approach includes monitoring and contingency plans that help determine whether targets are being met, and assists in modifying the strategy to help achieve the identified goals and objectives.

This section provides a summary of the management issues identified through the characterization and analysis phases of this Subwatershed Study (**Sections 1.0** through **5.0**), for each goal and objective.

The goals and objectives are summarized in **Section 1.3.1**. The management requirements, based upon the potential impacts identified in the analysis carried out (**Section 5**) are summarized and listed in **Table 6.2.1**. This provides the basis for developing the management strategy and targets, where appropriate.

Table 6.2.1 Management Requirements

GOAL	OBJECTIVES	MANAGEMENT APPROACH REQUIRED
Natural Hazards		
To prevent, eliminate or minimize the risks to life and property caused by flooding and erosion hazards.	• To ensure that new development does not create new hazards or aggravate existing hazards. • To ensure new development is located outside and appropriately setback from flooding and erosion hazards • To implement development standards and land use controls to prevent future development from occurring within areas prone to flooding or erosion hazards. • To ensure that new development, including infrastructure, incorporates appropriate mitigation measures that are necessary to avoid adverse impacts to natural features, areas and systems. • To consider cumulative impacts and changing climatic conditions when determining the characteristics and management of flooding and erosion hazards. • To ensure runoff from development is controlled such that it does not increase the frequency and intensity of flooding, the rate of natural stream erosion or increase slope instability. • To ensure Creek crossings (e.g. bridges and culverts) are designed appropriately to address potential channel migration without the requirements for armoring or impacting natural channel migration over the 100-year planning horizon. • Ensure higher frequency and higher magnitude storm (i.e. erosive) events caused by climate change do not negatively impact fluvial processes, cause excess scour, and/or lead to overall reach instability.	• Floodline delineation is required, with the appropriate regulatory setback as per Conservation Authority (CA) regulations and policy • Conservation Halton requires maintenance of floodplain storage and conveyance for all regulated features to remain on the landscape, regardless of the size of their catchment area. • Identify erosion hazard limits as related to slope stability for valley walls in accordance with Provincial and CA requirements, plus the appropriate regulatory setback. • Provide meander belt and associated setbacks as part of the watercourse corridors. • All road crossings to comply with municipal and provincial capacity and freeboard requirements and provide flood free access as per Town and CA requirements. • All watercourse crossings to span three times the bankfull channel width of the watercourse as well as a need to design crossings to allow sufficient light penetration within the structure to encourage the growth of herbaceous vegetation that will help maintain the structural morphology of the watercourse. The span of the crossing may need to be increased if it is found that the sizing of material needed (from a hydraulics perspective) is substantially larger than the native substrates in the watercourse. • Ensure that any potential changes to flow regime are controlled through stormwater management as per Conservation Authority (CA) policy.
Water Resources		
To protect, improve or restore water quality and quantity associated with surface water and groundwater features within and adjacent to and downstream of the primary study area, including their associated ecological and hydrologic functions.	• To implement water management measures and infrastructure design that protects, restores and enhances the natural hydrologic cycle and mitigates potential adverse impacts to the natural heritage system. • To develop robust servicing and stormwater management strategies capable of adapting to changing climatic conditions. • To ensure fluvial processes and stream morphology are maintained or improved recognizing important habitat attributes (pools, riffles etc.), dynamic channel form and diversity contribute to maintaining a sustainable natural heritage system. • To implement sustainable management practices, pollution prevention activities and design standards that protect, improve or restore water quality from the accelerated enrichment, contamination and increased temperatures within streams from development related pressures and activities. • To encourage the protection, improvement or restoration of tableland and riparian vegetative cover for the protection and improvement of water quality and quantity associated with surface water and groundwater features. • To maintain groundwater conditions for downgradient users. • To ensure natural hydrogeologic functions are protected taking advantage of stream baseflow and groundwater discharge and recharge enhancement opportunities.	• Provide a SWM (Stormwater Management) approach that includes the implementation of low impact development approaches to meet water quality, erosion control, thermal mitigation, volume control and infiltration functions where feasible. • Set water quality targets as appropriate to meet local and downstream watershed conditions (enhanced level is recommended). • Provide a SWM approach that in compatible and complementary with the local servicing needs and still appropriate to meet SWM targets • Provide a riparian corridor system that will protect and enhance the stream functions from a terrestrial, aquatic, and water quality perspective. This is to include the fluvial geomorphologic functions including sediment transport. • Provide the appropriate consideration to water quality protection related to the Region's Wellhead Protection Strategy. • Maintain existing hydrologic response characteristics by providing water balance to match existing conditions. • Identify and recommend enhancement works for terrestrial features that will assist in the protection of features with future land use change by improving their resiliency. This is to include strategic placement of compatible land uses that would provide clean runoff, and the use of roof leaders and third pipe systems to maintain hydrologic regimes. • Rely on 'at source controls' wherever feasible as a part of a treatment train approach to storm water management." • Identify a minimum requirement for watercourse crossings to span three times the bankfull channel width of the watercourse as well as a need to design crossings to allow sufficient light penetration within the structure to encourage the growth of herbaceous vegetation that will help maintain the structural morphology of the watercourse.
Natural Heritage		
To protect, restore, and enhance the biodiversity, connectivity and ecological and hydrologic functions of	• To ensure natural heritage features and areas, including their ecological and hydrologic functions, are appropriately protected from the potential adverse impacts of development including the use of	• Develop a buffer approach that complies with policies, and will provide the appropriate level of protection given the proposed future land use.

GOAL	OBJECTIVES	MANAGEMENT APPROACH REQUIRED
natural features, areas and systems throughout, and adjacent as appropriate, to the primary study area.	appropriately sized vegetation protection zones (i.e. buffers). • To adopt appropriate land use controls and development standards that protect existing natural features and areas and prevents future development from negatively impacting or occurring within the natural heritage system. • To encourage achieving an ecological gain through the development of the natural heritage system. • To ensure that significant natural corridors and wildlife linkages are identified, protected or enhanced through the development of the natural heritage system. • To develop an adaptive environmental management plan, including monitoring and mitigation measures that considers pre, during and post construction and development activities.	• Recommend an enhancement approach that will protect the identified features and improve reliliency. • Develop thresholds for response to unacceptable impacts within the adaptive management plan to ensure that the overall goal is achieved.
Other Considerations		
Additionally, the following with respect to environmental and potential downstream impacts from development should be addressed within the Sixteen Mile Creek Subwatershed, Silver Creek Subwatershed and the Region of Halton Natural Heritage System	• The aquatic habitat in the creeks within and downstream of the subwatershed areas are maintained or where possible, enhanced. • Discharges from proposed land uses to the receiving watercourses do not degrade the existing levels of biological diversity and productivity, nor adversely impact on stream forms. • Any necessary alteration to the stream systems within the subwatershed incorporates the objectives of achieving natural and dynamically stable channel form and appropriate habitat characteristics. • Existing watercourses and drainage features are identified, and evaluated in sufficient detail, and that appropriate recommendations/strategies are established to protect, restore and manage these features and their functions. • A sustainable natural heritage system is established which protects, preserves and where appropriate, enhances the natural environment. • Baseflows are protected and enhanced to improve ecological health of the creeks and maintain groundwater conditions for downgradient users. • Groundwater resources and functions are maintained and, if possible, enhanced (including investigation of flow paths and maintenance of these paths where required, considering the aquatic habitat requirements of the stream. • The quality and quantity of groundwater is not adversely impacted by proposed SWM measures (i.e. infiltration basins) and/or proposed land use. Any proposed servicing does not detrimentally lower the water table or adversely affect the groundwater resources. • Stormwater runoff is controlled to ensure that peak flow rates and associated flood levels are not increased as a result of the proposed development. • Retain stormwater onsite to achieve an annual volumetric water balance relative to pre-development conditions, where feasible. • The prolonged discharge from detention facilities does not increase downstream peak flows or channel erosion or negatively impact stream morphology. • Water quality and thermal regime of stormflow from the development meets all identified requirements and is maintained or enhanced as compared to existing conditions. • The stormwater management system will be robust enough to adapt to the changing climate. • All areas regulated by the Conservation Authorities should be considered in the development of the Natural Heritage System and management strategies, as appropriate.	• The stream characterisation approach has identified the stream network to be protected and enhanced to provide a functioning natural watercourse system. The management strategy is to include enhancement and rehabilitation requirements to meet the functionality needs from a watershed perspective. • Provide the appropriate SWM plan (including LID) that will meet the watershed needs and targets. • A management approach that considers the linkages between the riparian corridor systems (streams) and the terrestrial features that will protect the watershed and enhance where possible. • Provide a SWM approach that takes water balance, infiltration and interflow into account. • Water quality targets for SWM need to consider the requirements from a surface and groundwater perspective. • The SWM plan and targets need to incorporate flow controls considering the protection of downstream lands from potential flood increases and increases in streambank erosion

6.3 Management strategy

6.3.1 Overview

The management strategy has been developed to meet the goals, objectives. The proposed management strategy addresses both the form and the function (or process) that support those characteristics. The characterization and analysis provide an understanding of the environmental conditions and related processes (as well as potential impacts) throughout Southwest Georgetown. Based on this understanding of form and function in the area, an ecosystem approach was used to develop a strategy that will protect and enhance the watershed features.

6.3.2 Overall Approach to Management Strategy

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

- Natural Heritage System:
  - Terrestrial and Wetland (**Section 6.3.3**) – The development of a management approach for terrestrial and wetland features that will protect and enhance overall biodiversity including the flora and fauna associated with terrestrial and wetland features in an environmentally sustainable fashion. This includes the provision of a corridor system to provide for any necessary linkages for wildlife and plant movement;
  - Streams (**Section 6.3.4**) – The provision of a corridor system for streams that have been identified as having environmental characteristics or watershed functions that require protection and/or enhancement to meet the watershed goals and objectives. A riparian corridor approach is to be applied which will consider all of the stream functions including:
    - hydrologic;
    - hydrogeologic;
    - geomorphologic; and
    - environmental.
- SWM (**Section 6.3.5**) – The development of an approach that will protect and enhance environmental characteristics through managing related stormwater response and conveyance processes.

6.3.2.1 Management Implications in Southwest Georgetown

The text in the preceding section involved a generic description of management strategies that is applicable to most subwatershed studies. The challenge inherent in this subwatershed planning study is taking the general principles of a management strategy and applying them to a relatively diverse landscape and environmental conditions. For instance, the geology and topography across this area is varied from the valley at Tributary B and the flat plain in the upper part of Tributary A. This variability presents challenges in developing and implementing an effective management strategy. These challenges can, however, be overcome through the application of sound, comprehensive assessment and science. Before presenting the overall management strategy, a review and discussion regarding several of the physical issues and variability across the study area which influence the management strategy is warranted.

6.3.2.2 Physical Variability

The geological and hydrogeological character of the study area varies from east to west and north to south. This variation has influenced the development of existing conditions and will influence the management of the area for the future. Consequently the management of the area must address these variations in character and the features present in the area. Characteristics and features of note in the study area include:

- The low permeability silt and clay till soils throughout the entire study area;
- The valley along Tributary B;
- The well-defined corridor in the lower reaches of Tributary A and flat lands in the upper reaches;
- The potential for localized and isolated groundwater discharges near Eighth Line;
- The limited contribution that groundwater makes to the perennial flow of water in the study area streams;
- Relative isolation of the terrestrial features; and
- Past changes to the drainage courses impacting on fisheries habitat.

The land development process changes the physical characteristics of the land surface and land use, most notably increasing the degree of imperviousness which increases runoff and decreases infiltration. The water collected from urbanized areas has higher concentrations of some chemical constituents than natural water. This urban runoff is then channeled to water courses via the storm sewer system, delivering these constituents to the local watercourses. In evaluating ways and means of determining the highest and best use of the land, opportunities are available to meet water quality and other objectives at the source (the land use activity), in the drainage conveyance system, and at the end-of-pipe prior to discharge. The preference and focus for achieving the groundwater related objectives are those that can be done at the source (*e.g.,* at the local or lot level).

Based on the discussion in **Section 4.0**, it is apparent that the physical nature of the study area, as summarized above, manifests itself through the stream system, aquatics and, to a certain degree, the ecology of the area. Differentiation of some of the management approaches would greatly enhance the ability of a management strategy to be effective through the development of specific goals and targets that will ensure natural functions and processes are maintained throughout the development of the entire area.

To be realistic, too much differentiation could result in overly complex management recommendations and a strategy that may be cumbersome and unwieldy.

6.3.2.3 Headwater Areas

The study area is comprised of the headwater areas of several catchments and, as a result, is more sensitive to land use change. While the importance of headwater channels is generally recognized, a quantitative analysis of their formative requirements, basin contributions, and the impacts of channel loss through development and land use change is lacking. First order streams (streams with no contributing upstream tributaries) are formed when the tractive force exerted by overland flow is sufficient to transport surface sediment (Rogers and Singh, 1986) (**Figure 6.3.1**). Several sources offer insight regarding the approximate drainage area required to produce such flows. Brummer (2004) states that for mountain stream systems, drainage areas of one to several kilometres will support headwater systems. Takashi *et al.* (2002) cite a smaller value of 0.01-1km^2 for the formation of headwater channels. This latter range of values is mirrored in work by Leopold (1994) and the Sierra Club (2004), who offer similar values of 0.23 and less than 1 km^2 for first order streams and headwater streams respectively (headwater streams are defined as first and second order streams).

While the specific pattern of network development reflects the combined influence of topography, geology and climate, these first order channels eventually merge with other channels and erode the surface until a slope develops. At this point, alluvial streams reach a quasi-equilibrium form in which the surface runoff is sufficient to transport the sediment delivered by the headwater tributaries (Whiting *et al.*, 1999). This sediment is eventually deposited in the lowland tail water system where the stream reaches its confluence with a receiving water body such as a lake or ocean (**Figure 6.3.2**).

From a management perspective, when facing development pressures and land use planning decisions in a headwater system, the question remains: to what extent can one manipulate the production aspect of this delicate equation and still maintain the overall function of the system? This becomes particularly challenging when the main stem and tail water portions of the network have already undergone drastic alterations through urbanization and many of the low-order streams in these downstream portions of the watershed have been lost. Additionally, development in the downstream portions of the watershed produce increased surface runoff that exacerbates erosional issues caused by the decrease in sediment supply from the missing headwater tributaries.

Figure 6.3.1 Headwater Stream Formation (Selby, 1982)

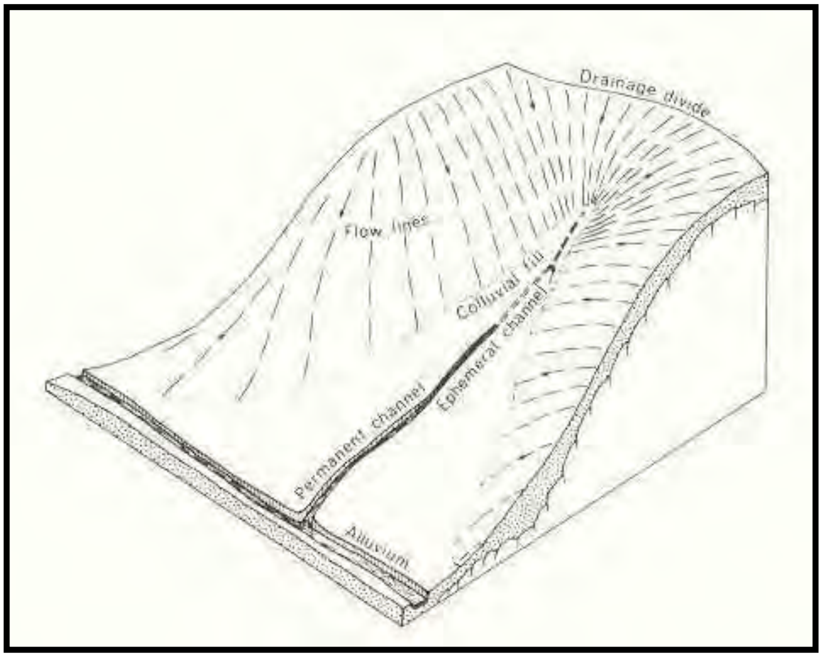
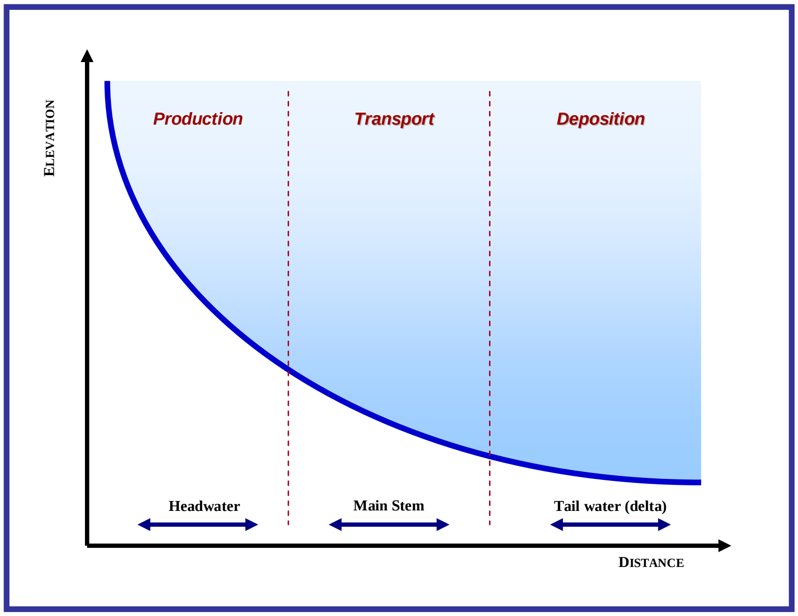


Figure 6.3.2 Transition Zones Along a Fluvial System (Schumm, 1977)



In a study of the Chattooga River watershed in the Blue Ridge Mountains area of the United States, Hansen (2001) reported that, of the total stream network, 55% of the contributing channels were ephemeral (undefined) channels, while 17% were intermittent and 28% were perennial. The majority of these ephemeral and intermittent channels were first and second order headwater tributaries. Based on these results, Hansen concluded that management decisions on a watershed basis should include the combined use of stream order and stream conditions based on field investigations.

To further emphasize the importance and difficulty of developing appropriate management for headwater areas, one only has to look at the drainage pattern and channels in the area. First, on an individual basis, most of the first order channels are ill-defined (*i.e.,* no bed or bank), are ephemeral (*i.e.,* flow for only a few weeks or months in the year), are often altered and could be actively farmed. It is often argued that the function of these channels can be replicated by SWM. A new management approach to headwater streams is to treat headwater channels in a more cummulative sense. That is to base stream length targets on catchment drainage densities which result in more "open" channels. These channels better maintain natural channel functions.

Another important element of true headwater areas is the greater proportion of first order streams. A headwater area is found at the subwatershed divide. In this area there are more first order streams than further downstream in the watershed. This is one reason why headwater areas are referred to as production areas (see **Figure 6.3.2**). Given these channels, this area produces the energy (from rainfall and corresponding runoff) and sediment to drive the downstream sections. Therefore, a management strategy that applies basin morphometrics in the form of stream order and regional drainage density values, in combination with field observations as the basis for subwatershed management decisions is necessary.

6.3.2.4 Terrestrial and Wetland Resources

The current landscape pattern of terrestrial and wetland habitats through the study area has resulted from a number of human and natural influences. The resulting pattern is associated with the main watercourses of Tributary A, B and C. For descriptive purposes in the characterization of natural heritage features the study area is divided into the

“Block Areas” A to D. The Block Areas have generalized boundaries (i.e., only meant for referencing the area), within which the feature boundaries are included (i.e., the limits of woodlands and Core Areas).

The four Block Areas will each be managed based on the features, functions and sensitivities within them following management goals and objectives specific to the Block. As the overall approach is systems based, management of terrestrial resources by Block Area still requires the integration of the adjacent features and supporting functions between Blocks.

The functional contributions and connections between adjacent Block Areas are an integral part of the management of the components and overall NHS. This in turn supports adjacent NHS.

6.3.3 Natural Heritage System – Terrestrial and Wetland

The overall goal relates to the sustainability of the natural heritage features and resources of the NHS, based on maintenance and restoration of biodiversity at a series of levels (species and habitats). From a vegetation perspective, the goals and objectives of the Subwatershed Study focus on the protection of important naturally vegetated features in terms of both structure and function.

The objectives of a sustainable NHS are to follow a systems-based approach that protects and maintains the identified ecological features (e.g., woodlands, wetlands, significant wildlife habitat), the ecological functions (breeding amphibian habitat, riparian/wetland water attenuation and control) and range of ecological interactions (coyote predation, wildlife movement through linkages).

Woodlands

The overall goal of protecting woodlands within the study area has been expressed in the original Terms of Reference and subsequently during discussions with agency staff and interested individuals. This goal is reflected in the objective of maintaining the role of the woodlands despite urbanization.

Woodland size and shape is a consideration in the analysis of the woodlands. This is discussed in **Section 5.7**

Based on the character of the woodlands in the study area, the following targets were identified:

- Woodlands are not to be fragmented;
- Maintain and enhance wherever possible the function of all woodlands that are >200m in width (i.e., provide potential interior conditions);
- Maintain and enhance wherever possible the function of woodlands associated with wetlands and watercourses;
- Provide enhancement of the woodland quality and shape wherever possible; and,
- Maintain and enhance woodland size in order to establish core woodland areas that are greater than 20 ha.

<u>Black Locust Management and Enhancing Block D Significant Woodland</u>

In accordance with ROPA 38, the Black Locust cultural woodland is technically considered part of the significant woodland as it is contiguous with the main forest block of Block D. As ROPA 38 does not discount invasive species in the identification of significant woodland, an analysis of the management of Black Locust in lowering functioning areas of Unit 16a has been recommended in the Subwatershed Study. The removal of Black Locust trees would in our view provide for opportunities to control and manage this invasive species community while maintaining and enhancing the Block D significant woodland.

Wetlands

The overall goal of protecting wetlands within the study area has been expressed in the original Terms of Reference and subsequently during discussions with agency staff and interested individuals. This goal is reflected in the objective of maintaining the role of the wetlands despite urbanization. The approach used here focuses on the identification of the roles and functions of the wetlands.

While there is limited representation of wetlands in the plan area, they provide supporting functions to the NHS (both terrestrial and aquatic). The wetlands in the study area are also known to provide habitats for a number of plant and wildlife species and play an important role in the hydrology of the watersheds.

Wetlands in the study area consist of the follow types:

1. Wetlands with no permanent inflow or outflow of water (isolated wetlands, as defined in the Wetland Evaluation System) – These are represented by small pockets of wetlands that are a result of accumulation of runoff in low areas with less permeable soils. Many of these are found as vernal components of woodland blocks, or in open field areas. Many have been plowed through, but some have retained or have established wetland vegetation. Examples of these are small (< 0.5 ha) isolated wetlands in the agricultural fields such as Units 2, 3a, 21b, 27 (**Figure 4.9.1**)

2. Wetlands with a direct outflow (palustrine wetlands, as defined in the Wetland Evaluation System) – These wetlands are associated with a watercourse or other wetland feature and may play an important hydrological role in addition to their ecological role. While small, the treed swamp (Unit 3c) generally falls into this category.

3. Wetlands associated with the channels of watercourses – These wetlands are generally online features that have established as a result of flow patterns in the channels (*e.g.,* low gradient systems and areas with impeded flows). Examples of these wetlands are the treed swamp (Unit 3b) and meadow marsh (Unit 21) along Tributary B, and the meadow marsh (Unit 10) along Tributary A.

<u>Targets:</u>

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

Terrestrial Feature Buffers

The identification of buffers around wetlands and woodlands has received considerable research in the recent past. There are a number of similarities in the approaches typically used to delineate these buffers. From review of numerous past studies on buffers, general components/approaches have been used to identify the extent of buffers:

1. Cases where the immediate protection of the edge of the natural habitat is considered. For example, buffers for the protection of wetland vegetation and control of runoff to wetlands. These dimensions are typically smaller (a dimension of 30m is in common usage for provincially significant wetlands; Environment Canada, 2013; Ministry of Municipal Affairs and Housing, 2005).

2. In some cases the protection of woodlands considers arboricultural approaches in which the focus is on the physical protection of the outer trees based on root zone protection. This type of approach results in a modest buffer normally in the range of 5 to 10m from the dripline. However in the case of hazard prevention some outer tier trees can be very tall, where buffers may be greater.

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

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

<u>Targets</u>

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

Plants and Wildlife

For the most part, the goals for plants and wildlife species overlap with those noted above for wetlands, woodlands, and other habitat types. The key objective for plants and wildlife is the preservation of biodiversity. Given the character of the habitats and species known from the study area, and relationship of these habitats to others outside the study area, the management of plants and wildlife species must be considered at the metapopulation level. This translates to considering the specific habitat patches within the study area, as well as linkages between these habitats and beyond the limits of the study area. Many wildlife species use a range of habitat types for different aspects of their life history, and this range of habitats must be considered. For example, protection of forest interior stands speaks to the nesting needs of certain sensitive forest interior species, but in many cases species forage and move outside these forested stands through other vegetation community types (see Wegner and Merriam, 1979). Amphibians provide a prime example on why metapopulations must be managed. Depending on their life cycle stage and season, amphibians require different habitats. Spring peepers, for example, use marsh habitats for breeding, but then migrate to upland areas once breeding is complete or once tadpoles have transformed. In winter, this species hibernate under logs, bark, or fallen leaves (Harding, 2000).

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

<u>Targets</u>

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

Local Linkages

As discussed in **Sections 4.9.4.6, 4.12.4** and **5.7.1**, a range of linkages and opportunities currently exist within the study area. Linkages are an integral part of the objectives of maintaining sustainable woodlands, wetlands, watercourse corridors and wildlife populations within the subwatershed.

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

Within the study area there is existing linkage between Block C and Block D along a wetland/woodland patch. There is also a good linkage function along the Tributary B ravine due to the length and extent of natural forest cover within the valleyland and adjacent tablelands.

To improve connectivity of features within the study area linkage opportunities exist along Tributary A between the isolated woodland at the south end and the downstream central woodland along the tributary. A general greenway (i.e., provides for accessory uses and may include surface water infiltration, a trail and landscaping plantings for recreational uses) between Block B and C may also benefit general use for wildlife movement.

Targets

- Minimize the discontinuities in linkages (especially >20 m).
- Local linkages to be generally a minimum 60 m wide as recommended by the Sustainable Halton background report.
- Crossing structures such as culverts must take into account terrestrial and aquatic wildlife passage.
- Allow for linkages to habitats or other linkages located outside the study area (for example Silver Creek connection to the north and Sixteen Mile Creek connection to the east).

Management Background

Management of natural habitats in an urbanizing landscape includes:

- Identification and delineation of the natural feature(s) in question;
- Management of the feature in question (*e.g.* subject woodland or wetland);
- Management of the interface between the feature and neighbouring development lands (generally by way of a buffer); and
- Management of the uses of the lands beyond the buffer that may influence the feature (*e.g.* grading, SWM, and servicing).

6.3.3.1 Woodlands

Feature Management

One of the key components in the management of woodland features is protection of the stable woodland edge, as well as a buffer. The stable edge provides protection for the sheltered interior microclimate from excess sunlight or winds that may affect the interior of the stand, as well as invasive edge species and predators. Burke and Nol (1998) report on how stable edges actually reduce edge effects in woodlands to the point where the size of the woodland is no longer significant. The following general approaches are provided:

1. Arboricultural approaches to the protection of the edge vegetation. These are often based on root spread as well as possible hazard protection; and

2. Ecological approaches to woodland protection which consider the use of neighbouring lands by species that reside in the woods.

The matrix surrounding habitat patches and corridors is an integral component of landscapes and should be considered when designing a NHS to increase dispersal in a fragmented landscape (Baum *et al.*, 2004).

Numerous studies have been completed that have identified the value of larger blocks of woodland in terms of sustainability and provision of habitats. The larger blocks of woodland are necessary to provide the sheltered microclimate that is found within the interior of these woodland stands. Because certain edge effects (such as predation) can extend up to 600m into a forest, Riley and Mohr (1994) present the notion of "mega-woodlands" that are 400 ha or larger. While woodlands of this size are not found in the study with the identified significant woodlands ranging from 0.67 (southern woodland in Block A) to 4.99 ha (main woodland in Block D), within the local landscape scale (i.e., Regional NHS areas adjacent to the study area), the study area woodlands can provide supporting habitat contribution. Environment Canada (2013) recommends that 30% of all watersheds should be in forest with some larger than 200ha. The MNR's *Big Picture Project* also recommends the inclusion of 200ha woodland patches in Natural Heritage Systems (Jalava *et al.,* 2000). Site level identification of significant woodlands as part of the Regional NHS is part of the broader natural heritage planning in moving toward these thresholds.

The breeding bird information compiled for the Block Areas was used to identify which bird species breed in the woodlands and those that are considered to be forest interior species. The presence of these types of breeding birds was compared to rules of thumb in common usage for the identification of potential forest interior (*i.e.*, amount of interior habitats over 100, 200, and 300m from the forest edge). This distance from the forest edge is commonly used to describe interior habitat (*e.g.,* Puric-Mladenovic *et al.*, 2000). As well, in many of these cases the amount of interior was found to be less than the 4ha, the minimum amount of forest required to have forest interior habitat 100m from the edge (Riley and Mohr, 1994; Region of Halton, 2002a).

As part of the characterization and analysis of the woodlands in the study area (see **Section 4.9** and **5.7**), few of the habitats units were found to provide interior habitat over 100m from the forest edge (e.g., marginal representation in Block C and some representation in Block D). Woodlands with no interior habitat were recorded to have presence of area-sensitive species (e.g., White-breasted Nuthatch in Block A, Hairy Woodpecker in Block B), which is indicative of suitable habitat being in close proximity and the contributing function of smaller woodlands within the landscape.

The Environment Canada (2013) guideline on habitat recommends at least one 200ha forest patch in each watershed. The Framework recommends 10% of the watershed should be interior forest habitat 10m from the edge, and 5% should be 200m from the edge. The guideline also suggests a forest cover of 30% for each watershed. With the proposed management and enhancement of Block D (see **Section 6.3.3.6**), which will include increasing forest interior habitat and connecting the Block C and D forests through widening of the linkage (creating a contiguous woodland that is > 20 ha), management of such habitat should be a key objective.

As noted above, some wildlife species that use the woodlands require neighbouring habitats such as open country. This can be dealt with as either a component of larger buffers around the woodlands, or where applicable by using an approach in which woodlands are clustered with other habitats.

Land and Process Management

As discussed further below with respect to wetlands, in cases where smaller arboricultural-based buffers are used around woodlands, the ecological needs of species that reside within the woodland may not be addressed, and these would need to be reflected in the identification of compatible adjacent land uses, buffer size and local linkages. For example, the vernal pool complex identified as SWH for amphibians on the northwest side of Block C may receive surface drainage from lands outside of the woodland that contribute to water quantity requirements for habitat function.

Research into the potential for urban lands to impact woodland systems has found that impacts can be detected in some cases where development occurs as far as 100m from the woodland (Friesen *et al.*, 1995). Friesen *et al.* (1998) reported that the number of houses surrounding a woodlot had a significant impact on the forest's neotropical bird community. Neotropical migrants decreased in diversity and abundance as development around the woodlot increased, regardless of the woodlot's size. A study done by Matlack (1993) revealed human impact up to 70m into a suburban forest. Much greater distances of intrusion are found where vehicle access is provided. Matlack (1993) stated that human impacts are worse than natural edge effects and do not decline in severity by distance into the woodland. Besides the nature of the surrounding landscape, the shape of a forest will impact how much interaction of biota there is between the forest and the matrix. The greater the edge to interior ratio (*i.e.,* the more convoluted the edge), the greater the interchange (Saunders *et al.*, 1991; Dramstad, 1996).

The characteristics of wooded linkages between woodlands are an important land management issue. Connectivity between woodlands can be achieved where contiguous wooded corridors are provided. As well, certain wildlife and plant species will move between nearby wooded patches despite the lack of a direct connection (Saunders *et al.*, 1991; Taylor *et al.*, 1993).

6.3.3.2 Wetlands

Presence of wetlands within the study area consists of some riparian communities and small, isolated pockets in or directly adjacent to agricultural fields. Wetlands that have been identified as significant as discussed in **Section 5.7.3** are part of the NHS and are to be preserved and maintained. Isolated wetlands in the fields have been identified as replication features (**Figure 4.12.1**) and are to be provided within existing agricultural lands in the Local Linkage between Block C and D, which will contribute to functional attributes of the linkage and NHS.

The total combined area of these wetlands is approximately 0.2 ha. The key considerations in the design and construction of the replication wetlands include:

- the wetland replication design and implementation will be completed in consultation with the Town, landowners and representative agencies,
- confirm the total area of the three existing wetlands to be removed and establish the final size of the replication feature
- confirm the final location of replication feature within the agricultural lands in the Block C and D Linkage Area
- assess the soil conditions, existing moisture regime, pre-existing and post-construction grades in the area of the replication feature
- assess and determine what hydrological regime options are feasible in the proposed location for the replication feature
- determine the type of wetland to be created (e.g., meadow marsh, shallow marsh, swamp thicket) which will establish the necessary hydrological regime design parameters and species composition for the restoration plan
- develop a monitoring and adaptive management plan

To this extent management goals and objectives for wetlands within the study area are not as prominent as for upland terrestrial woodland and cultural communities.

Feature Management

The management of wetlands has undergone considerable research and study throughout North America. This has been triggered by policies that require the protection of the function and in many cases, the structure of wetlands.

Structure and function are generally closely linked since the character of wetlands is directly related to the factors that drive the water regime and other aspects of wetlands (*e.g.*, Pearsell and Mulamoottil, 1996).

The approach to protection of wetlands has included extensive research into the buffers necessary to protect the wetland system and especially the species that use it. Environment Canada (2013) stated that literature increasingly indicates large buffer requirements based on wildlife attributes, especially around marshes. In some cases these distances have been found to extend over several hundred metres from the wetland (Environment Canada, 2013; Semlitsch and Bodie, 2003), for example waterfowl that nest in open meadows adjacent to marshes.

Wetlands serve a function from a watershed perspective in the hydrologic response to rainfall and snowmelt events. They act to retain or detain water to allow it to infiltrate, evaporate or evapotranspirate. Specific examples within the study area are discussed in **Section 5.7.1**. This role is provided for by wetland features that are linked to a stream, as well as those that are isolated. As discussed above, there also areas of small wetlands and wet pockets that are outside of the NHS and have been identified as replication features.

Land and Process Management

Perhaps the most important consideration for the maintenance of wetlands as features is the management of factors on lands that are located outside the wetland buffer that drive the functioning of the wetland system.

The key land and process management considerations for wetlands relate to the maintenance of the factors that drive the wetland. These factors include land management issues that affect the hydrological regime within the wetland, including water quantity and delivery pattern, as well as water quality. In some cases, larger dimension buffers have been identified to deal with land management issues.

Water level fluctuations created as a result of land development (*i.e.*, from the changes to land drainage, servicing, and especially related to impermeable surfaces) can lead to impacts on wetland biodiversity through the change in water availability to biota. Sedimentation release into wetlands during the development or “build out” stage can have significant effects to wetlands.

A number of researchers were reviewed in a recent document compiled by the Centre for Watershed Protection (2003), with a series of impervious cover thresholds noted. Many cited 10%, above which a decline in wetland diversity was noted. Water level fluctuations as little as 8 inches (approximately 20 cm) have been cited to impact wetland vegetation and amphibian species (Center for Watershed Protection, 2003). As most of the key wetlands within the study area are associated with watercourses, maintaining the flow regimes of the aquatic features will be part of the management of these wetlands. Grading, drainage, and SWM are important processes and land management issues. For wetlands associated with watercourses, preservation of flow regime including the pattern of flows is critical. The management of these is discussed in other sections of this report. For wetlands that are not associated with watercourses, options include strategic placement of compatible land uses that would provide clean runoff, and the use of roof leaders and third-pipe systems to maintain hydrologic regimes.

In cases where smaller buffers are used, it is important to consider compatible land uses.

As noted above, some wildlife species that use the wetlands require neighbouring habitats such as woods and open habitat. Within the study area existing adjacent upland habitat is a component of larger buffers around the key wetlands that have been identified.

6.3.3.3 Other Vegetation Communities – Enhancement Areas

Feature Management

This section covers early successional stands that can be transitory in nature, which in the context of the study area consist of cultural thicket and cultural woodland areas that have been identified as Enhancement Areas (EAs) and replication wetlands that are part of the NHS (see **Section 4.12.3** and **Figure 4.12.1**). These vegetation communities are a result of human influences that have triggered succession or have arrested natural succession. Many of these systems can re-establish in a short period of time (especially meadows), and many include a considerable number of non-native species.

These types of vegetation communities are often not specifically targeted for management or inclusion in Natural Heritage Systems in subwatershed or planning studies. These features and their ecological roles are usually relegated to buffers, and this has lead in some recent studies to recommendations of larger buffer widths from some features. More recently this has begun to change due to the recognition of the supporting habitat functions of cultural communities, particularly those contiguous to NHS components or those in close proximity that support SAR (i.e., grasslands).

The management of these features must consider the ultimate goal for the stand, in some cases encouraging natural succession to habitats dominated by woody species, and in other cases maintenance of early successional characteristics with few woody species (e.g., for habitat requirements of species such as Red-bellied Snake as discuss in other section of the report). The latter is likely to require intervention to control the establishment of woody species.

For this study area Enhancement Areas have identified as lands that contribute to the NHS providing supporting functions and opportunities for protecting, restoring, connecting and improving the natural heritage features of the NHS. For example, Enhancement Areas can help maintain wetland hydrology by providing surface drainage function and reduce edge effects of woodlands and habitats.

Objectives for improving the natural heritage value of Enhancement Areas include identifying activities that further augments the identified significant features and functions directly adjacent to or in proximity to the Enhancement Area. This may include the following:

1. Develop an Enhancement Area plan in consultation with the agencies as early as possible.
2. Allow for infill succession through a management approach that encourages the establishment of native woody and herbaceous species.
3. Install plantings as part of an edge management plan in cultural meadow and thicket communities on perimeter of woodland.
4. Complete vegetation community restoration and enhancement in areas of localized erosion at valley inflow locations.
5. Complete invasive species control and management for species that represent a threat (e.g., Black Locust, European Buckthorn).
6. Develop a monitoring and adaptive management plan

Land and Process Management

The implications of development on neighbouring cultural vegetation communities is less pronounced as these anthropogenic based areas are typically more tolerant to disturbance and edge effects. Effects such as erosion and introduction of invasive species that can help to buffer impacts to adjacent woodlands or wetlands.

6.3.3.4 Linkages

Feature Management

Linkages are linear pieces of land that differ from the matrix on either side, and connect larger habitat areas (patches) (Barnes, 2000). The identified linkages within the study area are either along existing watercourses with some element of naturalization that requires enhancement (e.g., Tributary A local linkage), an existing linkage and supporting vegetation that requires enhancement (e.g., local linkage between Block C and D), or linkage areas that require restoration.

Linear habitats either associated with riparian habitats or other upland features may provide an intrinsic habitat function as well as other ecological and human values (see Riley and Mohr, 1994). In addition to providing intrinsic habitat, these features role in providing important avenues for the movement of plant and wildlife species is noted. The optimum design of the movement corridor must be a balance between ecological factors and realistic space and financial constraints (Adams and Dove, 1989).

Corridors function as conduits, habitat, filters, barriers, sources, and sinks (USDA, 1999; Hess and Fischer, 2001). Some researchers have recognized that some linkages may have disadvantages such as increased immigration of undesirable non-native species of plants and animals into previously isolated habitats, or increased edge and interior-edge effects such as predation (Simberloff *et al.*, 1992, reviewed in Dougan and Associates, 2005). However, most evidence shows that the benefits of connectivity in fragmented landscapes far outweigh the potential disadvantages (Naiman *et al.,* 1993; Beier and Noss, 1998; Environment Canada *et al.,* 1998; Soulé and Terborgh, 1999; Barnes 2000; Kirchner *et al.,* 2003; Dougan and Associates, 2005). Linkages have been shown to benefit those species most, whose survivorship is low when dispersing through unsuitable (matrix) habitat (Hudgens and Haddad, 2003). Throughout much of southern Ontario, the natural heritage landscape has been reduced so significantly, “that a natural landscape can be thought of only in terms of long-term restoration or replacement. On these landscapes, it will be necessary to restore and replace natural areas and linkages to allow landscapes to sustain minimum conservation functions. Connecting links can be considered as <u>potential</u> corridors on the landscape” (Riley and Mohr, 1994, p. 46).

Ecological linkages must be designed or identified with an understanding of the species that are anticipated to use the connection. Some species, called “passage species” use corridors for brief passage between habitat patches (Beier and Loe, 1992; Stephenson, 1999; Hess and Fischer, 2001). In this case, the connection must at least provide suitable conditions to motivate species to enter and use the area. “Corridor dwellers” may require several days or even generations to pass through the connection (Beier and Loe, 1992; Hess and Fischer, 2001), and individuals must therefore be able to live in the connection for extended periods.

The protection of the existing linkages is recommended. In most cases this must be accompanied by restoration of neighbouring lands to make these linkages wider and more continuous. The use of woody species (either naturally established or planted) is recommended for these areas. A structurally diverse linkage (with deciduous and coniferous trees, shrubs, especially those that produce berries, and herbaceous species), provides greater benefit to more species than a simple corridor (Fleury and Brown, 1997; Pearson and Manuwal, 2001).

Discontinuities in linkages are noted in background research to occur when breaks of over 20m are found (MNR, 2000), and in some cases discontinuities over 50m are seen as creating sufficient gaps to preclude significant movement of certain more sensitive wildlife species (Hounsell, 1982). Some authors, such as Noss (1987) and Hickman (1990) report that even narrow clearings such as roads, utility corridors, and nature trails can create breaks large enough to produce edge effects. However, connectivity between habitat patches can occur simply as a result of proximity (without a direct physical connection). In these cases plant and wildlife species that can tolerate gaps or use saltatory movements (*e.g.,* flying over gaps) are able to benefit from this type of connection. In effect, habitat units that are close to each other can be used as “stepping stones” (Dramstad *et al.,* 1996). The lands neighbouring the linkages have an impact on the potential use of these areas (*e.g.,* Knaapen *et al.*, 1992; Taylor *et al.,* 1993; Collinge, 1996).

The provision of suitable culverts and bridges should be considered on a site specific basis. As well, considerations to prevent wildlife and vehicular interactions should also be considered (Langton, 1989; Collinge, 1996). Measures described in literature include, but are not limited to:

- Selecting sizeable roadway and linkage alignments to avoid unsafe intersections (*e.g.,* at curves);
- Use of plantings and barrier/directional fencing to direct wildlife using the linkage to culvert/bridge crossings; and
- Design of culverts/bridges to accommodate wildlife movement.

In a larger landscape context, the provision of a linked system of habitats can be based on a network with some redundancy in which multiple linkages are available, or networks in which key major linkages are identified.

Land and Process Management

The land uses through which the linkages traverse, impact on which species use the corridor. Compatible land uses adjacent to the linkages must be balanced along with the number and size of discontinuities (see Saunders *et al.*, 1991; Knaapen *et al.,* 1992; Collinge, 1996). For example, park land adjacent to linkages is generally more compatible than high density development.

Multiple use linkages, especially associated with trail systems, must be reviewed in light of the objectives of the specific linkage. In some stream corridor linkages, trail systems may be accommodated without affecting the functioning of the linkage. This is further discussed in the following section.

6.3.3.5 Preferred Management Approach to Terrestrial Features

With respect to terrestrial and wetland resources in the study area, a preferred management approach was selected based on the management needs.

From the discussion in **Section 6.3.3.1** to **6.3.3.4**, two aspects of the management were highlighted:

1. The Treatment of Buffers as Part of the Management of the Feature – As discussed above, the consideration of the ecological needs of some species that reside within the wetlands and woodlands has implications on the extent of the buffer. Whereas the protection of the actual edge of the natural area may be accommodated by a modest buffer, the consideration of some of the foraging and movement aspects of species must either be considered as factors leading to substantially larger buffers, or as blocks of suitable habitats strategically associated with the woodlands and wetlands which leads to the concept of variable buffers; and

2. The Implications of Land and Process Management Issues and the Identification of Compatible Land Uses – In cases where small to modest sized buffers are used on individual natural features simply to protect the edge of the feature, the identification of compatible land uses becomes more important.

The *Provincial Policy Statement* provides direction for a natural heritage system approach that incorporates connectivity of natural heritage features to maintain long-term ecological function and biodiversity.

The natural heritage feature components of the system include wetlands of significance, habitat of endangered and threatened species, habitat for special concern species, significant woodlands, significant valleylands, significant wildlife habitat and ecological linkages that were identified and described in **Section 5.7**.

Inherent in the management and protection approach is consideration of the function of the feature that requires an analysis of the context of the feature and the relationship of the feature to areas beyond its borders. The management plan therefore includes the maintenance and enhancement of linkages as part of the natural heritage system for the protection and long-term sustainability of the natural heritage features.

Selected Features versus Core Areas

The selected feature approach is premised on the delineation of natural features, the identification of suitable buffers around the feature and consideration of land and process management implications on the feature's structure and function. For example, in the case of wetlands, the use of a standard modest buffer of 30m and the identification of compatible land uses, grading and drainage constraints around the individual wetland leads to a "ripple effect" in which the protection of the individual wetland has a broad zone of influence on land use. This is similar with woodlands, although the zone of influence of an individual woodland may be less since water regime may provide less of a functional role.

In the Core Area approach the natural features are treated as clusters of habitats. This clustering has a number of effects that may vary depending on Core Area size:

- Linkages between habitats within the cluster are readily accommodated and linkages between clusters are fewer and can be more focused than in the selected features approach;
- In some cases modest edge protection buffers can be used around the perimeter of features where they are at the outside of the cluster since diverse habitats are included within the cluster; and
- Compatible land use concerns would be less of an issue especially where open country habitats form the boundary of the cluster.

Although definitions for Core Area can vary, within the Southwest Georgetown Subwatershed Block D is considered the only area to have the attributes of a Core Area and supports a cluster of habitats and natural features. Based on the size and natural heritage feature composition, Blocks A, B and C are represented by identified special features. For all features within the study area, the applicable environmental policies, definitions and criteria of the PPS, ROPA 38 and the Town's OP are a requisite for the identification of the NHS components.

Management of Block Areas A to D

Through the baseline characterization, the functional analysis of terrestrial natural heritage features and the management strategy presented in the preceding sections of **Section 6.3.3**, management recommendations have been provided below. These have been divided into management themes that encompass wetlands, woodlands, target flora and fauna habitat, and linkages. These further relate to the natural heritage features and functions of the NHS and are described at the site level to be specific and tangible with further planning and detailed design to be completed at the EIR or EIS stages.

Block A Management

The following management opportunities have been identified for Block A:

Vegetation Communities and Flora

- The species richness is low (dominantly Reed-canary grass), and vegetation layering and structure along the riparian wetland Unit 10 is lacking due to limited shrub and tree cover. This represents an enhancement and restoration opportunity.
- While invasive species have not been identified as a specific issue in this Block, there are opportunities for enhancing floristic quality and diversity, which will help to reduce invasive species issues.
- Opportunities for enhancing forest cover exist in old field meadow and cultural thicket communities adjacent to the central forest area.
- The hydrological requirements of the wetland Unit 10 should be maintained and enhanced.

Wildlife Habitat

- The existing wildlife habitats for breeding bird communities represent opportunities for enhancements (e.g., improving and increasing riparian habitat) for improved function. This can be incorporated with natural channel design of reaches of Tributary A.
- Enhancement and management is required to maintain the breeding bird community.
- Management to include breeding amphibian habitat enhancement and monitoring.
- Buffer planting objectives adjacent to the central and isolated woodland could include increasing winter wildlife habitat function through enhancement of forest cover and presence of coniferous species.

Linkage

- A linkage opportunity enhancement exists along Tributary A between the isolated woodland (Unit 1a), woodland area (Units 6b, 6c and 22), through to Eighth Line.
- The southern woodland Unit 1a is not directly along Tributary A and is an isolated feature. The woodland represents a node for potential linkage opportunities along Tributary A for connectivity along watercourse corridor to Side Road 10, Trafalgar Road and north to Eighth Line to adjacent lands outside of the study area.
- A linkage along Reaches A2-1 and A2-2 would connect Block A along the tributary and across Trafalgar Road to continue the linkage on the west side of the road.

Block B Management

The following management opportunities have been identified for Block B:

Vegetation Communities and Flora

- Management of trees (e.g., pruning and limbing) damaged during the December 2013 ice storm in the central part of the woodland should be considered.
- Enhancement plantings and edge management of cultural thick and cultural woodland communities (Unit 14a, 14b and 18b) will support the function of the forest (Unit 13).

Wildlife Habitat

- The presence of some Spring Peepers in Unit 9g provides an opportunity to enhancement breeding habitat that can be supported by adjacent summer habitat in Unit 13.
- American Toads calling from standing water along Tributary C represents a habitat enhancement opportunity as part of the enhancement of the corridor and riparian area.

- Maintaining the rectangular shape of Block B is to be incorporated as part of the buffer plantings and enhancement to preserve the function of supporting forest birds including two SAR (Eastern Wood Pewee and Wood Thrush).
- Enhancement and management is required to maintain the breeding bird community.
- Management to include breeding amphibian habitat enhancement and monitoring.

<u>Linkage</u>

- Providing a greenway between Block B and C that allows for accessory uses and general wildlife movement. Monitoring of snakes through the continued use of the Snake Covers there were deployed around Block C and Block D will be part of the management for snakes.

Block C Management

The following management opportunities have been identified for Block C.

<u>Vegetation Communities and Flora</u>

- Enhancement plantings and edge management of cultural thick and cultural woodland communities (Unit 4 and 5) to support the functions of the forest (Unit 7).
- The cultural thicket Unit 4 requires active management and enhancement (e.g., removal of buckthorn and potential sapling under-planting) for increasing the area of contiguous woodland in Block C.
- Three small isolated wetlands in the fields have been identified as replication features and are to be construction within existing agricultural lands in the Local Linkage between Block C and D, which will contribute to functional attributes of the linkage and NHS.

<u>Wildlife Habitat</u>

- Enhancing the linkage between Block C and D as well as other habitat enhancements (e.g., potential hibernaculum construction) within Block C, are management tasks that may contribute to habitat opportunities for reptiles.
- Management to include breeding amphibian habitat enhancement and monitoring.
- Enhancement and management is required to maintain the breeding bird community.
- The overland sheet flow from the lands adjacent to the vernal pool complex contributes to the hydrological maintenance of this feature (SWH) and is an important consideration in maintaining these features. A feature based water balance will be required.

<u>Linkage</u>

- The woodland and swamp (Unit 3c/8) are an important habitat patch connection between Block C and D and enhancement along this linkage will provide further buffering of amphibian habitat, increase the function of the connection and maintain a hydrological link between the subwatersheds.
- Seasonal water outflow toward Tributary B from the pool in swamp Unit 13 creates a hydrological link between Block C and D across the subwatershed boundary and is an important attribute in the management of Block C.

The following management opportunities have been identified for Block D.

Block D Management

<u>Vegetation Communities and Flora</u>

- Enhancement plantings and edge management of cultural meadow (Units 9a, 9b, 9c, 9d, 9e) and cultural thick (Unit 18a) communities on perimeter of forest Unit 11 where adjacent to agricultural lands.
- There are localized erosion issues at some inflow locations into the valleyland that represent opportunities for vegetation community restoration/enhancement.
- The cultural thicket (Unit 18) has been identified as an enhancement area opportunity for improving sediment and erosion control, and vegetation and habitat enhancement.
- Invasive species of the Black Locust woodland (Unit 16a and 16b) has been identified as an issue and threat to adjacent native vegetation communities. Invasive species control and management of Unit 16a/16b is an important objective for the study area. This would provide for opportunities to control this invasive species community and transition to a native species dominated woodland.
- A management and enhancement assessment has been completed to allow for encroachment into the Black Locust cultural woodland Unit 16a.

<u>Wildlife Habitat</u>

- Unit 3a has limited function and is considered a replication feature to be relocated into the NHS and enhanced to provide for functional breeding amphibian habitat
- Enhancement and management is required to maintain the breeding bird community.
- Semi-open edge areas provide foraging and basking opportunities for reptiles and are to be integrated as part of the edge management and buffer restoration design for Block D.
- Enhancement opportunities to replace vernal pool habitat for American Toads that form in the agricultural lands are to be integrated into the NHS, buffer areas and potentially within the regional flood limits within the plan area.

<u>Linkage</u>

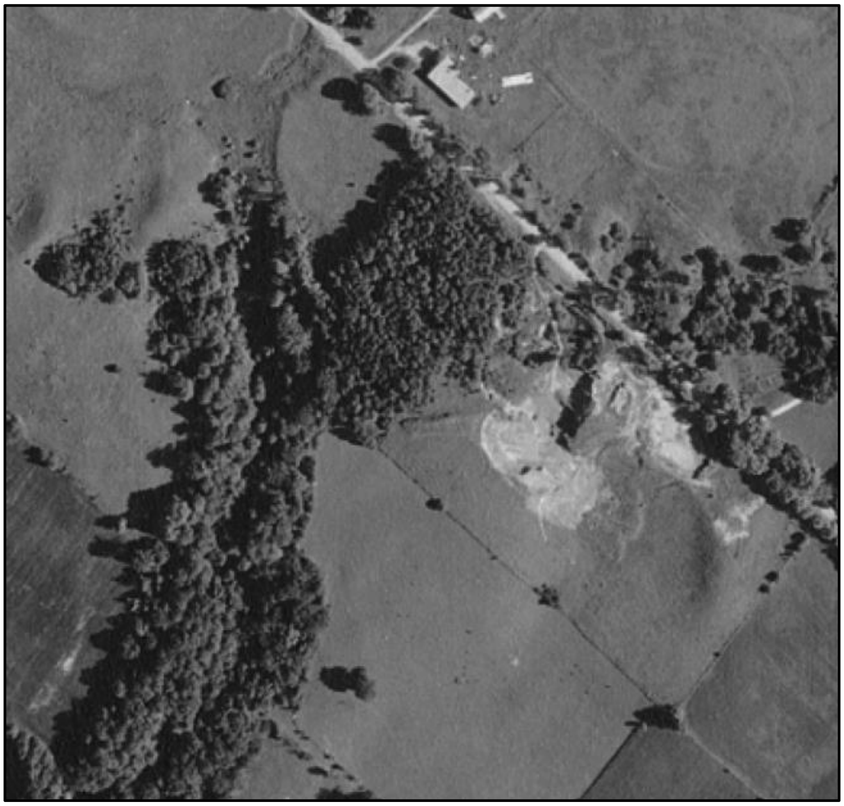
- Unit 3c and 8 are an important habitat patch connection between Block C and D and enhancement along this linkage will increase the function of the connection and maintain a hydrological link between the subwatersheds

6.3.3.6 Black Locust Management for Maintaining and Enhancing Block D Woodland

<u>Impeded Succession of Black Locust Woodland</u>
The existing conditions within the Black Locust woodland consist of limited natural regeneration of native trees and shrubs due to the poor soil conditions and the allelopathic effects of this species. The successional change and transition to a native woodland will continue to be very slow (likely in the order of many decades). Based on site observations and review of historic and recent aerial photography (late 1970's to 2016, see **Air Photos A to C**), the limited extent of vegetation change in the main pit extraction areas (which remain largely open) will continue to regenerate very slowly.

This is due to the past land use as a wayside pit. The extraction resulted in the stripping and removal of the organic and nutrient rich upper horizon of soil (see **Air Photo A**). Without the topsoil, weathered subsoil and associated microorganisms, the opportunities for the regeneration and establishment of native trees and forest cover is greatly limited. The development of even marginal organic content in the soil will take many decades. In comparison, the removal of Black Locust and restoration of a native woodland in the proposed reforestation areas (which currently support agricultural uses and good topsoil conditions), the successional establishment of a native woodland would development to a level that provides greater ecological function to Block D then the impeded succession of the Black Locust woodland. This would result in a net benefit and is a key factor that has been identified for the management and enhancement of Block D.

Air Photo A Overview of Block D with active wayside pit (circa late 1970's)



Air Photo B Overview of Block D showing Black Locust in November 2004 (Google Earth)

Air Photo C Overview of Block D showing Black Locust in April 2016 (Google Earth)

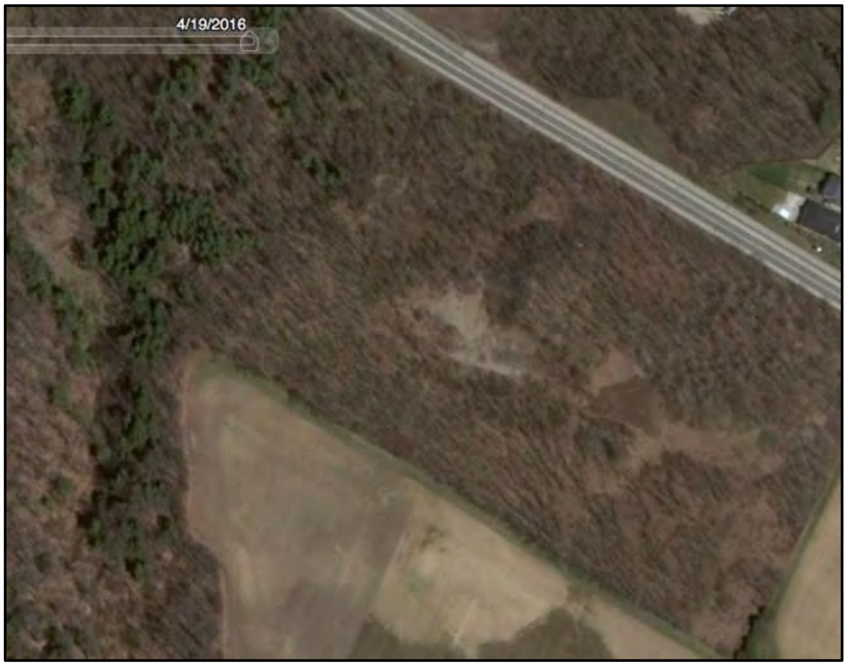
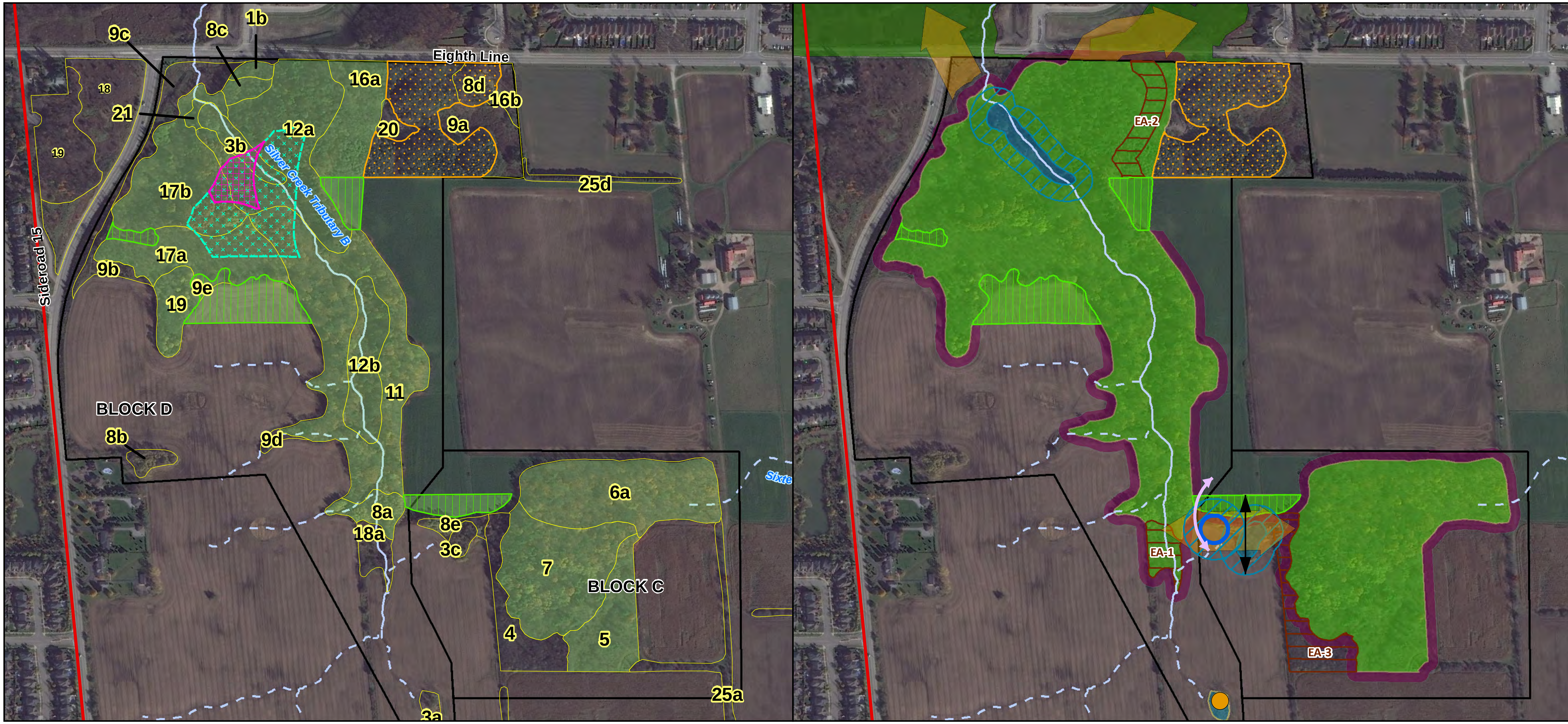


Figure 6.3.3 identifies the 2.47 ha of Black Locust cultural woodland that has been identified for removal based on the assessment provided in **Section 5.7.2**. Approximately 2.0 ha of reforestation areas (reforestation areas as shown on **Figure 6.3.3**) have been identified based on factors that include the replacement of an invasive species woodland, existing stem densities of Black Locust, and final determination of a tree replacement ratio and planting densities in the reforestation areas.



Legend

- Study Area
- Existing Interior Forest Habitat (0.43ha) - 100 m from edge
- Potential Enhanced Forest Interior (2.32ha) - 100 m from edge
- Reforestation Areas (2.00 ha)
- Area of Black Locust Trees to be Removed (2.47 ha)
- ELC Communities
- Woodland Buffer (15 m minimum)
- Block
- Significant Woodlands [ROPA38, Section 115.3(1)]
- Compensation Feature
- Block C - D Linkage Width (120 m)
- Infrastructure Easement Alignment - 10 m
- Unclassified Watercourse
- Intermittent Watercourse
- Permanent Watercourse
- Wetland Compensation Area
- EA-1: Enhancement Areas
- Wetland Buffer (25 m minimum)
- Forest Community
- Invasive Plant Community
- Wetland Community
- Local Linkage (60 m)
- Regional NHS (Adjacent Lands)

Black Locust Management and Block D Woodland Enhancement

Figure 6.3.3

Southwest Georgetown NHS

Drawn by: CB Checked by: DJ 25/05/2016

UTM Zone 17 N, NAD 83

0 75 150 300 Meters

1:6,000

PALMER ENVIRONMENTAL CONSULTING GROUP INC.

Project 15881

C:\Egnyte\Shared\Projects\Active\1588 - Meridian Planning\15881 - Southwest Georgetown NHS\mxd\Figure_633_Compensation_and_Enhancement.mxd

Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Key enhancement opportunities for Block D include improving the function of forest interior habitat and increasing the ecological linkage function between Block C and Block D. Both of these approaches contribute to the overall enhancement of the Southwest Georgetown NHS. The following management strategy is supported by **Figure 6.3.3**

An important consideration of the management and enhancement plan is the timing and staging of implementation. For example, the native tree plantings and reforestation could commence early in the development process and concurrent to the management and removal of Black Locust trees. This would allow for the establishment of reforestation areas to advance prior to development activities.

Enhancing Forest Interior Function and Reducing Edge

A GIS assessment was completed to identify the existing extent of forest within Block D that is 100 m from the forest edge (see **Figure 6.3.3**). This was determined to be about 0.43 ha and is located within the northern portion of valleyland. Based on the size (18.7 ha), and the linear and relatively narrow character of the Block D forest, functional interior habitat for area-sensitive birds is marginal. While forest interior birds are present as identified through field surveys, it is likely that breeding success is very limited. There is no interior habitat at the south end of Block D, within Block C or in the Black Locust woodland.

The existing forest area that is greater than 100m from the woodland edge includes some riparian Willow deciduous swamp (Unit 3b), Sugar Maple-Hemlock mixed forest (Unit 12a) and White Ash deciduous forest (Unit 17) as shown on **Figure 6.3.3**.

Through the GIS assessment various configurations for placing reforestation areas around the perimeter of Block D were reviewed to identify an approach that increases the forest interior through planting infill of embayments that will also reduce the extent of edge. This was completed in the context of also increasing the ecological linkage between Block C and D as discussed below. The reforestation areas as shown on **Figure 6.3.3** will provide for approximately an additional 2.32 ha of forest interior resulting in a total of 2.75 ha within Block D. Once the reforestation areas are established, the increase in forest interior will enhance habitat function and improve opportunities for breeding success for area-sensitive birds. To achieve the desired functions of the reforestation areas, a detailed planting plan with the appropriate selection of native species and tree planting densities would be implemented. Improving forest interior habitat function will provide specific benefits to a Special Concern species identified from Block D, Eastern Wood Pewee, as well as provide greater overall habitat opportunities for area-sensitive species. This will also help to maintain the existing breeding bird community.

Core Area Enhancement and the ecological linkage between Block C and D is discussed in **Section 6.3.3.7**.

No Negative Impact Test

To demonstrate consistency with the applicable natural heritage policies for the proposed management of the Black Locust within the Block D woodland, an assessment of no negative impacts has been completed.

<u>Woodland Features and Functions</u>

The Black Locust cultural woodland <u>does not</u> support the following ecological features or functions that are found in the remainder of Block D:

- significant wetland
- confirmed presence and identified habitat of a species concern species (Block D native forest supports Eastern Wood-Pewee)

- habitat for four locally rare plants
- intermittent and permanent watercourse reaches
- surficial drainage to a watercourse
- groundwater discharge zones
- forest interior
- breeding amphibian habitat

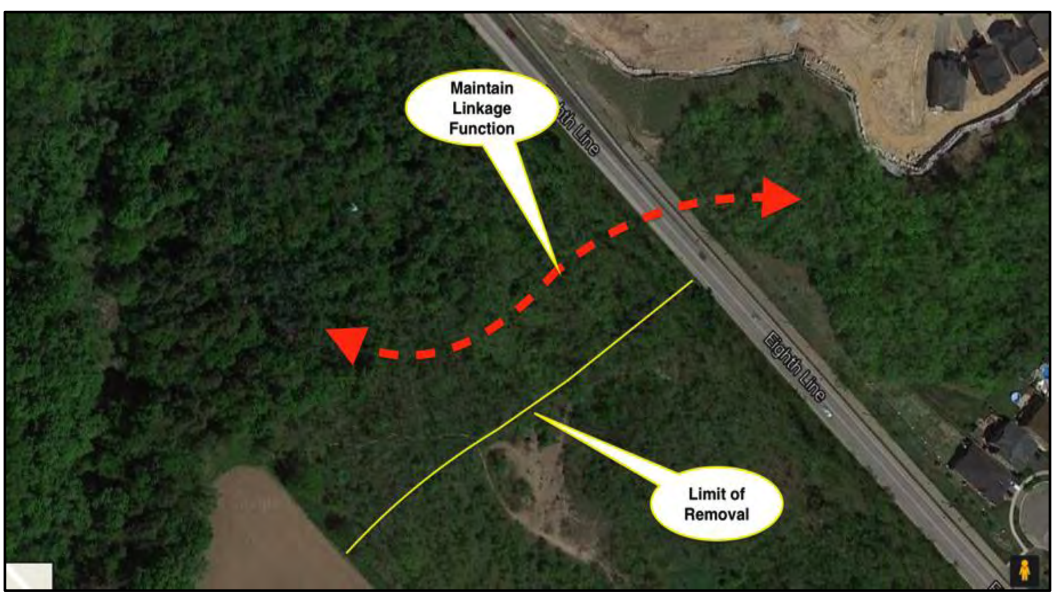
Portions of the Black Locust cultural woodland do support the following ecological features or functions that are also found in the remainder of Block D:

- linkage function to other woodland areas on the east side of Eighth Line.
- habitat for one locally rare plant
- supporting habitat for Eastern Wood-Pewee

Based on the proposed limit of the Black Locust removal as shown on **Air Photo D** and **Figure 6.3.3**, the linkage function, habitat for rare plants and supporting habitat for Eastern Wood-Pewee are within the western portion of retained Black Locust woodland. All of the ecological features and functions of Block D would therefore be maintained.

The significant wetland and hydrological features found in the main Block D are associated with the riparian zone and discharge areas of the valley bottom. The hydrological setting and soils in the Black Locust woodland preclude the development of wetlands, groundwater discharge zones, breeding amphibian habitat, or a watercourse. With the exception of the northern limit the Black Locust woodland (which is proposed to be retained) the area does not provide surface drainage to the watercourse as the lands slopes away from the valleyland. The woodland is dominated by edge habitat and therefore does no support forest interior (>100 m from woodland edge).

Air Photo D View of maintained linkage function through northern part of Black Locust woodland (Google Earth, 2005)



Provincial Policy Statement

The PPS states that "(d)*evelopment and site alteration shall not be permitted in ….b) significant woodlands south and east of the Canadian Shield;…unless it has been demonstrated that there will be no negative impacts on the natural features or their ecological functions.*

Under the PPS negative impacts means *"c) in regard to other natural features* (including significant woodlands) *and areas,* ***degradation*** *that threatens the* ***health*** *and* ***integrity*** *of the natural features or ecological functions for which an area is identified due to single, multiple or successive development or site alteration activities".*

Some general interpretations of the following terms are provided in the context of ecosystems.

Degradation: can be described as the deterioration of a natural feature through factors such as habitat loss/destruction, displacement of native species, loss or reduction of habitat connectivity and key environmental functions.

Health: is the condition of the environment/natural feature that can change from the result of many human activities, flooding, fire, severe weather and other reasons. In healthy systems, natural processes and flora/fauna communities are maintained.

Integrity: is a synonym to describe the level to which a natural feature is intact, carrying out ecological functions, and integrated with other natural areas in the landscape.

The Natural Heritage Reference Manual (OMNR 2010c) under Section 13.2 provides guidance on "Determining Negative Impacts".

> *To determine negative impacts on a significant natural heritage feature or area, the cumulative negative impacts from development or site alteration activities (e.g., impacts that adversely affect the stability of the feature and its ability to continue) must be considered against the integrity of the feature. The current and future ecological function of the natural feature or area as they relate to the surrounding natural heritage system (e.g., connectivity) must be considered as well. The PPS definition for "negative impacts" does not sate that all impacts are negative, nor does it preclude the use of mitigation to prevent, modify or alleviate the impacts to the significant natural heritage feature or area. For example, demonstration of no negative impacts on a significant woodland through mitigation measures may be contemplated, provided that factors such as the successional status and replaceability of the woodland components and functions within a reasonable time frame (e.g., 20 years) are considered* (OMNR 2010).

Applying the above to the no negative impact test for the proposed management of the invasive of Black Locust, the following can be determined under a scenario with and without the proposed mitigation and enhancement/reforestation:

No negative impacts without mitigation/enhancement

- There will be no cumulative negative impacts as the existing features and functions of Block D will remain intact, natural processes will continue and species populations will be maintained. Integration with the adjacent features, landscape connectivity and the hydrological contributions to Tributary B/watercourse/wetland will be maintained as the portion of Black Locust woodland proposed to be removed does not provide functional contribution to these features.

- The locations within the Block D feature for the proposed Black Locust removal are localized to one area and not throughout Block D. The removal is away from the sensitive and high functioning areas (i.e., outside of native forest communities, riparian wetlands, area sensitive habitat, rare plants).

<u>No negative impacts with mitigation/enhancement</u>

- The proposed mitigation measures and enhancement through reforestation will provide a net benefit with greater functional contribution to the Block D woodland (e.g., native treed forest replacing non-native and invasive treed woodland; removing threat to the buffers/NHS from Black Locust; increase of interior habitat from 0.43 ha to 2.75 ha; reducing edge through planting embayments; achieves a minimum 20 ha threshold size of core area; and, enhancing linkage to Block C). With the proper design, implementation and management, these functions can be achieved in a 20 year timeframe as recommended by the OMNR in the NHRM.

As part of the determination of no negative impacts, the Block D woodland must still meet the evaluation criteria at both the Provincial and Regional levels for the designation as significant following removal of Black Locust.

The evaluation criteria for determining significant woodlands as provided by the Province in the Natural Heritage Reference Manual (MNRF 2010c) consist of:

- **woodland size criterion** (woodland size based on % forest cover in the municipality);
  - Halton Region supports approximately 22.3% forest cover while at the local municipal level the Town of Halton Hills supports about 32.2% (Gartner Lee Limited 2002). The minimum size for designation as significant in the NHRM would therefore be 20 ha.
  - The proposed removal of 2.47 ha of Black Locust would not result in reducing the existing size of Block D below the 20 ha threshold as it is currently about 18 ha. With the proposed enhancement of the linkage between Block C and D the combined woodland would be about 26 ha.
  - The removal of Black Locust will not result in a change to this criterion at the regional or local municipal landscape level as it will not affect the size threshold.
- **ecological functions criterion** (woodland interior, proximity to other woodlands or habitats, linkages, water protection, woodland diversity);
  - as described above all of the identified ecological functions for Block D will be maintained with no negative impacts.
- **uncommon characteristics criterion** (unique species, rare vegetation communities or habitat, older woodlands);
  - Uncommon characteristics such as the rare plant species and their habitat and habitat for Special Concern species (Eastern Wood-Pewee) will be maintained and their long term persistence is not dependent on the Black Locust woodland or would be threatened by the removal.
- **economic and social functional values criterion** (provide economically valuable products, special services such as air quality, education/cultural value).
  - There are no identified economic or social values associated with Block D or specifically the Black Locust woodland as they are located on private lands and are not use for purposes such as education. The Black Locust woodland is used for paintball gun activities which has resulted in degradation of the area and therefore should not be considered a social value.

The Natural Heritage Reference Manual identifies a number of woodland benefits. These include soils erosion prevention, nutrient cycling, hydrological cycling, flood and erosion reduction, clean air and the long-term storage of carbon, wildlife habitat, outdoor recreational activities, sustainable harvest of woodland products. It can be demonstrated that each of the applicable benefits would be retained both with or without mitigation/enhancement. With regard to clean air and storage of carbon, this would be offset with the reforestation planting. In the scenario of no forest enhancement, it is unlikely that the loss of 2.47 ha of semi-open, young forest would result in a negative impact to local climate and atmospheric regulation and carbon sequestration. Such an effect is likely only measurable and would have an impact in the context of a large landscape scale removal such as in a larger forestry operation.

Based on the foregoing, it is our opinion that the no negative impact test for the removal and management of Black Locust can be met and demonstrated to be consistent with the Provincial Policy Statement under Section 2.1.5 b) in both the non-enhancement/mitigation and with enhancement/mitigation scenarios.

ROPA 38

With respect to the ROPA 38 policy Section 118(2), which states that a systems based approach to implementing the RNHS must be applied, the following is provided:

> *"118(2) b) Not permitting the alteration of any components of the Regional Natural Heritage System unless it has been demonstrated that there will be no negative impacts on the natural features and areas or their ecological functions;….."*

With regards to completing an Environmental Impact Assessment, Section 118(3) states that:

> *"The purpose of an EIA is to demonstrate that the proposed development or site alteration will result in no negative impacts to that portion of the Regional Natural Heritage System or unmapped Key Feature affected by the development or site alteration by identifying components of the Regional Natural Heritage System as listed in Section 115.3 and their associated ecological functions and assessing the potential impacts, requirements for impact avoidance and mitigation measures, and opportunities for enhancement."*

Similar to the PPS and NHRM as discussed above, ROPA 38 provides direction on identifying mitigation measures and opportunities for enhancement as part of the no negative impact test. The Natural Heritage System Definition & Implementation (Sustainable Halton Report 3.02) is, similar to the NHRM for the PPS, a supporting document to the Region's environmental policies. There is limited information in this document regarding the assessment of "no negative impacts". This term is only used in reference to impacts from agricultural lands uses. The description of "adverse impacts" to ecological features and functions is used in reference to assessment of impacts. As there are no specific thresholds or guidelines provided regarding no negative impacts, reference to the NHRM is needed.

In completing the assessment for no negative impact and review of consistency with ROPA 38, evaluation of the Region's criteria for significant woodlands is therefore a key test to be considered. For Block D, which is located within an Urban Area, significant woodlands are those that are 0.5 ha or larger and meet one or more of the following criteria:

- **contains forest patches over 99 years old criterion;**
  - while there are scattered individual trees within Block D that are older than 99 years, there are no large patches and these trees are not within the Black Locust woodland.
- **patch size of woodland is 2 ha or larger and located in Urban Area criterion;**
  - Block D is over 18 ha and the removal of 2.47 ha of Black Locust will not result in the patch size criterion not being met.
- **supports interior core area of 4 ha or larger (based on 100m from edge) criterion;**
  - Block D supports 0.43 ha of interior habitat, the Black Locust woodland has no interior habitat and provides marginal supporting habitat and if removed would not result in a functional change.
- **woodland is wholly or partially within 50 m of major of certain headwater creek criterion.**
  - The portion of Black Locust woodland proposed to be removed is over 100 m from Tributary and provides no direction surficial drainage, erosion control or shading function to the creek.

As part of the determination of no negative impacts, the Block D woodland would still meet the Region's evaluation criteria for the qualification as significant woodland. It is our opinion that the removal and management of Black Locust can occur with no change in the designation of significant woodland or negative impacts to the ecological features and functions of the Block D woodland.

Do Nothing Scenario and Negative Impact of Black Locust to the NHS

Given the shade intolerance of Black Locust as described above, this species will have only a localized ability to invade into the interior portion of the native woodland of Block D. However, while it may not pose a large direct threat to the integrity of the interior plant community of Block D, Black Locust still represents a substantial threat to the adjacent lands of Block D and the other woodland blocks in the study area. The negative effects of the spread and invasion of Black Locust into other components of the NHS are currently being contained by the active agricultural uses (annual plowing, seeding, harvesting). With the change in land use the adjacent lands of the woodland will start to vegetate and regenerate. In the scenario where the Black Locust woodland is not removed, this tree will invade into other components of the NHS and would likely occur even with an ongoing management plan to control the spread and establishment of regenerating Black Locust saplings.

Black Locust will compete with regenerating and planted native trees and shrubs, and will have a negative effect on the establishment of native woodland cover in the buffers, linkages and enhancement areas that will reduce the quality and function of these areas. Once the agricultural practices stop along the forest edge, the establishment of Black Locust will increasingly become a threat as it expands, effecting the health and integrity of the buffer and functional support of the woodland. The result would be a negative impact to the adjacent lands of the significant woodland.

One of the key concerns in the integrity of the components of the NHS within the study area, including linkages, enhancement areas and buffers, is the establishment of Black Locust in the floodplain of Tributary A. Once agricultural activities have stopped and following restoration activities for the proposed enhancement of the watercourse and riparian corridor, the area will provide suitable conditions (i.e., disturbed habitat, low nutrient soils, limited species competition and non-shade conditions) for the establishment of this species (Warne 2016). Once Black Locust has become established it will spread given the size of the seed source and size of the floodplain. While the scale of threat would be decreased with active and ongoing control and management, this will require extensive resource allocation with a lower potential for successful control compared to the option of removing the Black Locust and associated seed source. The identified risk of not removing the Black Locust trees would be that the components of the NHS along Tributary A become becomes a recipient location for the establishment and potential dominance of this species.

6.3.3.7 Core Area Enhancement and Ecological Linkage between Block C and D

Enhancing the ecological linkage between Block C and D will provide benefits to wildlife movement (e.g., for Red-bellied Snake), buffering of the existing wetland (Unit 3c) and associated breeding amphibian habitat, and buffering for the future replication wetlands in this location (see **Figure 6.3.3)** Furthermore, the ecological connection between the headwaters of two subwatersheds will be maintained and enhanced.

A GIS assessment was completed to identify and calculate a reforestation area that would further enhance the linkage between Block C and D. The area shown on **Figure 6.3.3** will increase the maximum width of the ecological linkage to approximately 120 m (from the edge of the 25 m wetland buffer to the eastern limit of the reforestation area). The increased linkage width of up to 120 m between Block C and D will functionally combine the Block C and D woodlands into one contiguous forested block of over 26 ha depending on the final buffer widths and enhancement prescription.

Section 4.5 of *Core Area Enhancements* (pg. 22-23) of the Region's Sustainable Halton Report 3.02 provides the following definition: (c)*ore area enhancements are areas made up of individual and/or groups of natural heritage features (or core areas as defined above) that have been enhanced through the addition of adjacent supporting areas intended to increase the ecological resilience and function of the individual and/or groups of natural heritage features that make up a core area within the NHS. Supporting areas may consist of meadowlands, early successional woodlands or agricultural lands.*

The Region's Sustainable Halton Report 3.02 provides the following five criteria for defining and identifying core area enhancements:

- *achieving a minimum threshold size of core area;*
- *grouping natural heritage areas that are likely to have important inter-dependent ecological functions;*
- *reducing the amount of edge of a core area by including embayments within cores;*
- *increasing the proportion of "interior": conditions (as defined by a 100 m buffer) within cores areas; and,*
- *including catchments critical to the quantity and quality of water sustaining cores areas.*

All five of these have been incorporated into the enhancement of Block C and Block D, which includes the linkage between these areas. Each of these are discussed below and addressed specifically in **Table 6.3.1**.

Report 3.02 also provides guidance on the degree of flexibility in determining the final boundary of proposed enhancements to core areas:

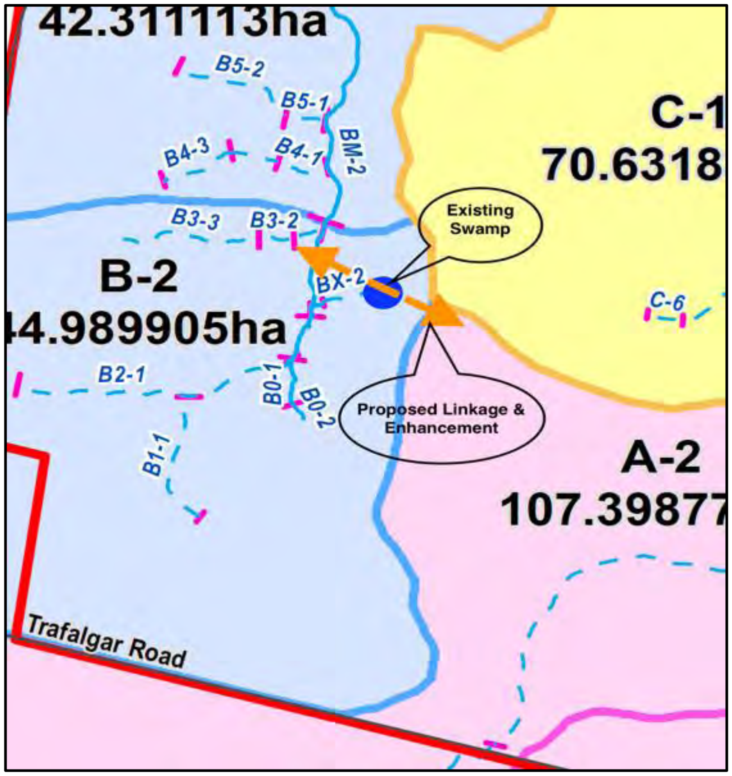
- if the intent of the enhancement is to increase the size of an existing woodland to achieve a minimum 20 ha threshold, and if the proposed enhancement maximizes the amount of interior forest present, then it does not matter where the enhancement occurs, as long as those objectives are achieved. The proposed core area and Block C-D linkage enhancements do maximize the area of interior forest;
- if the intent of the enhancement is to improve the shape of core natural area (i.e. maximizing interior habitat and minimizing edge impacts), then boundary adjustments that continue to achieve the core shape are acceptable. The proposed Block D enhancement and the Block C-D linkage meet the objective of improving the core shape; and,
- If the intent of the enhancement is to join one or more natural features and provide enhanced ecological linkage, boundary adjustments must continue this linkage. The proposed Block C-D enhancement does enhance the ecological linkage between Blocks C and D and also includes the surface water catchment limits of the wetland in this area (see **Figure 6.3.4**).

Table 6.3.1 Enhancement Area Criteria (Halton Region)

Criteria		SWGSS Refinements
Local Linkage	60m to 100m width	*Criterion met*: as shown on **Figure 6.3.3** the proposed local Linkage ranges from 100 to 120 m and therefore meets and goes beyond the recommended 100 m width provided in the Region's guidelines.
Core Area Enhancements	Based on boundaries developed in other natural heritage protection programs	*Criterion n/a*
	Achieving a minimum threshold size of a core area (20 ha)	*Criterion met:* based on the proposed 100 to 120 m wide Local Linkage (which is wider than the Region's recommended width) this will provide the functional requirement needed to create one

Criteria		SWGSS Refinements
		continuous woodland comprise of Block C and D over 26.0 ha.
	Grouping natural heritage areas that are likely to have important inter-dependent ecological functions	*Criterion met:* the physical connection of the two woodland blocks will, for example, allow for unimpeded movement of wildlife as they can travel through continuous habitat; and, improved hydrological connection with the increase in natural vegetation cover rather than the existing agricultural land cover.
	Reducing the amount of edge of core area by including embayments within cores	*Criterion met:* in the analysis to identify how best to meet this criterion (and in the context of assessing the entire Block areas for a systems based approach), it was determined that areas where the reforestation of embayments resulted in both reducing the extent of edge and also contributing to an increase in forest interior, would result in the best enhancement for the woodland. Infill of embayments in the northern portion of Block D will result in reduced edge areas and an increase in forest interior as shown on **Figure 6.3.3**. This combined objective cannot be met with the reforestation of the Region's proposed Enhancement Area between Block C and D based. Based on this evaluation we are of the opinion that this criterion has been met in the context of the best functional enhancement for Block C and D as a whole.
	Increasing the proportion of "interior" conditions	*Criterion met:* as described above, the reforestation areas as shown on **Figure 6.3.3** will provide for approximately an additional 2.32 ha of forest interior (light green hatched areas) resulting in a total of 2.75 ha within Block D. Reforestation within the Enhancement Area proposed by the Region between Block C and D would not result in any increase of forest interior due to the narrowness and configuration of the two woodlands at this location. In the context of the entire Block D, it is our opinion that this criterion has been fulfilled.
	Including catchments critical to the quantity and quality of water sustaining the core areas.	*Criterion met:* the physical location of the area between Block C and D is within subcatchment B-2 as identified by AECOM in the subwatershed study (see **Figure 6.3.4**). The watershed divide for Silver Creek and Sixteen Mile Creek is in this immediate area. The existing wetland in the linkage outlets into the BX-2 drainage and flows towards Block D into Tributary B. Surface drainage from the northwest limit of Block C flows into the Sixteen Mile Creek watershed. Under the current conditions of agricultural land use, which includes tilling and disturbance of the BX-2 drainage channel, there are impacts to water quality from sedimentation/erosion, and interference with the seasonal water quantity contributions to Tributary B. The proposed wetland creation, reforestation, vegetation buffers and enhancement of the local linkage will result in an improvement of the quality and quantity of surface water drainage in this area.

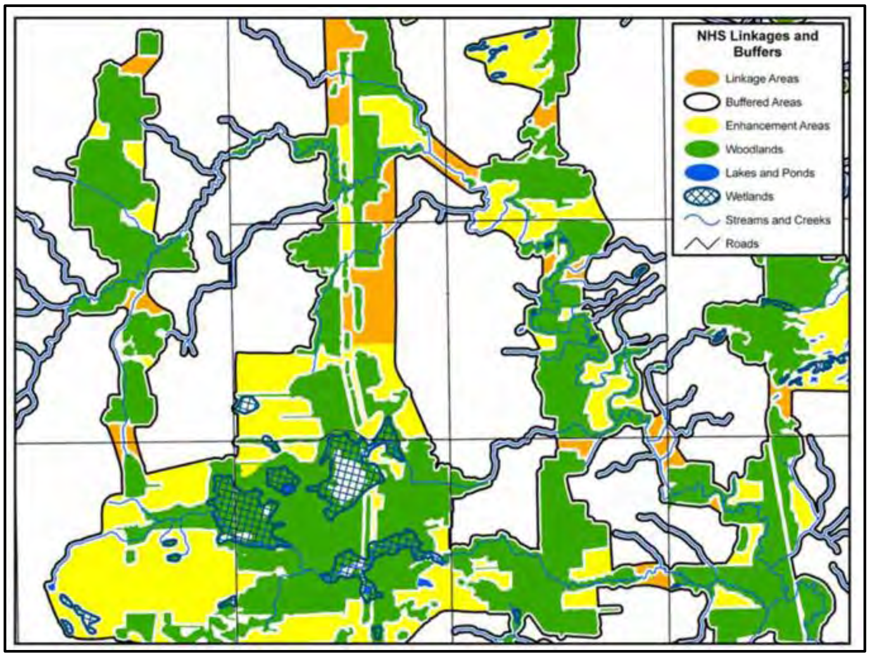
Figure 6.3.4 Drainage catchments and illustration of proposed linkage/enhancement that includes catchment and water quality/quantity for Tributary BX-2



Sustainable Halton NHS Components

In Region's development of the NHS provided in the Sustainable Halton report, a step by step process is provided in Section 2.0 for identifying the NHS components. This includes the identification of: 1) natural heritage features such as woodlands and woodlands (part of the Key Features); 2) identification of Core Areas/Enhancement Areas; and, 3) the identification of Ecological Linkages and Buffers. **Figure 6.3.5** is an example from the Region's report that provides a conceptual map illustrating of the layering of NHS components, which comprises the full NHS.

Figure 6.3.5 Example of Region's NHS Components (taken from Figure 3, Sustainable Halton Report 3.02)



While the Region has not provided the project team with site level mapping similar to **Figure 6.3.5**, it is our understanding that the area between Block C and D is comprised of Ecological Linkage, Enhancement Area and Buffer components. The rationale for the linkage is due to the close proximity of the two woodlands, while it was discussed that the Enhancement Area is due to the historic presence of additional woodland connecting Block C and D. A review of the historic conditions of this area was completed as part of our core area and linkage enhancement analysis.

Review of Historic to Current Conditions
A series of historic and current air photos have been compiled to review the extent and types of changes in woodland cover and agricultural uses in the area between the Block C and D woodlands. This spans a time frame of over 50 years from 1965 to 2016 (see **Air Photos E** to **H**) and provides important context to reviewing past and current ecological linkage functions between the two woodlands. From the 1965 and 1972 air photos it is evident that within at least the past 50 years there hasn't been a woodland area that directly connects Block C and D. Rather, there was an extension of woodland along the southeast side of Block D approximately 150 m from the linkage area. Additionally, there were two hedgerows located between the two Blocks (see **Air Photo E**, **F** and **G**). Based on the air photo review, the woodland extension and hedgerows were present up to at least 2004. Agricultural practices have been ongoing within the majority of the area between Block C and D from at least 1965 to present day. The enhancement between Block C and D as proposed in the subwatershed study is therefore a substantial improvement compared to the historic and existing conditions identified through the subwatershed study.

Air Photo E 1965 view of area between Block C and D

Air Photo F 1972 view of area between Block C and D

Air Photo G 2004 view of area between Block C and D

Air Photo H 2016 view of area between Block C and D

<u>Summary</u>

In completing a review and assessment of the core area enhancement and Block C – D linkage and the Region's proposed Enhancement Area in this location, it is critical to do so in the context of the features and function of the entire Block C and Block D woodlands for a systems based approach. This also includes consideration of the proposed management of the Black Locust area and proposed reforestation areas for the enhancement of Block D and its linkage to Block C.

The Sustainable Halton report provides direction on the *"flexibility"* (pg. 23) in determining the final boundary of core area enhancements. All four examples provided where flexibility in boundary changes would be appropriate have been implemented for the Block C-D enhancement and meet the objectives as outlined by the Region. This includes (as identified in **Table 6.3.1** increasing the Block D woodland from approximately 18 ha to 26 ha; maximizing the amount of interior forest in the north end of Block D through improving woodland shape in this area (i.e., filling embayments and reducing edge); combine natural heritage features and provide enhanced ecological linkage; and, include catchment areas for wetlands. In regard to these examples of flexibility, the Region's report states that it does not matter where the enhancements occur provided that the objectives have been met and that the boundary adjustments would be acceptable. The assessment through the subwatershed study has provided the detail necessary to identify the principles and framework that meet the Region's objectives and the proposed approach is in our view consistent with the guidelines of the Sustainable Halton report and policies of ROPA 38.

6.3.4 Natural Heritage System – Aquatic Resources

Aquatic

Maintenance of a healthy aquatic ecosystem requires that predevelopment flows be maintained or enhanced to a level within the fluvial capacity of the streams. There are two main components that contribute to streamflow: surface runoff and infiltration, followed by groundwater discharge. In an urban setting, surface runoff is collected by a stormwater management system, treated and discharged. The method of stormwater treatment can have considerable impact on the quality and quantity of the water being discharged, as well as the timing of these discharges in relation to the natural setting. Land development can alter infiltration volumes which may affect subsurface flows and discharges to streams. Therefore, consideration of the degree to which surfaces are hardened is necessary since diverting too much infiltration flow to a surface treatment system can impact fish and fish habitat by changing the flow regime of a watercourse primarily by larger flow input from a point source and increased turbidity.

<u>Targets</u>

- Protect aquatic habitat and fish communities based on existing conditions.
- Maintain predevelopment flow conditions
- Maintain and where possible, enhance thermal conditions within watercourses
- Achieve Ministry of the Environment (MOECC) “enhanced” level of SWM protection (80% Total Suspended Solids (TSS) Removal)

The assessment of streams and stream corridors and development of a management strategy has included existing conditions and the potential for enhancement. The enhancement of the stream using methods such as channel stabilization leads to subsequent improvement in quality of fish habitat, diversity of fish communities and water quality.

In developing a management approach, the form and function of the stream system by reach was considered using a riparian corridor approach. This approach considers the broad scope of characteristics and processes that affect the health of the stream system throughout the watershed including:

- Environmental – both aquatic and terrestrial conditions are included, such as the type of aquatic habitat, species (fish and benthic), the condition of riparian vegetation, linkage to other terrestrial features, and ability to provide nutrients to life in the stream;
- Geomorphologic – the overall condition of stream form including structural aquatic habitat, severity of erosion, bedload condition and source of bedload for downstream reaches;
- Hydrologic – influence on hydrologic response of stream, primarily through the floodplain adjacent to the stream and hydraulic characteristics (i.e., ability to detain flows), influence of vegetation and storage on base flows; and
- Hydrogeologic – the presence of recharge and discharge functions locally and regionally, and the associated contribution to base flow.

6.3.4.1 Fluvial Geomorphology

The role of the stream corridor is multipurpose from a geomorphic standpoint. It not only provides flow and sediment storage during high flow events, it also acts as a filter to prevent sediment and particulate inputs from surface water runoff from embedding coarse substrates within the streams. The longitudinal profile of the watercourse controls the energy available to transport sediment throughout the system. The slope of the watercourse therefore influences the rate of channel degradation and aggradation during channel adjustment processes. A steeper channel gradient contributes to a higher stream power and an erosive channel. Changes to the geometric parameters and substrate composition of a watercourse can impact the water quality and aquatic habitat of the channel. Sections of watercourses that may be realigned need to consider that slopes of existing stream reaches within the study area (with the exception of two) are greater than 0.5%. It is imperative that channels are designed to maintain a balance of erosion, transport, and sediment deposition over the long term in order to remain relatively stable. The maintenance of riparian vegetation within the stream corridor stabilizes banks and also provides inputs of organic materials and debris which aid in creating a diverse morphology. The meander belt width incorporated into the corridor allows the channel to migrate naturally within its floodplain without the loss of property or structural integrity. As discussed in **Section 5.6,** the streams were evaluated from a fluvial geomorphologic standpoint, which is summarized in **Appendix H.** The overall categorization is outlined as follows:

Streams Corridors – Conveyance Corridors

1. **High Geomorphic Classification** as it relates to Stream Morphology **(Table 5.9.1**): These reaches have been identified as high quality resource, based on their form and function. These corridors contain a defined channel with well-developed channel morphology (i.e. riffle-pool) and/or a well-defined valley. These corridors offer both form and function. Management options for these reaches include the following:
    a. Do nothing: If the reach is unlikely to be affected by future development, leave the corridors in their present condition and develop outside of their boundaries; and
    b. Enhance existing conditions: If the reach is likely to be affected by future development, maintain the present location of the corridor but enhance both the geomorphic and aquatic habitat conditions (*e.g.,* bank stabilization, re-establish a meandering planform, and connect channel to functioning floodplain).
    c. If watercourses with a high geomorphic classification are to be enhanced, are to be enhanced in-situ.

2. **Medium Geomorphic Classification** as it relates to Stream Morphology **(Table 5.9.1**): These reaches have a defined channel (bed and banks) or valley (e.g. gullies), may or may not have well-defined bed morphology (form) but do maintain geomorphic function and have potential for rehabilitation. In many cases, these reaches are presently exhibiting evidence of geomorphic instability or environmental degradation due to historic modifications and land use practices. Management options for these reaches include the following:
    a. Do nothing: leave the corridors in their present condition and develop outside of their boundaries;
    b. Enhance existing conditions: maintain the present location of the corridor but enhance the existing conditions (*e.g.*, bank stabilization, re-establish a meandering planform, and connect channel to functioning floodplain); and
    c. Relocate and enhance existing conditions: many of the reaches within the study area have undergone extensive straightening and modification for agricultural drainage purposes. As such they are not as sensitive to relocation and would benefit from enhancements such as the reestablishment of a meandering planform with functioning floodplain and development of a riffle-pool morphology.

3. **Low Geomorphic Classification** as it relates to Stream Morphology (**Table 5.9.1**): In general, these reaches consist of ephemeral headwater swales that lack defined bed and banks but do perform a geomorphic function through the conveyance of flow and sediment. Although many of the minor swales were given a low rating from a geomorphic standpoint, the cumulative impact of these features should not be overlooked. Management options for these reaches include the following:
    a. Do nothing: leave the channels/swales in place (no corridor required) and develop the surrounding lands;

b. Combination of SWM and open conveyance techniques: the function of headwater streams can be mimicked through the implementation of SWM techniques and;
c. Open conveyance techniques: the function of the ephemeral swales is replicated entirely through a system of open conveyance techniques (*e.g.*, backyard swales).

6.3.4.2 Environmental/Fisheries

Stream corridor

Biodiversity is a measure of the number of species present in an ecosystem as well as the distribution of individuals among species. As ecosystem health improves, new and improved habitats can be expected to lead to an increase in the biodiversity of aquatic life.

The management approach to stream corridors for this study will ensure protection of instream aquatic habitat, as well as a maintaining or incorporating a vegetative buffer along the corridors. The re-establishment of vegetation along the watercourses, and in some cases the maintenance and improvement of stream morphology, is expected to result in improved habitat conditions, temperature moderation and ultimately improved biodiversity. For example, the upper reaches of Tributary A have been highly altered by agricultural practices. Seasonal fish habitat is supported in these reaches because of the resiliency of the flow regime but the absence of riparian vegetation compromises the habitat quality. Restoration efforts targeted at improved morphology and replacement of the riparian corridor will improve the habitat function of this section of Tributary A. Conversely, the flow regime of Tributary C is not sufficient to support a fish community regardless of restoration implemented along the watercourse. Rather, the riparian enhancement proposed for this feature would contribute to temperature moderation and nutrient contribution to reaches downstream of Eighth Line.

The diversity of the fish communities in Silver Creek and Sixteen Mile Creek subwatersheds is fair for both (CVC 2013 and HRCA 2009). A review of data collected from available sources (CVC 2001 and HRCA 2009) reveals that Silver Creek supported 23 species of fish in 2001 and Sixteen Mile Creek supported 26 species of fish in 2009. Site specific fish sampling undertaken in 2013 of the reaches within the study area identified only one species within Silver Creek (Tributary B) and two species in Sixteen Mile Creek (Tributary A). Both of these systems have the potential to support more diversity as the benefits of habitat improvement are realized. The biodiversity targets for these two creeks should be to maintain or increase the biodiversity of the fish community.

In addition, water quality control and improvement is considered important for aquatic habitats (see **Section 6.3.5.3)** for additional detail).

Riparian buffers along streams protect the integrity of the system from the impacts of surrounding land use change and anthropogenic stressors. According to a review article by Castelle *et al.* (1994), buffer widths in the 15 to 30 m range are required to maintain the biological components of many wetlands and streams. Castelle *et al.* (1994) also indicate that the need for larger buffers increases in some situations, for example, where a wetland or stream is highly sensitive or the adjacent land use is intense. Environment Canada (2013) recommends a minimum buffer of 30 m for streams and recognizes that vegetating the riparian areas associated with lower order streams is very important for maintaining and improving the function of the watercourse. MNR (1994) *Fish Habitat Protection Guidelines for Developing Areas* recommended buffers of 15 m from important fisheries habitats. Conservation authorities in southern Ontario often recommend buffer widths ranging from 15 m to 30 m depending on fish community and habitat conditions.

Conservation Halton's fish habitat setbacks include:

- A 15 metre setback from the bankfull width of the watercourse where a warm water baitfish community is present.
- A 30 metre setback from the bankfull width of the watercourse where a warm water sport fish community is present.
- A 30 metre setback from the bankfull width of the watercourse where a cool or cold water fish community is present.

Based on a review of the literature and consultation with planning authorities, minimum buffer widths are recommended that would provide an appropriate level of protection for the watercourses based on existing conditions as well as to achieve the targets set out for the systems. Review of the literature and of current practice in southern Ontario suggests that a minimum width of 15 m would be appropriate for warmwater reaches and 30 m for cool/coldwater reaches. These widths are recommended for Southwest Georgetown, although in some cases, fluvial/floodplain buffers far exceed these recommended buffer widths. Wherever the recommended buffer widths are not met by floodplain and fluvial corridors requirements, it will be necessary to include upland habitat outside this zone to maintain the recommended buffer width along all watercourses.

A balanced approach to riparian buffer establishment, which recognizes the need for recreational opportunities and the importance of stormwater management within an urban environment, is required. Although, limiting encroachment into the riparian buffer increases the effectiveness of aquatic habitat functions, there is often a requirement to incorporate anthropogenic features within the buffer area. The location of these features within buffers area should be limited and will need to be assessed for the potential for detrimental impacts to the aquatic system.

<u>Targets</u>

- Develop and implement appropriately sized riparian buffer area that ensures that stream systems, including their ecological and hydrologic functions, are appropriately protected from the potential adverse impacts of land use change.
- Identify stream corridors for protection within the natural heritage system to encourage achieving ecological gain.
- Identify reaches which will benefit from enhancement opportunities to provide an increase in ecological function through fluvial geomorphology and erosion control targets (See **Section 6.3.4.5**).
- Maintain or if possible increase biodiversity within the fish community in the subwatershed area.
- Adopt appropriate land use controls to achieve enhanced stormwater quality control and water quality targets (See **Section 6.3.5.3**).
- Develop an adaptive environmental management plan, including monitoring and mitigation measures that considers pre, during and post construction and development activities.

Watercourse Crossings – Roads

It is suggested that all infrastructure crossings over watercourses should be sized with a minimum three times bankfull channel width span. It is also recognized that the size of the crossing openings should be sized to help facilitate the penetration of sunlight to the creek bed underneath the crossing to help allow the establishment and maintenance of herbaceous riparian vegetation which will help maintain a vegetatively-controlled channel morphology. The suggested sizing of infrastructure crossings over watercourses is also proposed to help ensure long term functioning of the fluvial functions of watercourses, to maintain fish and wildlife passage functions, floodplain connectivity, flood conveyance and human safety around crossing structures.

Services (Watermain/Sanitary)

Low Risk Crossings

Where a crossing has been deemed low risk, Conservation Halton staff require a minimum of 1.5 metres of cover between the invert of the creek and the top of the utility pipe/casing.

A crossing will be considered low risk where generally all of the following are present:

- There are no signs of active erosion
- There are no proposed changes in upstream land use or any proposed change in land use will be supported by best/current stormwater management practices
- The gradient is low (generally less than 1.5% but preferably less)
- Small drainage area (generally less than 150 ha)
- Low erosive substrates (e.g., silty clay tills)
- Crossing is relatively small diameter (generally equal or less than 300 mm if trenchless technology being utilized; 600 mm or less if open cut)

The presence of an existing or proposed culvert overtop of the utility crossing should be taken into consideration and may allow for designation of a crossing as low risk even if one or more of the above criteria cannot be met. There may also be other situations where one or more of the above are not met but where it is appropriate to deem the crossing as low risk based on the site's specific conditions.

Medium Risk Crossings

Crossings other than those deemed low or high risk are considered to be medium risk. A minimum cover of 2.5 or 3.0 m (to be confirmed during detailed design or FSS stage) must be provided at these crossings unless supported by a detailed geotechnical assessment (including hydrogeological component) and 100-year scour analysis.

High Risk Crossings

High Risk crossings are those crossings proposed in sensitive areas (e.g., Redside Dace habitat, Main Bronte/Sixteen/Grindstone Creek, etc.). In these areas, a detailed geotechnical assessment (including hydrogeological component) as well as a 100-year scour analysis must be undertaken to determine the appropriate amount of cover.

Reach Specific Management Recommendations

High-level management recommendations which are appropriate to achieve the objectives for the aquatic system have been discussed, **Figure 5.9.1** summarizes the management recommendation that will ensure the objectives of enhancing the riparian corridor system and improving aquatic habitat conditions are realized. These objectives are reflected in the stream classification system developed for the study area and allow for reach specific management recommendations, based on the management rating. The management rating considers a combination of functions and features that influence the aquatic system. This approach has identified areas within the stream network that would benefit from protection, restoration and enhancement to provide a benefit to the overall aquatic system which meets the functionality needs from a watershed perspective.

The reach specific management recommendations at a high-level include the following management guidelines:

- Maintain flow densities for low ranking reaches to continue providing downstream contributions;
- Preserve and enhance functions of medium ranking reaches recognizing the potential need for channel realignment; and
- Preserve, enhance and protect high ranking reaches

More specific management recommendation from an aquatic habitat perspective include the following measures. Examples of reaches that would benefit from each measure are also identified and illustrated on **Figure 5.9.1.**

- Rehabilitate channel form which has been degraded through past land use, incorporating natural channel design principles to enhance morphology and habitat complexity (AM-4, AM-5);
- Realign reaches which have been historically straightened ensuring that reach length is maintained (Reaches AM-6, AM-7, AM5-1 and Tributary C);
- Tributary C, Reach C5 is intended to be managed as a “greenway” that would function as a link between Blocks B and C. It could also provide multi-use such as a trail, utility corridor and potentially collect surface drainage as an LID measure. Regardless of final use, it should still be vegetated with trees and/or shrubs;
- Enhance low flow channel to maintain aquatic habitat accessibility during periods of low flow (Reaches A4-1, A5-1, AM-6, AM-7);
- Enhance riparian vegetation with woody plantings (Reach AM-1);
- The cross-section for any rehabilitated reach (particularly red dashed and blue streams) should be designed in a manner which is conducive to a diversity of locally native and common riparian plantings that can be successfully established and grow in a succession of vegetative community types in a self-sustaining manner.
- Incorporate riparian corridors into the natural heritage system;
- Remove barrier at Trafalgar Road to restore flows through A2;
- Install up to 6 temperature loggers along Reaches AM-3 and AM-4 to identify exact location of thermal transition; and
- Remove barrier at Eighth Line for Tributary B.

Ponds

Ponds are typically not considered fish habitat unless an inlet and/or outlet to a watercourse or other feature forms a connection. Ponds are also not usually regulated and can be removed from the landscape. The only pond present in the study area is located adjacent to Reach AM-1 of Tributary A. This pond has no surface connection to Tributary A and in this regard would not be considered fish habitat. If fish are present within the feature, they need to be rescued prior to the pond being removed.

6.3.4.3 Flood Protection

As part of the stream corridor management strategy, the stream corridors that require protection and the associated level of protection is summarized in **Section 5.9** and illustrated in **Figure 5.9.1**. **Figure 5.9.1** shows stream reaches that have been classified as being either those that require form and function to be maintained (red), those that are required to remain as open watercourses but whose form can be altered (blue), or those whose geomorphic function can be duplicated through the use of backyard swales or SWM ponds (green). All red and blue streams, regulated floodplain limits and associated buffers will form part of the NHS. The management approach is discussed in **Appendix R** and **Section 7.4.3.3**.

Red streams must remain in their current form or enhanced as possible. The reaches with the greatest enhancement potential are shown as hatched. The floodplain and hazard lines indicate areas to be protected, under Conservation Authority policies.

For the stream reaches that have been identified as being blue or green, opportunities may exist to deepen the streams, or relocate as part of a land development proposal. If modified, blue streams need to be reconstructed using natural channel principals. In addition, any modifications to floodplains need to be carried out in accordance with Conservation Authority policies.

Floodplain in Vicinity of Trafalgar Road and Side Road 10

As illustrated on **Figure 4.7.2** the floodplain in the vicinity of tributaries A2-1, A2-2, AM-5, AM-6, AM-7 and A5-1 are quite extensive. This is a result of the flat topography adjacent to the watercourses in the area and a constrained location in reach AM-5. Given the extent of land constrained from urban development in this area, additional work has been carried out by the consultants working for the area landowners to modify the floodplains. There is opportunity to refine the floodlines in this area, however the revisions need to couple with the management strategy provided in this document, and comply to current Conservation Halton policies. It is anticipated that floodplain modifications would include reaches AM5, A2-1, A2-2, AM-6, AM-7 and A5-1 as well as C3, A4-3 and A4-4. **Appendix V** provides the performance criteria for a natural flow channel and floodplain to be followed in any approach to modifications. These performance criteria are intended as a guide to follow to ensure that any modifications comply to the recommended management strategy and Conservation Halton policies. A corresponding reduced floodplain area will likely be used in the Secondary Plan for the study area, but will be required to adhere to performance criteria outlined in **Appendix V**. If the floodplain (plus setbacks) forms the outside limit of the stream corridor, this will be reflected in the NHS boundary.

Conditions Downstream of Eighth Line

The floodplain delineation for this study started at the Eighth Line crossings. Additional analysis has been requested by each Conservation Authority to carry out a flood hazard risk analysis downstream of Eighth Line to ensure that proposed future development with the recommended SWM approach does not increase flood risk downstream of Eighth Line. This can be carried out at the Master Drainage and SWM plan stage or as part of the EIR process (as long as the EIR is carried out to include the entire tributary).

6.3.4.4 Hydrogeology

The components to the hydrogeologic system that require management with respect to maintaining natural ecologic function: infiltration (and ultimately groundwater recharge), groundwater flow and groundwater discharge. This section discusses the management strategy for mitigating impacts to these hydrogeologic system components.

Given that urbanization of the study area will change components of the hydrologic cycle, including a decrease in infiltration, the overall goal will be to maintain infiltration as close to current levels as possible. Within areas where the natural conditions will be preserved, the contribution to groundwater recharge will remain unchanged. In areas where development will occur, the increase in impervious ground cover has been evaluated to have the potential to decrease groundwater recharge. Similarly, the groundwater discharge/groundwater support to the tributaries on site was simulated to decrease under post-development conditions. Given the importance of groundwater inputs to stream function/stream health, it is imperative that the land areas delineated as contributing to groundwater discharge are managed appropriately. These areas should be maintained as close to natural conditions as possible, with as little land being covered with impervious material, as is possible. Further, where alterations to the ground surface occurs, Low Impact Development measures are required to mitigate the infiltration reductions related to the alteration. The management strategy of stormwater quality (**Section 6.3.5.3**) should be implemented in areas being maintained for groundwater recharge. Following this strategy will ensure that water of reduced quality is not directed towards areas being maintained for natural recharge. Adherence to the Source Water Protection policies discussed in **Section 6.3.5.3** will also contribute to the protection of water quality as it pertains to groundwater recharge and discharge.

6.3.4.5 Riparian Corridor Management

The riparian corridor widths of the unconfined reaches within the subwatershed are composed of three components, which include the meander belt width (defined in **Table 5.6.3**), a 15m setback allowance, and a factor of safety. The three components are illustrated in **Figure 6.3.6** and **Figure 6.3.7** provides a decision making flowchart that outlines the riparian corridor width determination protocol. **Table 6.3.2** lists the stream corridor widths for the study area for the unconfined systems.

Reaches that are defined as confined systems, where the watercourse is located within a valley corridor either with or without a floodplain and confined by valley walls, must include a stable top of bank (3:1 slope), a toe erosion allowance, and an erosion hazard allowance as outlined within the MNR (2002) Technical Guide and the CVC (2014) guidelines. The stable top of bank may or may not coincide with the physical top of bank.

Table 6.3.2 Stream Corridor Widths for the Study Area

Reach	Corridor Width (m) Belt Width + 15m Setback + Factor of Safety	Corridor Width (m) Total
AM-7	29+30+6	65
AM-6*	42+30	72
AM-5*	60+30	90
AM-4*	65+30	95
AM-2*	76+30	106
AM-1*	71+30	101
A4-2	23+30+16	69
A4-1	36+30+7	73
A5-1	21+30+6	57

**The TRCA (2001) empirical meander belt formula includes the addition of 2 standard errors. The addition of the factor of safety is considered redundant.*

As mentioned in **Section 5.6.1**, Reach AM3 along Tributary A meanders through a defined valley within which the valley walls are between approximately 5m to 6m high. The channel is therefore considered to be confined, with alternate valley wall contact on the left and right bank within the reach. Tributary B is also confined and flows through a relatively narrow and deep (up to 25m high) valley. Confined system protocol identified in CVC's "Slope Stability Definition and Determination Guideline" (CVC, 2011), as well as the Ontario Ministry of Natural Resources (MNR) Technical Guide, River and Stream Systems: Erosion Hazard Limits (2002) were used to determine the erosion hazard limit. The three (3) components that define the erosion hazard limit for confined systems are shown in **Figure 5.6.1**.

Additional borehole logs adjacent to Reach AM-3 and Tributary B will be required to complete a full geomorphic hazard assessment of these reaches in order to determine the geotechnical stable slope. Details on the specific requirements will need to be obtained from Credit Valley Conservation. Until then it is recommended that the hazard line deliviation on **Figure 4.8.9** be used for planning purposes.

Figure 6.3.6 Conceptual Belt Width

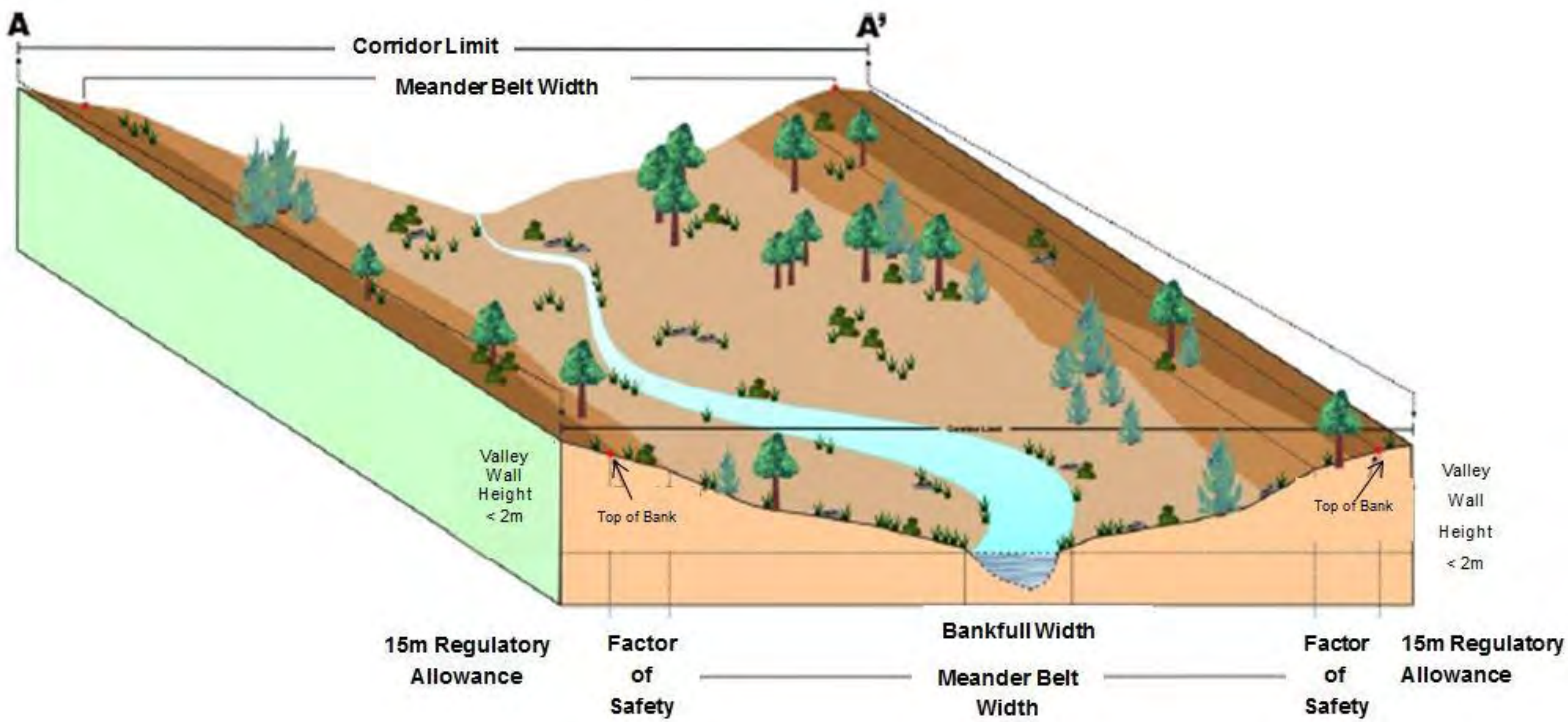
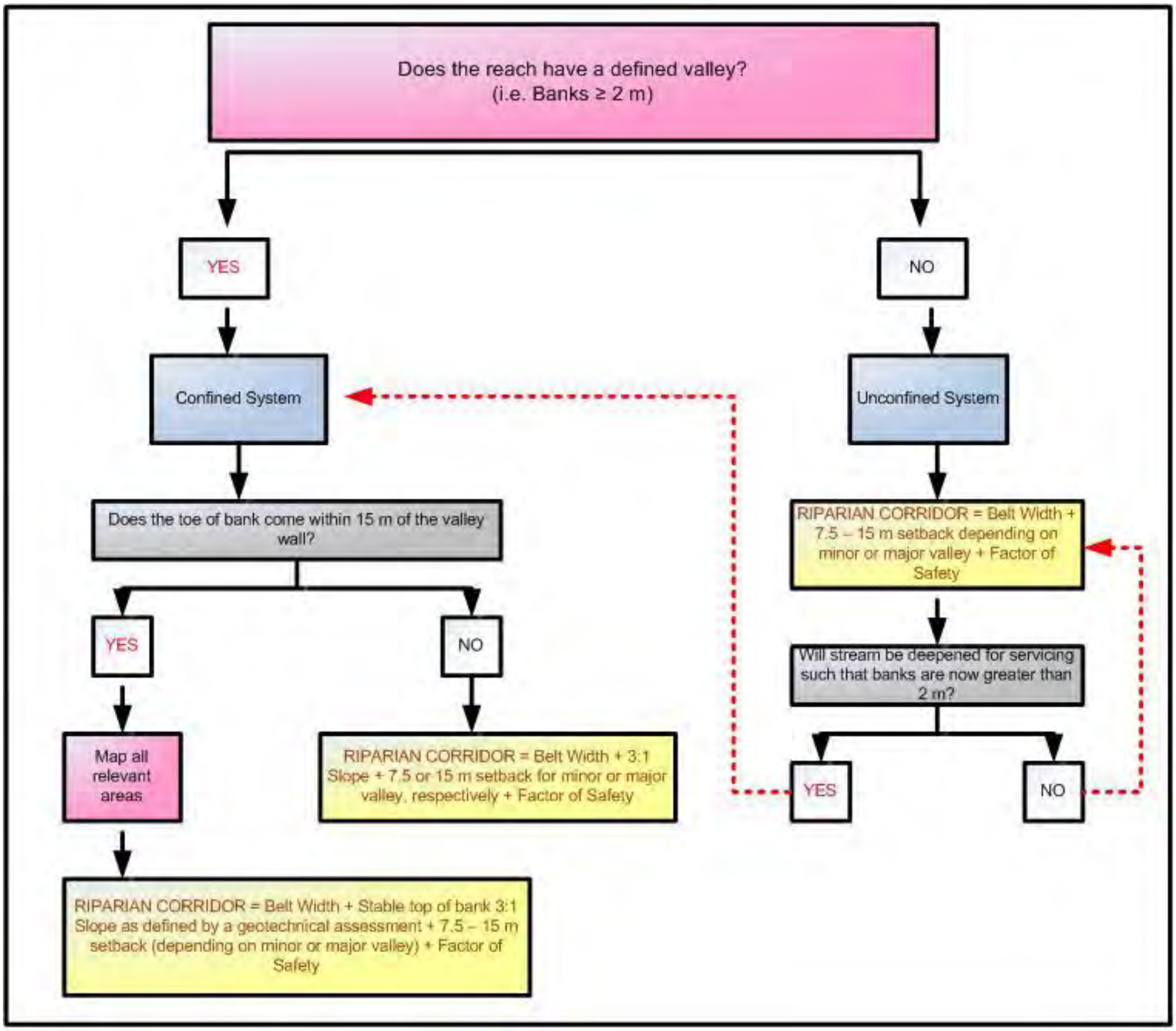


Figure 6.3.7 Belt Width Flowchart



Note:

- *A 15m setback is required by Conservation Halton in the Sixteen Mile Creek watershed.*
- *For reconstructed confined riparian systems Conservation Halton is supportive of sizing the corridor on the basis of belt width plus stable top of bank, plus a factor of safety.*

As mentioned in **Section 5.9.1**, the reaches within the Southwest Georgetown study area have been characterized based on three (3) categories for stream management. This includes high constraint streams where current form and function are to be preserved (red streams), medium constraint streams where the current function is to be preserved (blue streams) but they can be relocated or enhanced, and low constraint streams that can be replaced through infrastructure or SWM (green streams), as long as both the drainage density targets are met and where appropriate, incremental floodplain storage is maintained.

Development of Regional Drainage Density Targets

Drainage densities were calculated for the study area and compared to those reported elsewhere within the Credit River watershed, Greater Toronto Area, and those in close proximity to Georgetown (Huttonville Creek and Springbrook watershed). Results for Southwest Georgetown were derived based on dividing the total stream length for each sub-catchment by its respective drainage area. Preliminary calculations of drainage density based on stream length per unit area of subcatchment within the study area utilized 1:10,000 Ontario Base Maps (OBMs). Drainage density targets were calculated for Tributary A and C together, and Tributary B separately.
Results of the drainage density target calculation (**Section 5.6.1**) show that the majority of the subcatchments within Tributary A and Tributary C met and/or exceeded the established drainage density targets, but there were a few cases where the density target could not be met. Despite individual basins having a deficit, there is an overall surplus indicating that the incorporation of green streams is not necessary. Tributary B on the other hand, did not meet the drainage density target and was short by 0.02km. This deficit can be addressed by preserving sufficient length of green streams and through the establishment of stormwater management ponds.

Erosion Threshold

The critical discharge is defined as the flow (m^3/s) at which significant bedload movement can occur. If development causes an increase in magnitude and duration of flows above the critical discharge then it can negatively affect the channels pre-existing and sediment transport processes. Erosion thresholds have been determined at three sensitive tributaries within the Southwest Georgetown subwatershed in order to prevent an increase and decrease in erosion and deposition along the watercourse. Applying SWM techniques such as swales and SWM ponds can mitigate issues associated with changes in land-use by providing a decrease in peak flow durations and mimicking or reducing pre-development runoff volumes. The erosion thresholds identified in **Table 5.6.4** provide targets for the drainage network.

Future erosion threshold monitoring work will be required to confirm site/reach specific erosion thresholds for proposed development. This will include conducting additional geomorphic field work at more site specific locations in order to determine the erosion thresholds, as well as continual monitoring of the baseline data collected at the current erosion threshold sites. The additional erosion threshold field work should be completed by a qualified geomorphologist and will conform to the CVC (2010) guidelines that were used during the initial assessment. At the EIR/FSS stage the analysis is to be carried out in Tributary A as one analysis area and the same for Tributary B and Tributary C. Detailed analysis will be carried out to confirm or modify the targets, however the target site should be used to ensure that the targets are met. In this way, the overall system will be protected. The individual pond outlets should only be investigated on a local site basis to ensure that there is no potential for local scour.

Tributary B Regression

For Tributary B, although Silver Creek is the base point towards which the profile would be adjusting, Eighth Line serves as a local control point since the grade of the channel is determined by the invert of the culvert. The profile of Tributary B reveals a steep channel bed with a marked knickpoint through Reach BM-3. This is an intermittent channel near the headwaters of Tributary B. It is expected that this knickpoint will continue to regress, in conjunction with continued development of Tributary B the valley, due to the fact that it is composed of erodible materials (i.e. not hard bedrock). Regression will continue until a lower grade, concave up profile is attained. **Section 4.8.6.3** in the Characterization Report states that the upstream projection of slope unit BM-3 and the tableland channel profile suggests that head of the valley may move 210 m upstream from its current position. Reviewing of mapping suggest that this point would occur either north of Side Road 15, or west of Trafalgar Road, depending on the trajectory of headwater movement.

In order to prevent/limit further headcutting (currently occurring in BM-3) it is recommended that flows are diverted from upstream of BM-4 to more a morphologically stable area upstream of the Eighth Line (i.e. reach BM-1 or BM-2). The existing catchment area for Reach BM-3 is 0.45 km^2 with a 2-year return flow of 0.44 cms. Diverting flows from BM-4 will reduce the drainage area of BM-3 to ~0.12 km^2 and result in a 2-year return flow of 0.11 cms. The proposed reduction in drainage area and more importantly in flow regime will significantly reduce the magnitude and frequency of erosive flows within BM-3 which will curtail or eliminate upstream knickpoint migration and decrease the risk of slope failure in the main branch. The downstream reaches (BM-1 or BM-2) will still have an adequate drainage area (to ensure hydrologic and morphological function is upheld in these reaches.

Fish Habitat Considerations

Fish habitat in Tributary B is limited to Reach BM-1. This reach is the furthest downstream of Tributary B, and exits the study area across Eighth Line. The steep gradient of the valley feature that forms the upstream reaches of Tributary B precludes any direct fish habitat; however these reaches provide flow and nutrient input downstream. The primary source of this input is from surface water flow, that would be generated during spring freshet and other high flow events. In this regard, a diversion of flows would not be expected to impact the flow regime or nutrient contribution to the downstream reaches provided the flow is directed to the downstream reach of Tributary B.

Terrestrial Considerations

Specific terrestrial features within the Block D valleyland that have a functional hydrologic association with Tributary B consist of two riparian wetlands, Unit 3b (willow mineral deciduous swamp) and Unit 21 (forb mineral meadow marsh), see Figure 4.9.1. While evidence of groundwater input to these wetlands was observed (seepage), the primary source of water is from surface inputs associated with Tributary B. Both Unit 3b and Unit 21 are within reach BM-1 and are therefore found well downstream of the proposed flow diversion at BM-4. The linear distance and flow conveyance along BM-3 and BM-2 into these wetlands, as well as adjacent tributary inputs, provide the primary flow inputs that sustain the riparian wetlands during the key seasonal period of summer. Under current conditions there is a proportionately limited surface water contribution from upstream of BM-4 during this period. As the contribution of surface flows to these wetlands from upstream of BM-4 is largely in the spring when surface water inputs are abundant, the diversion of this flow is not expected to result in a change to the form and function of Unit 3b and Unit 21. The diversion of flow will also reduce the annual sediment inputs to Tributary B. Extensive areas of sedimentation along the riparian areas were observed in 2014.

Furthermore, a knickpoint can only migrate as far as the upstream limits of the drainage basin (i.e. source of water). Even if knickpoint migration continued within BM-3 it would only migrate as far as the flow diversion in BM-4 as this would be the most upstream point of the drainage basin. BM-4 (i.e. the location of drainage diversion) is greater than 0.5 km north of Trafalgar Road.

6.3.5 Stormwater Management

Flood Protection

Flood protection goals include protecting the public and property from flood damages that could result from increased runoff rates and volumes due to new development. Also, downstream riparian landowners have the right to receive runoff quantity and quality in the current state. The targets will maintain runoff peak flow rates from new development to existing levels for the 2-year through 100-year return periods and the Regional Storm.

In order to protect existing and future development from flood potential, the floodlines that have been developed are used to delineate flood hazard lands. Regional and 100-year storm controls will maintain the existing condition regulatory floodplain. Any changes to watercourses will be addressed at EIR/FSS stage. All development is to be excluded from within the regulatory floodplain. In areas where floodplains are not delineated, conveyance for flood events, (*i.e.,* the greater of the Regional Storm or the 1:100-year storm) is to be provided for in the conveyance system, in accordance with Town of Halton Hills drainage standards.

In addition, floodplain storage plays a role in mitigating the potential for increase in flood flows downstream through the storage of runoff. This storage is currently provided by the “natural” storage of the current stream corridors or by the storage along modified streams that currently exist. This storage serves to store surface water during runoff events and control peak flows when the stream is at overbank conditions.

If the stage-storage conditions along stream reaches are reduced, peak flows will increase downstream. Increases in peak flows or changes in flow regime conditions from current levels would result in an increased risk of flooding and erosion. To mitigate this, the target of maintaining the current stage-storage relationship along selected reaches has been adopted. In addition, peak flows after development must be controlled to current levels, including the use of threshold targets for erosion control.

<u>Targets</u>

- Maintain existing peak discharge rates for all design events, particularly high flows.
- Preserve discharge rates for each subwatershed up to and including Regional Storm level (unit area).
- Maintain stream reach floodplain storage relationships to protect existing floodplain storage.
- Remove flood potential at identified locations within the study area.
- Delineate floodplains to provide development limits.
- Restrict development in the floodplains as per Provincial and Conservation Authority (CA) policies.

In addition to the above, it is recommended that a further “Risk Assessment” study be carried out downstream of Eighth Line for Tributaries A, B and C. Regional storm controls are recommended for the subwatershed due to capacity restrictions at the Eighth Line crossing of Tributary B and concerns regarding limited capacity of the Sixteen Mile Creek watercourse between Eighth Line and Side Road 10. A risk analysis should be carried out as part of a separate study to determine if further works should be carried out at Eighth Line or downstream to mitigate any risk in these areas.

It is also noted that the existing major and minor flows from Tributary D catchments (D-1, D-2 and D-3, total 29.6 ha) are conveyed by multiple outlets to the existing ditch drainage on the east side of Eighth Line, discharging to the constructed bypass pipe through the Fernbrook Phase 3 subdivision, ultimately discharging to the East Branch of Sixteen Mile creek. According to GHD’s 2013 report for the development, the bypass pipe was only sized for the 10-year flows from upstream for a much smaller catchment area (10.8 ha), equivalent to Catchment D-1 and D-2 (10.6 ha). The downstream development was previously approved by the Town of Halton Hills and Conservation Halton, and is now fully built. The existing downstream infrastructure is to be considered as a design constraint for Tributary D lands under proposed conditions.

Minor flows from Catchment E-1 discharge through an existing road crossing culvert along Side Road 10 (Structure #22). Flows are conveyed southeast along existing ditch drainage parallel to Eighth Line, eventually discharging to the East Branch of Sixteen Mile Creek approximately 3 km downstream. Under existing conditions, major flows spill at the intersection of Eighth Line and Side Road 10, and are conveyed north east down Side Road 10 to the East Branch of Sixteen Mile Creek. The capacity of the existing crossing along Side Road 10 is to be considered as a design constraint for proposed conditions for Catchment E-1.

Details regarding the SWM pond location and outlet configuration are beyond the scope of this study. Preliminary locations and footprint sizes were developed as part of this study, but should not be considered as final in any manner. These details will be developed as part of the Stormwater Management and Drainage report that will be carried out in conjunction with the Secondary Plan. This study will include details on LID measures to be applied.

6.3.5.1 Hydrogeology

Management of stormwater in the subwatershed alters the natural function of the system in that precipitation is directed to collection systems where it is stored and/or conveyed with runoff from the surrounding areas. This process has the potential to reduce groundwater infiltration and recharge by reducing the opportunity for precipitation to interact with the undeveloped lands. The interaction of runoff with developed land and mixing of runoff from adjacent areas also has the potential to impact water quality prior to infiltration to the groundwater system. This section addresses the strategy for managing stormwater with the goal of minimizing impacts to groundwater quantity and quality.

Water Quantity

This section focuses on the management of impacts to water quantity from a groundwater supply perspective, as the management of impacts to ecological groundwater contribution are discussed separately (**Section 6.3.4**). The potential reduction of infiltration in the study area has been identified through the water balance modelling presented in **Section 5.4.5**. This modelling assumed that the Natural Heritage Systems and Environmental Linkages (**Figure 4.12.1**) will remain largely undeveloped and therefore have low % impervious surface values. It is not anticipated that stormwater management structures will be installed in these areas and therefore, current natural infiltration to the groundwater system will continue. Further to this, it is recognized that the existing tile drainage system will be removed as part of development. The infiltration recommendations were developed, taking this into consideration.

Other features in the study area such as Public Parks, the existing Public Cemetery, and the Regional Floodplains, will also have low % impervious surface values. Therefore, the quantity of water infiltrating and becoming groundwater recharge in these areas will not change significantly. The areas of Residential, Commercial and Institutional development will result in higher % impervious surface values and therefore it is anticipated that a higher reduction in infiltration will occur here.

Given the low permeability soils over much of the study area, mitigating the potential reduction to infiltration in these areas will be difficult; however, LID options are available and should be considered (TRCA, 2013). Opportunities for infiltration are site specific, requiring more detailed studies on individual land parcels to identify and take advantage of infiltration opportunities. Site-specific determinations of water table position and variability will be required prior to development of the study area, particularly in the southern portion where high water levels were observed. As a guiding principle, the use of Best Management Practices and LID are required to minimize the predicted reduction of infiltration. Overall recommended infiltration targets for LID control volumes are further discussed and provided in **Section 6.3.5.2.**

With respect to mitigating potential effects on municipal groundwater supply, the focus should be on the lands where the surficial geology is composed of sand and gravel in the general northern portion of the Study Area. This area is unique in that it is partially within the WHPA-Q1/Q2[7] (**Figure 4.4.4),** as defined in the Halton Hills Tier 3 Water Budget report (AECOM and AquaResource, 2014a). The WHPA-Q1/Q2 designation means that, within this area, a land use that reduces recharge to the groundwater system poses a Moderate Risk to the Georgetown municipal water supply wells. Therefore, any future land use within the WHPA-Q1/Q2 is subject to the Water Quantity Policies

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[7] *The Source Water Protection Water Quantity Policies refer to the WHPA-Q2. In the Study Area, the WHPA-Q2 is coincident with the WHPA-Q1/WHPA-Q2 C (AECOM and AquaResource, 2014a).*

of the CTC and Halton-Hamilton Source Protection Regions. As discussed in Section 4.4.5, the development within the Study Area is subject to the SPP Transition Policy that interprets between "existing" and "future" land uses.

Examples of the policies that apply to the WHPA-Q1/Q2[8] and must be addressed and implemented through further planning stages (eg. subwatershed impact study, subdivision plans, stormwater management plans, site plans etc.) include:

Table 6.3.3 Summary of Applicable CTC Policies for WHPA–Q2

Policy ID	Threat Description	Policy	When Policy Applies	Related Policies	Policy Application
REC-1	An activity that reduces recharge to an aquifer	**Land Use Planning** (Planning Policies for Protecting Groundwater Recharge) For applications under the Planning Act within the Tier 3 Water Budget WHPA-Q2 identified as having significant water quantity threats, the relevant Planning Approval Authority shall ensure recharge reduction does not become a significant drinking water threat by: 1) Requiring new development for lands zoned Low Density Residential (excluding subdivisions) or zoned Agricultural to implement best management practices such as Low Impact Development (LID) with the goal to maintain predevelopment recharge. 2) Requiring that that all site plan (excluding an application for one single family dwelling) and subdivision applications for new residential, commercial, industrial and institutional uses provide a water balance assessment for the proposed development to the satisfaction of the Planning Approval Authority which addressed each of the following requirements: a) maintain pre-development recharge to the greatest extent feasible through best management practices such as LID, minimizing impervious surfaces, and lot level infiltration; and b) where pre-development recharge cannot be maintained on site, implement and maximize off-site recharge enhancement (within the same WHPA-Q2) to compensate for any predicted loss of recharge from the development, c) for new development (excluding a minor variance)within the WHPA-Q2 and within an ICA (for sodium, chloride or nitrates), the water balance assessment shall consider water quality when recommending best management practices and address how recharge will be maintained and water quality will be protected. 3) Only approving settlement area expansions as part of a municipal comprehensive review where it has been demonstrated that recharge functions will be maintained on lands designated significant groundwater recharge areas within WHPA-Q2. 4) Amending municipal planning documents to reference most current Assessment Reports in regards to the significant groundwater recharge areas within WHPA-Q2.	Future: Immediately(T-9) Amend OPs for conformity within 5 years and ZBLs within 3 years of OP approval (T-8)	N/A	The Town of Halton Hills is responsible for implementing this policy, within the context of the Transition Policies. .

Policy ID	Threat Description	Policy	Policy Application Notes
T-59-C	Any activity that reduces the recharge of an aquifer	**Land Use Planning** Within a wellhead protection area Q2 where a future reduction in recharge would be a significant drinking water threat, a. the municipal planning authority shall require that planning applications demonstrate that all attempts have been made to achieve a pre-development recharge condition using best management practices and including low impact development measures. b. the municipal planning authority shall report on actions taken to implement this policy to the Source Protection Authority by February 1 of each year.	The Town of Halton Hills is responsible for implementing this policy, within the context of the Transition Policies.

The applicable Source Protection Plans must be consulted going forward as part of the further planning approval and engineering design stages to ensure that applicable policies relating to water quantity are addressed and implemented as appropriate.

Water Quality

This section focuses on the management of impacts to water quality. The private domestic groundwater supply wells in the study area obtain water from either permeable sediments within the overburden, or from the Queenston Formation shale, which is the local upper bedrock unit. The surficial soils over much of the study area are composed of fine grained Halton Till, which is a local aquitard that inhibits downward movement of surface water into the groundwater system. The surficial soils in the vicinity of Eighth Line and Side Road 15 are distinct from the glacial till in that they are more permeable glaciofluvial deposits. In contrast to the Halton Till aquitard soils, these soils do not offer protection from contaminant migration to the underlying aquifer(s). These permeable soils, as well as a larger surrounding area, are part of a Wellhead Protection Area (WHPA) for the Georgetown Municipal Wells (**Figure 4.4.8**).

The Source Protection Plans discussed previously also include policies that address water quality for the municipal wells and their associated WHPAs. Specifically the policies impose restrictions on the following land use activities to protect water quality in WHPAs:[8]:

- Waste storage or disposal;
- ***Sewage (storage, conveyance and discharge);***
- Agricultural source material (application, storage, and management);
- Non-agricultural source material (application, handling, and storage);
- Commercial fertilizer (application, handling, and storage);
- Pesticide (application, handling, and storage);
- ***Road salt (application, handling, and storage);***
- ***Snow storage;***
- Fuel (handling and storage);
- Dense Non-Aqueous Phase Liquid (DNAPL) and organic solvents (handling and storage);
- Management of runoff that contains Aircraft de-icing chemicals; and
- The use of land as livestock grazing or pasturing land, an outdoor confinement area, or a farm-animal yard.

[8] *Activities in bold italics are subject to policies when they occur in either a WHPA or an ICA for chloride.*

Policies related to the bold/italicized land use activities apply to both the WHPA and the ICA for chloride. The management of potential impacts to groundwater quality in the municipal supply aquifer will be accomplished through adherence to the Source Protection Plan polices.

Examples of the water quality policies that apply to the WHPA and must be addressed and implemented through further planning stages (eg. subwatershed impact study, subdivision plans, stormwater management plans, site plans etc.) are included below and are organized by SPA.

CTC Source Protection Plan Policies

The CTC water quality policies that are currently relevant to the project are presented in **Table 6.3.4**. **Table 6.3.5** describes the relevant policies and their application in detail.

Table 6.3.4 Summary of Relevant CTC Policies by Vulnerable Area

Area	Relevant Policies
WHPA – B: Vulnerability Score of 8	No relevant policies at this stage in the process.
WHPA – B: Vulnerability score of 10	Policies SWG-11, SWG-12, SWG-13, SWG-14, SAL-2, SAL-3, and SNO-1.
WHPA – C: Various vulnerability scores	No relevant policies at this stage in the process.
Issue Contributing Area for Sodium/Chloride	Policies SAL-2, SAL-3, and SNO-1.

Table 6.3.5 Relevant CTC Policies for WHPA

Policy ID	Threat Description	Policy	When Policy Applies	Related Policies	Policy Application Notes
SWG-11	Discharge from a Stormwater Retention Pond	**Prescribed Instrument** 1) Discharge, including infiltration, from a stormwater retention pond shall be prohibited into an area where the discharge would be a significant drinking water threat in the following area: • WHPA-A (future).	Future: Immediately (T-3)	SWG-12	The MOECC is required to include conditions in the Environmental Compliance Approval (ECA) to ensure that SWM Pond discharge does not become a threat.
		2) Where the discharge from a stormwater retention pond is in an area where the activity is, or would be, a significant drinking water threat, the Environmental Compliance Approval that governs the activity shall be reviewed or established to ensure appropriate terms and conditions are included so that the activity ceases to be, or does not become, a significant drinking water threat in the following areas: • WHPA-A (existing); or • WHPA-B (VS = 10) (existing, future); or • WHPA-E (VS ≥ 8) (existing, future); or • the remainder of an Issue Contributing Area for Nitrates, Pathogens or Chloride (existing, future). Not limiting any other conditions to be included in the Environmental Compliance Approval, the Issuing Director should include the following conditions, where possible: • no stormwater is discharged from the pond into a WHPA-E where it would be classified as a significant drinking water threat;	Future: Immediately (T-3) Existing: 3 years (T-1)	GEN-3 SWG-12	

Policy ID	Threat Description	Policy	When Policy Applies	Related Policies	Policy Application Notes
		• existing infiltration ponds are lined to prevent infiltration of contaminants; and • in an Issue Contributing Area for Chloride, require actions to reduce salt loading into the pond from upstream lands where the application of road salt occurs.			
SWG-12	Discharge from a Stormwater Retention Pond	**Land Use Planning** 1) The use of land for the establishment of new stormwater retention ponds shall be prohibited where the discharge (including infiltration) of stormwater would be into a significant threat area in the following area: • WHPA-A (future). 2) The use of land for the discharge from a stormwater retention pond in an area where the activity would be a significant drinking water threat shall only be permitted where it has been demonstrated by the proponent through an approved Environmental Assessment or similar planning process that the location of discharge from a stormwater retention pond is the preferred alternative and the safety of the drinking water system has been assured in any of the following areas: • WHPA-B (VS = 10) (future); or • WHPA-E (VS ≥ 8) (future); or • the remainder of an Issue Contributing Area for Nitrates, Pathogens or Chloride (future).	Future: Immediately (T-9) Amend OPs for conformity within 5 years and ZBLs within 3 years of OP approval (T-8)	SWG-11	Due to the SPP Transition Policies, the SWM Ponds to be constructed in the Study Area are considered "existing" and therefore the policy does not apply.
SWG-13	Sanitary Sewers and Related Pipes	**Prescribed Instrument** Where sanitary sewers and related pipes are in an area where the activity is, or would be, a significant drinking water threat, the Environmental Compliance Approval that governs the activity shall be reviewed or established to ensure appropriate terms and conditions so that the activity ceases to be, or does not become, a significant drinking water threat in any of the following areas: • WHPA-A (existing, future); or • WHPA-B (VS = 10) (existing, future); or • WHPA-E (VS = 10) (existing, future); or • the remainder of an Issue Contributing Area for Nitrates or Pathogens (existing, future). Not limiting any other conditions to be included in the Environmental Compliance Approval, the Issuing Director should include the following conditions, where possible: • requiring higher construction standards; and • inspections by the owner for leaks.	Future: Immediately (T-3) Existing: 3 years (T-1)	GEN-3 SWG-14	The Region will consider and address this policy through the design and approval process for the sewer system.
SWG-14	Sanitary Sewers and Related Pipes	**Land Use Planning** New development dependent on sanitary sewers and related pipes, in an area where the activity would be a significant drinking water threat, shall only be permitted where it has been demonstrated by the proponent through an approved Environmental Assessment or similar planning process that the	Future: Immediately (T-9) Amend OPs for conformity within	SWG-13	The Region will consider and address this policy through the design and approval process for the sewer system.

Policy ID	Threat Description	Policy	When Policy Applies	Related Policies	Policy Application Notes
		location for the sanitary sewer and related pipes is the preferred alternative and the safety of the drinking water system has been assured in any of the following areas: • WHPA-A (future); or • WHPA-B (VS = 10) (future); or • WHPA-E (VS = 10) (future); or • the remainder of an Issue Contributing Area for Nitrates or Pathogens (future).	5 years and ZBLs within 3 years of OP approval (T-8)		
SAL-2	Application of Road Salt (Public Roads)	**Part IV, s.58** For public roads, the application of road salt is designated for the purpose of s.58 under the *Clean Water Act*, requiring risk management plans where the threat is, or would, be significant in any of the following areas: • WHPA-A (existing, future); or • WHPA-B (VS = 10) (existing, future); or • WHPA-E (VS ≥ 9) (existing, future); or • the remainder of an Issue Contributing Area for Sodium or Chloride (existing, future). Without limiting other requirements, risk management plans shall include provisions for: a) the reduction of salt usage through best management practices such as alternative de-icer materials (with lower sodium and chloride) and/or contemporary technology; and b) the use of trained individuals in the application of road salt (could include technicians and technologists and others responsible for salt management plans, winter maintenance supervisors, patrollers, equipment operators, mechanics, and contract employees).	Future: Immediately (T-7) Existing: 1 year/ 5 years (T-6)	GEN-1 GEN-2 SAL-3	The Region will be reviewing and updating the Regional Salt Management Plan in 2017 to address this policy. The Town of Halton Hills will update their Salt Management Plans within 2 years.
SAL-3	Application of Road Salt	**Land Use Planning** Where the application of road salt to roads and parking lots would be a significant drinking water threat, the planning approval authority shall: 1) Prohibit the establishment of new parking lots with greater than 2000 square metres in: • WHPA-A not in an Issue Contributing Area for Sodium or Chloride (future); 2) Prohibit the establishment of new parking lots with greater than 200 square metres in: • WHPA-A in an Issue Contributing Area for Sodium or Chloride (future); and 3) Require a salt management plan, which includes a reduction in the future use of salt, as part of a complete application for development which includes new roads and parking lots where the application of road salt is significant in any of the following areas: • WHPA-B (VS = 10) (future); or • WHPA-E (VS ≥ 9) (future); or	Future: Immediately (T-9) Amend OPs for conformity within 5 years and ZBLs within 3 years of OP approval (T-8)	SAL-1 SAL-2	Due to the SPP Transition Policies, the parking lots to be constructed in the study area are considered “existing” and therefore the policy does not apply.

Policy ID	Threat Description	Policy	When Policy Applies	Related Policies	Policy Application Notes
		• the remainder of an Issue Contributing Area for Sodium or Chloride (future). Such plans should include but not be limited to mitigation measures regarding design of parking lots, roadways and sidewalks to minimize the need for repeat application of road salt such as reducing ponding in parking areas; and directing stormwater discharge outside of vulnerable areas where possible.			
SNO-1	Storage of Snow	**Part IV, s.57, s.58** Where the storage of snow is, or would be, a significant drinking water threat, the following actions shall be taken: 1) The storage of snow is designated for the purpose of s.57 under the *Clean Water Act*, and is therefore prohibited where the threat is, or would be, significant in any of the following areas: • WHPA-A (existing, future); or • WHPA-B (VS = 10) (future); or • WHPA-E (VS ≥ 9) (future); or • the remainder of an Issue Contributing Area for Sodium or Chloride (future). Notwithstanding the above, emergency snow storage may be permitted outside of WHPA-A as determined by the risk management official and the municipality responsible for snow storage.	Future: Immediately (T-5) Existing: 180 days (T-4)	GEN-1	Due to the SPP Transition Policies in the Plan, any snow storage areas to be constructed in the study area are considered "existing" and therefore the policy does not apply.

Halton-Hamilton Source Protection Plan Policies

The Halton-Hamilton policies that are currently relevant to the project are presented in **Table 6.3.6.**

Table 6.3.7 describes the relevant policies and their application in detail.

Table 6.3.6 Summary of Relevant Halton-Hamilton Policies by Area

Area	Relevant Policies
Groundwater – Significant Threats Group 1[a]	Policies T-4-C, T-9-C, T-6-C, T-35-C, T-37-C, and T-39-C.
Groundwater – Significant Threats Group 2[b]	Currently no relevant policies.
Groundwater – Significant Threats Group 3[c]	Currently no relevant policies. It is noted that a risk management plan may be required for the storage of the chemicals relevant to this group.

Notes: a – WHPA-A and WHPA-B with a vulnerability score of 10.
b - WHPA-A, B, and C with a vulnerability score of 8 or 10.
c - WHPA-A, B, and C.

Table 6.3.7 Summary of Relevant Halton-Hamilton Policies for Groundwater – Significant Threats Group 1

Policy ID	Threat Description	Policy	Policy Application Notes
T-4-C	Stormwater discharges	**Prescribed Instrument** For future systems that would discharge stormwater from stormwater retention ponds where this activity would be a significant drinking water threat, a) the Ministry of the Environment and Climate Change shall ensure that the environmental compliance approvals that govern the systems include appropriate terms and conditions to ensure that the systems do not become significant drinking water threats. As part of its program to review environmental compliance approvals that are affected by source protection plans the following conditions shall be considered for inclusion - the requirement for regular maintenance, periodic removal of accumulated sediment, lining of the pond where warranted, the use of an oil/water separator, and other requirements to address site conditions. b) the Ministry of the Environment and Climate Change shall document the number and locations of applications received for environmental compliance approvals for these systems and the actions taken and report this information to the Source Protection Authority by February 1 of each year with copies of any issued approvals.	The MOECC is required to include conditions in the Environmental Compliance Approval to ensure that SWM Pond discharge does not become a threat.
T-9-C	Stormwater discharges	**Landuse Planning** In consideration of Planning Act applications where the future discharge of stormwater effluent from stormwater retention ponds would be a significant drinking water threat, a) where possible, the municipal planning authority shall require the applicant to locate stormwater retention ponds outside of the vulnerable area. b) the municipal planning authority shall document the number of applications reviewed for stormwater retention ponds, whether the application was approved, and whether the pond was located within or outside of the area where a significant drinking water threat would occur and report this information, including the rationale for decisions made, to the Source Protection Authority by February 1 of each year.	Where possible SMW ponds should be located outside of the vulnerable area.
T-6-C	Sanitary sewers and pipes	**Prescribed Instrument** Where the future installation of sanitary sewers and pipes would be a significant drinking water threat, a) the Ministry of the Environment and Climate Change shall ensure that the environmental compliance approvals that govern these systems include appropriate terms and conditions to ensure that the sewers and pipes do not become significant drinking water threats. As part of its program to review environmental compliance approvals that are affected by source protection plans the following conditions shall be considered for inclusion - requirement for regular maintenance and inspection.	The MOECC is required to ensure ECAs for sewers include appropriate terms and conditions.

Policy ID	Threat Description	Policy	Policy Application Notes
		b) the Ministry of the Environment and Climate Change shall document the number and locations of applications received for environmental compliance approvals for sanitary sewers and pipes and the actions taken on the applications and report this information to the Source Protection Authority by February 1 of each year with copies of any issued approvals.	
T-35-C	The application or handling and storage of road salt	**Other Tools** Where the existing and future application, or handling and storage of road salt would be significant, moderate or low drinking water threats, a. within two years of the date that the Source Protection Plan comes into effect, the municipalities shall amend their salt management plans to identify the location of wellhead protection areas, issue contributing areas, and intake protection zones and to enhance best management practices in these areas. b. the municipalities shall advise the Source Protection Authority of the revision to the salt management plans when completed and provide a status update by February 1 of each year until completed.	The Region will be reviewing and updating the Regional Salt Management Plan in 2017 to address this policy. The Town of Halton Hills will update their Salt Management Plans within 2 years.
T-37-C	The storage of snow	**Land Use Planning** Where the future storage of snow would be a significant drinking water threat a. in a wellhead protection area and issue contributing area, the Region of Halton, the Towns of Milton and Halton Hills and the City of Hamilton shall prohibit through *Planning Act* tools snow storage facilities that are at or above grade at greater than one hectare in size or, below grade, at or greater than 0.01 hectare in size. b. the Region of Halton, the Towns of Milton and Halton Hills and the City of Hamilton shall provide copies of their planning documents to the Source Protection Authority when they have been amended to conform with the policy to prohibit snow storage facilities of these sizes.	
T-39-C	The storage of snow	**Land Use Planning** Where the future storage of snow would be a significant drinking water threat in an issue contributing area, a. the municipal planning authority shall require at site plan approval that best management practices for site design to protect drinking water sources be included to manage snow storage and the associated melt water at snow storage facilities at or above grade between 0.01 and 1 hectare in size. b. the municipal planning authority shall document the number of new site plan applications reviewed, and the conditions imposed for the management of snow storage and melt water runoff and report this information to the Source Protection Authority by February 1 of each year.	

The applicable Source Protection Plans must be consulted going forward as part of the further planning approval and engineering design stages to ensure that applicable policies relating to water quality are addressed and implemented as appropriate.

The following general recommendations which summarize the applicable source protection policies are provided below for consideration and implementation going forward:

- Stormwater Management Ponds should be located outside of vulnerable areas. (Note: reference should be made to the Provincial Table of Circumstances definition of a stormwater management pond. Proposed ponds may not meet the definition of "stormwater management pond" in terms of drainage areas and chemicals present etc.).
- Snow storage should be directed outside of vulnerable areas in general and is prohibited in specific vulnerable areas.
- Sewer design and installation should consider vulnerable areas.
- Salt management plans and parking lot designs and locations should consider vulnerable areas and are prohibited in specific vulnerable areas.

6.3.5.2 Surface Water Modeling (peak flow, erosion, volume controls)

This section addresses the strategy for managing stormwater with the goal of minimizing impacts to surface water quality, water quantity, erosion control, and runoff volume control through regional SWM facilities and source control measures.

Hydrologic Model Representation

The uncontrolled future development scenario depicted in **Section 5.4** was updated to include a representation of the conceptual stormwater servicing design and is referred to as the "Post-Development Conditions" model. To properly evaluate and establish post development SWM targets for quantity and erosion control, catchment areas were further discretized into regional SWM facility control areas, uncontrolled development areas, natural corridor areas, and external areas. The catchment discretization allows for the proper representation and timing of post-development hydrographs such that appropriate SWM targets for erosion and quantity control can be established. Refer to **Figure 6.3.8** for an overview of the catchment area delineation and potential regional SWM facility locations. It should be noted that **Figure 6.3.8** is conceptual only and in no way reflects what the final SWM pond location and contributing area distribution will be. The final plan will be developed as part of the SWM and Servicing Plan as part of the Secondary Plan. That plan should be developed in providing SWM facilities for all of the lands as possible.

Regional SWM facility control areas were based on maintaining a diffused network and maximizing the capture of upstream tributary drainage areas. Pond locations were selected based on existing subcatchment boundaries and in consideration of protected watercourses (i.e., ponds are off-line with respect to Medium and High Constraint Streams). The number of ponds was determined based on total impervious area reflected in the current concept plan for future development of the subject lands, ideally as downstream as possible with an upper limit of approximately 25 ha of future impervious area per pond. The preferred location of these facilities are adjacent to planned parks and low density residential developments, and avoiding placement within natural heritage areas, environmental linkage corridors, and floodplains. At this concept stage, off-line facilities were only evaluated, reflecting full capture and treatment of upstream contributing areas.

Uncontrolled development areas were delineated, based on the condition that not all areas of the proposed development can be easily serviced by a regional facility due existing grade constraints. Where required for peak flow mitigation, source control measures/minimum runoff capture facilities have been assessed. Future servicing studies (as part of the Secondary Plan) may investigate other quantity/quality control facilities to manage runoff from these uncontrolled areas. The ability to provide SWM controls for all areas will depend upon final land use designation, grading and drainage layout. These details are beyond the scope of this study. Uncontrolled areas will require water quality controls and are strong candidates for water quantity source controls and other smaller scale BMPs.

Natural corridors include existing natural heritage areas, proposed environmental linkage corridors, and floodplains. These areas will remain generally as per existing conditions or enhanced as part of the ecological linkages and riparian buffer management programs.

External areas include lands outside the study area that will remain as per existing conditions in the post development scenario (Catchment A-4a and portions of A-2, A-5, and A-6). Any future development of these lands will require separate SWM quality, quantity and erosion controls.

Surface water hydrology parameters were developed for discretized areas in the same manner as described in **Section 5.4.2**. A summary of the resulting area-weighted hydrologic parameters for post-development land use conditions are shown in **Table 6.3.8**.

Table 6.3.8 Post-Development Land Use Condition Hydrologic Parameters

Hydrologic Unit Name	Area (ha)	% Imperv-ious	% Routed	% Imprev. Without Storage	Manning's "n"		Dep. Storage (mm)			Slope	Width
					Imperv-ious	Pervious	Imperv-ious	Pervious	LID[1]		
A-1_Nat1	5.4	4.0	87.2	7.7	0.031	0.346	7.9	16.9	0.0	7.1	681
A-1_SWMA1	2.6	60.9	34.5	17.8	0.019	0.192	3.7	7.4	0.1	2.0	433
A-1_Unc1	4.5	82.6	18.8	20.4	0.016	0.164	10.5	13.3	7.6	2.0	748
A-1_Unc2	0.6	80.2	20.4	20.9	0.017	0.166	2.9	5.8	0.0	2.0	101
A-2_Nat1	5.3	4.6	82.3	7.1	0.029	0.323	6.9	15.4	0.0	2.5	1333
A-2_RES	28.4	5.5	73.0	5.7	0.029	0.293	6.3	12.1	0.0	1.1	948
A-2_SWMA2	30.4	55.9	38.4	16.8	0.020	0.200	8.6	12.4	4.8	2.0	5059
A-2_SWMA3	24.8	64.3	32.0	18.2	0.019	0.188	5.7	9.2	2.2	2.0	4126
A-2_Unc1	6.0	59.9	35.3	17.7	0.019	0.194	3.6	7.3	0.0	2.0	992
A-3_Nat1	7.5	4.7	82.1	7.1	0.029	0.321	6.9	15.3	0.0	2.6	2504
A-3_SWMA4	40.7	64.0	32.3	18.0	0.019	0.189	6.2	9.7	2.7	2.0	6780
A-3_Unc1	1.8	67.5	29.6	18.6	0.018	0.182	4.1	7.5	0.8	2.0	300
A-4_Nat1	8.2	8.1	75.8	7.7	0.027	0.284	5.8	12.8	0.0	1.3	1643
A-4_SWMA6	17.6	62.0	33.7	17.6	0.019	0.191	5.3	9.0	1.8	2.0	2939
A-4a	152.7	5.1	74.6	5.8	0.029	0.300	6.4	12.7	0.0	1.0	5091
A-4b_SWMA5	39.0	66.6	30.4	18.5	0.018	0.185	6.1	9.5	2.7	2.0	6497
A-5_Nat1	11.5	7.0	78.1	7.5	0.027	0.299	6.2	13.8	0.0	0.7	958
A-5_RES1	25.1	17.8	67.9	7.9	0.027	0.286	6.1	12.5	0.0	3.6	836
A-5_RES2	69.5	4.4	73.9	5.4	0.030	0.297	6.4	12.3	0.0	3.1	2316
A-5_SWMA7	7.3	86.3	16.1	21.2	0.016	0.159	12.4	15.2	9.7	2.0	1209
A-5_Unc1	0.9	79.6	20.9	18.3	0.017	0.167	7.9	10.9	5.0	2.0	147
A-5_Unc2	2.3	62.2	33.5	18.0	0.019	0.190	3.8	7.4	0.3	2.0	379
A-6_RES	28.3	5.6	74.9	5.7	0.029	0.303	6.5	13.2	0.0	1.2	987
B-1_Nat1	21.7	2.3	93.2	8.4	0.033	0.375	8.9	18.6	0.0	9.4	2416
B-1_SWMB1	11.2	57.6	37.0	17.2	0.019	0.197	4.7	8.5	1.0	2.0	1870
B-1_Unc1	5.2	69.0	28.6	18.0	0.018	0.181	5.5	8.9	2.2	2.0	864
B-1_Unc2	3.7	59.8	35.3	17.7	0.019	0.194	3.6	7.4	0.0	2.0	624
B-1_Unc3	0.4	59.8	35.3	17.7	0.019	0.194	3.6	7.4	0.0	2.0	70
B-2_Nat1	2.8	2.3	89.7	8.3	0.031	0.352	8.2	17.1	0.0	4.7	565
B-2_SWMB2	41.7	62.5	33.4	17.9	0.019	0.191	5.3	9.0	1.8	2.0	6948
B-2_Unc1	0.5	59.8	35.3	17.7	0.019	0.194	3.6	7.4	0.0	2.0	80
C-1_Nat1	19.0	3.0	90.2	8.3	0.032	0.359	8.4	17.6	0.0	3.1	633
C-1_SWMC1	24.7	63.3	32.9	18.0	0.019	0.190	7.0	10.6	3.5	2.0	4121
C-1_SWMC2	33.9	59.2	36.0	17.5	0.019	0.196	5.0	8.8	1.3	2.0	5645
C-1_Unc1	2.4	61.1	34.4	17.7	0.019	0.192	3.9	7.6	0.3	2.0	393
D-1_SWMD1	5.6	69.1	28.7	18.7	0.018	0.182	7.9	11.3	4.6	2.0	930
D-2_SWMD1	5.0	61.5	34.0	17.9	0.019	0.191	3.6	7.3	0.1	2.0	831
D-3_SWMA1	19.0	59.8	35.5	17.5	0.019	0.195	6.4	10.2	2.8	2.0	3162
E-1_SWME1	13.5	65.3	31.4	18.3	0.018	0.187	7.4	11.0	4.0	2.0	2255

Notes:

1. LID retention volumes (mm) modeled as initial abstraction normalized across the correspond catchment areas. LID volume added to impervious and previous values for modeling purposes.

Proposed Stormwater Management Facilities

Regional SWM facilities were designed to water quality, quantity and erosion and baseflow control. The conceptual design criteria included the following:

- Water quality control: "Enhanced" level of protection, as designated in the Ontario Ministry of Environment and Climate Change (MOECC) Stormwater Management Planning and Design Manual (March 2003).
- Water quantity control:
  - Post-development peak flow rates along the receiving watercourses do not exceed pre-development rates for the 2-year through Regional Storm design storm events, as identified in **Section 4.6.8**.
- Erosion and Baseflow control:
  - Erosion control measures are provided such that there is no adverse erosion impacts to downstream reaches.
  - Erosion index exceedances for post-development flows match existing conditions as identified in **Section 4.6.9**.

Two types of facilities were represented in the hydrologic and hydraulic surface water models:

- Regional detention facilities (e.g., wet ponds), primarily intended to achieve water quality treatment, erosion control and peak flow attenuation, ideally one large facility per subcatchment; and
- Source control measures/minimum runoff capture facilities (e.g., low impact development), primarily intended to achieve runoff volume control and waterbalance through on-site retention and distributed throughout the study area (i.e., many small facilities per subcatchment).

Proposed regional detention facilities are shown in **Figure 6.3.8** overlain with the future land uses in the concept development plan. There are a total of 12 such facilities and their location was selected based on existing subcatchment boundaries within the study area. The final location and number of regional detention facilities will be confirmed through the SWM and Servicing Plan as part of the Secondary Plan, as there may be opportunities to consolidate depending on phasing and servicing. The total study area (730.6 ha) comprises the following:

- Regional SWM facility capture area: 316.8 ha
- Uncontrolled development area: 28.2 ha
- Natural Corridor area: 81.5 ha
- External drainage area: 304.1 ha

To maintain peak flows, some uncontrolled development areas will require quantity controls.

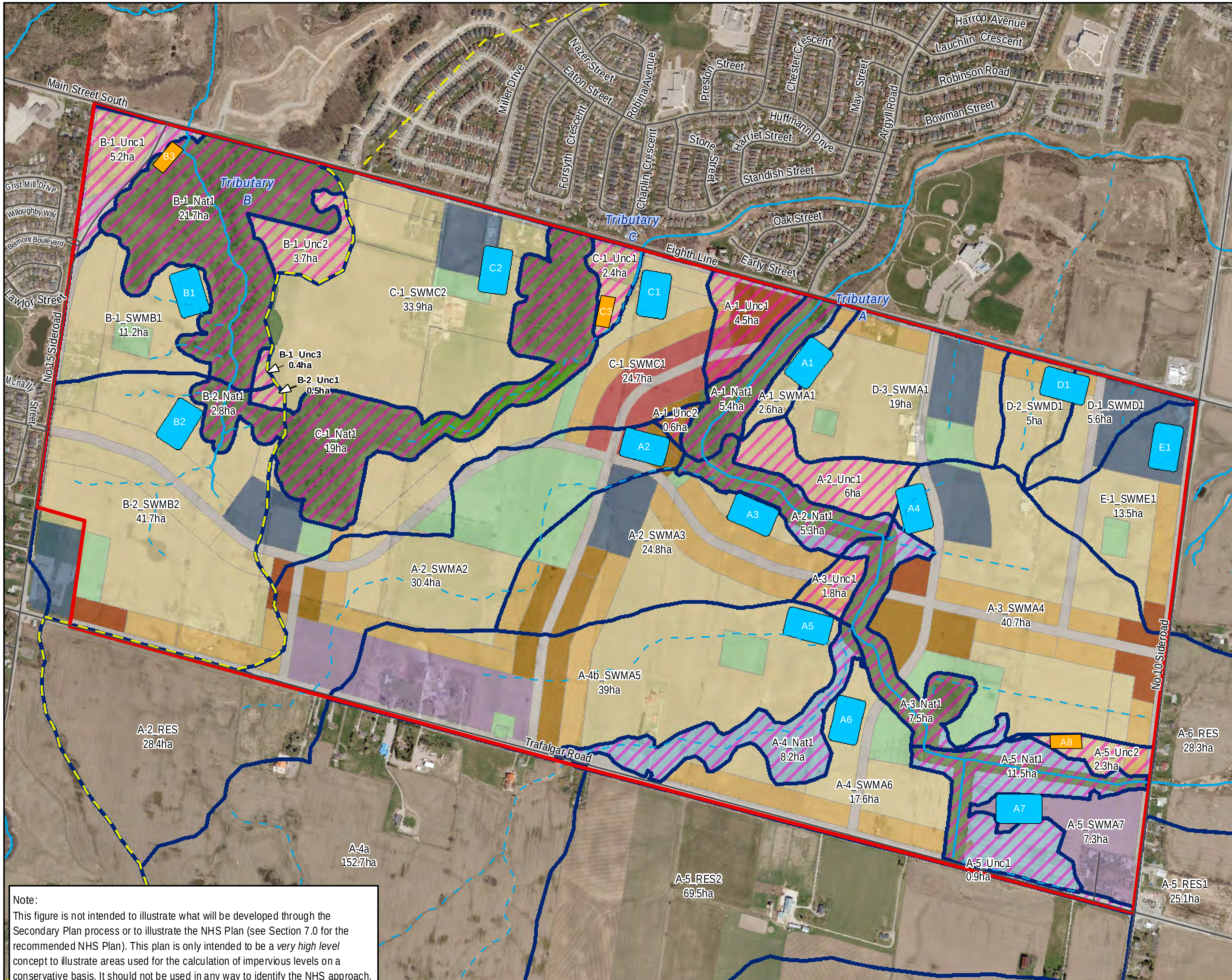
For Tributary A and C, minimum capture facilities are required for catchment A-5_Unc2 (2.3 ha) and C-1_Unc1 (2.4 ha) to control to the 5-year storm event.

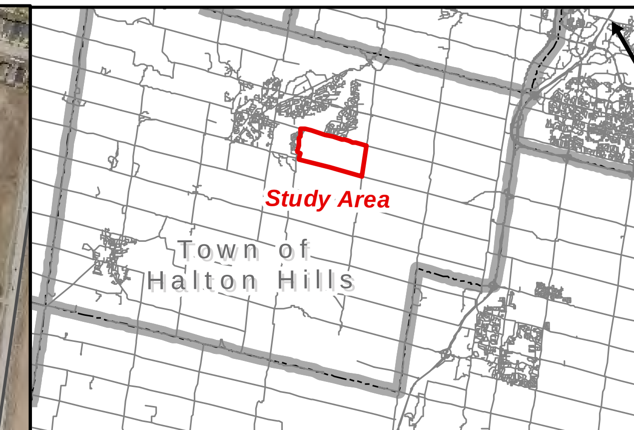
For Tributary B, a minimum capture facility is required for catchment B-1_Unc1 (5.2 ha) to control to the 10-year storm event. Runoff from this catchment area may be controlled through enhancements to the existing filter bed SWM facility located in the southeast corner of Eighth Line and 15th Side Road, or through source control measures (low impact development measures) throughout the subcatchment. Refer to Pond B3 on **Figure 6.3.8.** It is noted that the existing filter bed was designed for drainage from 15th Side Road only. Flows from the recent development to the west of 15th Side Road are diverted around the filter bed and outlets on the downstream side of Eighth Line. Drainage from the remaining uncontrolled areas in Tributary B are anticipated to include mostly backlot drainage to the existing Natural Heritage system and has been assumed for modeling purposes. Runoff from uncontrolled areas in Tributary A, C and D were not provided quantity controls at this concept stage. Future servicing studies that are

being carried out as part of the Secondary Plan should investigate other quantity/quality control facilities to manage runoff from these uncontrolled areas including potential capture into a Regional SWM facility.
As previously identified, major and minor flows from Catchment D-1, D-2 and D-3 (29.5 ha) are conveyed by multiple outlets to the existing ditch drainage on the east side of Eighth Line, discharging to the constructed bypass pipe through the Fernbrook Phase 3 subdivision, ultimately discharging to the East Branch of Sixteen Mile Creek. According to GHD's 2013 Draft report for the development, the bypass pipe was only sized for the 10-year flows from upstream for a much smaller catchment area (10.8 ha), equivalent to Catchment D-1 and D-2 (10.6 ha). Furthermore, the previous study by GHD assumed that majors would not enter the development, but they will. The downstream development was previously approved by the Town of Halton Hills and Conservation Halton, and is now fully built. The existing downstream infrastructure is considered as a design constraint for Tributary D lands under proposed conditions. To address the inadequate downstream design, proposed condition flows immediately upstream along Eighth Line could either be a) controlled back to the allowable release rate to the by-pass pipe or b) redirected north along Eighth Line to discharge directly to Tributary A. The current SWM concept has assumed that Catchment D-3 (19.0 ha) will be diverted to Tributary A, via discharge to the regional SWM facility PondA1. Catchment D-1 and D-2 (10.6 ha) have been assumed to discharge to a regional SWM facility outletting at the Fernbrook Phase 3 by-pass pipe at an assumed allowable rate. For the purpose of the concept plan, the peak allowable discharge has been estimated based on the 10-year existing peak flow from Catchment D-1 and D-2 at 0.47 m^3/s.

Minor flows from Catchment E-1 discharge through an existing road crossing culvert along Side Road 10 (Structure #22) under existing conditions. Flows are conveyed south along existing ditch drainage parallel to Eighth Line, eventually discharging to the East Branch of Sixteen Mile Creek approximately 3 km downstream. Under existing conditions, major flows spill at the intersection of Eighth Line and Side Road 10, and are conveyed east down Side Road 10 to the East Branch of Sixteen Mile Creek. This existing major flow spill cannot be utilized under proposed condition for a regional SWM facility outlet. Potential SWM facility outlet arrangements for Catchment E-1 under proposed conditions may include a) control flows back to the allowable release rate of the Side Road 10 culvert, b) construction of a major flow diversion pipe or roadside ditch east down Side Road 10discharging directly to Sixteen Mile Creek, or c) diversion of flows to another regional SWM facility (Pond D1) discharging to the by-pass pipe through the Fernbrook Phase 3 subdivision. For the purpose of the concept plan, flows have been assumed to discharge from a regional SWM facility to the existing culvert crossing along Side Road 10. The size of the culvert has been assumed at 450 mm providing an allowable release rate of 0.16 m3/s for the regional SWM facility PondE1.

As part of the existing condition assessment of Tributary B, it was recommended that flows be diverted to the downstream part of the valley (upstream of Eighth Line), to mitigate the valley incision. Therefore, for the purpose of the concept plan, outflows from the regional SWM facility PondB2 have been piped to upstream of Eighth Line.
The Drainage and SWM Master Plan (part of the Secondary Plan) and EIR will refine the drainage and SWM approach provided in this concept plan. It is noted that the existing downstream on-line facility control structure and channel conveyance works along Sixteen Mile Creek upstream of Side Road 10 have not been assessed as part of the current concept plan. The Town of Halton Hills has committed to completing this assessment outside of the subwatershed study. This assessment will ensure that recommended stormwater management approaches mitigate development impacts as intended, for water quantity control and erosion control.





Note:
This figure is not intended to illustrate what will be developed through the Secondary Plan process or to illustrate the NHS Plan (see Section 7.0 for the recommended NHS Plan). This plan is only intended to be a *very high level* concept to illustrate areas used for the calculation of impervious levels on a conservative basis. It should not be used in any way to identify the NHS approach.

Legend

N

General Features

- Identified Reaches
- Roads
- Study Area
- Conservation Authority Boundary*

Potential Stormwater Management Facilities

- Regional Detention Facility
- Minimum Runoff Capture Facility
- Subcatchment Boundary
- Future Uncontrolled Catchments

Potential Land Use

- Collector Road Rights-of-Way
- Mixed Use - Main Street
- Neighbourhood Commercial
- Institutional
- Regional Floodplain
- High Density Residential
- Environmental Linkage
- Low Density Residential
- Medium Density Residential
- Mixed Use
- Natural Heritage System
- Open Space

Note
*Division between Credit Valley Conservation and Conservation Halton Jurisdiction

0 100 200 400 600
Meters

Southwest Georgetown Integrated Planning Project

Proposed Stormwater Management Facilities and Catchments

March 2017	1:10,000	Datum: NAD 83, Zone 17 Source: Chapman and Putnam, 2007. Ontario Geological Survey, MRD 228, LIO
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Figure 6.3.8

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Water Quality Treatment

The permanent pool of a wet pond is intended to provide an appropriate water quality treatment volume based on MOECC requirements that achieve an “enhanced” protection level, which is presumed to provide 80% suspended solids removal rate on an average annual basis. The required water quality treatment volume varies by the imperviousness of the tributary area. A portion of the permanent pool volume can be included in a sediment forebay, which receives minor flows from the inlet storm sewer system and is shaped to enhance the initial settling of suspended solids. The permanent pool elevation can be maintained by a quality control orifice within a ditch-inlet catchbasin as shown in **Figure 6.3.9**. Alternatively, the permanent pool can be maintained by the invert elevation of a reverse sloped bottom-draw pipe.

The pond control structures and available storage volume was optimized in order to achieve the design constraints. Once the minimum footprint size of the permanent pool was determined per MOECC criteria (required volume based on tributary area and imperviousness, divided by an average permanent pool depth of 1.0 m), the available pond volume was adjusted by varying the following pond characteristics:

- Permanent pool length:width ratio ranged from 3:1 to 10:1;
- Planting shelf width ranged from 0-5 m; and
- Embankment sideslopes ranged from 5:1 to 7:1.

Additional design details are shown in **Table 6.3.9**. For each detention facility, the drainage area and imperviousness tributary to each pond is shown. The required permanent pool volume and surface area are shown in the next two columns, the former determined using the MOECC criteria for enhanced water quality protection. The extended detention and flood control volumes in **Table 6.3.9** do not include the permanent pool volumes.

Figure 6.3.9 Regional Detention Facility Concept Design

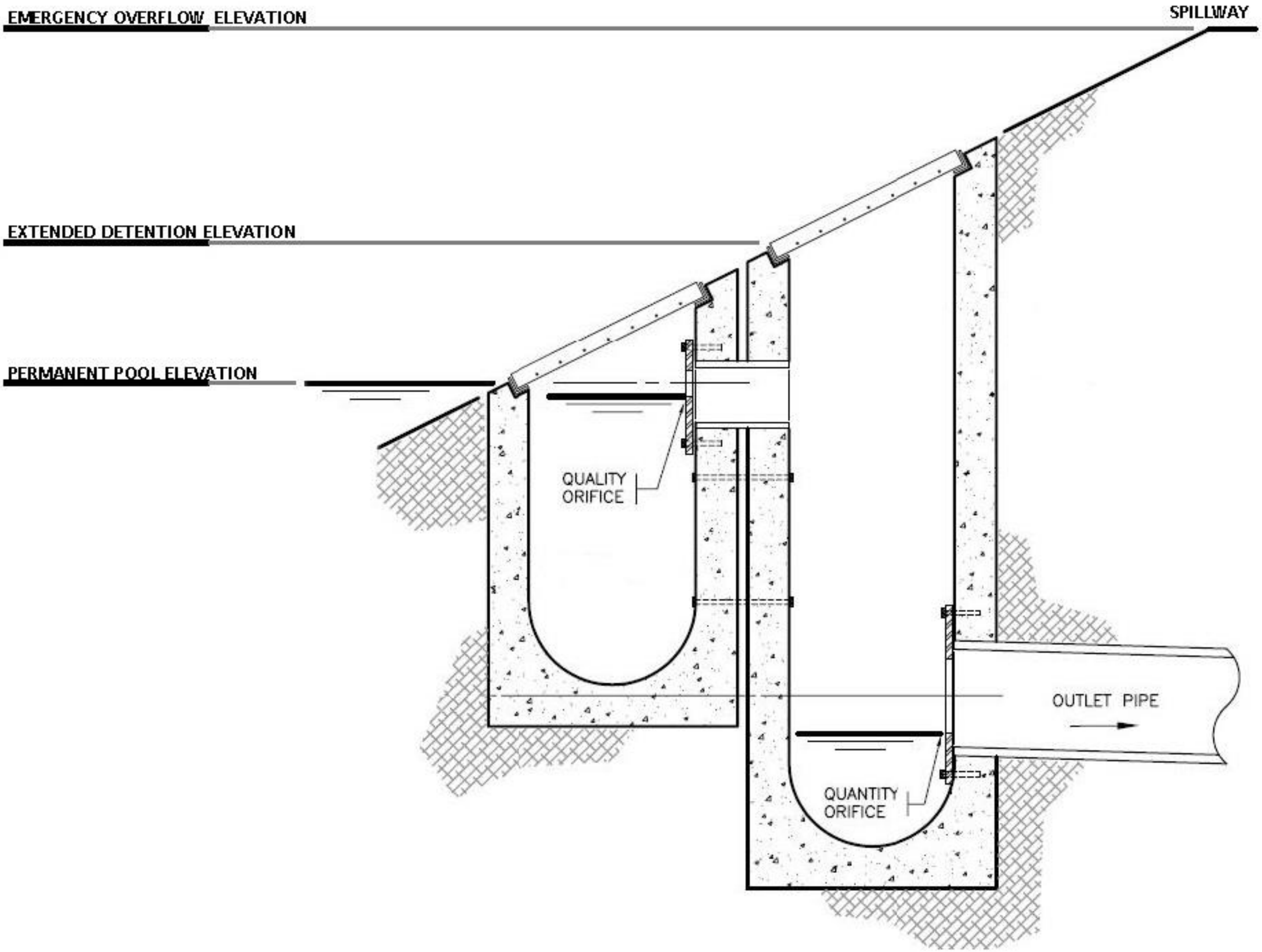

Table 6.3.9 Post-Development Conditions - Regional Detention Facility Conceptual Design Details

Facility	Tributary Area (ha)	Percent Imperv-iousness	Permanent Pool		Extended Detention		Flood Control[1]			
			Volume (m^3)	Surface Area (m^2)	Orifice (mm)	Detention Volume (m^3)	Quanity Control Orifice (mm)	High Flow Control Orifice (mm)	Volume (m^3)	Surface Area (m^2)
PondA1	21.6	59.9%	4,350	2,668	150	6,470	200	500	21,318	12,542
PondA2	30.4	55.9%	5,840	9,044	200	9,106	400	475	27,743	18,538
PondA3	24.8	64.3%	5,240	6,912	180	7,428	300	475	23,464	16,091
PondA4	40.7	64.0%	8,580	8,424	200	12,204	400	600	40,969	23,125
PondA5	39.0	66.6%	8,460	6,440	200	11,694	400	625	39,038	23,477
PondA6	17.6	62.0%	3,640	2,680	150	5,291	300	350	16,197	11,638
PondA7	7.3	86.3%	1,830	5,120	75	2,177	75	300	7,610	5,968
PondB1	11.2	57.6%	2,200	2,668	75	449	75	250	11,136	8,581
PondB2	41.7	62.5%	8,650	8,424	100	1,667	130	475	47,901	26,170
PondC1	24.7	63.3%	5,210	3,312	160	7,417	200	425	29,305	17,615
PondC2	33.9	59.2%	6,770	7,416	190	10,161	200	525	28,955	19,003
PondD1	10.6	65.5%	2,270	7,400	200	3,169	320	-	10,740	7,065
PondE1	13.5	65.3%	2,900	7,401	180	4,059	180	-	25,970	15,838

Facility	Tributary Area (ha)	Imperv-iousness	Outflow Rate- Conceptual Design					
			2-year		100-year		Regional	
			m3/s	L/s/ha	m3/s	L/s/ha	m3/s	L/s/ha
PondA1	21.6	59.9%	0.04	**2.0**	1.10	**51**	1.10	**51**
PondA2	30.4	55.9%	0.07	**2.3**	1.55	**51**	1.69	**56**
PondA3	24.8	64.3%	0.06	**2.4**	1.28	**51**	1.38	**56**
PondA4	40.7	64.0%	0.08	**2.0**	1.95	**48**	2.09	**51**
PondA5	39.0	66.6%	0.08	**2.1**	1.95	**50**	2.01	**51**
PondA6	17.6	62.0%	0.04	**2.4**	0.88	**50**	0.94	**53**
PondA7	7.3	86.3%	0.05	**6.3**	0.35	**48**	0.38	**52**
PondB1	11.2	57.6%	0.02	**1.9**	0.27	**24**	0.30	**27**
PondB2	41.7	62.5%	0.06	**1.5**	0.98	**23**	1.11	**27**
PondC1	24.7	63.3%	0.05	**1.9**	0.91	**37**	1.01	**41**
PondC2	33.9	59.2%	0.05	**1.6**	1.25	**37**	1.37	**41**
PondD1	10.6	65.5%	0.07	**6.6**	0.42	**40**	0.46	**43**
PondE1	13.5	65.3%	0.05	**3.5**	0.13	**10**	0.15	**11**

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Notes:

1. Flood control volume required for Regional storm controls.

Extended Detention

The volume component above the permanent pool is referred to as extended detention, which has multiple functions in controlling downstream flows from the higher frequency, smaller volume rainfall events. While extended detention plays a large role in water quantity control (i.e., for rainfall events with a return period of 5 years or less), it also provides additional water quality treatment and streambank erosion protection. Discharge from this component is controlled by means of the quality control orifice plate as shown in **Figure 6.3.9**. All quality control orifices were assumed at 75 to 200 mm. During detailed design, the orifice size will be confirmed to ensure the extended detention is drawn down over a minimum period of 24-48 hours for appropriate erosion control. The sizing of the extended detention was optimized using the continuous post development model to achieve the pre-development erosion indices. The erosion threshold analysis and required level of erosion protection is summarized in the model results below.

Flood Control

Flood control storage refers to the volume component above the extended detention storage and serves to mitigate water quantity impacts downstream of the facility for the lower frequency (larger volume) rainfall events. While some water quantity control is provided in the extended detention component below, the primary function of this upper component is flood control.

In this concept stage, three orifice levels were used. The first orifice level, the quality control orifice, controls the extended detention volume as described above. The second orifice level, the quantity control orifice is controlled by the grate elevation set at the top of the extended detention volume to control the 2-year to 5-year storm events, as shown in **Figure 6.3.9**. The third orifice level, the high flow orifice (not shown in **Figure 6.3.9**.) is controlled by a grate set at the 5-year design high water level and is sized to control the 10-year to Regional storm events. All grate drop structures were represented by a 1200 mm manhole. The top of the flood control volume is marked by the top of the pond embankment and is controlled by an emergency spillway. The emergency overflow elevation for all ponds was set to 2.5 m above the permanent pool and the top of embankment elevation was set to 3.0 m above permanent pool. The storage volume was optimized such that Regional Storm design high water level remains below the spillway crest for all ponds. The top of embankment elevation can be modified during the preliminary design stage to achieve the appropriate freeboard requirements. The outlet arrangement is concept only, and structures are to be modified during the SWM plan or FSS stage to control to the allowable discharge.

The sizing of the quantity and high flow control orifice diameter was optimized to achieve the 2-year through Regional Storm pre-development discharge and varies for each pond. The rightmost columns of **Table 6.3.9** show the flood control characteristics for regional detention facilities including the quantity control and high flow orifice diameter, flood control volume and total surface area at the top of berm elevation. The flood control volume reflects the total water quantity control volume for the regional storm event (i.e., includes the extended detention volume, but not the permanent pool volume). The total pond surface area shown in the final column includes the permanent pool footprint. The outlet pipe shown in **Figure 6.3.9** was conservatively set to 3000 mm diameter for all ponds (concept only – size is set to minimize head loss for modelling, to be refined during final design.) and sloped at 2% to match the existing watercourse (or to match the proposed trunk sewer for the subcatchments B-2 diversion.

The emergency spillway is intended to convey excess runoff from above the regional storm event from the pond control structure to the receiving watercourse. The emergency spillway was represented in the hydraulic model as an overflow channel with the following characteristics:

- Length: 10 m
- Height: 0.5 m (i.e., to top of berm)

- Bottom Width: 8 m
- Side Slopes: 5:1
- Roughness: 0.022 Manning's friction factor

Source Controls and LIDs (Low Impact Development)

Source control measures and LIDs are recommended for multiple objectives including water quality, erosion control, volume control, thermal mitigation, and infiltration functions to meet water balance targets.

The potential reduction of infiltration in the study area due to the proposed development has been identified through the water balance modelling presented in **Section 5.4.4**. The overall reduction in recharge rates from existing to proposed landuse conditions corresponds to an estimated reduction in surficial groundwater recharge volume from 1,298 to 774 m^3/d (**Table 5.4.11**). To mitigate the groundwater recharge deficit identified, infiltration targets were developed. The additional infiltration required (under future development conditions) is 1.3 mm over the entire site. It is recommended that this target be met through the use of LID. It is anticipated that the proposed conditions will consist primarily of residential landuse, making it difficult to practice LID effectively over the entire site. As such, targets were set for ICI lands, parks and road right-of-way's. This could be modified through the development of the servicing study for the area. The entire site target of 1.3 m could be distributed as follows:

- 10 mm LID unit area retention volume (for infiltration) for neighbourhood commercial, institutional, mixed use-mainstreet, mixed use and open space (parks) landuses.
- 3 mm to 5 mm LID unit area retention volume (for infiltration) along ROWs (depending on suitability of soils and site conditions).

The LIDs targets are considered functionally feasible for the landuses they have been assigned. Recent studies have shown that several LID approaches in tight/cohesive clay and silt soils and can achieve up to 25 mm retention (EPA, 2014; TRCA, 2010). The proposed LID controls are recommended along non-residential lands to better ensure the long term operation and maintenance of LIDs. LIDs on private residential properties are encouraged but have conservatively been omitted for the purpose of the SWM strategy impact analysis.

The current concept plan for future urban development and SWM in the study area is illustrated in **Figure 6.3.8**. Applying the recommended LID retention volume targets to the subject land uses will achieve the projected water balance deficit. The proposed LIDs are estimated to provide a total of 1,653 m^3/d of stormwater retention. Note that, to address the recharge goals, specific LID practices that promote infiltrate stormwater are desired, not those which largely provide evapotranspiration. Accounting for partial infiltration, partial sub-par performance of some installations, and partial long term reductions in infiltration due to lagging maintenance, the identified LID targets are felt to be appropriate to address recharge objectives under post development conditions. LID retention rates at 100% capacity are summarized in **Table 6.3.10**. As a result, the retention volume applied in the modelling carried out is conservative. This would need to be refined during the future servicing study and design.

Table 6.3.10 Proposed LID Retention Volume

Total LID Area (ha)	Retention Volume (mm)	Total Annual Precipitation (mm/yr)[1]	Total Annual Rainfall Captured[2]	Total Annual Retention (mm/year)	Total Retention Volume (m^3/day)
32.9 (ROWs)	3 - 5	877	30 - 47%	263 - 412	237 - 372
75.8 (ICI and OS)	10	877	70%	614	1,275
				Total LID Retention	**1,512 - 1,647**

1. Total Annual Rainfall from Georgetown WWTP, Canadian Climate Normals 1981-2010. Environment Canada.
2. Total Annual Rainfall Captured based on City of Toronto Wet Weather Flow Management Guidelines (2006)

Proposed source control measures were represented in the hydrologic model as an initial abstraction term added to the corresponding depression storage parameters. LID Retention volumes were normalized across the corresponding catchment area and are summarized in **Table 6.3.10** above. This approach implicitly accounts for the storage retention volume of source control measures and is appropriate at this concept stage. For design purposes, facilities should be modeled explicitly using the LID module of SWMM5 or other model. Site specific soil and groundwater investigations are required as part of the EIR and FSS to identify appropriate LID measures and maintenance requirements. Potential LID measures are summarized in **Section 6.3.5.4.**

Model Results

A summary of the level of peak flow control provided by the proposed regional detention facilities is included in **Table 6.3.11**. The computed peak flowrate for post-development conditions reflects the composite flow hydrograph along the receiving watercourse from the pond outlet pipe, the emergency spillway and upstream inflow. Occurrences where the post-development peak flow exceeds the corresponding pre-development value are highlighted in red. These exceedances are to be addressed during preliminary design. It is noted that PondD1 has been controlled to the assumed allowable release rate to the downstream by-pass pipe of 0.47 m^3/s, and Pond E1 has been controlled to the assumed capacity of the existing culvert crossing of Side Road 10 of 0.16 m^3/s, respectively.

Table 6.3.12 summarizes additional details related to the level of quantity control provided by the proposed regional detention facilities. For each pond, the permanent pool elevation is shown for reference along with the design high water depths for the various design storm events. Results confirm that all peak flood stages are below the top of berm elevation (i.e., design high water levels are less than 3.0 m above the permanent pool elevation). Therefore all ponds contain and control the Regional event.

The upper bound 2100 year climate change scenario for the100-year return period as described in **Section 4.6.2** was applied to the recommended SWM strategy. As summarized in **Table 6.3.12**, it is furthered confirmed that the sizing of the regional control facilities is sufficient for the upper bound climate change conditions such that no overtopping of the spillway occurs. It is recommended that the FSS include the upper bound climate change scenario as part of the detailed design of the proposed system.

Table 6.3.11 Post-Development Conditions - Regional Detention Facility Peak Flow Control

Pond	Link	Peak Flow Rate (m^3/s)																				
		2-Year/24-Hour			5-Year/24-Hour			10-Year/24-Hour			25-Year/24-Hour			50-Year/24-Hour			100-Year/24-Hour			Regional Storm		
		Pre-	Post-	Δ	Pre-	Post-	Δ	Pre-	Post-	Δ	Pre-	Post-	Δ	Pre-	Post-	Δ	Pre-	Post-	Δ	Pre-	Post-	Δ
A1	CJ477.76	2.4	1.5	-38%	4.9	4.6	-6%	8.4	8.0	-5%	13.2	12.5	-5%	17.2	16.9	-2%	21.4	21.4	0%	46.8	39.0	-17%
A2	CAMA4	2.3	1.5	-35%	4.8	4.4	-8%	8.2	7.6	-7%	12.9	11.9	-8%	16.8	16.0	-5%	21.0	20.2	-4%	45.9	37.5	-18%
A3	CAMA4	2.3	1.5	-35%	4.8	4.4	-8%	8.2	7.6	-7%	12.9	11.9	-8%	16.8	16.0	-5%	21.0	20.2	-4%	45.9	37.5	-18%
A4	CJ1233.42	1.9	1.3	-32%	3.9	3.8	-3%	6.6	6.3	-5%	10.2	9.9	-3%	13.3	13.4	1%	16.4	16.4	0%	36.8	32.5	-12%
A5	CAMA2	1.7	1.2	-29%	3.7	3.4	-8%	6.2	5.6	-10%	9.5	8.8	-7%	12.4	11.8	-5%	15.3	14.5	-5%	34.8	30.4	-13%
A6	CAMA2	1.7	1.2	-29%	3.7	3.4	-8%	6.2	5.6	-10%	9.5	8.8	-7%	12.4	11.8	-5%	15.3	14.5	-5%	34.8	30.4	-13%
A7	CAMA5	0.9	0.9	0%	2.0	2.1	5%	2.9	2.9	0%	4.0	4.1	2%	5.0	5.2	4%	6.1	6.3	3%	14.1	13.5	-4%
B1	J1	0.1	0.1	0%	0.6	0.4	-31%	1.4	1.0	-30%	2.6	2.6	0%	3.6	3.5	-3%	4.0	3.8	-5%	4.7	3.9	-17%
B2	J1	0.1	0.1	0%	0.6	0.4	-31%	1.4	1.0	-30%	2.6	2.6	0%	3.6	3.5	-3%	4.0	3.8	-5%	4.7	3.9	-17%
C1	CJ900	0.1	0.1	0%	0.7	0.4	-43%	1.4	1.1	-20%	2.2	2.3	5%	3.0	2.9	-3%	3.7	3.2	-14%	5.8	4.3	-26%
C2	CJ900	0.1	0.1	0%	0.7	0.4	-43%	1.4	1.1	-20%	2.2	2.3	5%	3.0	2.9	-3%	3.7	3.2	-14%	5.8	4.3	-26%
D1[4]	dD1_Out	0.4	0.07	-83%	0.9	0.22	-76%	1.4	0.39	-72%	2.1	0.41	-80%	2.6	0.41	-84%	3.2	0.42	-87%	3.4	0.46	-87%
E1[5]	dE1_Out	0.2	0.05	-76%	0.4	0.12	-68%	0.6	0.13	-78%	0.8	0.13	-85%	1.1	0.13	-88%	1.3	0.13	-90%	1.5	0.15	-90%
Minimum				-83%			-76%			-72%			-80%			-84%			-87%			-87%
Maximum				0%			5%			0%			5%			4%			3%			-4%

Filename: SWGeorgetown_PostDevpt_XXyr_90.inp/rpt

Notes:
1. "Pre-" refers to Pre-Development conditions (existing land use / existing drainage system) and "Post-" refers to Post-Development conditions (future land use / proposed drainage system).
2. Δ indicates the difference in peak flow rate between Post- and Pre-Development conditions. Values are rounded to the nearest 10 L/s.
3. Red highlighting indicates occurrences where the Post-Development flow rate exceeds Pre-Development.
4. Pond D1 has been controlled to the assumed allowable release rate to the downstream by-pass pipe of the Fernbrook Phase 3 development, at 0.47 m^3/s
5. Pond E1 has been controlled to the assumed allowable release rate to the existing culvert crossing of Side Road 10 (Structure #22) at 0.16 m^3/s

Table 6.3.12 Post-Development Conditions - Regional Detention Facility High Water Summary

Pond	Perm. Pool Elev. (m)	2-Year/24-Hour	5-Year/24-Hour	10-Year/24-Hour	25-Year/24-Hour	50-Year/24-Hour	100-Year/24-Hour	Regional Storm	100-YearCC/24-Hour
		High Water (m)	High Water (m)	High Water (m)	High Water (m)	High Water (m)	High Water (m)	High Water (m)	High Water (m)
A1	247.58	0.79	1.02	1.14	1.25	1.36	1.50	2.23	1.79
A2	263.19	0.69	0.92	1.00	1.13	1.23	1.37	2.00	1.65
A3	263.19	0.75	0.91	1.02	1.14	1.25	1.37	1.95	1.64
A4	251.57	0.88	1.07	1.20	1.35	1.47	1.62	2.38	1.93
A5	252.33	0.87	1.04	1.17	1.31	1.43	1.57	2.27	1.86
A6	255.85	0.78	0.94	1.03	1.15	1.28	1.41	1.94	1.67
A7	253.44	0.65	0.88	0.93	0.99	1.06	1.16	1.72	1.37
B1	243.17	0.49	0.75	0.83	0.95	1.08	1.19	1.87	1.42
B2	247.50	0.61	0.92	1.02	1.15	1.31	1.45	2.47	1.75
C1	253.88	0.76	0.98	1.09	1.20	1.33	1.46	2.33	1.75
C2	253.88	0.53	0.86	0.98	1.11	1.22	1.35	2.04	1.62
D1	243.50	0.69	0.90	0.99	1.17	1.32	1.45	2.12	1.73
E1	247.75	0.52	0.68	0.83	1.01	1.13	1.26	2.40	1.50

Filename: SWGeorgetown_PostDevpt_XXyr_90.inp/rpt

Notes:
1. Design high water levels are referenced as the depth above the permanent pool.
2. Emergency spillway crest elevation is 2.5 m above the permanent pool.

Hydraulic Gradeline Analysis

A hydraulic gradeline analysis was conducted, comparing peak computed water surface elevations to the corresponding road centerline elevations as a means of identifying potential road flooding occurrences under post-development conditions with stormwater management applied. **Table 6.3.13** shows the model results, which follows the format of **Table 5.4.5** as discussed in **Section 5.4.3.2**. These values were compared to pre-development land use conditions to determine impacts to road flooding as follows:

- 2-year return period/24-hour duration: no new road flooding occurrences, maximum flood depth decrease of 0.13 m (0.15 m pre-dev'pt, 0.02 m post-devp't)
- 5-year /24-hour: no new road flooding occurrences, 0.01 m flood depth decrease (0.40 m pre-dev'pt, 0.39 m post-devp't)
- 10-year /24-hour: 1 less occurrence, 0.01 m flood depth decrease (0.51 m pre-dev'pt, 0.50 m post-devp't)
- 25-year /24-hour: no new occurrences, no flood depth decrease (0.60 m pre-dev'pt, 0.60 m post-devp't)
- 50-year/24-hour: no new occurrences, no flood depth decrease (0.67 m pre-dev'pt, 0.67 m post-devp't)
- 100-year /24-hour: no occurrences, 0.01 m flood depth decrease (0.72 m pre-dev'pt, 0.71 m post-devp't)
- Regional storm: no new occurrences, 0.03 m flood depth decrease (0.88 m pre-dev'pt, 0.85 m post-devp't)

The hydraulic performance is indicated by the level of service provided at each road crossing, which reflects the largest design storm event that does not yield any road flooding. The existing and post-development levels of service are compared in **Table 6.3.14** , which follows the format of **Table 5.4.7**. Under future (uncontrolled) land use conditions there was a decrease in service levels at three culverts Structure #13 on Trafalgar Road, Structure #10 on Side Road 10, and the Tributary B crossing at Eighth Line). However, under post-development conditions with stormwater management applied, there are no service level reductions. It is noted at structure #13, the existing condition model loads all of Catchment A-2 upstream of the culvert. Under proposed conditions, Catchment A-2 has been further descritized, and only the upstream external area is routed to this culvert and results in an actual service level of 100-year event.

Culvert Capacity Analysis

Table 6.3.15 compares the peak computed flowrates for the various design storm events to the culvert capacity, which follows the format of **Table 5.4.6** as discussed in **Section 5.4.3.2**. These values were compared to pre-development land use conditions to determine culvert capacity impacts as follows:

- 2-year return period/24-hour duration: 1 new capacity violation, maximum flow increase of 0.05 m^3/s
- 5-year /24-hour: 1 less capacity violation, 1.02 m^3/s maximum flow decrease
- 10-year /24-hour: 1 less capacity violation, 1.42 m^3/s maximum flow decrease
- 25-year /24-hour: no new capacity violations, 1.61 m^3/s maximum flow decrease
- 50-year/24-hour: no new capacity violations, 1.15 m^3/s maximum flow decrease
- 100-year /24-hour: no new capacity violations, 2.46 m^3/s maximum flow decrease
- Regional storm: no new capacity violations, 2.51 m^3/s maximum flow decrease

Figure 6.3.10 shows the peak computed depth and flow velocities for all road flooding occurrences during the 100-year design storm event, in the same format as **Figure 5.4.2**. Exceedances of these envelopes are indicated at the following location under existing land use conditions:

- Tributary A, Reach AM-4 (Bridge 1000, private internal road): peak depth = 0.71 m, peak velocity = 3.7 m/s

Road flooding impacts are generally improved under post-development conditions, with only one exceedance similar to existing conditions:

- Tributary A, Reach AM-4 (Bridge 1000, private internal road): peak depth = 0.72 m, peak velocity = 2.3 m/s

Figure 6.3.10 Road Flooding Impacts (100-Year Design Storm Event)

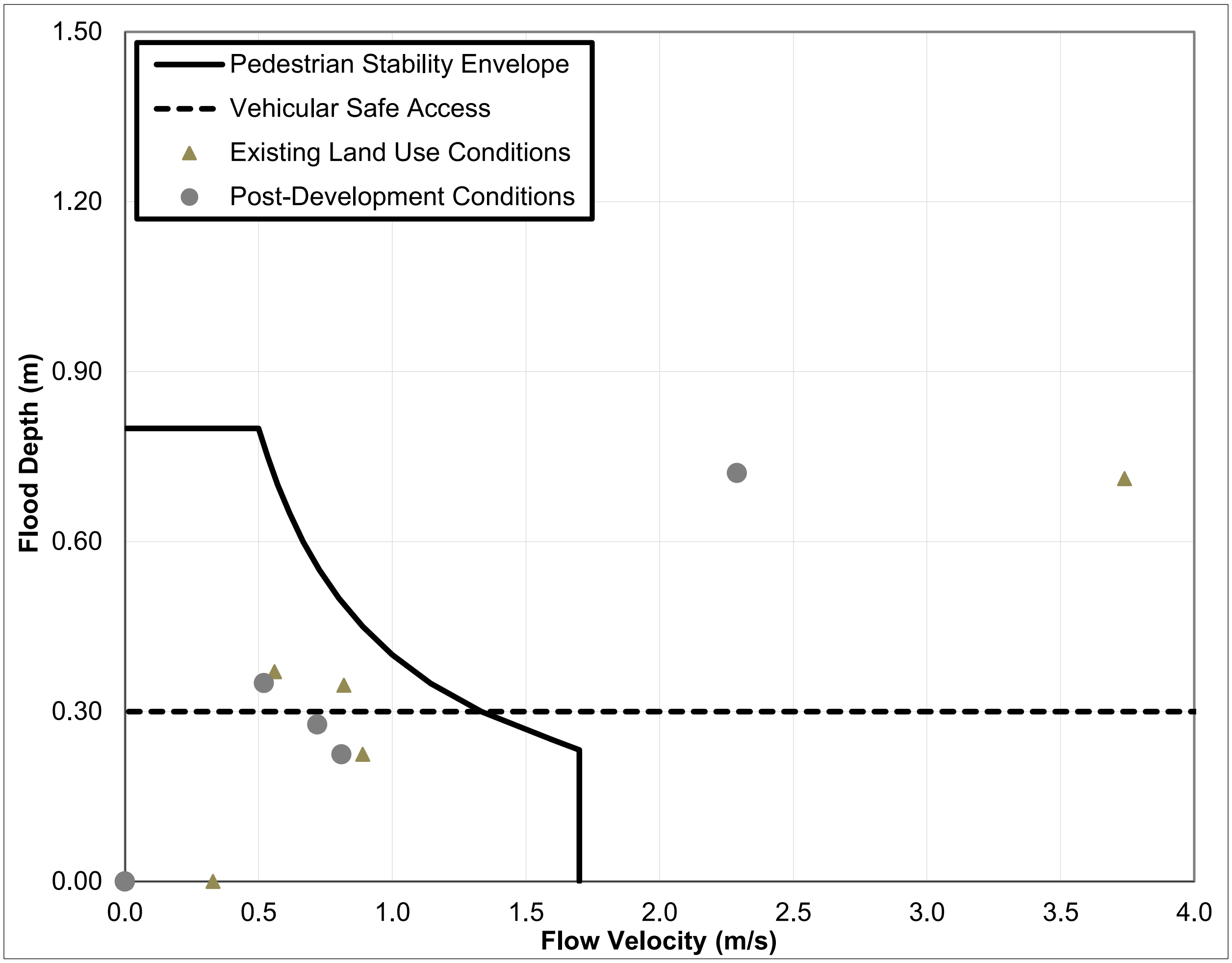


Table 6.3.13 Post-Development Conditions - Hydraulic Gradeline Analysis

			2-yr/24-hr			5-yr/24-hr			10-yr/24-hr			25-yr/24-hr			50-yr/24-hr			100-yr/24-hr			Regional Storm		
Junction Name	**Location**	**Road Overtop Elev. (m)**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**
Tributary A: Reach AM-1, AM-2, and AM-3																							
J0		n/a	231.62			231.68	-0.05		231.77	-0.04		231.89			231.94			231.96			231.96	-0.04	
J60.29	d/s end of culverts at Bridge 180	n/a	242.51	-0.03		242.58			242.63			242.68			242.72			242.76			242.89	-0.05	
J105.06	u/s end of culverts at Bridge 180	244.98	242.62	-0.08		242.88	-0.02		243.09	-0.02		243.32	-0.04		243.52	-0.02		243.72			244.39	-0.46	
J138.04		n/a	242.83	-0.10		243.13	-0.02		243.35	-0.03		243.57	-0.02		243.71			243.85			244.42	-0.44	
J195.83		n/a	243.45	-0.05		243.61			243.71			243.81			243.88			243.94			244.45	-0.43	
J228.22		n/a	243.54	-0.07		243.74			243.86			243.97			244.05			244.12			244.51	-0.39	
J274.82		n/a	244.01	-0.09		244.27			244.40			244.51	-0.02		244.59			244.66			244.90	-0.17	
J299.64		n/a	244.21	-0.07		244.42	-0.02		244.56			244.68	-0.03		244.77			244.84			245.07	-0.12	
J361.59		n/a	244.47	-0.11		244.79	-0.02		245.00	-0.02		245.20	-0.10		245.35			245.46			245.69	-0.09	
J404.79		n/a	244.80	-0.11		245.13	-0.02		245.35	-0.02		245.57	-0.06		245.74			245.86			246.15	-0.10	
J441.39		n/a	245.11	-0.07		245.33			245.52	-0.02		245.75	-0.04		245.91			246.04			246.37	-0.11	
J477.76		n/a	245.47	-0.09		245.72			245.89	-0.02		246.09	-0.02		246.23			246.36			246.70	-0.11	
J525.66		n/a	245.76	-0.11		246.05	-0.02		246.22	-0.02		246.38	-0.03		246.50	-0.02		246.61	-0.02		246.98	-0.13	
J574.87		n/a	246.16	-0.07		246.36	-0.02		246.53	-0.03		246.73	-0.04		246.90	-0.02		247.00	-0.02		247.31	-0.12	
J626.25		n/a	246.93	-0.06		247.12	-0.02		247.28	-0.03		247.47	-0.04		247.62	-0.02		247.73			247.98	-0.09	
J689.29		n/a	247.54	-0.09		247.81	-0.03		248.00	-0.05		248.25	-0.03		248.37	-0.02		248.48	-0.02		248.81	-0.13	
AMA4		n/a	247.61	-0.10		247.90	-0.03		248.11	-0.04		248.34	-0.04		248.47	-0.02		248.58	-0.02		248.92	-0.13	
Tributary A: Reach AM-4																							
J726.16		n/a	247.75	-0.08		248.06			248.27	-0.03		248.47	-0.02		248.59			248.69			249.04	-0.11	
J741.53		n/a	247.91	-0.06		248.17	-0.02		248.37	-0.02		248.54	-0.02		248.65			248.75			249.08	-0.11	
J784.64		n/a	248.09	-0.08		248.42			248.58			248.71			248.81			248.90			249.21	-0.09	
J810.50		n/a	248.31	-0.06		248.54			248.67			248.80			248.90			248.98			249.29	-0.08	
J837.80		n/a	248.44	-0.07		248.70			248.82			248.94			249.03			249.10			249.39	-0.07	
J869.45	d/s end of culvert at Bridge 1000	n/a	248.53	-0.07		248.77			248.89			249.00			249.09			249.16			249.45	-0.06	
J881.13	u/s end of culvert at Bridge 1000	248.85	248.87	-0.13	**0.02**	249.24		**0.39**	249.35		**0.50**	249.45		**0.60**	249.52		**0.67**	249.57		**0.72**	249.70	-0.03	**0.85**
J933.10		n/a	248.88	-0.13		249.24			249.35			249.45			249.53			249.58			249.72	-0.02	
J961.51		n/a	248.94	-0.09		249.25			249.36			249.46			249.54			249.59			249.75	-0.03	
J1009.21		n/a	249.02	-0.06		249.27			249.39			249.49			249.57			249.62			249.79	-0.03	
J1058.64		n/a	249.17	-0.07		249.37			249.47			249.57			249.64			249.69			249.89	-0.03	
J1097.22		n/a	249.25	-0.07		249.45			249.54			249.63			249.71			249.76			249.95	-0.04	
J1146.62		n/a	249.36	-0.06		249.55			249.65			249.75			249.83			249.88			250.09	-0.04	
J1215.03		n/a	249.52	-0.09		249.80			249.93			250.04			250.12			250.16			250.33	-0.04	
J1233.42		n/a	249.55	-0.09		249.84	-0.02		249.98			250.10			250.18			250.22			250.37	-0.04	
J1251.14		n/a	249.60	-0.08		249.90			250.05			250.16			250.24			250.28			250.45	-0.03	
J1312.09		n/a	249.69	-0.09		250.01	-0.02		250.19	-0.03		250.36	-0.02		250.47			250.54			250.80	-0.05	
J1328.03		n/a	249.76	-0.08		250.06	-0.02		250.24	-0.04		250.42	-0.02		250.53			250.60			250.87	-0.05	
J1362.31		n/a	250.03	-0.06		250.28	-0.02		250.50	-0.03		250.64	-0.02		250.73			250.80			251.07	-0.06	
J1400.64		n/a	250.16	-0.07		250.47	-0.02		250.60	-0.03		250.73	-0.02		250.82			250.89			251.17	-0.06	
J1429		n/a	250.33	-0.06		250.59	-0.02		250.70	-0.02		250.81	-0.02		250.89	-0.02		250.96			251.24	-0.06	
AMA2		n/a	250.40	-0.07		250.65	-0.02		250.75	-0.02		250.86	-0.02		250.94	-0.02		251.01			251.29	-0.06	
Tributary A: Reach AM-5																							

			2-yr/24-hr			5-yr/24-hr			10-yr/24-hr			25-yr/24-hr			50-yr/24-hr			100-yr/24-hr			Regional Storm		
Junction Name	**Location**	**Road Overtop Elev. (m)**	**Peak Stage (m)**	**Δ$_{Ex}$**	**Depth Above Road**	**Peak Stage (m)**	**Δ$_{Ex}$**	**Depth Above Road**	**Peak Stage (m)**	**Δ$_{Ex}$**	**Depth Above Road**	**Peak Stage (m)**	**Δ$_{Ex}$**	**Depth Above Road**	**Peak Stage (m)**	**Δ$_{Ex}$**	**Depth Above Road**	**Peak Stage (m)**	**Δ$_{Ex}$**	**Depth Above Road**	**Peak Stage (m)**	**Δ$_{Ex}$**	**Depth Above Road**
J1482.68		n/a	250.45	-0.06		250.69	-0.03		250.80	-0.03		250.91	-0.03		250.99	-0.03		251.06	-0.02		251.35	-0.06	
J1516.26	d/s end of culvert at Bridge 150	n/a	250.58	-0.03		250.77	-0.03		250.87	-0.05		251.01	-0.04		251.10	-0.04		251.17	-0.03		251.45	-0.06	
J1534.07	u/s end of culvert at Bridge 150	251.15	250.85	-0.06		251.19	-0.06	**0.04**	251.33	-0.04	**0.18**	251.41	-0.03	**0.26**	251.46	-0.03	**0.31**	251.50	-0.02	**0.35**	251.65	-0.03	**0.50**
J1551.87		n/a	250.86	-0.05		251.19	-0.07		251.33	-0.04		251.42	-0.02		251.46	-0.03		251.50	-0.03		251.66	-0.03	
J1608.03		n/a	250.88	-0.05		251.20	-0.06		251.34	-0.04		251.42	-0.03		251.47	-0.02		251.51	-0.02		251.67	-0.03	
J1671.38		n/a	250.89	-0.05		251.20	-0.06		251.34	-0.04		251.42	-0.03		251.47	-0.03		251.51	-0.03		251.67	-0.03	
J1710.16		n/a	250.98	-0.04		251.25	-0.06		251.37	-0.04		251.45	-0.03		251.50	-0.02		251.53	-0.03		251.70	-0.03	
J1764.95		n/a	251.08	-0.04		251.34	-0.07		251.45	-0.03		251.51	-0.03		251.55	-0.02		251.59	-0.02		251.72	-0.03	
J1821.83		n/a	251.30			251.50	-0.02		251.59			251.64			251.68			251.72			251.83		
J1860.66		n/a	251.34			251.56			251.67			251.74			251.79			251.83			251.93		
J1887.99		n/a	251.37			251.57			251.67			251.75			251.79			251.83			251.94		
AMA5		n/a	251.42			251.61			251.68			251.76			251.80			251.83			251.94		
Tributary A: Reach AM-6 and AM-7																							
J2021.40		n/a	251.42			251.61			251.69			251.76			251.80			251.84			251.95		
J2072.56		n/a	251.43			251.62			251.69			251.76			251.80			251.84			251.95		
J2126.95		n/a	251.52	-0.02		251.63			251.69			251.76			251.80			251.84			251.95		
J2176.63		n/a	251.59	-0.02		251.72	-0.03		251.77			251.79	-0.02		251.82			251.84			251.95		
J2244.43		n/a	251.75			251.79			251.81			251.83			251.84			251.85	-0.02		251.96		
J2254.97		n/a	251.79	-0.02		251.88	-0.02		251.92	-0.02		251.97	-0.02		252.01	-0.02		252.03	-0.12		252.16		
J2299.97		n/a	252.11			252.18	-0.02		252.23			252.26			252.28			252.30			252.32	-0.02	
J2340.31		n/a	252.46	-0.02		252.53			252.55			252.59			252.60			252.62	-0.02		252.65	-0.02	
J2362.75		n/a	252.61	-0.02		252.70	-0.02		252.74	-0.02		252.78	-0.02		252.81	-0.02		252.82	-0.03		252.86	-0.03	
J2401.07		n/a	252.71	-0.03		252.83	-0.03		252.88	-0.03		252.93	-0.03		252.97	-0.02		252.99	-0.03		253.03	-0.02	
J2433.86		n/a	252.89	-0.02		252.98	-0.04		253.04	-0.02		253.09	-0.02		253.11	-0.03		253.14	-0.03		253.18	-0.03	
J2450.6		n/a	253.09			253.14	-0.02		253.17	-0.02		253.21	-0.02		253.23	-0.03		253.26	-0.03		253.30	-0.03	
J2479.5	d/s end of culvert at Structure #10	n/a	253.19	-0.02		253.27	-0.02		253.31	-0.03		253.36	-0.03		253.39	-0.04		253.42	-0.04		253.48	-0.04	
J2509.5	u/s end of culvert at Structure #10	254.90	253.53	-0.04		253.74	-0.07		253.88	-0.11		254.08	-0.18		254.28	-0.41		254.63	-0.26		254.92	-0.06	**0.02**
J2524		n/a	253.71	-0.02		253.78	-0.05		253.90	-0.10		254.08	-0.18		254.28	-0.41		254.63	-0.27		254.92	-0.06	
Tributary A: Reach A2-1 and A2-2																							
J22268.08		n/a	250.56	-0.02		250.65	-0.02		250.76	-0.02		250.87			250.95			251.01	-0.02		251.29	-0.06	
J222110.7		n/a	251.05	-0.02		251.13			251.19			251.24	-0.02		251.27	-0.03		251.31	-0.02		251.41	-0.03	
J222181.0		n/a	251.20	-0.05		251.36	-0.03		251.47	-0.03		251.55	-0.03		251.61	-0.03		251.66	-0.03		251.79	-0.04	
J222256.8		n/a	251.69	-0.02		251.74			251.81	-0.02		251.88	-0.03		251.93	-0.04		251.98	-0.03		252.11	-0.04	
J222345.5		n/a	251.83			251.88			251.95	-0.02		252.04	-0.02		252.07	-0.02		252.10	-0.02		252.20	-0.03	
J222411.2		n/a	252.19	-0.04		252.27	-0.02		252.36	-0.02		252.43	-0.02		252.47	-0.02		252.50	-0.03		252.59	-0.02	
J222445.0		n/a	252.38	-0.03		252.47	-0.02		252.54	-0.02		252.60	-0.02		252.65	-0.02		252.68	-0.03		252.79	-0.03	
J222503.2		n/a	252.52	-0.03		252.65	-0.03		252.76	-0.03		252.85	-0.03		252.90	-0.04		252.95	-0.04		253.09	-0.03	
J222581.8		n/a	252.82	-0.02		252.89	-0.02		252.95	-0.02		253.00	-0.02		253.03	-0.02		253.06	-0.02		253.14	-0.03	
J222652.7		n/a	253.29			253.34			253.38			253.41			253.43			253.44	-0.02		253.49		
J222721.4		n/a	253.64	0.02		253.74			253.81			253.87			253.91			253.94			254.01		
J222740	d/s end of culvert at Bridge 2400	n/a	253.74			253.91			254.02			254.06			254.09			254.12			254.18		
J222795.9	u/s end of culvert at Bridge 2400	254.41	254.26			254.57		**0.16**	254.61		**0.20**	254.65		**0.24**	254.68		**0.27**	254.69		**0.28**	254.74		**0.33**
J222831.9		n/a	254.26			254.57			254.62			254.65			254.68			254.70			254.76		
J222880.7		n/a	254.32			254.57			254.62			254.67			254.70			254.73			254.82		

			2-yr/24-hr			5-yr/24-hr			10-yr/24-hr			25-yr/24-hr			50-yr/24-hr			100-yr/24-hr			Regional Storm		
Junction Name	**Location**	**Road Overtop Elev. (m)**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**
J222914.5		n/a	254.75			254.84			254.93			255.01			255.06			255.10			255.22		
J222968.0	d/s end of culvert at Bridge 2530	n/a	254.84			254.94			255.01			255.08			255.14			255.18			255.31		
J223004.5	u/s end of culvert at Bridge 2530	256.99	256.16			257.08		**0.09**	257.14		**0.15**	257.18		**0.19**	257.20		**0.21**	257.21		**0.22**	257.27		**0.28**
J223038.1		n/a	256.17			257.08			257.14			257.18			257.20			257.22			257.28		
J223116.5		n/a	256.21			257.08			257.15			257.20			257.24			257.27			257.39		
J223199.9		n/a	256.84			257.09			257.18			257.25			257.30			257.35			257.51		
Tributary A: Reach A4-1, A4-2, A4-3, and A4-4																							
J44414.18		n/a	248.31	-0.15		248.39	-0.12		248.45	-0.15		248.48	-0.22		248.50	-0.29		248.58	-0.27		248.92	-0.14	
J44452.82		n/a	248.44	-0.27		248.59	-0.20		248.69	-0.19		248.75	-0.22		248.77	-0.28		248.80	-0.31		248.98	-0.30	
J44495.83		n/a	249.23	-0.18		249.33	-0.14		249.40	-0.12		249.43	-0.15		249.46	-0.16		249.47	-0.19		249.53	-0.22	
J444130.4		n/a	249.72	-0.25		249.86	-0.18		249.97	-0.14		250.00	-0.19		250.02	-0.21		250.03	-0.24		250.12	-0.22	
J444160.3		n/a	249.98	-0.22		250.12	-0.11		250.20	-0.07		250.21	-0.11		250.22	-0.14		250.23	-0.16		250.28	-0.19	
J444198.8		n/a	250.20	-0.17		250.30	-0.12		250.36	-0.14		250.39	-0.20		250.41	-0.25		250.42	-0.30		250.52	-0.30	
J444266.6		n/a	250.58	-0.18		250.72	-0.09		250.76	-0.08		250.78	-0.12		250.80	-0.14		250.80	-0.17		250.85	-0.20	
J444328.7		n/a	251.20	-0.05		251.24	-0.03		251.25	-0.06		251.26	-0.07		251.27	-0.07		251.27	-0.09		251.31	-0.09	
J444380.8		n/a	251.44	-0.10		251.51	-0.07		251.54	-0.09		251.56	-0.10		251.57	-0.09		251.58	-0.10		251.64	-0.10	
J444460.7		n/a	251.58	-0.44		251.87	-0.22		252.00	-0.21		252.05	-0.25		252.08	-0.26		252.09	-0.28		252.23	-0.20	
J444521.1		n/a	252.36	-0.06		252.40	-0.05		252.42	-0.07		252.44	-0.09		252.44	-0.12		252.45	-0.14		252.49	-0.16	
J444543.8		n/a	252.55	-0.08		252.60	-0.06		252.63	-0.08		252.64	-0.12		252.65	-0.15		252.65	-0.17		252.72	-0.17	
J444594.6		n/a	252.91	-0.20		253.04	-0.14		253.10	-0.17		253.14	-0.23		253.16	-0.28		253.17	-0.32		253.29	-0.33	
J444655.7		n/a	253.40	-0.11		253.47	-0.09		253.51	-0.13		253.54	-0.18		253.55	-0.22		253.56	-0.25		253.65	-0.26	
J444726.7		n/a	253.70	-0.05		253.74	-0.04		253.76	-0.05		253.76	-0.10		253.77	-0.12		253.77	-0.15		253.82	-0.17	
J444793.7		n/a	254.11	-0.08		254.17	-0.05		254.19	-0.07		254.21	-0.09		254.22	-0.10		254.22	-0.12		254.27	-0.11	
J444867.4		n/a	254.58	-0.05		254.62	-0.04		254.63	-0.07		254.65	-0.10		254.65	-0.13		254.66	-0.15		254.72	-0.15	
J444936.3		n/a	255.28	-0.05		255.31	-0.04		255.32	-0.07		255.34	-0.09		255.35	-0.11		255.35	-0.14		255.40	-0.13	
J4441008		n/a	255.71	-0.07		255.76	-0.05		255.78	-0.07		255.79	-0.12		255.80	-0.15		255.81	-0.17		255.86	-0.19	
J4441090		n/a	256.16	-0.19		256.30	-0.08		256.34	-0.12		256.37	-0.16		256.37	-0.20		256.38	-0.22		256.48	-0.19	
J4441201		n/a	257.67	-0.14		257.76	-0.09		257.80	-0.11		257.82	-0.15		257.84	-0.17		257.84	-0.20		257.92	-0.18	
J4441280		n/a	258.14	-0.09		258.19	-0.08		258.22	-0.11		258.25	-0.14		258.26	-0.17		258.27	-0.20		258.34	-0.19	
J4441342		n/a	258.61	-0.11		258.69	-0.08		258.72	-0.12		258.74	-0.17		258.76	-0.20		258.77	-0.23		258.85	-0.23	
J4441419		n/a	259.16	-0.10		259.23	-0.08		259.26	-0.13		259.29	-0.19		259.30	-0.23		259.31	-0.26		259.41	-0.26	
J4441488		n/a	259.69	-0.11		259.77	-0.06		259.79	-0.09		259.82	-0.13		259.82	-0.18		259.83	-0.21		259.90	-0.23	
J4441559		n/a	260.14	-0.12		260.22	-0.10		260.26	-0.15		260.29	-0.22		260.31	-0.28		260.32	-0.32		260.43	-0.34	
J4441588	d/s end of culvert at Structure #13	n/a	260.56	-0.07		260.61	-0.05		260.63	-0.08		260.64	-0.12		260.65	-0.14		260.66	-0.15		260.72	-0.15	
J4441640	u/s end of culvert at Structure #13	262.15	261.23	-0.39		261.46	-0.67		261.60	-0.74		261.76	-0.67		261.87	-0.60		261.97	-0.53		262.36	-0.21	**0.21**
J4441665		n/a	261.36	-0.27		261.47	-0.66		261.61	-0.73		261.76	-0.67		261.87	-0.60		261.97	-0.53		262.36	-0.21	
J4441750		n/a	261.67	-0.14		261.76	-0.37		261.81	-0.54		261.85	-0.58		261.88	-0.59		261.97	-0.54		262.36	-0.22	
Tributary A: Reach A5-1																							
J555272.5		n/a	251.70			251.79	0.02		251.83			251.89	0.03		251.92	0.02		251.95	0.02		252.02		
J555210.0		n/a	251.65			251.75			251.79			251.84	0.02		251.87	0.02		251.90	0.02		252.00		
J555130.6		n/a	251.62			251.73			251.77			251.81	0.02		251.83			251.86	0.02		251.98		
J55560.97		n/a	251.49	0.02		251.61			251.69			251.76			251.80			251.84			251.95		
Tributary B																							
J0		n/a	231.62			231.68	-0.05		231.77	-0.04		231.89			231.94			231.96			231.96	-0.04	

			2-yr/24-hr			5-yr/24-hr			10-yr/24-hr			25-yr/24-hr			50-yr/24-hr			100-yr/24-hr			Regional Storm		
Junction Name	**Location**	**Road Overtop Elev. (m)**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**	**Peak Stage (m)**	**Δ_{Ex}**	**Depth Above Road**
J1	d/s end of culvert at Bridge 1.5	n/a	232.90			232.95	-0.04		233.02	-0.03		233.11			233.14			233.15			233.16	-0.02	
J2	u/s end of culvert at Bridge 1.5	239.05	234.43			234.54	-0.13		234.80	-0.13		235.28			235.61	-0.16		236.06	-0.29		236.15	-1.12	
J3		n/a	235.85	-0.02		235.90	-0.05		235.97	-0.03		236.03	-0.02		236.07	-0.02		236.10	-0.25		236.15	-1.12	
J4		n/a	238.57	-0.02		238.60	-0.03		238.64	-0.03		238.69	-0.02		238.72	-0.02		238.74	-0.03		238.72	-0.07	
J5		n/a	240.69	-0.04		240.75	-0.06		240.84	-0.05		240.93	-0.04		240.98	-0.05		241.03	-0.05		240.98	-0.13	
J6		n/a	Proposed development from subcatchment B-2 to be routed through proposed new trunk storm sewer (watercourse values not shown here)																				
J7		n/a																					
Tributary C																							
J900	d/s end of culvert at Bridge 950	n/a	246.97	0.02		247.03	-0.04		247.11	-0.02		247.18			247.20			247.21	-0.02		247.25	-0.04	
J1000	u/s end of culvert at Bridge 950	249.78	247.11	0.03		247.27	-0.10		247.47	-0.07		247.75			247.91	-0.03		247.98	-0.17		248.39	-0.53	
J1100		n/a	248.22			248.25	-0.03		248.30			248.34			248.36			248.37			248.39	-0.53	
J1115		n/a	248.60	-0.07		248.67	-0.08		248.69	-0.10		248.71	-0.12		248.73	-0.13		248.74	-0.14		248.78	-0.17	
J1150		n/a	249.55	-0.05		249.62	-0.08		249.66	-0.09		249.69	-0.11		249.72	-0.12		249.74	-0.13		249.78	-0.15	
J1200		n/a	251.39	-0.03		251.42	-0.04		251.43	-0.05		251.45	-0.06		251.46	-0.07		251.47	-0.08		251.49	-0.09	
					1			**4**			**5**			**5**			**5**			**5**			**6**

Future land use: SWGeorgetown_PostDevpt_XXyr_90.inp/rpt

Notes:
1. All values are rounded to the nearest 10 mm.
2. Δ_{Ex} indicates the difference in peak flood stage compared to Existing land use conditions. No value is shown if the peak stage is within 12.5 mm.
3. Depth Above Road indicates the depth (m) that the peak flood stage rises above the road centerline elevation or top of ground at a culvert crossing.

Table 6.3.14 Post-Development Conditions - Flow and Culvert Capacity Analysis

			2-yr/24-hr			5-yr/24-hr			10-yr/24-hr			25-yr/24-hr			50-yr/24-hr			100-yr/24-hr			Regional Storm		
Conduit Name	Structure, Location	Full-Flow Capacity (m^3/s)	Peak Flow (m^3/s)	Δ_{Ex}	Q_p/Q_{full}	Peak Flow (m^3/s)	Δ_{Ex}	Q_p/Q_{full}	Peak Flow (m^3/s)	Δ_{Ex}	Q_p/Q_{full}	Peak Flow (m^3/s)	Δ_{Ex}	Q_p/Q_{full}	Peak Flow (m^3/s)	Δ_{Ex}	Q_p/Q_{full}	Peak Flow (m^3/s)	Δ_{Ex}	Q_p/Q_{full}	Peak Flow (m^3/s)	Δ_{Ex}	Q_p/Q_{full}
Tributary A																							
J105.06	Bridge 180, Eighth Line	66.8	1.5	-0.81	2%	4.6	-0.25	7%	8.0	-0.42	12%	12.5	-0.72	19%	16.8	-0.31	25%	21.4	-0.04	32%	38.9	-7.28	58%
J881.13	Bridge 1000, private road	5.17	1.3	-0.47	26%	3.8	-0.11	73%	6.3	-0.19	122%	10.0	-0.11	192%	13.5	0.29	260%	16.6	0.29	320%	33.0	-3.77	639%
J1534.07	Bridge 150, private road	2.5	0.9	-0.13	38%	1.8	-0.22	73%	2.6	-0.50	104%	3.9	-0.62	154%	4.9	-0.74	197%	6.0	-0.92	240%	13.9	-2.53	555%
J2509.5	Structure #10, 10th Side Rd.	2.64	0.2	-0.06	9%	0.6	-0.16	22%	0.9	-0.24	34%	1.3	-0.36	51%	1.7	-0.43	65%	2.1	-0.59	79%	2.9	-0.79	109%
J222795.9	Bridge 2400, private road	0.3	0.3		102%	1.0		338%	2.4		810%	4.2		1410%	5.9		1964%	7.5		2498%	13.0		4338%
J223004.5	Bridge 2530, Trafalgar Road	0.42	0.4		84%	1.3		317%	2.7		651%	4.5		1069%	6.1		1442%	7.6		1808%	13.0		3100%
J4441640	Structure #13, Trafalgar Road	0.98	0.1	-0.46	8%	0.3	-0.88	33%	0.5	-1.26	52%	0.7	-2.48	76%	0.9	-3.67	94%	1.1	-4.74	109%	2.0	-7.35	207%
Tributary B																							
CJ2	Bridge 1.5, Eighth Line	10.5	0.1		1%	0.3	-0.31	3%	1.0	-0.41	10%	2.8	0.18	27%	4.0	0.13	38%	5.2	0.18	49%	4.6	-0.59	44%
Tributary C																							
CJ1000	Bridge 950, Eighth Line	1.39	0.1		9%	0.4	-0.38	31%	1.2	-0.36	84%	2.5		181%	3.2	-0.27	230%	3.5	-0.88	253%	4.4	-1.85	317%

Filename: SWGeorgetown_PostDevpt_xxyr_90.inp/rpt

Notes:
1. Δ_{Ex} indicates the difference in peak flow compared to Existing land use conditions. No value is shown if the peak flowrate is within 10 L/s.
2. Culvert full-flow capacity based on Manning's equation.
3. Peak computed flowrates that exceed 85% capacity are highlighted.

Table 6.3.15 Level of Service Comparison - Existing vs. Post-Development Conditions with Stormwater Management

Location	Description	Structure Name	Service Level Provided	
			Existing	Post-Devp't
Tributary A				
Eighth Line	twin 2.42m × 3.78m concrete box culverts	Bridge 180	Regional	Regional
private road	0.95m × 1.50m concrete box culvert	Bridge 1000	<2-yr	<2-yr
private road	1.40m Ø concrete round culvert	Bridge 150	2-yr	2-yr
10th Side Rd.	1.18m Ø concrete round culvert	Structure #10	100-yr	100-yr
private road	0.70m Ø concrete round culvert	Bridge 2400	2-yr	2-yr
Trafalgar Rd.	0.77m Ø PVC round culvert	Bridge 2530	2-yr	2-yr
Trafalgar Rd.	0.92m Ø corrugated steel round culvert	Structure #13	100-yr	100-yr
Tributary B				
Eighth Line	1.40m Ø corrugated steel round culvert	Bridge 1.5	Regional	Regional
Tributary C				
Eighth Line	1.43m × 2.02m corrugated steel box culvert	Bridge 950	Regional	Regional

Watercourse Flow Targets

The allowable discharges from the proposed SWMFs was determined by optimizing the peak outflow rates while maintaining pre-development peak flows along the receiving watercourse. The following provides the allowable peak outflows per SWM facility catchment area (ha) for each receiving watercourse.

- Tributary A:
  - 2-year return period/24-hour duration: 2.4 L/s/ha peak flow
  - 100-year /24-hour: 50 L/s/ha peak flow
  - Regional storm: 53 L/s/ha peak flow, with no overtopping of emergency spillway

- Tributary B:
  - 2-year return period/24-hour duration: 1.6 L/s/ha peak flow
  - 100-year /24-hour: 24 L/s/ha peak flow
  - Regional storm: 27 L/s/ha peak flow, with no overtopping of emergency spillway

- Tributary C:
  - 2-year return period/24-hour duration: 1.7 L/s/ha peak flow
  - 100-year /24-hour: 37 L/s/ha peak flow
  - Regional storm: 41 L/s/ha peak flow, with no overtopping of emergency spillway

- Tributary D *(Catchment D-1 and D-2 Only):*
  - 2-year to Regional Storm return period/24-hour duration: 6.6 L/s/ha peak flow
  - 100-year /24-hour: 40 L/s/ha peak flow
  - Regional storm: 43 L/s/ha peak flow, with no overtopping of emergency spillway

- Tributary E:
  - 2-year return period/24-hour duration: 6.6 L/s/ha peak flow
  - 100-year /24-hour: 40 L/s/ha peak flow
  - Regional storm: 43 L/s/ha peak flow, with no overtopping of emergency spillway

Table 6.3.16 summarizes the allowable peak outlflows (L/s/ha) for 2-year through to Regional storm event, per SWM facility catchment area. Existing condition unit flow rates (L/s/ha) are also provided. The overall future SWM servicing strategy (including regional SWM facility control areas, uncontrolled development areas, natural corridor areas, and external areas) must not exceed existing unit flow rates (L/s/ha). Due to existing capacity constraints in existing downstream infrastructure provided through the Fernbrook Phase 3 development, it is noted that for Tributary D, Catchment D-1 and D-2 (10.6 ha) has been controlled to the assumed allowable release rate to the downstream by-pass pipe of 0.47 m^3/s, and Catchment D-3 (19.0 ha) has been diverted to Tributary A, via discharge to the regional SWM facility PondA1. It is also noted that Tributary E (Catchment E-1) has been controlled to the assumed capacity of the existing culvert crossing of Side Road 10 of 0.16 m^3/s.

Low unit flow rate targets for Tributary B and C can be attributed to the existing soil composition of sandy-loam and loam soil, which has significantly higher infiltration capacity then the predominate Clay Loam found within the drainage area of Tributary A and D. Existing soil textures are outlined in **Section 4.6.6** and illustrated in **Figure 4.3.3.** Tributary B and C are also significantly smaller total catchment areas then Tributary A, and are much more sensitive to the impact of proposed uncontrolled areas (5-year to Regional events). Thus under the current proposed condition concept plan, proposed regional SWM facilities are over controlling some events to meet existing peak flows.

It is important to recognize that the post-development targets for regional SWM facility control areas provided in **Table 6.3.16** are representative of the SWM concept that was developed as part of the modelling for this study. This concept was developed as a means of assisting identifying SWM requirements to mitigate the impacts of future development. The final SWM plan for the area will depend upon the final land use details and the overall grading and servicing plan.

The existing condition unit area flow rates provided in **Table 6.3.16** are to be used as the target flow rates for quantity control with any future SWM plan. These conveyed to the existing condition (controlled) flow provided in **Table 4.6.10**.

Table 6.3.16 Unit Area Flow Targets (L/s/ha)

Contributing Catchment	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	Regional Storm
Post-Development Conditions Unit L/s/ha Rate - Regional SWM Facility Control Areas							
A	2.4	12	23	42	49	50	53
B	1.6	1.7	13	23	23	24	27
C	1.7	4.0	13	30	36	37	41
D[2]	6.6	20	37	38	39	40	43
E[3]	3.5	9	9	10	10	10	11
Existing Condition Unit L/s/ha Rate – Total Area							
A	4.5	9	16	25	33	41	90
B	1.0	7	16	30	*37*[1]	*43*[1]	54
C	2.8	10	19	32	43	55	82
D	12	31	47	70	89	109	116
E	11	28	42	63	80	98	112

1. *CVC's GAWSER existing condition unit flows from CVC Peak Flow study (2003), applied were Gawser flows are less then SWMM5 modelled existing flows.*
2. *Pond D1 has been controlled to the assumed allowable release rate of the downstream by-pass pipe of the Fernbrook Phase 3 development, at 0.47 m^3/s.*
3. *Pond E1 has been controlled to the assumed allowable release rate to the existing culvert crossing of Side Road 10 at 0.16 m^3/s.*

The overall unit-area peak discharge values for post-development conditions are given in **Table 6.3.17**, which follows the format of **Table 5.4.3** as discussed in **Section 5.4.3.1**. The overall impacts of proposed development and stormwater servicing compared to the pre-development peak discharge flowrates (average for all watercourses) include:

- 2-year return period/24-hour duration: 2 L/s/ha peak flow decrease
- 5-year /24-hour: 2 L/s/ha peak flow decrease
- 10-year /24-hour: 3 L/s/ha peak flow decrease
- 25-year /24-hour: 5 L/s/ha peak flow decrease
- 50-year/24-hour: 8 L/s/ha peak flow decrease
- 100-year /24-hour: 12 L/s/ha peak flow decrease
- Regional storm: 20 L/s/ha peak flow decrease

Compared to existing land use conditions, peak discharge rates were reduced by 0-87% for the 2-year through 100-year design storm events, an average of reduction of 35%.

For Tributary B, post development unit flow targets were developed in consideration of both the CVC's Gawser flows and existing condition SWMM5 flows. The proposed development unit flows meet both the CVC's Gawser and SWMM5 unit rates for the 2-year to regional storm events as summarized **Table 6.3.18**, with the exception of a minor 3 and 1 L/s/ha exceedance for the CVC's Gawser 50-year and 100-year runoff unit rates, respectively. The regional storm event is over controlled in order to meet the 2-year to 100-year pre-development flows. Therefore the recommended SWM strategy satisfies peak flow control for both the CVC's GAWSER and SWMM5 existing condition unit-area flow rates

Table 6.3.17 Post-Development Conditions - Unit-Area Peak Discharge

		2-yr/24-hr			5-yr/24-hr			10-yr/24-hr			25-yr/24-hr			50-yr/24-hr			100-yr/24-hr			Regional Storm		
Contributing Subcatchments	**Area (ha)**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Δ_{Ex}**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Δ_{Ex}**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Δ_{Ex}**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Δ_{Ex}**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Δ_{Ex}**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Δ_{Ex}**	**Peak Flow (m^3/s)**	**Q_{unit} (L/s/ha)**	**Δ_{Ex}**
all of Tributary A[1]	**539.3**	**1.5**	**3**	**-2**	**4.6**	**9**	**-1**	**8.0**	**15**	**-1**	**12.5**	**23**	**-2**	**16.9**	**31**	**-2**	**21.4**	**40**	**-2**	**39.0**	**72**	**-18**
A-2,3a,3b,4,4a,4b,5,6	507.2	1.5	3	-2	4.4	9	-1	7.6	15	-1	11.9	23	-2	16.0	32	-2	20.2	40	-2	37.5	74	-17
A-2_Res	28.4	0.1	3	-3	0.3	11	-1	0.5	18	-1	0.7	26	-8	0.9	32	-16	1.1	38	-24	2.0	71	-28
A-3,4,4a,4b,5,6	412.4	1.3	3	-1	3.8	9	0	6.3	15	-1	9.9	24	-1	13.4	32	0	16.4	40		32.5	79	-10
A-4,4a,4b,5,6	362.4	1.2	3	-1	3.4	9	0	5.6	15	0	8.8	24	0	11.8	33	1	14.5	40	1	30.4	84	-6
A-4_Nat & A-4a	160.9	0.2	1	0	1.1	7	-1	2.6	16	-1	4.5	28	-2	6.3	39	-2	8.0	49	-3	13.8	86	-2
A-4a	152.7	0.4	2		1.3	9		2.7	18		4.5	29		6.1	40		7.6	50		13.0	85	
A-5 & A-6	144.8	0.9	6		2.1	14	1	2.9	20	1	4.1	28	2	5.2	36	2	6.3	43	3	13.5	93	0
A-5	114.2	0.8	7	1	2.6	23	4	4.0	35	5	6.2	55	9	8.3	73	13	10.2	89	15	11.8	103	4
A-6_RES	28.3	0.2	8	0	0.6	21	0	0.9	32	0	1.3	47	0	1.7	61	1	2.1	73	-1	2.9	102	0
all of Tributary B	**87.3**	**0.1**	**1**	**0**	**0.3**	**3**	**-4**	**1.0**	**12**	**-5**	**2.6**	**30**	**-1**	**3.5**	**40**	**-4**	**3.8**	**44**	**-14**	**3.9**	**44**	**-23**
all of Tributary C	**79.9**	**0.1**	**2**	**-1**	**0.4**	**5**	**-5**	**1.2**	**15**	**-5**	**2.5**	**31**	**0**	**3.2**	**40**	**-4**	**3.5**	**44**	**-11**	**4.4**	**55**	**-27**
all of Tributary D	**10.6**	**0.1**	**7**	**-6**	**0.2**	**20**	**-11**	**0.4**	**37**	**-10**	**0.4**	**38**	**-31**	**0.4**	**39**	**-50**	**0.4**	**40**	**-69**	**0.5**	**43**	**-73**
all of Tributary E	**13.5**	**0.0**	**4**	**-8**	**0.1**	**9**	**-19**	**0.1**	**9**	**-33**	**0.1**	**10**	**-53**	**0.1**	**10**	**-70**	**0.1**	**10**	**-88**	**0.2**	**11**	**-100**
	Min:		1			3			9			10			10			10			11	
	Avg:		**4**			**11**			**19**			**30**			**38**			**46**			**72**	
	Max:		8			23			37			55			73			89			103	

Filename: SWGeorgetown_PostDevpt_xxyr_90.inp/rpt

Note:

1. Includes diversion of catchment D-3 to Tributary A

Table 6.3.18 Post-Development Conditions – Comparison to GAWSER Flows

		2-yr/24-hr		5-yr/24-hr		10-yr/24-hr		25-yr/24-hr		50-yr/24-hr		100-yr/24-hr		Regional Storm	
Model	**Area (ha)**	**Peak Flow (m^3/s)**	**Qunit (L/s/ha)**	**Peak Flow (m^3/s)**	**Qunit (L/s/ha)**	**Peak Flow (m^3/s))**	**Qunit (L/s/ha)**	**Peak Flow (m^3/s)**	**Qunit (L/s/ha)**	**Peak Flow (m^3/s)**	**Qunit (L/s/ha)**	**Peak Flow (m^3/s)**	**Qunit (L/s/ha)**	**Peak Flow (m^3/s)**	**Qunit (L/s/ha)**
Post-Development - all of Tributary B[1]	87.3	0.1	**1**	0.3	**3**	1.0	**12**	2.6	**30**	3.5	**40**	3.8	**44**	3.9	**44**
Existing Conditions - all of Tributary B[1]	87.3	0.1	**1**	0.6	**7**	1.4	**16**	2.6	**30**	3.6	**41**	4.0	**46**	4.7	**54**
GAWSER[2]	127.0	1.4	**11**	2.5	**19**	3.5	**27**	4.2	**33**	4.7	**37**	5.4	**43**	9.5	**75**

1. *Tributary B SWMM5 Flows from Downstream of Eighth Line crossing (CJ1)*
   Filename: SWGeorgetown_PreDevpt_xxyr_75.inp/rpt ; SWGeorgetown_PostDevpt_xxyr_90.inp/rpt
2. *CVC's GAWSER Flows from CVC Peak Flow Study (2003)*
3. *Exceedances in unit peak flowrates are highlighted.*

Table 6.3.19 Post-Development Conditions - Unit-Area Runoff Volume

		2-yr/24-hr			5-yr/24-hr			10-yr/24-hr			25-yr/24-hr			50-yr/24-hr			100-yr/24-hr			Regional Storm		
Contributing Subcatchments	**Area (ha)**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Δ_{Ex}**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Δ_{Ex}**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Δ_{Ex}**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Δ_{Ex}**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Δ_{Ex}**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Δ_{Ex}**	**Total Volume (m^3)**	**V_{unit} (m^3/ha)**	**Δ_{Ex}**
all of Tributary A[2]	**539.3**	**79,000**	**146**	**80**	**142,000**	**263**	**88**	**194,000**	**360**	**95**	**266,000**	**493**	**105**	**320,000**	**593**	**107**	**376,000**	**697**	**113**	**913,000**	**1,693**	**194**
A-2,3,4,4a,4b,5,6	507.18	70,000	138	73	128,000	252	80	176,000	347	85	243,000	479	95	294,000	580	97	345,000	680	101	841,000	1,658	170
A-2_Res	*28.4*	496	17	-40	2,310	81	-93	4,180	147	-121	6,860	241	-152	9,200	324	-170	11,500	404	-187	30,300	1,066	-453
A-3,4,4a,4b,5,6	412.35	50,000	121	54	95,600	232	59	134,000	325	63	187,000	453	70	227,000	551	70	269,000	652	75	661,000	1,603	121
A-4,4a,4b,5,6	362.36	37,100	102	39	76,400	211	43	110,000	304	48	156,000	431	54	192,000	530	58	228,000	629	62	568,000	1,567	110
A-4_Nat & A-4a	160.9	3,810	24	-12	14,900	93	-19	26,000	162	-24	41,800	260	-28	55,200	343	-32	68,600	426	-35	183,000	1,137	-77
A-4a	152.7	2,540	17		12,500	82		22,600	148		37,200	244		49,700	325		62,200	407		166,000	1,087	
A-5 & A-6	144.8	13,000	90	17	30,900	213	19	45,700	316	24	65,400	452	27	81,000	559	30	96,600	667	33	236,000	1,630	54
A-5	114.2	9,670	85	20	23,000	201	24	33,900	297	27	48,300	423	30	59,600	522	31	70,800	620	32	178,000	1,559	72
A-6_RES	*28.3*	3,240	114	1	7,260	256	1	10,400	367	1	14,600	515	-1	17,800	628	1	21,000	741	1	53,100	1,874	2
all of Tributary B	**87.3**	**13,900**	**159**	**153**	**20,800**	**238**	**209**	**27,800**	**318**	**251**	**37,300**	**427**	**294**	**44,900**	**514**	**320**	**52,400**	**600**	**344**	**107,000**	**1,226**	**672**
all of Tributary C	**79.9**	**15,800**	**198**	**189**	**25,300**	**317**	**260**	**33,200**	**415**	**302**	**43,900**	**549**	**352**	**52,000**	**651**	**378**	**60,100**	**752**	**405**	**134,000**	**1,676**	**751**
all of Tributary D	**10.6**	**3,940**	**373**		**5,690**	**538**	**258**	**7,030**	**665**	**272**	**8,840**	**836**	**298**	**10,100**	**956**	**306**	**11,400**	**1,079**	**313**	**26,500**	**2,507**	**594**
all of Tributary E	**13.5**	**4,870**	**360**	**225**	**7,100**	**525**	**245**	**8,820**	**652**	**260**	**11,100**	**820**	**280**	**12,800**	**946**	**295**	**14,500**	**1,072**	**303**	**33,800**	**2,498**	**584**
	Min:		17			81			147			241			324			404			1,066	
	Avg:		**139**			**250**			**344**			**473**			**573**			**673**			**1,627**	
	Max:		373			538			665			836			956			1,079			2,507	
	Available Rainfall:		**558**			**734**			**871**			**1,054**			**1,178**			**1,309**			**2,860**	
	Avg. Runoff Coefficient:		**25%**			**34%**			**40%**			**45%**			**49%**			**51%**			**57%**	

Notes:
1. Δ_{Ex} indicates the difference in unit-area runoff volume compared to Existing land use conditions. No value is shown if the total volume is within 100 m^3.
Filename:
2. Includes diversion of catchment D-3 to Tributary A

Existing land use: SWGeorgetown_PreDevpt_XXyr_75.inp/rpt
Future land use: SWGeorgetown_PostDevpt_XXyr_90.inp/rpt

Unit-area total runoff volumes for post-development conditions are given in **Table 6.3.19**, Table 6.3.20 which follows the format of **Table 5.4.4**. The overall impacts of proposed development and stormwater servicing compared to the pre-development runoff volume (average for all watercourses) include:

- 2-year return period/24-hour duration: 21% runoff volume increase
- 5-year /24-hour: 20% runoff volume increase
- 10-year /24-hour: 18% runoff volume increase
- 25-year /24-hour: 17% runoff volume increase
- 50-year/24-hour: 16% runoff volume increase
- 100-year /24-hour: 15% runoff volume increase
- Regional storm: 14% runoff volume increase

It should be noted that, although the modelling of individual design events show or increase in flow volume, this is only for individual events. The infiltration targets have been set based upon overall hydrogeologic water balance modelling, done on a continuous annual basis.

Erosion Threshold Analysis

To determined the required level of erosion protection (extended detention), the proposed development model was applied to the long-term rainfall dataset. The SWM facility extended detention volume was iterated until the cumulative erosion indices matched the predevelopment levels for the most sensitive and limiting reaches. Erosion indices were calculated using the method outlined in **Section 4.6.9**. **Table 6.3.20** summaries the cumulative erosion indices for existing conditions, uncontrolled future conditions (no SWM controls), and proposed conditions with the optimized erosion control volume. The recommended erosion control volume is provided.

Table 6.3.20 Erosion Index Comparison - Existing vs. Proposed Land Use Conditions

Scenario	Tributary A Reach AM3 J477.76	Tributary B Reach BD1 J2	Tributary C Reach C2 J1100
Existing Condition Erosion Index	47	4	32
Uncontrolled Future Development Erosion Index (No SWM Controls)	212	132	832
Proposed Development Erosion Index (SWM Controls)	50	9	1365
Proposed Development Erosion Control Volume (m^3/ha)	**300**	**40**	**300**

For Tributary A, pre-development erosion indices are matched when 300 m^3/ha of extended detention is provided to all development areas, including uncontrolled catchments not diverted to regional facilities as per the current concept plan. Erosion control targets in uncontrolled areas may include the erosion target through volume detention LID measures (30 mm detention equivalent). It is noted that the provided erosion control target is sufficient to mitigate erosion impacts of the diversion of Catchment D-1 to Tributary A..

For Tributary B, pre-development erosion indices cannot be matched under proposed developed conditions. Providing erosion control storage volumes larger than the MOECC minimum 40 m^3/ha provides no reduction to the cumulative erosion index. It is noted that the erosion index is extremely small for existing and proposed development conditions along Tributary B; this represents a very short total duration of erosive flows and is not considered significant. The low existing condition erosion index is related to the extremely small amount of runoff generated in

Tributaries B and C for events smaller than a 2-year storm. Peak flow control for higher frequency, smaller volume rainfall events (i.e. 2-year and 5-year storms) will provide the required erosion storage volume and release rate such that downstream impacts do not occur.

For Tributary C, the erosion indices cannot be matched to existing conditions. Geomorphologically significant discharge rates are typically in the range of 10-30% of the existing condition 2-year return period discharge, which is the case for Tributary A and B. However, the critical discharge for Tributary C is an order of magnitude smaller (i.e., the critical discharge is 0.01 m^3/s, which is only 1% of the Q_2 value of 0.71 m^3/s). As illustrated in **Figure 6.3.11,** this watercourse is narrowly classified as a defined channel. A bankfull discharge rate of 0.025 m^3/s was calculated from the survey data and featured cohesive substrate material, resulting in an extremely low critical discharge threshold. The large difference between bankfull discharge and modelled Q_2 value is typical of small, poorly defined channels. Providing erosion control for this catchment increases the post-development erosion indice from 832 to1365. Tributary C will require channel adjustment to reduce potential stream instability and serve as an adequate stormwater servicing outlet, and will be addressed at the servicing study and EIR/FSS stage. The recommended erosion control target has been assumed as per Tributary A, with 300 m^3/ha as both Tributary A and C drain to the Sixteen Mile Creek.

No erosion analysis was conducted was for Tributary D reaches A9-1, A10-1 and A11-1) or Tributary E, due to the fact that the existing reaches have limited channel dimension and therefore do not fit the protocols for the erosion threshold analysis. Similarly to Tributary C, the recommended erosion control target has been assumed as per Tributary A, with 300 m^3/ha.

Further analysis carried out at either the Master Planning or EIR stage should confirm that quantity and erosion controls are in place and functioning as required to ensure no adverse downstream impacts. Demonstrate achievement of quantity and erosion controls through the refinement of the post development watershed model on the basis of the conceptual stormwater management strategy advanced in the EIR/FSS. The model is to be updated based on constructible rating curves consistent with the proposed design advanced by the EIR/FSS.

Figure 6.3.11 Tributary C Watercourse Cross-Section (Reach C-2)

6.3.5.3 Water Quality

Analysis carried out on existing conditions resulted in the identification of concerns regarding potential surface water quality impacts and the need for mitigation through the management strategy. These included:

- Current nutrient levels in the streams, the potential increases in nutrients and associated impacts on algae growth;
- The potential increase in suspended solids and associated pollutants;
- The need to manage stream temperature for fisheries protection.

Water quality parameters deemed relevant in **Table 4.10.2**, as well as cadmium (which is added to the proposed baseline monitoring program) were selected for management targets and further monitoring. Numerical target values for these parameters are recommended based on the MOECC guidelines.

The MOECC provides a listing of Provincial Water Quality Objectives (PWQO) that apply to surface waters including Southwest Georgetown Subwatershed. “The PWQO are numerical and narrative criteria which serve as chemical and physical indicators representing a satisfactory level for surface waters (*i.e.,* lakes and rivers) and, where it discharges to the surface, the ground water of the province. The PWQO are set at a level of water quality which is protective of all forms of aquatic life and all aspects of the aquatic life cycles during indefinite exposure to the water” (MOECC, 1994). In assessing water quality conditions, a comparison can be made between the water quality and the PWQO. One of the following two cases would apply:

- Policy 1: In areas which have water quality better than the PWQO, water quality shall be maintained at or above the objective.
- Policy 2: In areas where water quality presently does not meet the PWQO, water quality shall not be further degraded and all practical measures shall be undertaken to upgrade the water quality to the objectives.

Policy 1 applies to pH and chloride in wet weather in this study. For the parameters exceeding the PWQOs under current baseline conditions (the remaining parameters), the water quality targets are suggested to be defined at the average of baseline concentrations plus 1.5 standard deviations (adapted from CCME 2003). The recommended values based on current results are shown in **Table 6.3.21**. These may be modified once the proposed baseline monitoring is complete.

Table 6.3.21 Water Quality Targets

Parameter	Units	Standard	Baseline*	Proposed Target*
pH	-	6.5 - 8.5	Within standards	6.5-8.5
Temperature	°C	Thermal Classification		
Chloride	mg/L	120	400 (dry) ; 120 (wet)	400 (dry) and 120 (wet)
Dissolved Oxygen	mg/L	Temperature-dependent: 8 at 0-5°C; 7 at 5-10°C; 6 at 10-20°C; 5 at 20+°C	~2 (dry) ; 5 (wet)	6
Nitrate-N	mg/L	Long-term Exposure: 3.0 mg/L Short-term Exposure: 124 mg/L	20 (dry and wet)	20
Total Phosphorus	mg/L	0.03	0.3 (dry); 0.45 (wet)**	0.3
Total Suspended Solids	mg/L	24-hour period: max increase of 25 mg/L from background 24-hour; 30 day period: max average increase of 5 mg/L from background	170 (dry); 110 (wet)	170 (dry); 110 (wet)
Cadmium	mg/L	Hardness dependent: 0.0001 at hardness ≤ 100 mg/L 0.0005 at hardness >100 mg/L	-	-
Copper	mg/L	Hardness dependent: 0.001 at hardness ≤ 20 mg/L 0.005 at hardness >20 mg/L	0.005 (dry); 0.02 (wet)	0.005 (dry); 0.02 (wet)
Zinc	mg/L	0.02	0.16 (dry); 0.05 (wet)	0.16 (dry); 0.05 (wet)

Notes:
** Baseline was defined as the average plus 1.5 standard deviations of 2013 data for all locations sampled. The values will be updated following the completion of baseline monitoring program.*
*** excluding one apparent anomaly*
- not measured but addressed in the proposed baseline monitoring program.

Surface Drainage

Water quality protection is needed to protect downstream receiving systems, including Lake Ontario. The primary focus is fisheries protection and nutrient control to mitigate impacts on algae growth. Consideration is needed to provide full SWM measures including at source conveyance and end-of-pipe works for the most effective approach in water quality control.

The watercourses in the study area will act as receivers for discharge from SWM facilities. These facilities typically treat for a certain efficiency of suspended solids removal which in turns controls Phosphorus as this nutrient is typically bound to suspended particles. Two options for the level to which suspended solids are controlled were considered:

- For all watercourses, MOECC “enhanced” level of protection could be employed (80 % removal of suspended solids); and
- Protection levels for individual facilities could be set based on the sensitivity of the aquatic community in the receiving watercourse to suspended sediment.

The water quality control approach for SWM is recommended to focus on phosphorus, suspended solids, chloride, and temperature. These are intended to provide controls to meet the objective of not permitting further enrichment of the streams (*i.e.*, nutrient control), fisheries protection and overall water quality protection.

Future Scenario with SWM

The loading model developed in **Section 5.5.6** was modified to reflect proposed SWM, included for the new urban developments to enhanced level of control for enhanced fishery protection (80% TSS removal and 65% TP removal). The results are summarized in **Table 6.3.22** (Note: that with controls, the TSS levels and the TP levels are reduced below pre-development conditions at most subcatchments, resulting in a total reduction of 33% for TSS and an increase of 16% for TP). Infiltration was not accounted for in this model; however it is expected that infiltration will occur in pervious areas of each sub catchment leading to a lower TSS and TP loading in post development conditions than what is estimated through this calculation. Application of the proposed LIDs will also help reduce phosphorus load. In order to incorporate such load reduction mechanisms and gain a better estimate of the magnitude of any change, it is recommended that a more detailed assessment be conducted at the EIR/FSS stage.

Table 6.3.22 Future Scenario - Development with controlled Stormwater

Management Area	A-1	A-2	A-3a	A-3b	A-4	A-4a	A-4b	A-5	A-6	B-1	B-2	C-1	D-1	D-2	D-3	E-1
Total Runoff Volume 1000 m^3	83	433	156	149	158	406	156	365	121	245	271	473	32	32	111	81
Runoff percent of Precip	72	52	65	70	69	30	56	36	38	66	69	68	66	73	67	68
% Increase over Base	139	73	117	137	107	0	79	10	25	109	119	116	116	139	115	117
Runoff as mm over each area	632	457	568	616	607	266	494	319	336	580	603	592	580	641	587	600
TSS Load - tonnes/yr	1.5	15.9	3.4	2.6	2.8	39.7	3.6	28.2	8.4	4.6	5.0	9.2	0.5	0.6	2.2	1.5
% Increase over Base	-132	-57	-113	-139	-154	0	-135	-11	-14	-149	-140	-131	-184	-127	-127	-146
TP Load - tonnes/yr	0.01	0.06	0.02	0.02	0.02	0.08	0.02	0.07	0.02	0.03	0.03	0.06	0.00	0.00	0.01	0.01
% Increase over Base	32	17	28	31	16	0	11	0	7	21	24	24	18	32	23	20

The modelling illustrates that the proposed SWM approach will provide the required control levels for water quality.

6.3.5.4 Stormwater Management Applications

Most features are to be protected and remain in their natural state with vegetation preserved or enhanced. As such the features contribute to water quality improvement in several ways:

- Maintain water balance, including maintaining infiltration to groundwater and natural runoff at low rates;
- Vegetation prevents erosion of soil; and
- Vegetation intercepts nutrients and pollutants in natural flow.

The land development process changes the land use and the physical characteristics of the surface, most notably increasing the degree of imperviousness increasing runoff and decreasing infiltration. The impervious surfaces collect pollutants from traffic, urban activities on the land and aerial fallout. The drainage system delivers these pollutants to the local watercourses. In developing the land, opportunities are available to meet water quality and other objectives at the source (the land use activity), the drainage conveyance system, and at the end-of-pipe prior to discharge. A treatment train approach, which utilizes more than one measure in series to achieve objectives, is preferable to expecting the end-of-pipe facility to perform all functions to meet targets.

Master Drainage Plans and SWM Plans that are prepared as part of the development process will include consideration of management measures to meet different objectives. Many of the measures usually built for one purpose or objective can contribute to meeting more than one target of other objectives. In choosing measures it is preferable to consider source control methods first and methods such as infiltration that satisfy multiple objectives. In sizing end-of-pipe elements, consideration should be given to reductions in flow volume or pollutant loadings that occur upstream in the drainage system. This “treatment train” approach will result in cost savings for the structural end-of-pipe measures such as SWM ponds.

In the case of SWM ponds, ponds are not to be on-line facilities or located within the NHS boundaries, as per Conservation Authority policies. The number of ponds should be minimized to reduce maintenance costs, however, ponds should be located in such a manner as to maintain flow distribution throughout the open watercourse reaches to maintain fluvial geomorphologic functions as well as aquatic habitat conditions.

A final proposed location, sizing and preliminary concepts for the SWM ponds are not provided as part of this management strategy but will be developed as part of the SWM and stormwater servicing strategy being prepared with the Secondary Plan.

Each type of measure is discussed below, with emphasis on phosphorus control.

Low-impact Development (LID)

The *National Guide to Sustainable Municipal Infrastructure* (2003) describes LID as a site design strategy that aims to maintain or replicate the predevelopment hydrologic regime by creating a functionally equivalent hydrologic landscape. **Figure 2.1.1** illustrates the components of the hydrologic cycle of a watershed ecosystem, and the interrelationships between the various components. In a relatively natural watershed, the flow of water is controlled by topography, soil type and vegetation. Urbanization typically involves the clearing of vegetation and large-scale earth grading that alters the topography and soil characteristics. The topography is often sculptured to create a smooth surface. For example, lawns that efficiently drain water to a drainage system and convey the runoff to a SWM facility where it is stored and treated before being released from the site.

The LID approach looks at using a variety of micro-scale controls that help to restore or replicate some of these natural hydrologic pathways. Typical LID measures include:

- Conservation of Natural Features;
- Reducing impervious areas;
- Bioretention areas;
- Rain gardens;
- Topsoil Management;
- Green roofs;
- Rain barrels;
- Cisterns;
- Vegetated filter strips; and
- Porous pavements or permeable pavements.

LID attempts to replicate components of the hydrologic cycle to restore rainfall back to the hydrologic pathways. Retaining native vegetation or planting vegetation maintains interception and evapotranspiration. Rain gardens and bioretention areas may act as depressional storage areas and can aid in promoting infiltration. Rainbarrels, cisterns and green roofs may act as the interception component. When applying these micro-scale controls across a drainage area, the cumulative impacts could potentially reduce the required SWM pond size, achieve predevelopment water balance targets, and mitigate stream erosion and thermal impacts to receiving watercourses.

Many of these practices are identified as stormwater BMP's in the MOECC's *Stormwater Management Planning and Design Manual (2003)*. This should also follow CVC's *Stormwater Management Criteria (CVC, 2012)* and TRCA document *Preserving and Restoring Healthy Soils: Best Practices for Urban Construction (TRCA, 2012)*. Micro-scale controls can be integrated into the infrastructure and located throughout a site making LID an effective means of reducing runoff volume and for treating stormwater runoff by filtering out the pollutants.

The main difference between the LID approach and past approaches is that the current approach focuses on conveying, storing and treating stormwater runoff at the base of the drainage area with emphasis on end of pipe facilities. LID practices on the other hand can be integrated into infrastructure throughout the site, and are more cost effective and aesthetically pleasing than traditional stormwater conveyance systems (EPA, 2000).

Accordingly, maximizing opportunities for stormwater management at the site level using the LID approach is recommended for all future land uses.

Source Pollution Prevention

Source pollution prevention measures such as reduced fertilizer and pesticide use, or road salt reduction programs are addressed at specific pollutants and often do not meet other objectives. It should be noted that some pollutants, such as road salt, are not removed well by other measures, and that pollution prevention may be the only effective means of reducing the effect of the pollutant.

Additional ways to remove phosphorus include source control or pollution prevention. This involves reducing the amount of chemicals used and thus reducing the amount available for discharge to the environment. Since this type of measure can involve changing behaviour of individual residents or commercial workers, education and community action programs can play a large part of any pollution prevention program. Many measures for controlling pollutants at source are outlined in a Stormwater Pollution Prevention Handbook, (MOECC, 2001). Some measures are outlined below.

- Reduced Fertilizer And Pesticide Use – Education is required for residents to apply only needed amounts to lawns. Many municipalities are reducing the area of cultivated grassed areas and allowing more natural areas to prevail in parks and other public spaces.

- Alternate Lawn Practices – Naturescaping promotes natural lawn care techniques and encourages lawn replacement with alternatives, including drought-tolerant plants. Xeriscape landscaping is an alternative landscape method that emphasizes water conservation. Replacement of lawns with meadow grasses or rock gardens with low maintenance requirements will reduce water usage and reduce the need for fertilizers and pesticides and herbicides.
- Pet Litter Control – Pet feces (often called pet litter) are deposited primarily by dogs and left uncollected by owners. This material ends up in storm drainage and causes problems of oxygen depletion, aesthetic nuisance, bacterial contamination and nutrient enrichment from phosphorus and nitrogen. Control programs involve changing individual behaviour by preventing the littering action. Public education to prevent the littering activities by individuals and their pets has the most promise. Several municipalities have dog litter control "Stoop and Scoop" bylaws.
- Municipal Operations – Some reduction in the discharge of pollutants to stormwater from street surfaces can be accomplished by conducting street cleaning on a regular basis. The primary and historical role of street cleaning is for sediment and litter control. Catch basin and stormwater inlet maintenance should be done on a regular basis to remove pollutants, reduce high pollutant concentrations during the first flush of storms, prevent clogging of the downstream conveyance system and restore the catch basin's sediment-trapping capacity.
- Salt Management Plan – Environment Canada has released a Code of Practice for the Environmental Management of Road Salts (Canada Gazette, April 3, 2004). Accordingly the Town of Halton Hills Salt Management Plan should be updated in respect to the following: "The environmental impact indicators listed in Annex A, the guidance for identifying vulnerable areas provided in Annex B and the data gathering and reporting provisions in Annex C of this Code should be considered during the development and implementation of the salt management plan." (Section 10). In particular, streams identified as vulnerable areas should receive consideration and possibly increased application of best management practices to reduce the salt impact on those areas.
- Sewer Use By-law – The Sewer Use By-law is a useful tool for the Town to control discharges to storm sewers, especially from industrial, commercial and institutional sites. By-laws in most Ontario municipalities have allowable limits on water quality parameters that may be discharged to storm sewers. They also prohibit cross connections of sanitary sewage to storm sewers. Town of Halton Hills By-law needs to be reviewed to see if it has the necessary measures and powers to provide for control of dischargers after the development process is completed.

Source and Lot-Level Quantity Controls

Source quantity controls, such as rain barrels, backyard ponds, rain gardens, rooftop storage, downspout disconnection, pervious pavements, reduced lot grading, rooftop gardens, retaining existing vegetation canopy and planting vegetation reduce the quantity of runoff. Some of the water may percolate into the ground and contribute to infiltration and baseflow targets, however much of this water evapotranspires into the atmosphere. The reduction in the volume of water aids in meeting erosion and flood protection objectives. The pollutant load in the water leaves the runoff system and remains on the surface or is filtered in the soil matrix, helping to meet water quality objectives.

- Rain Barrel Program - This provides for the reduction in runoff volume as well as reducing wash off from lawns for water quality control.
- Rain gardens (absorptive landscaping) - Designed to capture storm runoff from roof areas and infiltrate a portion directly into the ground. These depressions are planted with a variety of native wetland and terrestrial plant species and the soils can be conditioned to enhance infiltration and water storage. Enriching the soils with organic substrate store and hold water that can be used for evapotranspiration by plants.
- Vegetation - Retain existing vegetation wherever possible and plant tree and shrub species that will mature to create canopy cover.

Conveyance System Controls

- Infiltration trenches or basins - designed to percolate surface runoff into the ground below the root zone. The water enters the groundwater flow system and contributes to meeting baseflow targets. The reduction in the volume of water aids in meeting erosion and flood protection objectives. The pollutant load in the water leaves the runoff system and is filtered in the soil matrix, helping to meet water quality objectives. The trenches or basins can be located at the source, or in the conveyance system (or at the end of the drainage system discussed below).
- Exfiltration/Filtration System - Involves the use of pervious pipes in sewer installation to promote infiltration. This has been applied as part of a road reconstruction project. The road and sewer replacement costs would be borne in any event, so the exfiltration system need only consider additional costs of the exfiltration trench and permeable pipe. The system is suitable where soils are permeable (gravel, sand, and sandy loam). Benefits and limitations are similar to infiltration ponds. No additional space is required for the method since it is built in the road right-of-way (ROW). In industrial and commercial areas and arterial roads, the exfiltration elements should be preceded by an oil/grit separator to provide pre-treatment and additional protection for groundwater. The system can be modified for use where soils are not very permeable to provide retention and filtration as well as some infiltration.
- Natural surface Drainage - allows runoff to flow over vegetated swales and open ditches. Some of the water may percolate into the ground and contribute to infiltration and baseflow targets, however much of this water evapotranspires into the atmosphere. The reduction in the volume of water aids in meeting erosion and flood protection objectives. The pollutant load in the water that percolates leaves the runoff system and the water also is filtered by the vegetation and remains on the surface or and in the soil matrix, helping to meet water quality objectives.
- Open Ditch Enhancement - Existing ditch systems with driveway culverts provide reasonable environmental benefits. Systems that avoid curb and gutter, and also avoid deep ditches and culverts can be installed. These also improve infiltration and filtering action and enhance TSS removal by 80% or more. In areas with existing ditches, a conversion to standard curb and gutter draining with conventional storm sewers would increase the solids load by 80% if no other control measures were added.
- Bioinfiltration and Bioretention Systems – Typically have multiple components that perform different functions in storing stormwater runoff and pollutant removal. The typical components of the system include vegetation, granular drainage layers, vegetated buffer strips, topsoil, ponding or storage areas and organic layers. The diversity of different substrate types provide habitat for a diversity of microrganisms capable of removing different containments and nutrients in the stormwater runoff. These systems also have features that help to filter and promote sedimentation of larger discrete particles in the stormwater runoff.

Suitability Criteria is where space is available, soils are permeable and groundwater is not vulnerable to stormwater contaminants.

End-of-Pipe Facilities

- Wet Ponds - Typically at the end of the drainage system as part of the SWM pond. The wet pond portion serves a water quality improvement function primarily by sedimentation, to remove total suspended solids and associated pollutants such as total phosphorus and metals. The overall shape of the SWM pond should be designed to reduce short circuiting of flows, allow effective settling of suspended particles, provide effective riparian coverage.
- Infiltration Ponds - Infiltration systems remove pollutants from the runoff system, increase base flow and help control temperature. Soil permeability must be suitable to allow rapid draining of water into the soil. Concern about contamination of drinking water aquifers will limit the application to residential areas and roof drains from other types of land uses. They have a space requirement similar to SWM ponds with higher

benefits. They are suitable where space is available, soils are permeable and groundwater is not vulnerable to stormwater contaminants.

- Outlet Filter - Addition of an under-drained filter following a pond will increase performance. High flows will be bypassed. Since the pond attenuates flow, smaller outlet filters are economical. There must be additional head to allow for the water to pool 1m above the filter and for the under-drain to function under gravity flow. There is an additional area requirement of approximately 50% increase in the conventional pond size. If space is limited, underground filters as described below may be used. For phosphorus control specifically, special media can be used to increase performance at a higher capital and operating cost.
- Extended Detention - Usually included in a SWM pond and is that portion of runoff that is allowed to fill the pond during a rain event and drain out slowly over 48 or 72 hours. This slow release of water contributes to meeting baseflow, erosion and flood protection targets. Sedimentation of this water also occurs contributing to water quality targets.
- Thermal mitigation will be required to ensure that the receiving water body is capable of supporting a healthy fish community. There are a number of new and emerging technologies for thermal mitigation of stormwater facilities including the use of bottom draw outlets, cooling towers, cooling trench outlets, planting techniques and artificial shade systems, as well as selection of pond orientation and shape. Detailed discussions are provided in CVC (2011): Thermal Impacts of Urbanization Including Preventative and Mitigation Techniques.

Treatment Train Evaluation of Performance

A procedure for calculating the efficiency of several measures applied in series or treatment train is provided in *A Stormwater Retrofit Plan for the Centennial Creek Subwatershed* by James Li, Don Weatherbe, Derek Mack-Mumford, and Michael D'Andrea, (1998 W. James ed.).

> "A multi-efficiency model is used to estimate the cumulative volume (N_v) and solids loading (N_s) reduction efficiencies of a series of RSWMPs

$$N_v = \left[1 - \prod_{i}^{n} (1-\eta_v) \right] * 100\%$$

$$N_s = \left[1 - \prod_{i}^{n} (1-\eta_v)(1-\eta_s) \right] * 100\%$$

where i is the i^{th} RSWMP, n is the total number of RSWMPs, η_v is the runoff volume reduction efficiency of a RSWMP, and η_s is the solids concentration reduction efficiency of a RSWMP. For a RSWMP which reduces solids concentration only (*e.g.*, oil/grit separators, ponds), η_v is zero (the large *pi* is the symbol for product summation). For a RSWMP which reduces runoff volume only (*e.g.*, downspout disconnection, stormwater exfiltration systems), η_s is zero.

6.3.6 Conclusions

The proposed management strategy provides an approach that will meet the subwatershed goals and objectives set. This will be accomplished through the management elements proposed including SWM targets set. The specific SWM component targets for water quantity, water quality, erosion, and infiltration are summarized below.

Water Quantity:	2-year to Regional peak flow control required, with no overtopping of emergency spillway (see **Table 6.3.16** for allowable unit flow rates)
Water Quality:	Enhanced (Level 1) protection corresponding to 80% of suspended solids removal is required for all lands subject to future land use change

Erosion Control: 300 m3/ha minimum storage for Tributary A, C, D (Sixteen Mile Creek)
40 m^3/ha minimum storage for Tributary B (Silver Creek)

Infiltration: 10 mm LID unit area retention volume for neighbourhood commercial, institutional, mixed use-mainstreet, mixed use and open space (parks) landuses.
3 - 5 mm LID unit area retention volume along ROWs, depending on soil types and local conditions.

Temperature Control: Coolwater targets for Tributaries A and B, warm water for Tributary C.

The overall management strategy for the Natural Heritage System, which includes both terrestrial features and the riparian corridors, is depicted on **Figure 4.12.1** and **Figure 5.9.1**. The terrestrial component of Natural Heritage System is composed of the Core Areas, Key Features, Enhancement Areas, Local Linkages and Buffers. All red and blue streams, regulated floodplain limits and associated buffers are part of the NHS. Outside the NHS natural habitats are limited and less likely to be sustained.

6.4 Monitoring Strategy

6.4.1 Principles of Monitoring Program

Traditional master drainage planning has evolved since the 1970's into the comprehensive subwatershed planning now practised. The concerns addressed have increased the complexity and scope of the studies from quantity control for flood and erosion protection, with the addition of many issues such as water quality, aquatic biota and habitat, and geomorphology. Monitoring has been included in the more recent studies as an integral part of implementation. The Subwatershed Planning Report (MOECC, MNR, 1993) stated the following:

> *"A subwatershed plan cannot be considered complete until its monitoring program is established. Monitoring programs should be designed to assess environmental changes in the subwatershed, to evaluate compliance with the plans, goals and objectives, and to provide information which will assist custodians of the plan to implement it and update it. The monitoring program should be presented as part of the subwatershed implementation plan."*

Monitoring is now considered as a necessary continuation of the subwatershed plan, designed to evaluate the need to review or update subwatershed plans, or to trigger the implementation of contingency plans that may include remedial measures needed to achieve the subwatershed goals and objectives.
The following principles are proposed as the basis of the monitoring framework.

1. Monitoring must be directed at fulfilling one or more objective sets, be subject to analysis and lead to potential actions.
2. Monitoring of receiving streams should be for identifying problems, establishing a background reference, and evaluating the effectiveness of controls.
3. Technology performance monitoring should be to confirm that the facility operates as designed, if not, determine if remedial design improvements are needed, or if it needs maintenance. This will assist in improving future designs.
4. An ideal monitoring program should be directed at connecting receiving stream impact analysis with technology performance assessment in a watershed context.
5. The strategy should recognize and incorporate existing monitoring programs, for example protocols already in use by Conservation Halton for monitoring ecological parameters.
6. Reporting on results and taking appropriate follow-up action is a key component that fulfils due diligence expectations.

Although a monitoring approach is provided as part of this Subwatershed Strategy, further details should be expanded upon as part of the servicing strategies to be developed with the Secondary Plan and at the EIR/FSS stage.

6.4.2 Erosion and Sediment Control (ESC) Planning

Future construction activities taking place in Southwest Georgetown will require clearing of vegetation, topsoil stripping and earth grading that leaves exposed soils vulnerable to wind and water erosion. Stringent sediment and erosion control measures will need to be implemented to ensure that the adjacent natural heritage system is not negatively impacted by construction practices. Sediment release due to construction activities is not only detrimental to the health of the receiving NHS but will also result in costly future maintenance work of the existing downstream drainage infrastructure.

Prior to construction, comprehensive erosion and sediment control (ESC) plans must be submitted to the Town and respective Conservation Authority detailing the methods that will be used to prevent the release of sediment laden runoff from the construction site. There are extensive sediment and erosion control guidelines available that describe the design considerations, application and function, implementation procedures, maintenance procedures and removal procedures for a wide variety of sediment and erosion control measures for construction sites. The following is a list of existing guidelines currently used in Ontario:

- *MNR Technical Guideline: Erosion and Sediment Control;*
- *MTO Drainage Management Manual (1995 – 1997); and*
- *Erosion and Sediment Control Guidelines for Urban Construction (2011).*

The *Erosion and Sediment Control Guidelines for Urban Construction* has been prepared by Greater Golden Horseshoe Conservation Authorities. In order to develop the most effective ESC plans for the Town of Halton Hills, these guidelines must be consulted before submission of an ESC plan. The comprehensive checklists provided in these guidelines are specifically designed to assist developers, contractors and inspectors with developing and implementing effective ESC plans.

Typical sediment and erosion control best management practices currently in use today include but are not limited to:

- Sediment traps, dewatering traps;
- Sediment control fencing;
- Check dams;
- Inceptor swales and ditches;
- Compost filled filter sock;
- Temporary stabilization measures of exposed soils (*e.g.,* erosion control matting, seeding, hydro seeding, and mulches);
- Construction mud matts; and
- Protecting surface inlets with filter cloth.

In order for these measures to be truly effective, they will need to be monitored regularly by the contractor to ensure that these measures are maintained in proper working order throughout the construction phase and until the site has become fully stabilized.

6.4.2.1 ESC Inspection

Approved sediment and erosion control plans are to be monitored at the start of construction and throughout the construction phase until the site has become fully stabilized. The contractor will be required to perform routine (minimum once a week) sediment and erosion control inspections to ensure that the sediment and erosion control measures are maintained and functioning as intended. Sediment and erosion control measures shall be inspected:

- Prior to forecasted rainfall events to ensure that the measures are in proper working condition;
- During rainfall events to observe in-situ performance; and
- After rainfall events to identify measures that may require immediate repair or maintenance.

The following provides examples of thresholds for when maintenance work is required:

- Once sediment accumulation in sediment traps, sedimentation basins, dewatering traps, catchbasins among others occupies 60% of the available volume a cleanout will be required;
- If sediment accumulation depths behind silt control fencing, granular berms, etc. exceeds 300mm the sediment must be removed; and
- Filter fabric protection of surface inlets and discharge points to be checked and replaced regularly (i.e., after heavy rainfall events).

The inspection reports will verify that the sediment and erosion control measures are in place and properly maintained. In the event that the proposed ESC plans are not operating as intended corrective measures shall be taken immediately.

Appendix S provides a generic sample checklist style report that the contractor can fill out and submit to the Town of Halton Hills and respective Conservation Authority as part of the inspection program. The checklist should be developed based on templates provided in the Erosion and Sediment Control Guidelines for Urban Construction Guidelines and modified accordingly for Southwest Georgetown.

6.4.2.2 ESC Monitoring

In addition to weekly inspections the contractor shall also be responsible for submitting regular water quality monitoring reports. As explained above, the inspections will verify and ensure that sediment and erosion control measures are in place and maintained. The water quality testing will ensure that the sediment and erosion control measures are performing and preventing the release of sediment laden water into the receiving watercourses and NHS.

The water quality parameter to be measured is Total Suspended Solids (TSS) and samples shall be required during and after rainfall events applying the following criteria:

- Stormfall events greater than 10mm (verify rainfall volume with on-site rain gauges); and
- Take discrete water quality samples of stormwater runoff leaving the site at all outlets regardless of where they outlet during and after rainfall events.

The measured TSS concentrations will provide Town staff with an indication of how the concentrations compare to typical TSS concentrations for construction sites with similar soil types. Threshold concentrations will be established to trigger when town staff need to perform independent inspections. Through site inspections it can be determined whether the sediment and erosion control measures are in need of maintenance, are improperly installed or whether additional measures need to be added to the existing treatment train to lower TSS concentrations to acceptable levels.

6.4.3 Monitoring Parameters

A major component of a subwatershed plan is SWM. It usually results in the construction and operation of built works such as stormwater ponds, conveyance features and infiltration facilities. These facilities are typically designed to meet some receiving water objectives such as: flood control, channel erosion control, water quality protection/improvement, habitat protection, and protection of biota, including fish. Thus, monitoring may involve both water quality and quantity monitoring that may be in stream or at other locations.

In-stream monitoring parameters can be both specific constituents or surrogates. The specific parameters are typically related directly to the objective or use being protected, whereas, for stormwater facilities, indirect parameters or surrogates are often used as indicators when monitoring system performance. In other words, different parameters will have to be identified and monitored to evaluate the system effectiveness in-stream and performance in the facility. The effectiveness is measured by comparing the monitoring results to the targets established for the parameters for each objective. **Table 6.4.1** illustrates this point. Monitoring in a watershed for the facility and watercourse elements will take advantage of the common elements for all objectives (*i.e.,* rain, flow, water quality, and toxicity data). Objective specific data will have to be collected for erosion control, and aquatic habitat and biota.

Table 6.4.1 Monitoring Parameters for SWM Objectives

Objectives	Flood Control	Channel Erosion Control	Water Quality Improvement	Habitat/Biota Protection
System Element				
SWM Facility	Rainfall, peak flow rate, water level, flood flow routing, draw down time	Rainfall, flow rate and duration, water level	Pollutant removal efficiency, sediment accumulation, temperature	Discharge water quality, toxicity
Watercourse	Peak flow rate, water level, property damage	Flow rate and duration, water level, bank erosion, channel modifications stable, velocity, bed substrate, bank recession, down cutting of channel, bank vegetation	Water quality improved? PWQO met? Subwatershed targets met?	Habitat parameters /indices (including physical parameters), toxicity, macro invertebrate indices/fish health indices, biomonitoring

For the Southwest Georgetown Subwatershed, two types of monitoring programs are proposed:

i) performance assessments of stormwater facilities, and
ii) watershed effectiveness assessment to ensure targets are met, following the successful establishment of functional and stable natural channels.

6.4.4 Performance Assessment Monitoring for Stormwater Facilities

Objectives

- Determine whether performance of control facility meets design objective
- Can facility be assumed by the Town from the developer?
- What level of continued monitoring and maintenance are needed?

Following construction, each facility should be inspected and compared to the design by municipal staff to ensure compliance and a monitoring policy should be implemented. Baseline Monitoring should be carried out for a period of two years prior to construction. A monitoring report should be provided to the Town, Region, and respective Conservation Authority twice per year for the two year period. Responsibility for and ownership of facilities would be assumed by the agencies after a period of five consecutive years of monitoring that confirms the targets and objectives have been met. Should the monitoring show non-compliance, the developer would be responsible for implementing contingency plan remedial measures and continue monitoring until the monitoring confirms compliance for three consecutive years.

Analysis

- Operations Monitoring
  - Compare infiltration, flood control and quality control pond hydraulics to design specifications for flow splitting, volume controlled, drawdown time and released flow rates. Compare total capture to expected volumetric control level. Compare quantity control hydrology to what was expected as the modelled performance. May need to apply models for some analysis steps. Calculate removal rate efficiency of parameters and compare to established targets.
- Maintenance Monitoring
  - Observe or measure sedimentation in channels, sediment build-up in ponds, berm erosion, litter build-up, clogging of inlet and outlet structures, free operation of moveable control elements, health of wetland plants, pond security and gratings, etc.

Action Plan/ Remedial Action

- Facility functioning as designed – Town assumes facility from developer;
- Modify pond hydraulics – continue monitoring until facility meets targets and can be assumed from developer;
- Maintain pond;
- Replant aquatic plants;
- Remove sediment buildup; retrofit additional controls in pond or upstream in drainage area – continue monitoring until facility meets targets and can be assumed from the developer;
- Modify design and/or targets for future similar cases.

6.4.5 Effectiveness Assessment Monitoring

Proposed Program

Following construction, each stream course should be inspected by municipal staff to determine whether targets are being met. The stream should be monitored by the developer for compliance for a minimum period as specified by the Town of Halton Hills. A monitoring report should be provided to the Town, Region, and respective Conservation Authority twice per year for period specified by the Town of Halton Hills. Responsibility for future monitoring will be discussed with the agencies after the monitoring confirms the targets and objectives have been met. Monitoring should be carried out for a period of five years after full build-out (all land development completed). Should the monitoring show non-compliance, the developer would be responsible for implementing the contingency plan/remedial measures and continued monitoring until the monitoring confirms compliance for three consecutive years.

Objectives

- Determine effectiveness of measures (upstream control facilities) in-stream.
- Flow rates not increased over pre-development (flood and erosion objective).
- Flow velocities (impulse) not increased (erosion control objective).
- Maintenance of base flows.
- Channel and bank erosion not increased.
- Water quality improved.
- Establishment of healthy riparian plantings.
- Aquatic habitat conditions acceptable.
- Biota diverse and healthy.
- Lack of toxicity.

Analysis

- Compare observed conditions to Subwatershed Study results. Reference can be to upstream control, pre-development conditions at the same site or to a parallel site. Also compare to published standards, (i.e., PWQO), or acute lethality criteria. Compare to subwatershed targets.

Contingency Plan/Remedial Action

- Remedial measures in stream.
- Additional controls upstream.
- Retrofit control within existing facilities.
- Modify control requirements for future sites.

6.4.6 Monitoring Program

6.4.6.1 Terrestrial

Ecological monitoring is described as "*a measurement or estimation of change in an indicator's status over time*" (Busch and Trexler 2003). The monitoring provides data on the feature of interest. Data on the ecosystem are measured against targeted, measurable objectives set out in the beginning of the monitoring program. If the data collected at a given point in time of the monitoring match the goals and objectives then the success of the project objective are on track. If these data do not match, then some form of mitigation, remedial action or adjustment is required (Ecological Engineering 2000).

The focus of the terrestrial monitoring program is to detect potential changes in the quality and quantity of wildlife habitat, species richness and diversity, wetland and woodland features and functions, local landscape connectivity and wildlife movement, and habitat enhancement and restoration. Monitoring methods and specific requirements are to be determined during the Implementation Phase. The overall objective is the preservation, maintenance and enhancement of the NHS.

Monitoring protocols that have been established by the conservation authorities should be incorporated into the monitoring program in consultation with the agencies. This will allow for comparisons of monitoring results within the watersheds. For example, Conservation Halton's Long-term Environmental Monitoring Program provides specific methods for vegetation and amphibians that would be applicable to the study area.

Vegetation Communities

Monitoring changes in vegetation community composition (i.e. number of species, native, non-native and invasive species) and boundaries (i.e. encroachment) will assist in detecting changes as a result of natural succession, plantings (see below), and potential impacts as a result of development.

The use of the standardized Ecological Land Classification (ELC) system allows for the review and monitoring of vegetation community composition and boundaries over time. This approach has been used in a number of similar studies in which the extent of vegetation communities has been monitored using field surveys and/or aerial photography.

Woodlands

Woodland monitoring should consist of a series of standard permanent monitoring plots following a standard protocol (for example, see City of Waterloo 1998). The monitoring should include evaluations of the various strata within the woodlands (canopy tree, regeneration, herbaceous vegetation). This monitoring should be conducted in concert with wildlife monitoring (see below).

Wetlands

The treed and shrub dominated swamps should be monitored as per the woodlands (see above). Marsh wetlands should also be monitored for vegetation composition as well as limits. This monitoring should also be conducted in concert with wildlife monitoring (see below). For isolated wetlands and woodland vernal pools that are sustained by surrounding surface water inflow, that catchment areas are to be determined at the EIR stage to ensure that the wetland hydrology is maintained post-development (e.g., feature-based water balance). Pre and post construction monitoring of the wetland hydrology is to be carried out.

Enhancement

In a number of locations recommendations are provided for the enhancement of features or functions, for example the enhancement of the riparian corridor of a watercourse or the enhancement (or creation) of breeding amphibian habitat. Some of the enhancement may occur by natural regeneration, active management (e.g., removal and control of invasive Black Locust trees), or increased functionality of a linkage.

Restoration

Restoration projects are seen as occurring on a continuum as the restoration of an ecosystem involves the development and re-establishment of complex interactions that are continually succeeding. Early stage and regular evaluations of the advancement of a restoration project can greatly improve the success of the overall project.

Monitoring is therefore recognized as a key component to increasing the success of restoration projects at the local and broader landscape scale. Such documentation and analysis of past and ongoing project experience is an important contribution to the science of restoration ecology (Lefler 2006).

Measuring or evaluating the success of restoration projects is still relatively uncommon and does not occur at all for many projects, or at least not in a manner which makes the results readily available. This is largely due to lack of funding, limited allocation of time from the project on set or lack of available personnel that are appropriately trained. As a result, there is limited availability of monitoring results for restoration projects that can be used to learn from and build upon (Lefler 2006).

Restoration vs. Enhancement

Restoration ecology is the science of restoring a site or preferably, a landscape that has been disturbed to a natural state to varying degrees of ecosystem function. This may be undertaken through referencing a historic ecosystem or similar baseline system in order to restore the biotic and abiotic processes and replicate pre-disturbance conditions to the extent possible. An example of a restoration project is the replanting of trees and actively managing the establishment of plantings until a forest community becomes established and starts to function in a self-sustainable fashion.

Enhancement could be perceived as a component of restoration, or termed “passive restoration” whereby an active anthropogenic disturbance or effect that is affecting the natural processes of an ecosystem is removed or in some cases re-established.

An example of enhancement is removing cattle from a riparian area through the provision of fencing, thereby removing the grazing pressure, reducing high nitrogen and phosphorus levels from cow dung, removing erosion potential from cattle trails/access to watercourse, and allowing the riparian area to regenerate into a natural or semi-natural plant community. Another more unusual example is the ending the management of fire suppression to allow natural fires, which vegetation communities such as prairie and oak savannahs require, thereby re-establishing the natural disturbance regime.

Wildlife

Wildlife monitoring is recommended to consist of breeding bird surveys, as well as amphibian monitoring. These two groups of species are fairly readily monitored and are sensitive to changes in habitats and potential impacts of development. Standard monitoring protocols are in use throughout southern Ontario and can be used to track changes in species overtime.

- Birds **-** The Ontario Breeding Bird Atlas protocols should be used to monitor breeding birds at strategic locations in the study area.
- Amphibians - Redback Salamanders surveys in forest blocks; Early spring call surveys following the standard Marsh Monitoring protocol should be conducted at strategic wetland areas.

6.4.6.2 Streams

Fluvial Geomorphology

As land-use changes within the watershed, there are several monitoring program recommendations that can be made to evaluate changes and/or issues along the watercourses potentially due to development. It is proposed that with future development within the Southwest Georgetown Subwatershed and subsequent changes to flow, that monitoring of channel morphology occur.

High quality baseline monitoring data has already been collected over the duration of this study, including the detailed survey data that was established as part of the erosion threshold analysis on sensitive reaches. These reaches include Reach AM-3 in Tributary A, Reach C2 in Tributary C, and downstream of Eighth Line on Tributary B. These sites can continue to be monitored and monitoring should occur during the pre-construction, construction, and post construction periods. The following information was collected at each site:

- Sediment size distribution of bed substrate based on a modified Wolman (1959) pebble count (50 samples at each cross section) and fine material estimated based on a visual percentage;
- Ten detailed cross-sections representing at minimum two complete meanders and covering the range of typical geomorphic units within the reach. Each of the cross-sections extended beyond bankfull indicators and the distance between the measurements was less than 5 percent of the bankfull width;
- Longitudinal profile, the length was 20-40 times the bankfull width;
- A photographic record to provide support for documented bed and bank at each cross section, as well as channel observations.

Field surveys should be completed once every five years to assess channel migration and planform adjustment on a larger scale and should include the insertion of erosion pins at each location. Key to this effort will be landowner permission to access all of the monitoring sites. This data will prove invaluable in assessing the effects of urbanization on the stream network and will allow for the identification of changes to channel width, depth, cross sectional area, riffle and inter-pool gradients, and lateral migration of the watercourse. These variables should not increase or decrease in excess of 20%, but baseline data should be analyzed by a qualified fluvial geomorphologist and based on the results, the proposed thresholds may be modified. If significant adjustments are identified then they will be further investigated by the fluvial geomorphologist to determine the cause and consultation with stakeholders will occur.

Fisheries

<u>Riparian Vegetation</u>

Ecological Land Classification (ELC) mapping as well as site specific monitoring of success of restoration/ enhancement planting is proposed. Riparian vegetation monitoring will be incorporated with the terrestrial monitoring program described above. This monitoring will also be undertaken to determine whether riparian vegetation is being effective in helping to maintain proper/healthy/functional channel morphology both where watercourses have been relocated and where they have been rehabilitated in situ. This program will determine if the desired increase in riparian vegetation is occurring.

<u>Stream Temperature</u>

Stream temperature monitoring should occur to determine success of maintaining or improving water temperatures. The methodology used should combine those detailed in the Department of Fisheries and Oceans "*Method to Determine the Thermal Stability of Southern Ontario Trout Streams*" (DFO 1996) and the *Evaluation of a Simple Method to Classify the Thermal Characteristics of Streams Using a Nomogram of Daily Maximum Air and Water Temperatures* Chu *et al*. 2009). The methodology will involve recording stream temperature at scheduled intervals (typically 15 minutes) using data loggers that have been installed at selected locations throughout the watercourses. The data are then plotted on a nomogram which uses the temperature data from July 1st to August 31st, when the daily maximum air temperature is typically above 24.5°C. On these days, the corresponding daily maximum water temperature as measured between 16:00 and 18:00 is plotted against the corresponding daily maximum air temperatures. The data are plotted against ranges of five thermal classifications (Cold, Cold-Cool, Cool, Cool-Warm, Warm) to determine the thermal classification of the watercourse. A monitoring system as described above will allow measurement of the success of control measures (riparian vegetation and stormwater management) in maintaining and/or improving stream temperatures.

Suspended Sediment

A monitoring program is required to confirm the success of SWM initiatives to control suspended solids to the intended levels. See **Section 6.4.2.2** for details on this monitoring program.

Biodiversity

Biodiversity monitoring is recommended for fish and benthic invertebrate communities within the study area. Both species richness (number of species) and evenness (distribution of individuals across species) must be incorporated in the measure of biodiversity. Simple biodiversity indices such as those developed by Shannon and Weaver and Simpson are recommended for both the fish and benthic invertebrate communities. While not solely a measure of biodiversity the Hilsonhoff Index should also be used to analyze the benthic invertebrate community, the results of this index can provide an overall assessment of water quality through benthic community species richness. Fish community sampling should be completed following the Multiple Pass Survey method as detailed in Section 3, Module 1 of the Ontario Stream Assessment Protocol (OSAP) (Stanfield et al 2007). The Multiple Pass method requires the use of block nets and offers the greatest probability of capturing all species within a site. The benthic community should be sampled following the Ontario Benthos Biomonitoring Network (OBBN) Transect Travelling Kick and Sweep collection method (Jones et al 2007). The collection of fish and benthic invertebrates following these two methodologies will result in data sets which will allow for trend over time assessment of the aquatic community. If the diversity of the fish community increases substantially in the future, Index of Biotic Integrity (IBI) could also be considered for monitoring.

6.4.6.3 Hydrology

Stream Flow

As outlined in **Section 4.6**, the streamflow monitoring carried out as part of this study, provided results that conflicted with the hydrogeologic characteristics at the study area. As a result, it is recommended that stream flows along Tributary A be carried out for a period of one year prior to draft plan considerations and if necessary, that information be used to update the hydrology models and corresponding unit area flow targets.

The monitoring strategy as development proceeds is to measure streamflow on a continuous basis at a minimum of three locations within the study area. The streamflow measurements will be located at the Eighth Line crossings for each Tributary.

Streamflow measurements will allow the calculation of annual peak flow rates as development progresses within the study area. Peak flow rates will determine if the Implementation Strategy has been successful. If peak flow rates increase, modifications may be required to the outlet works of the stormwater management facilities. In addition, continuous streamflow measurements will allow the determination of flow duration curves, baseflows, and annual runoff volumes. **Table 4.6.10** provides the target unit area peak flow rates for the existing land use.

6.4.6.4 Hydrogeology – Groundwater Monitoring

Changes to the groundwater regime are usually difficult to observe and quantify. The impact assessment completed for the Study Area indicated that future development could result in a reduction in baseflow/groundwater support to Tributaries A and B. Groundwater contributions to these features are an important factor in their ecological health and function. Therefore, for stream reaches where there is currently an observed or interpreted groundwater discharge, future monitoring should be done as an overall measure of stream health. This would focus on stream flow and the aquatic habitat function of the reach.

Because year to year variations in the condition and function of these tributaries are expected, the tracking and comparison of long term observations to both historical observations and predicted changes will enable a determination of the overall success of the management plan. Should significant variations occur that affect the health and function of the tributaries, opportunities for implementing alternative mitigation measures can then be explored.

In addition to the stream/habitat monitoring, the water table elevation should also be monitored. This could be accomplished by a continuation of the regional monitoring program currently conducted by Halton Region at MW4_09. Monitoring distribution would be improved by adding MW7_09, MW5_09, and MW17_09 into the program (**Figure 4.4.5**). These wells should be monitored at least semi-annually during periods of high and low water table (after spring melt and in late summer). As there are relatively large seasonal and year to year fluctuations in the water table, collected monitoring data should be compared to the existing baseline data to evaluate these fluctuations before conclusions are made regarding long term water level impacts, related to development in the Study Area. In order to achieve this monitoring program, the wells will have to be maintained in place and unaltered during the development (construction) process.

In addition, it is recommended that Halton Region review the monitoring program established for the Georgetown Municipal wells WHPA sentry wells as it relates to development in the study area. Water quality monitoring at these wells should be conducted to identify any impacts to water quality, particularly chloride, which has been identified as an issue for the Cedarvale municipal wells.

6.4.6.5 Further Hydrogeologic Analysis

The Subwatershed Study has identified hydrogeologic features within the Study Area and has described the overall hydrologic system. Further analysis related to the hydrogeological components of the system to be addressed prior to development include:

- A water balance evaluation, at the scale of each proposed development that addresses potential impacts to groundwater quantity and quality. For lands within the delineated WHPA-Q1/Q2 and/or ICA (chloride) these features should be addressed specifically;
- A characterization of all hydrologic features illustrated on the constraint mapping and their functions; A description of the relationship and interdependence of these features and functions.
- Site-specific soil and groundwater investigations to assess the potential for groundwater recharge and infiltration. This will assist in identifying appropriate Best Management Practices/ Low Impact Development, and
- Define other lot level measures that could be implemented, assess the relative benefits of these measures with respect to groundwater quantity and quality.

Documentation in the EIR should address pre and post development conditions, with a focus on maintaining infiltration (and groundwater recharge). This document must also specifically address how the Source Water Protection policies will be incorporated into each development that intersects the WHPA or ICA.

6.4.6.6 Water Quality Monitoring (baseline and post-construction)

The water quality monitoring program is to be based upon the management approach for water quality conditions as outlined in **Section 6.3.5.3.** The target is based on TSS controls for suspended solids, but the parameters to be included in monitoring are:

- Chloride;
- Total Phosphorus;
- Metals (cadmium, copper and zinc);
- Nitrates;
- Total Suspended Solids;
- Dissolved oxygen;
- Conductivity; and
- Water temperature and pH.

The monitoring of temperature is based primarily upon fisheries protection and is outlined in **Section 6.4.6.2.**

The remaining water quality parameters are to be monitored in-stream and can be linked to streamflow monitoring to provide a representation of overall effectiveness of the management strategy. It is recommended that water quality be monitored at the proposed streamflow monitoring sites, *i.e.,* the main branch of Silver Creek at Eighth Line and 16 Mile Creek at Eighth Line, tributaries monitored in the 2013 study (SWG-B1 on Silver Creek, and SWG-A3 and SWG-C1 on 16 Mile Creek), as well as downstream of stormwater management ponds.

The monitoring program should include nine rainfall events for the first year (to collect additional base information and establish event mean concentrations), followed by three rainfall events per year for each consecutive year. It is recommended to use automated flow-weighted samplers for monitoring of rainfall events at the two main stations. A temperature probe should be used to record water temperature at regular intervals (15-30 minutes). Other stations may be monitored using grab samples. Three dry weather events should also be monitored by collection and analysis of grab samples in each year including the first year.

7. Implementation of Subwatershed Plan

7.1 General

The management strategy outlined in **Section 6.0** of the Vision Georgetown Subwatershed Study (Subwatershed Study) provides a recommended approach for the management of the Natural Heritage System and guidance for future land use changes in accordance with the Vision Georgetown Secondary Plan.

- **Natural Heritage System – Terrestrial** (**Section 6.3.3**) – To meet the goals and objectives, a management approach was developed for the protection of the biodiversity of terrestrial and wetland features, (including the flora and fauna associated with terrestrial and wetland habitats), in an environmentally sustainable fashion. This includes provision for connections between habitats including linkages for species movements.

- **Natural Heritage System – Streams** (**Section 6.3.4**) – For streams that have been identified as having environmental characteristics or watershed functions that require protection and/or enhancement to meet the subwatershed goals and objectives. A riparian corridor approach is to be applied which will consider all of the stream functions including:
  - Hydrologic;
  - Hydrogeologic;
  - Geomorphologic; and
  - Ecological (aquatic and terrestrial habitats).

- **Stormwater Management (SWM)** (**Section 6.3.5**) – The development of an approach that will protect and enhance environmental characteristics through managing stormwater response and conveyance processes.

This report outlines the implementation requirements for the recommended management strategy. The implementation requirements discuss the planning process, environmental reporting requirements, agency responsibilities, and the approval process with the Town of Halton Hills, Halton Region, Conservation Halton and Credit Valley Conservation through the following sections:

- Implementation Process (**Section 7.2**);
- Land Use Planning Requirements (**Section 7.3**);
- Supporting Analyses Required (**Section 7.4**);
- Monitoring Strategy (**Section 7.5**);
- NHS Management (**Section 7.6**);
- Agency Responsibilities (**Section 7.7**); and
- Administration Issues (**Section 7.8**).

This report should be considered a “living document”. “Living document” refers to the ability of the document to be refined using the Adaptive Environmental Management (AEM) Approach. AEM means making decisions as part of an on-going process. Monitoring the results of actions provides a flow of information that may indicate the need to change a course of action or change the document. The management strategy also includes recommended policies that should be incorporated into Official Planning documents. Over time, government policies on relevant issues, such as terrestrial systems and SWM, will evolve. This strategy should always be applied with reference to the most recent applicable policies.

7.2 Implementation Process

The implementation plan should address the components outlined in the management strategy in **Section 6.0**. The implementation process that is included in these areas is illustrated in **Figure 7.2.1**

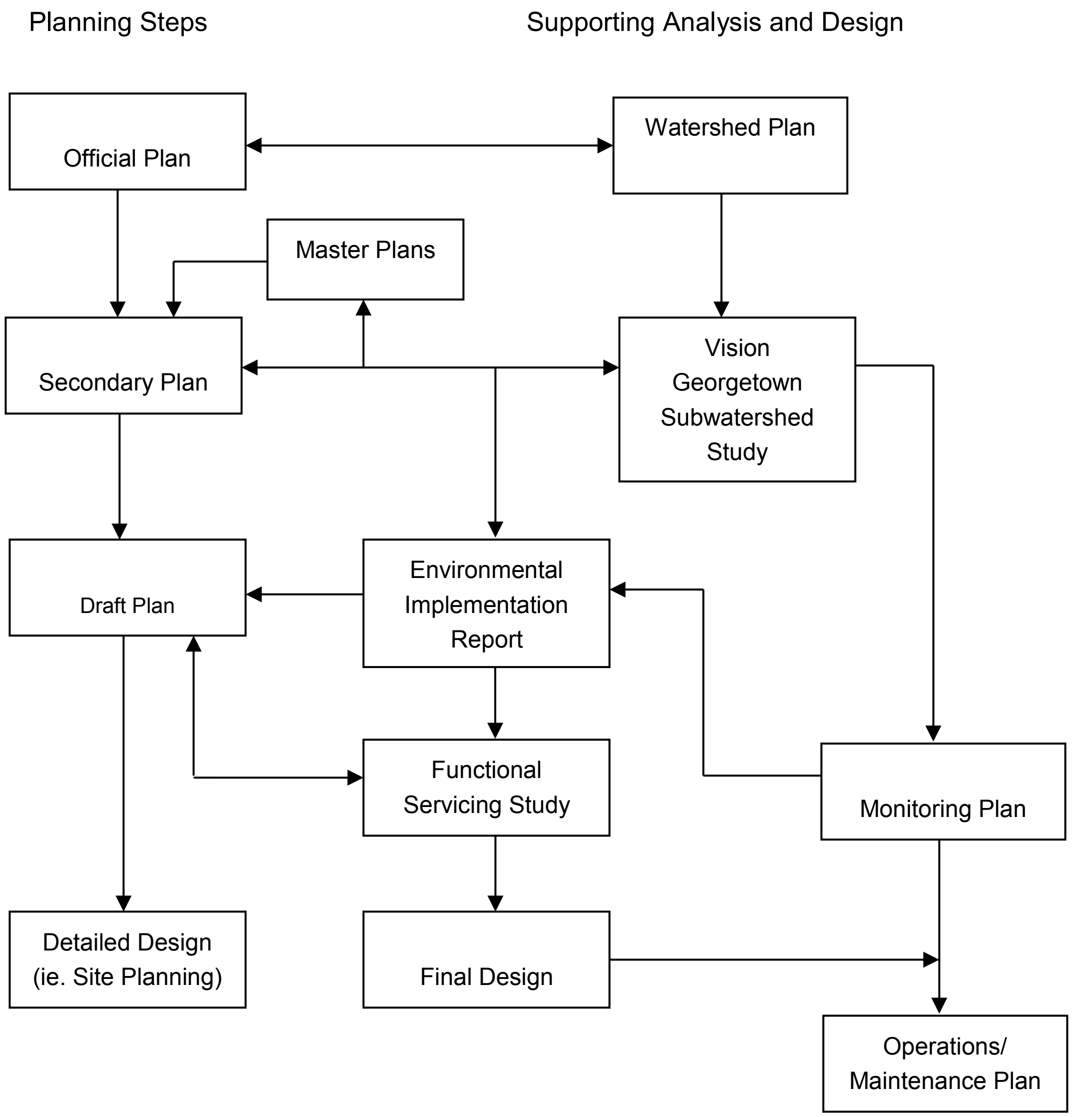
The planning process includes the major steps of:

- Official Plan (OP);
- Secondary Plan;
- Draft Plan (or site plan approval as necessary);
- Subdivision Design Plan; and
- Registered Plan.

The supporting studies that are necessary include:

- Subwatershed Study;
- Environmental Implementation Report (EIR) for the entire subcatchment area;
- Functional Servicing Study (FSS) for the proposed development;
  - Preferred Servicing Plan;
  - Draft Plan of Subdivision (or site plan);
- Final Design;
  - Grading Plan;
  - Erosion and Sediment Control Plan;
  - Servicing Plan;
  - Stormwater Management Design Plan;
  - Building Plot Plan;
  - Lot Certification; and
  - All other necessary plans, studies, steps, approvals, and permits as required by agencies and the Town.

Figure 7.2.1 Implementation Process



7.3 Land Use Planning Requirements

The Vision Georgetown Subwatershed Study has been prepared in conjunction with the Secondary Plan, as input into the planning process. The Secondary Plan will provide a framework for future development and set out the detailed studies required prior to any development approval. The following subsections summarize the directions in the management strategy, which have been considered in the finalization of the secondary plans.

7.3.1 Natural Heritage System

The management strategy identified the potential to create a Natural Heritage System. It also specified the land use requirements (*i.e.,* constraint lands), together with associated management requirements, for the lands associated with the Natural Heritage System.

Specifically, the management strategy recommended that the Natural Heritage System be comprised of the following areas which are identified in **Figure 7.3.1**.

- Terrestrial Features (Core Areas and Key Features);
- Linkages;
- Enhancement Areas;
- Buffers; and,
- Riparian Stream Corridors.

The Region's NHS as provided on Map 1G of ROPA38 is overlaid on **Figure 7.3.1** to provide for a comparison to the final site specific NHS that has been identified through the Subwatershed Study. This NHS has been refined from what was identified on **Figure 4.12.1** based on the Black Locust management and Block D woodland enhancement assessment provided in **Section 6.3.3.6**.

The Secondary Plan will incorporate these areas and has labelled them as "Natural Heritage System Area" on the land use schedule to the Plan. The Plan will identify the components of the System on another schedule as "NHS Preserve Area", "Linkage Preserve Area", "High Constraint Stream Corridor" and "Medium Constraint Stream Corridor". These terms are interchangeable with the terms used in the Subwatershed Study.

The Natural Heritage System, as reflected in the Secondary Plan, would be established by policies and designations which differentiate between NHS Preserve Area, Linkage Preserve Area, and High and Medium Constraint Stream Area.

In addition to the Natural Heritage System, it was recommended that the Secondary Plan include policy direction related to other hydrological features as discussed below.

The following subsections summarize the key policy directions proposed for each component of the Natural Heritage System and other hydrological features, and the Implementation Plan.

NHS Areas

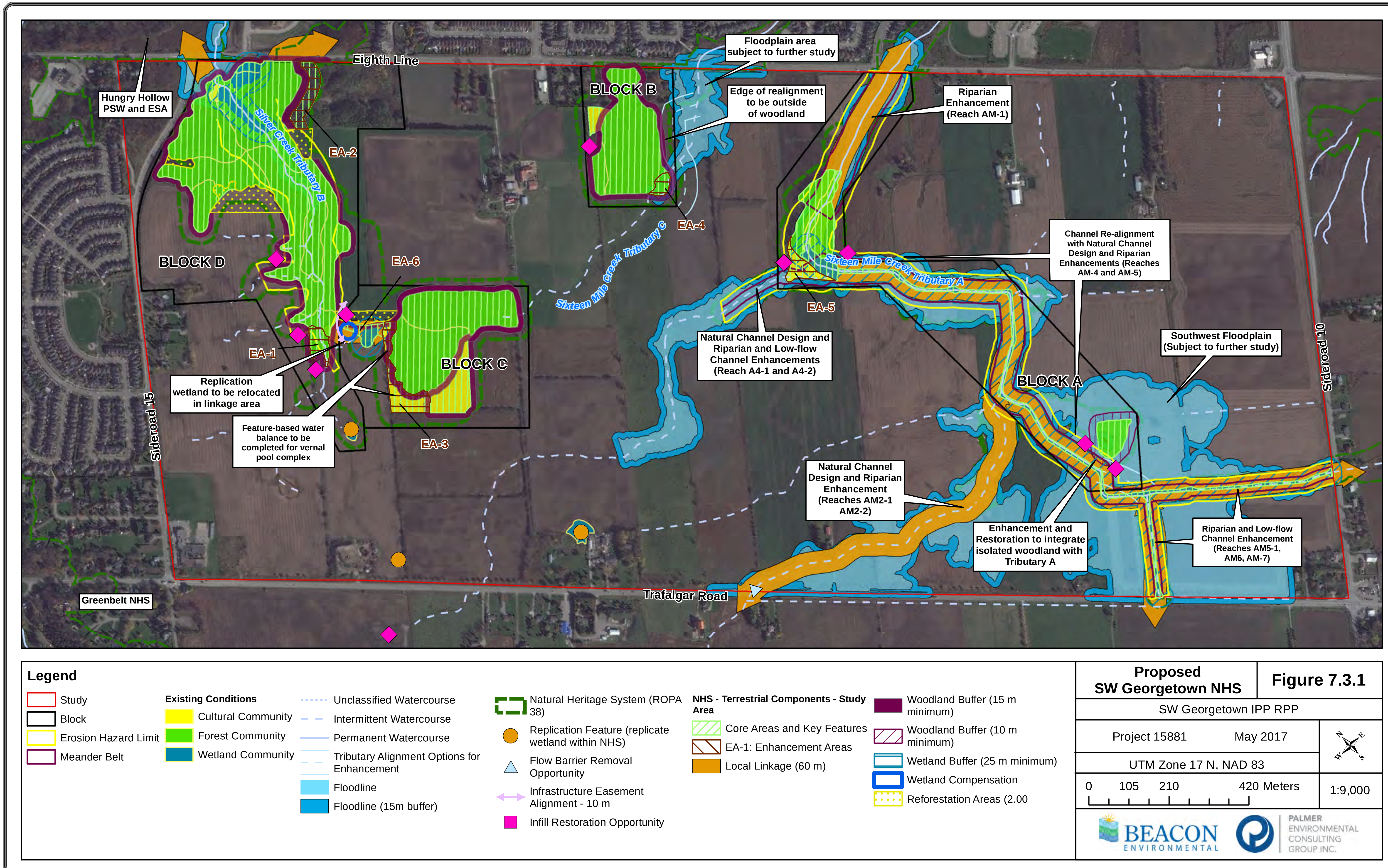
The NHS Areas, as shown on **Figure 7.3.1**, include key natural feature groupings together with their required buffers and related lands for the management of the area's ecological diversity and sustainability. The designation of these areas in the Secondary Plan is intended to protect the function of these features and provide for the long-term sustainability of the Natural Heritage System, within the urban context.

Linkages

The linkages identified on **Figure 7.3.1** include areas that are designed to link the Terrestrial features together to maintain and enhance their environmental sustainability. Linkages follow natural features whenever possible and are intended to be of sufficient size and character to ensure the functionality and sustainability of the Natural Heritage System.

High Constraint Streams (Red)

High Constraint Stream Areas (the red stream corridors shown on **Figure 5.9.1**) include certain watercourses with associated riparian lands, together with buffers measured from top-of-bank. High Constraint Stream Areas are located both inside and outside the NHS Blocks and Linkages. High Constraint Stream Corridors are to be protected in their current form and function.



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Medium Constraint Streams (Blue)

Medium Constraint Stream Areas (the blue stream corridors shown on **Figure 5.9.1**) are to be maintained as open watercourses with a full “riparian corridor” (meander belt width plus erosion allowance and setbacks). The Medium Constraint Stream Corridors may be identified in the Secondary Plan. However, since the final locations of the streams after development are not known, the policies should provide for the allowance of alteration of the Medium Constraint Streams. The requirements for any proposed alteration are to be identified at the EIR stage as outlined in the EIR discussion in **Section 7.4.1.3**.

Uses Permitted in NHS Areas, Linkages and Medium and High Constraint Stream Corridors

The policies of the Secondary Plan would, with a few limited exceptions, limit development to legally existing uses, buildings and structures as well as fish, wildlife and conservation management. These exceptions would be subject to detailed study, would likely have various conditions, and may include:

- Development or land disturbances for required flood and stream bank erosion control and protection of fish, wildlife, and conservation management;
- Infrastructure (such as road or pedestrian crossings) and utility access and crossings; and
- Public pedestrian trails.

In particular, the required study would address the placement of such facilities in these areas to ensure that they are compatible with NHS Area management, as discussed in **Section 7.4.2**.

The land use planning options and the functional servicing requirements within the study have identified the need for an infrastructure connection between Block C and D. To facilitate this is a 10 m wide easement located along the existing open connection (farm lane) between the adjoining agricultural fields

Under Section 117.1(9), subject to other polices of ROPA 38, permitted uses in the Regional Natural Heritage System include “*essential* transportation and *utility* facilities”.

Under Section 233 the definition for essential “*means that which is deemed necessary to the public interest after all alternatives have been considered*”.

The definition of “utility” under Section 228 outlines a number of infrastructure services including water supply, storm water or wastewater system among other works or systems necessary to the public interest.

Other Hydrological Features

In addition to the components of the Natural Heritage System discussed above (*i.e.*, NHS Areas, Linkages, and High and Medium Constraint Stream Areas), there are other hydrological features located outside of the Natural Heritage System have been identified in the study area. These features include:

- Low Constraint Streams (*i.e.*, the green streams shown on **Figure 5.9.1**);

Low Constraint Streams

Low Constraint Streams (the green streams shown on **Figure 5.9.1**) will serve as conveyance systems only. There is no requirement to maintain a riparian corridor associated with these watercourses. The requirements for alteration or replacement of the Low Constraint Streams are to be identified at the EIR stage as outlined in the EIR discussion in **Section 7.4.1.3**. It is preferred but not necessary or required that the Low Constraint Streams be maintained as open systems. The function of all low constraint streams can be maintained through infrastructure and the proposed storm management approach. At a minimum, low constraint streams would be needed to meet the subwatershed drainage density targets. They can be either in the form of a grassed drainage swale or SWM pond. Tributary C5 is a special case as it may provide a general "greenway" between Blocks B and C that allows for accessory uses such as a trail with landscaping plantings.

7.3.2 Secondary Plan Directions – Implementation

The Secondary Plan will include policies with respect to the management of the Natural Heritage System and required environmental studies. The Secondary Plan would include specific policies including the following directions:

- The description and process of the EIR to be prepared and submitted as a basis for the evaluation of development applications for new urban development. The requirements of an EIR are discussed in **Section 7.4.1.3**;
- The description and process of the FSS; and
- Recognition that the Subwatershed Study provides more detail on implementation and management.

7.4 Supporting Analysis Required

7.4.1 Introduction – Reporting Requirements

This section of the report outlines the items that are to be included in the EIR and FSS reports to demonstrate how any proposed land use meets the requirements of the management strategy.

7.4.1.1 Environmental Implementation Report (EIR)

The purpose of an EIR is to clearly demonstrate how the specific development application (such as a Draft Plan) will incorporate and follow the management strategy recommendations.

The proponent will be required to demonstrate, through the preparation of an EIR, that the issues of SWM, infiltration, Natural Heritage System delineation and stream corridors have been addressed through the Draft Plan of Subdivision process, for the entire subcatchment area.

During the preparation of the EIR, the boundaries of the Natural Heritage System as illustrated in **Figure 7.3.1** are considered final, subject to minimal refinements on surveying the edges of features and locating buffers. Additional refinements relate to the proposed Block D woodland management and enhancement plan where the limits of Black Locust removal and the areas of reforestation will require confirmation in consultation with the agencies.

The EIR reporting is to reflect the management requirements for the Natural Heritage as outlined in **Section 7.4.2**, and illustrated in **Figure 7.3.1**.

7.4.1.2 EIR – Study Boundaries

Figure 4.6.1 shows how the study area has been broken into separate subcatchment areas and should be followed for EIR preparation. As much as possible, the studies should be based on the total tributary drainage boundaries, namely, A, B, C, D. The study area for an EIR will include not only the detailed assessment of the lands included within the land use application, but also an evaluation of how the lands within the application function within the subwatershed context and the impacts beyond the application boundaries. The proponent should locate its application lands on **Figure 4.6.1**. An EIR will be required for the entire subcatchment draining to the EIR Study Node for the particular subcatchment area. The study node is the hydraulic crossing at the outlet of each study area (or drainage shed).

Where a portion of the Natural Heritage System is located within the subcatchment area, it will be important to demonstrate that the assessments required were completed with logical ecological boundaries or tributary areas. This may be accomplished with the co-operation of adjacent landowners to show consistency of treatment, or undertaken individually on a tributary area basis in the absence of other development plans.

7.4.1.3 EIR Requirements

The requirements for the EIRs are described specifically below and may be subject to refinement upon consultation with the approval agencies. The EIR will examine issues not detailed in the Subwatershed Study including:

- Watercourse relocations and modifications, as well as associated aquatic habitat assessment;
- Stormwater quantity and quality control requirements;
- Specific location and detailed design for Enhancement Area and Replication Wetlands;
- Specific buffer width requirements as following the outlined in **Section 7.4.2.3**;
- Multi-landowner facility design and locations;
- Operations and Maintenance Plans;
- Discrete monitoring requirements;
- Adherence to the Final Halton Source Protection Plan Policies;
- Facility cost sharing; and
- Conceptual fisheries compensation plans where necessary.

EIRs may also require a number of technical studies, the need for which will have been identified in the Subwatershed Study. Although individual studies are listed below, it is possible that they will be combined given the interrelationship of these issues. Studies may include:

- Aquatic habitat where watercourse relocations and modifications are proposed;
- Studies to demonstrate that stream protection meets subwatershed objectives;
- Impacts associated with transportation, servicing and utility corridors;
- Water balance assessment of recharge (quantity and quality) within the WHPA-Q1/Q2, ICA (chloride), and baseflow contributing areas;
- Additional monitoring of groundwater levels along the upper reaches of Tributary A to further refine hydrogeologic linkages with the watercourse;
- Additional flow monitoring of all three tributaries for one year (four seasons) to further verify and/or calibrate the model parameters.
- Functional SWM plan and outline approach and location of facilitates to meet management strategy requirements;
- Natural Channel Design where watercourse relocations and modifications are proposed;
- Additional flow monitoring on Tributary A to confirm hydrologic model parameters.
- Additional soils investigations to refine valley wall setbacks on Tributary B and a portion of Tributary A, reaches AM-2 and AM-3; and
- Additional water quality analysis with LID application to ensure that TP reduction targets are met.
- The floodplain delineation for this study started at the Eighth Line crossing. Additional analysis has been requested by each Conservation Authority to carry out a flood hazard risk analysis downstream of Eighth Line to ensure that proposed future development with the recommended SWM approach does

not increase flood risk downstream of Eighth Line. The can be carried out as part of the Master Drainage and SWM plan or as part of the EIR process (as long as the EIR is carried out to include the entire tributary).
- Additional servicing details for the proposed future development, either in the EIR or Master Drainage and SWM Plan needs to consider and coordinate with the proposed upgrades on Trafalgar Road.

The requirements and expectations for these additional studies are discussed in detail in the following sections.

7.4.1.4 Functional Servicing Study

The FSS will relate to the lands proposed for development and must be supported by an EIR of the subcatchment area within which the lands are located. The FSS shall include the following, at a minimum:

- A preferred servicing plan based on an analysis of servicing requirements including:
  - Servicing design requirements;
  - Layout for roads and other transportation systems including transit and trails;
  - Preliminary sizing and location of SWM facilities and integration with environmental features and development areas;
  - Phasing and sharing of costs for other utilities and transportation systems; and
  - Preliminary locations for large above ground utility structures.
- Draft plans of subdivision or detailed land use concepts where applications have not yet been submitted, in accordance with the policies of the Secondary Plan.

7.4.2 Natural Heritage System – Terrestrial

The following section presents a summary of the EIR and FSS requirements to ensure that the management strategy is correctly implemented in Southwest Georgetown with respect to the terrestrial natural heritage features of the Natural Heritage System.

7.4.2.1 Block D Woodland Management and Enhancement

Due to the identified threat of the highly invasive Black Locust tree (as discussed in **Section 5.7.2** and **Section 6.3.3.6**) to adjacent native vegetation communities and components of the NHS such as the buffers, linkages and enhancement areas, a framework has been provided for the management of the Black Locust in cultural woodland Unit 16a that maintains and enhances the Block D significant woodland. The objective is for the removal of approximately 2.47 ha of Black Locust trees and implementation of a comprehensive management and reforestation plan that will not result in long-term negative effects, impacts, or loss of the significant woodland features and functions of Block D.

At the EIR stage, the following additional analysis and studies will be required:

- Confirm the boundary limit of Black Locust tree removal along the west side of Unit 16a.
- Confirm the total restoration area and planting densities in the reforestation areas.
- Confirm the boundary limits of the proposed reforestation areas as Shown on **Figure 6.3.3.**
- Develop a detailed reforestation plan in consultation with the agencies that includes the planned timing and schedule for Black Locust tree removal and reforestation planting.
- Develop an adaptive management and monitoring plan.
- Integrate the wetland replication design and plan that is proposed for the linkage between Block C and D with the reforestation plan to co-ordinate the objectives of each.

7.4.2.2 Core Area and NHS Boundary Verification

The boundaries of the Natural Heritage System as illustrated in **Figure 7.3.1** are considered final, subject to minimal refinements on surveying the edges of features and locating buffers. Additional refinements relate to the proposed Block D woodland management and enhancement plan where the limits of Black Locust removal and the areas of reforestation will require confirmation in consultation with the agencies.

At the EIR stage, some refinement of the Core Area and NHS delineation will occur (see **Figure 4.12.1**). However, based on the extent of field verification and characterization completed as part of the subwatershed study it is anticipated that the refinement will be minimal and will focus on surveying the edges of features and locating buffers, as well as ensuring that overlapping factors/buffers are considered. The following discussion provides guidance for these refinements.

Dripline of Woodland – A minimum buffer of 10 m will apply from the dripline of the forest edge for the isolated woodland (0.67 ha) Unit 1 in Block A. A minimum 15 m buffer for all other Core Area woodlands of the NHS will apply. At the EIR stage, the dripline of the woodland will be staked in the field, reviewed by staff of the Municipality in consultation with the Conservation Authority. The agreed line will be surveyed and the minimum 10 m or 15 m buffer delineated based on this surveyed line (see further discussion below regarding buffers). Note, as these have been identified as minimum buffers, as part of the EIR it must be demonstrated that the ecological function of the NHS feature for which the buffer is being created is being maintained and that a larger buffer may be required based on considerations such as the proposed adjacent land use, ecological sensitivity and functional requirements of the NHS feature. For example, to maintain the surface water contributions to the vernal pool complex on the northwest side of Block C, a buffer of greater than the 15 m minimum may be required needed to maintain the function of the natural heritage feature (see **Section 7.4.2.3** below).

Edge of Wetland – A buffer of 25 m from the edge of wetlands has been identified for the delineation of Core Area boundaries where present. Wetlands that have been identified as significant that will be maintained as part of the NHS will receive a 25 m buffer. Two wetlands are found along the lower reach of Tributary B (Unit 3b and 21), where the outer limits of the Core Area woodland of the NHS are further than the 25 m buffer limit of the wetland. One isolated swamp located within a local linkage area (between Block C and D) will receive a 25 m buffer that will be part of the outer limit of the NHS. A long, linear wetland found along the riparian zone of Tributary A (Unit 10), where the outer limits of the Local Linkage of the NHS is further than the buffer limit of the wetland.

At the EIR stage, the limit of the wetland will be staked in the field, reviewed and approved by staff of the Municipality and in consultation with the Conservation Authority. The agreed line will be surveyed and the buffer delineated based on this surveyed line. The wetland boundary will be determined based on the 50/50 rule outlined in the Ontario Wetland Evaluation System (OWES).

Edge of Thicket/Open Field Vegetation – Existing areas of thicket or open field have been used in some locations (along with other factors) to delineate Core Areas. At the EIR stage, detailed delineation of vegetation communities within the Core will be used to verify the areas of habitat blocks within the Core. Areas of open field and thicket habitats will be considered when confirming boundaries. No buffers around thickets or field areas have been used for Core Area delineation. The delineation of these areas will, in some cases, relate to the boundary of the identified Enhancement Areas as described below.

As noted above, the delineation of the Core Areas considered a number of general habitat goals as well as site specific factors. At the EIR stage the multiple levels of factors and the overlap of factors must be considered.

Enhancement Areas – There are six Enhancement Areas that have been identified as illustrated on **Figure 4.12.1** and **7.3.1**. Enhancement Areas are identified as lands that contribute to the NHS providing supporting functions and opportunities for protecting, restoring, connecting and improving the natural heritage features of the NHS. These areas are considered part of the NHS although do not have buffers themselves but include the buffers of Core Areas. The Enhancement Areas include cultural vegetation communities (e.g., CUM1, CUT1) and some areas of existing agricultural lands (e.g., between Block C and D). At the EIR stage, the vegetation community boundaries of the meadow and thicket areas are to be identified and staked in the field, some of which will have been completed for the dripline staking of the woodlands. This will confirm the limits and total areas of each of the Enhancement Areas to be used as part of the management plan for these areas.

Stream Corridor – The delineation of stream corridors is discussed in detail in **Section 7.4.3**.
Floodplain – Delineation has been included in the identification of stream corridors (see **Section 6.3.4**) and will be reflected in the final NHS Plan for Secondary Plan purposes. The regional storm floodlines are illustrated on **Figure 4.7.2.** The final floodlines will need to be confirmed and/or modified as necessary during the EIR stage. This will be required to conform to Conservation Halton and CVC requirements including setbacks to meet their requirements for floodplain polices.

Width of Forest Interior Habitat – Minimum widths of Cores with forest interior habitat have been identified for Block D. At the EIR stage, detailed delineation of vegetation communities within the Core will be used to verify the areas of habitat blocks within the Core. For the Block D forest this will be an important consideration in the Management and Enhancement Plan for the Black Locust woodland.

Top of Bank – **Section 7.4.3** includes a discussion of the analysis of top of bank considerations. In some locations where Core Area boundaries are described associated with woodlands (or other features), top of bank considerations may override these factors once detailed field investigations are completed at the EIR stage.

Exclusion of Residence or Other Buildings – As part of the review of the Core Area boundaries, existing residences, buildings or other human-made structures in the vicinity of the Core Area were identified and not included in the Core. At the EIR stage, the presence of these types of features would be confirmed.

7.4.2.3 NHS Terrestrial Buffers

It is well documented that the land surrounding or adjacent to natural features such as woodlands and wetlands provides an important function to the health and maintenance of the natural heritage feature. For example, buffers can provide nesting habitat for turtles, movement corridors for wildlife, a buffer for fish and wetland fauna (amphibians and birds) habitat, and contribute to the maintenance of wetland hydrology. It is therefore important that through the EIR process appropriate buffers are determined so that proposed development can proceed in such a manner that the primary contributing functions of the adjacent lands are maintained through the buffers.

Buffers are generally defined as vegetated areas of land between development areas and sensitive natural features, such as wetlands, in which no or very limited site alteration occurs. These buffers function to protect the natural features by way of creating a biophysical barrier between an adjacent land use, such as a development, and the feature, or providing functional support. The buffer, or often referred to as “vegetation protection zone”, is intended to reduce or eliminate potential impacts from the development. Buffers also allow for many of the adjacent lands functions, such as turtle or waterfowl nesting habitat, or water infiltration, to continue.

The buffer widths may vary depending on the proposed land use adjacent to the wetland, the significant features and species associated with the woodland or wetland, and the contributing function of the lands adjacent to the wetland. In natural areas with lower sensitivity (e.g., those with existing disturbance, more limited significant features or functions or some isolated areas) and proposed land uses that are more passive, such as parkland or low density development; buffers can be narrower. For areas adjacent to highly sensitive features and/or where more intense land uses are proposed (e.g., high density housing development) larger buffers are appropriate. In such cases additional mitigation measures may also be required (e.g., LIDs).

NHS Buffer Framework

Within the study area a number of factors have been considered for determining appropriate buffer widths. These include: existing land uses, presence or absence of sensitive/significant wetland features, slope and contributing function of adjacent lands, soils, and the specific proposed new land uses.

The NHS buffers for the study area have been based on a variable buffer approach. This approach takes into consideration the natural heritage features and functions to be protected (with each feature considered separately based on function), buffer function (in relation to the individual feature), the proposed adjacent land uses, as well as the potential enhancement of the buffers. The minimum buffers consist of the following:

<u>Woodlands</u>

- A minimum buffer of 10 m will be applied from the dripline of the woodland edge for Block A and a minimum of 15 m from the woodland edge for Blocks B, C and D.

<u>Wetlands</u>

- A minimum 25 m buffer will be applied from the edge of wetlands (boundary determined through OWES), which includes the riparian wetlands along Tributary A (Block A) and isolated swamp located within Block C in the local linkage area between Block C and D.

The Credit Valley Conservation recommends minimum buffers in the range of 10 m for significant woodlands, non-significant protected wetlands, hazards; and, 30 m for provincially significant wetlands and from bankfull flow of watercourses.

Conservation Halton generally requires 15 m from non-provincially significant wetlands and wetlands less than 2 ha; and, 30 m from provincially significant wetlands and wetlands greater than 2 ha.

Halton Region recommends minimum buffers of 30 m for woodland and wetlands. The 30 m buffer is a precautionary distance that based on ROPA 38 is subject to refinement based on more detailed study such as a subwatershed study in support of a secondary plan, which is acceptable to the Region.

Based on the characteristics of the existing terrestrial and wetland vegetation communities, natural heritage features, wildlife habitat and species found within these areas (identified in Chapters 4 and 5), a number of significant features were identified. These features and the ones that require buffers are summarized below with site-specific reference to vegetation communities based on **Figure 4.9.1**.

- **Significant wetlands** include the riparian meadow marsh (Unit 10) along Tributary A (Block A), the deciduous swamp (Unit 3c) in the linkage between Block C and D; the riparian deciduous swamp (Unit 3b); and, the meadow marsh (Unit 21) along Tributary B (Block D).
- **Habitat of Endangered and Threatened Species** consists of foraging habitat for Barn Swallow along Tributary A.

- **Habitat for Special Concern Species** consisting of woodlands for Eastern Wood Pewee (Unit 13 in Block B; Units 6a and 7 in Block C; and, Units 11, 12a, 12b, 1b, 8a, 8c, 17a, 17b, and 19 in Block D); and, woodlands for Wood Thrush (Units 6b, 6c and 22 in Block A, and Unit 13 in Block B).
- **Significant Woodlands** includes Unit 1a in Bock A, combined Units 6b, 6c and 22 in Block A; Units 13, 14a and 14b in Block B; combined Units 6a, 7 and 5 in Block C; and, combined Units 11, 12a, 12b, 1b, 8a, 8c, 8d, 16a, 16b, 17a, 17b, and 19 in Block D.
- **Significant Valleylands** includes a minor valley/watercourse in Block A (along Tributary A) and significant valleyland in Block D (along Tributary B).
- **Significant Wildlife Habitat** includes specialized habitat for breeding amphibians (vernal pool complex) in Unit 7 of Block C. There is also a high potential for Block D to support a snake hibernaculum for Red-bellied Snakes.
- **Fish Habitat** is found through much of the Tributary A reach to approximately the boundary of AM-5/AM-6 and in the downstream portion of Tributary B within BM-1.

The natural features of the NHS provide the following ecological functions:

- Surface water attenuation, sediment retention and nutrient input to headwater watercourses from woodlands and riparian wetlands;
- Habitat for rare and uncommon plants;
- Breeding, summer and winter habitat for amphibians;
- Woodland habitat for Special Concern forest bird species;
- Wetland foraging habitat for Threatened bird species;
- Habitat for population of Red-bellied Snakes; and,
- Wildlife movement corridors and linkage.

The development of a buffer framework is to protect significant natural features and maintain the ecological function of the NHS.

Buffer Functions and Enhancing Buffers

Through the Sustainable Halton study Halton Region recommends that a minimum 30 m buffer be applied to the NHS. We are of the opinion that a prescribed 30 m buffer for all features does not take into consideration feature areas with low sensitivity or adjacent land uses with low potential threats. However, the Region’s precautionary approach with greater buffer widths has been taken into account where applicable. In considering this, and as part of our variable buffer approach, the proposed buffer framework includes enhancing buffers to provide for comparable buffer function within a reduced buffer width. While enhancing buffers was not considered as part of the Sustainable Halton study, this approach provides for early establishment of vegetation and habitat opportunities for some species; an immediate physical barrier (fencing); planning and management of the vegetation community succession within the buffer; greater control and prevention of the establishment of invasive plant species; and, social and aesthetic value. The value of enhancing buffers and the resulting comparable functions to the Region’s objectives are further summarized in **Table 7.4.1**.

Table 7.4.1 NHS Enhanced Buffer Functions

Sustainable Halton Buffer Functions (2009)	Enhanced Buffer Functions
-buffer that reduces access into a natural heritage feature such as related predation by dogs and cats, invasion of exotic species, or human intrusion	-enhanced buffers will provide a physical barrier (e.g., fencing and vegetation plantings) and deter anthropogenic access and activities that can result in impacts
-a zone of protection for the elements of the feature along its outer edges such as tree root compaction and damage from construction activity	-the variable buffers will be more than sufficient for the protection of root zones -delineation of the construction limit and tree/woodland protection fencing is standard practice during construction
-a safety zone such as tree fall zone next to a woodlot	-generally the minimum buffer for land uses with greater safety risks (i.e., residential) are wide enough to accommodate falling trees -in park, roadway and SWM areas tree hazards are typically managed through maintenance
-an area for wildlife to carry out part of their life cycle such as water fowl nesting nest to a wetland	-based on the species and habitats identified through the Subwatershed Study, the enhanced buffers will provide additional areas for habitat use and enhancement of habitat (i.e., edge habitat for Red-bellied snakes and reducing edge effects for forest birds) -larger buffers have been identified for the wetland in the linkage between Block C and D to support amphibian habitat functions
-a vegetated zone that encloses a water catchment sustaining flow volumes important to sustain an adjacent feature	-the buffer widths for the wetland within the Block C – D linkage (Unit 3c) are larger so the surface water contribution to the feature can be maintained for continued support of breeding amphibian habitat
-a vegetated zone to help control overland flow so as to reduce possible problems such as erosion on valley slopes	-there will be some form of vegetation in all buffers through the planting plan (e.g., meadow, thicket, woodland). In considering adjacent land uses and existing conditions within the buffer lands (e.g., agricultural use, slope, soil), the proposed buffers will function to control overland flow and attenuate sediment

Sustainable Halton Buffer Functions (2009)	Enhanced Buffer Functions
-an area to provide for wildlife movement	-the development of the NHS through the Subwatershed Study includes ecological linkages and protected woodlands/valleylands that will provide the primary areas for wildlife movement within the study area. The proposed enhanced buffers will provide supporting functions (e.g., cover habitat) for wildlife movement

Variable Buffer Width

The approach to determine an acceptable buffer width is based on a base buffer + risk-based assessment for which an example is provided below. In addition to the base buffer + risk-based assessment, the determination of buffer widths (as shown on **Table 7.4.2**) is also based on scenarios where the buffer lands are not enhanced (i.e., abandon agricultural use and allow lands to regenerate) compared to enhancing the buffers (i.e., planting plan, management, monitoring and fencing). The identified base buffers are what is frequently applied in other municipalities (outside of Provincial Plan areas). Through ROPA 38 Halton Region has taken a precautionary approach in recommending greater buffers. This has been taken into consideration.

Table 7.4.2 Vision Georgetown Buffer Framework

Block Area	Feature(s)	Function(s)	Site Conditions of Buffer Lands	Land Use Scenario	Non-enhanced Buffer	Buffer with Planting Plan and Fencing
Block Area A	<u>Southern Woodland</u> • Significant Woodland	• Proximity to headwater watercourse	• Agricultural lands • Little or no slope • Clay loam soils	Low Density Residential	15 m	10 m
				Public Road	12.5 m	10 m
				Public Parks	12.5 m	10 m
				SWM Facilities	12.5 m	10 m with planting in buffer 7.5 m with plantings around entire SWM perimeter
	<u>Northern Woodland and Tributary A</u> • Significant Wetland • Habitat for Species of Conservation Concern • Significant Woodland • Ecological Linkage • Fish habitat	• Headwater watercourse • Riparian wetland habitat • Breeding amphibian habitat • Wood Thrush and Barn Swallow habitat opportunities • Ecological linkage	• Agricultural lands / cultural thicket / old field meadow • Gentle to moderate slopes • Clay loam soils	Low Density Residential	30 m	20 m
				High Density Residential	25 m	17.5 m
				Main Street Area	25 m	15 m
				Public Parks	22.5 m	15 m
				SWM Facility	20 m	15 m with planting in buffer 12.5 m with plantings around entire SWM perimeter
Block Area B	• Habitat for Species of Conservation Concern • Significant Woodland	• Breeding amphibian habitat • Wood Thrush and Eastern Wood Pewee habitat opportunities	• Agricultural lands / cultural thicket / old field meadow • Little to no slope • Clay loam soils	Low and Medium Density Residential	30 m	20 m
				High Density Residential	25 m	17.5 m
				Public Parks	22.5m	15 m
				SWM Facility	20 m	15 m with planting in buffer 12.5 m with plantings around entire SWM perimeter

Block Area	Feature(s)	Function(s)	Site Conditions of Buffer Lands	Land Use Scenario	Non-enhanced Buffer	Buffer with Planting Plan and Fencing
Block Area C	Woodland Area • Habitat for Species of Conservation Concern • Significant Woodland • Significant Wildlife Habitat	• Breeding amphibian habitat • Presence of rare/uncommon plants • Eastern Wood Pewee habitat opportunities • Ecological linkage (between Block C and D)	• Agricultural lands / cultural thicket • Little to no slope • Clay loam soils	Low and Medium Density Residential, Schools	30 m	20 m
				Public Parks	22.5 m	15 m
				SWM Facility	20 m	15 m with planting in buffer 12.5 m with plantings around entire SWM perimeter
				Public Road	20 m	15 m
	Wetland Area • Significant Wetland • Ecological Linkage	• Breeding amphibian habitat • Ecological linkage (between Block C and D)	• Agricultural lands / woodland • Little or no slope • Clay loam soils	Low Density	30 m	25 m
				Public Parks	30 m	25 m
				SWM Facility	27.5 m	25 m
Block Area D	• Significant Wetland • Habitat for Species of Conservation Concern • Significant Woodland • Significant Valleyland • Ecological Linkage	• Headwater watercourse • Riparian wetland habitat • Breeding amphibian habitat • Presence of rare/uncommon plants • Eastern Wood Pewee habitat • Red-bellied snake concentration • Ecological linkage	• Agricultural lands / cultural thicket / old field meadow • Gentle to moderate slopes (local steep slopes at drainage inlets) • sandy loam, loam, clay loam soils	Low Density Residential	30 m	20 m
				Public Parks	22.5 m	15 m
				SWM Facility	20 m	15 m with planting in buffer 12.5 m with plantings around entire SWM perimeter

The following scenarios are provided to illustrate this approach. In **Scenario #1** the natural feature is adjacent to a land use that represents a high potential threat to the feature (e.g., residential).

Scenario #1

1. 15 m base buffer (non-enhanced) - will provide a level of feature protection but there is a higher risk of not achieving the intended buffer function. In Halton Region this level of risk is considered too high.
2. 15 m base + 15 m (non-enhanced 30 m buffer) – will provide an acceptable low risk of the buffer not achieving the intended function.
3. 15 m + 5 m + enhancing buffer, will provide an acceptable low risk of the buffer not achieving the intended function that is comparable to a non-enhanced 30 m buffer (i.e., a smaller buffer with same function).

In **Scenario #2** the natural feature is adjacent to a land use that represents a lower potential threat to the feature (e.g., SWM facility).

Scenario #2

1. 15 m base buffer (non-enhanced) - will provide a level of feature protection but there is still some risk of not achieving the intended buffer function.
2. 20 m base (non-enhanced) – will provide an acceptable low risk of the buffer not achieving the intended function.
3. 15 m + enhancing buffer, will provide an acceptable low risk of the buffer not achieving the intended function that is comparable to a non-enhanced 20 m buffer (i.e., a smaller buffer with same function).

Using this approach the recommended Buffer Framework is provided in the attached **Table 7.4.2**. The proposed buffer widths for the NHS are based on the following factors for each Block Area:

- Natural Features and Functions;
- Site conditions of buffer lands;
- Adjacent land use;
- Non-enhanced buffer; and,
- Enhanced buffer.

Other Considerations

To further support the development and enhancement of the buffers and achieve the intended functions, there are additional approaches that can be implemented through the planning process. This includes the early establishment and management of the buffer lands. The following considerations are provided:

- Develop the buffer planting plan and management/monitoring requirements in consultation with the agencies as early as possible.
- Cessation of agricultural use within the buffer lands to allow infill succession through sapling regeneration; this would include an initial management component that encourages the establishment of native woody species through control of herbaceous plant growth.
- Early control of Black Locust in the proposed area for removal and early management in the portion of Black Locust adjacent to the native forest; this is important to prevent the invasion of Black Locust into the buffer lands.

- Complete the vegetation planting as early as possible prior to the construction and build-out phase of the development; this would include the establishment of barrier and sediment/erosion control fencing and regular environmental inspection.
- Continued management and monitoring.

Some grading limits within the buffer can be considered in consultation with the agencies and on a site-specific basis where the protection of the feature and the function of the buffer is not compromised (e.g., any changes in overland flows and drainage do not result in an impact).

Trails

The Natural Heritage Reference Manual (OMNR 2010) recognizes that trails can be a compatible use within buffers. This allows for buffers to be public spaces where users advocate for the areas to remain in a natural state. This also contributes to healthy communities, an appreciation of the natural environment by residents, and provides for natural places that can be accessed by the public that are outside of sensitive natural heritage areas. Public use can also reduce the likelihood of encroachment into buffers from adjacent residents.

It is recommended that trails can be permitted in buffers based on the implementation of the following:

- Low impact design (e.g., gravel substrate or wood chips vs. asphalt) with 2.5 maximum width where the trail is within buffer; trails will not be permitted within 10 m of the woodland features or within 20 m of wetland features.
- Any additional buffer width requirements will be outside of the established buffer, in which case the trail would parallel the edge of the buffer lands (e.g., 2.5 m within buffer and remaining outside).
- Trail alignment to follow along public road ROW where applicable and on the land development side of SWM facilities (i.e., furthest away from the feature).
- Where trails are within the buffer, dense shrub plantings such as White Cedar are to be established on the natural feature side of the trail to discourage side trails and encroachment.
- Provide well marked, designated trail access points in areas where trials enter into buffers.
- Timing of trail construction to consider ecological windows and seasonal weather (i.e., not during wet fall or spring periods) to prevent potential impacts to adjacent features and functions.
- The buffer management and monitoring program is to include parameters that address trail activities and maintenance that recognize the importance of buffer functions.

7.4.2.4 Core Area Crossings

It is recommended that Core Area crossings not be permitted as the Core Areas represent the key features of the NHS and impacts such as fragmentation would result in loss or degradation of functions and direct impacts to species.

7.4.2.5 Verification of Locations and Width of Linkages

A detailed discussion of Linkages between Core Areas is included in **Section 4.9.4.6** and **Section 6.3.3**.

From a location perspective the following factors were considered:

- Existing linkages (primarily associated with riparian habitats and linkages between adjacent features); and

- Potential linkages which take advantage of an existing function that has been identified for terrestrial and aquatic natural features.

Where linkages have been identified to correspond to stream corridors considerations presented in **Section 7.4.3** regarding stream corridor width and location would be key to the consideration of linkages at the EIR stage. In some cases, based on the character of the stream, reaches have been identified that may be relocated. In these cases, the linkage function of these streams would need to be assessed to ensure that the connectivity function is maintained or enhanced (especially with respect to connecting the desired end habitats).

A linkage opportunity could be considered along AM2-1 and AM2-2 although the connection to natural areas west of Trafalgar Road is not strong. The issue of the final routing of watercourses in this area will also be a factor in establishing a link in this area. A general “greenway” is proposed along Tributary C between Block B and C with a width of 10 to 15 m. The purpose of the greenway is to provide an open space that permits accessory uses that may include surface water infiltration, a trail and general landscaping that would support recreational uses. This may also benefit general use for wildlife movement.

7.4.2.6 Crossings of Linkages

Section 6.3.3.4 provides a discussion of the roadway crossings of Linkages. At the EIR stage, site specific review of the characteristics of the Linkage would be requried to evaluate, for example, the need for and design of culverts and bridges (see **Section 7.4.2.3**). Since many of the linkages are proposed to coincide with stream corridors, crossings of the streams would also need to consider aquatic habitat, fluvial, and hydraulic considerations (see **Section 7.4.3**).

7.4.2.7 Wildlife Crossings

This section provides recommendations for wildlife crossings in cases where roads cross linkages. The recommendations are based on the analysis of linkages included in **Section 5.9** in conjunction with the management recommendations for the Natural Heritage System in **Section 6.3.3.4.**

A range of crossing types are recommended. This will include:

- At-grade crossings to allow for movement of larger wildlife such as deer and coyote;
- Signage along roads identifying a wildlife crossing area;
- Management of the road verges to allow for sight-lines allowing wildlife and motorists reaction time to avoid collisions; and
- Culverts associated with road crossings of watercourses, as well as strategically located dry culverts, would be included in these areas.

The culverts would be sized to accommodate predicted flows, as well as to allow dry “benches” and low flow channels within the culverts. The design of these crossings would be detailed at the EIR stage, and would include recommendations for focusing wildlife movements to appropriate crossing locations and/or structures. This could include landscaping, as well as the possibility of fencing. These measures would depend on site specific features and potential collision hazards. Culverts in the range of 1.8m in height with larger spans have been used successfully in other locations for wildlife crossings.

The recommended linkages will initially consist of open habitats and/or riparian habitats in cases where streams are found within the linkage. The narrower band of vegetation along the streams and small pockets of vegetation can provide good quality linkage habitats. This type of existing vegetation can focus wildlife movements, allow for patch to patch movements, and provide a source for the establishment of additional vegetation in the linkage. Linkages associated with watercourses will be planted to Conservation Halton's standards for landscaping within watercourse corridors though their permitting process. Linkages not associated with watercourses may also be planted to Conservation Halton standards to achieve the wooded condition necessary to provide an effective linkage between wooded endpoints.

7.4.3 Natural Heritage System – Streams

The following section presents a summary of the EIR and FSS requirements to ensure that the management strategy is correctly employed for the development of Vision Georgetown with respect to the aquatic components of the Natural Heritage System.

7.4.3.1 Geomorphology

Low Constraint Riparian Corridors

Although not necessary or required (except to maintain drainage density targets), Low Constraint Streams can be maintained as open systems within the subwatershed. The function of all low constraint streams can be maintained through infrastructure and the proposed SWM approach.

Drainage Density Targets

Based on the analysis completed for drainage density targets (**Section 5.6**), results show that the majority of the subcatchments within Tributary A and Tributary C met and/or exceeded the established drainage density targets, but there were a few cases where the density target could not be met. Despite individual basins having a deficit, there is an overall surplus indicating that the incorporation of green streams is not necessary. Tributary B on the other hand, did not meet the drainage density target was short by 0.02km. This deficit can be addressed by preserving sufficient length of green streams and through the establishment of stormwater management ponds.

Riparian Corridor Widths

Meander belt/stream corridor widths were developed on a broad scale and, as such, should be subject to refinement during the EIR stage. This would also determine whether they are the constraining parameter for watercourse extent. For example, the stable slope and toe allowance setbacks will only be required for confined systems (refer to **Figure 5.6.1**). The values would need to be reassessed with any significant change to ultimate flows or watercourse realignments. **Figure 6.3.6** provides a visual reference indicating all of the allowances contributing to the riparian corridor width for unconfined systems, while **Figure 6.3.7** provides a decision making flowchart that outlines the riparian corridor width determination protocol. In some instances terrestrial factors will be the constraining parameter for corridor width (e.g. minimum 60m).

7.4.3.2 Erosion

To ensure that stormwater management practices do not degrade or alter natural stream processes in the receiving channels, SWM facilities need to incorporate the recommended erosion control targets identified in **Section 6.3.5.2** and summarized in **Section 7.4.4.3.** The data collected during the field portion of the study aided in the analysis of stormwater discharge targets and was accomplished using traditional field protocols at the most sensitive reaches downstream of the proposed facilities. The sensitivity is defined based on Rapid Geomorphic Assessments and once the field data is collected, the threshold is determined using empirical approaches. Typically, a shear stress value is appropriate, although depending on the nature of the channel (controlling factors such as vegetation), another approach such as permissible velocity or stream power may be more appropriate. The result should be compared against local values provided within this Subwatershed Study. Erosion threshold assessments were carried out as part of the Analysis report for three reaches deemed sensitive by the RGA scores. The values calculated for these sites can be found in **Table 5.6.4**.

Riparian Corridor Widths

Meander belt/stream corridor widths were developed on a broad scale and, as such, should be subject to refinement during the EIR stage. This would also determine whether they are the constraining parameter for watercourse extent. For example, the stable slope and toe allowance setbacks will only be required for confined systems. Another critical point to consider is whether the reach is to be deepened during the development process to facilitate stormwater servicing requirements. In cases such as these, the meander belt width would not change, but the deepening may trigger the conversion of the reach status from an unconfined system to a confined system. Under these conditions, the riparian corridor width would then be subject to the additional safety factors. In some instances terrestrial factors will be the constraining parameter for corridor width (e.g. minimum 60m).

Tributary B is controlled within a significant valley with a series of smaller tributaries, cutting into the valley wall. The hazard setbacks have been defined considering stable slope setbacks. Further geotechnical works should be carried out at the EIR stage to confirm and/or refine the hazard setback for the main valley and its tributaries. In addition, the diversion of flows at the top of the valley is recommended to mitigate the valley incision that is occurring. Similarly, additional work is required at the Drainage and SWM Master Plan stage (part of the Secondary Plan) and EIR stage to refine the drainage and SWM approach to meet this objective.

As part of the drainage and SWM details that will be developed, it is further recommended that the piped drainage be diverted to the downstream part of the valley (upstream of Eighth Line) and that LID facilities (i.e. bioswales) be discharged to the valley. This flow split should be set to provide flows to maintain the valley characteristics. Details of this are to be developed at the Master Drainage and SWM Plan stage.

Figure 6.3.6 provides a visual reference indicating all of the allowances contributing to the riparian corridor width, while **Figure 6.3.7** provides a decision making flowchart that outlines the riparian corridor width determination protocol.

7.4.3.3 Aquatic Habitat - Fisheries

The management approach for aquatic habitat within the subwatershed area was developed based on the combination of a thorough background review and site-specific field investigations. Reaches that were identified as providing either direct fish habitat or having a contributing function were evaluated based on the management ranking system developed by the study team. Reaches were classified as either Low, Medium or High ranking. Management recommendations based on the ranking system include; Maintaining flow densities for low ranking reaches to continue providing downstream contributions, preserving and/or enhancing functions of medium ranking reaches recognizing the potential need for channel realignment, and preserving, enhancing and protecting high ranking reaches. This approach allows for application of appropriate treatment of aquatic habitat within the subwatershed area.

The EIR assessment is to be conducted at a subcatchment level so that the extent and inter-relationship between reaches can be assessed. This approach to delineating the study area for an EIR forces the inclusion and consideration of entire branches even though they may extend outside a specific landowners' property. The aquatic habitat characterization completed as part of the Subwatershed Study has been a broad based characterization that has grouped habitat into reaches based on homogeneity.

A more detailed assessment and documentation of habitat is required at the EIR stage. The discussion below provides guidance for the assessment of fish habitats at the EIR stage. There is considerable overlap in the various aspects of stream corridor management, and the recommendations/guidance provided in other portions of this report pertaining to hydrology/hydraulics, geomorphology, and SWM must be referred to.

Evaluation and Assessment of Habitat

The evaluation and assessment of aquatic habitats will be completed within the subcatchment study area. Within this area, the stream reaches assessed as part of the subcatchment study area are to be mapped and described. The study will include a review of the factors that lead to the identification of high, medium, and/or low constraint streams.

Aquatic habitats must be mapped at a scale that fosters a clear understanding of the habitat that might be affected as a result of development. To this end, the watercourse edges from top-of-bank to top-of-bank should be confirmed by survey. The wetted perimeter of the stream should also be surveyed at that time. This will provide an appropriate basemap on which to map aquatic habitat.

The mapping of aquatic habitat should build on the reaches that were identified in the subwatershed study, but should assess each of these in more detail. Examples include mapping and delineation of riffles, runs, and pools. The mapping should also identify important habitat features such as in-stream vegetation, boulders, undercut banks and woody debris, and the locations of such features should be clearly shown on the habitat map. If critical life stages of fish or other aquatic biota are being supported by a particular habitat area or feature, the extent of the features should appear on the map. For example, a spawning area or nursery habitat should be clearly shown on the aquatic habitat map.

The habitat map will serve as a basis for future review of individual permit applications for watercourse modification or relocation.

The off-line pond adjacent to reach AM-1 and Eighth Line is deemed to have no redeeming value and can be filled in as part of the final plan, subject to considering the environmental buffer needs for AM-1.

Aquatic Habitat Buffers

The management strategy in the subwatershed study identified recommended buffers for aquatic habitat protection. These setbacks are a minimum requirement for protection of aquatic habitat. The EIR should clearly demonstrate how these aquatic buffers will be implemented. Buffers for the purpose of protecting aquatic habitat were one factor considered in the identification of development limits adjacent to stream corridors. As such, the other factors must also be considered when arriving at a detailed review of buffers from watercourses.

Riparian Corridor Management

The overall management approach for the three types of riparian (stream) corridors as illustrated on **Figure 5.9.1** are summarized in this section. The management approach is also detailed in **Appendix R.**

High Constraint Streams (Red Streams) – The Subwatershed Study identified a number of stream reaches as high constraint streams. In these cases, the reach was deemed by the Study Team to provide current characteristics that suggested the reach could not be relocated. In addition, a number of specific reaches were identified that were recommended for enhancement. In many cases these enhancement areas were recognized based on fluvial needs. In all cases fisheries habitats will be maintained, and in the latter case, enhanced.

The EIR must identify the extent of these reaches. Any enhancement measures for these reaches must also be detailed as part of the EIR. The relationship of these reaches to any medium and/or low constraint reaches must be detailed.

Medium Constraint Streams (Blue Streams) – As noted above, the Subwatershed Study categorized stream reaches such that medium constraint streams could be relocated but the form and function of these reaches must be maintained. Many of these reaches were identified as medium constraint features based on a number of factors, including aquatic habitats.

Since the EIR will be done at a subcatchment level, the details of all channel modifications or relocations may not be detailed at this stage (*e.g.,* due to land ownership). However, at the EIR stage the relationship of proposed modifications/relocations throughout the subcatchment will be documented. The EIR must clearly demonstrate how ecological form and function will be maintained in modified or relocated channels. This analysis must first identify the types and extents of aquatic habitat in the existing channel and then demonstrate how that habitat type and extent will be replicated within the relocated or modified channel. This is anticipated to take the form of typical treatments for channel/habitat types within the area. These treatments are to be developed in consultation with pertinent agency and municipal staff. These plans will include conceptual location(s) for the channels, as well as typical sections of channel and typical cross-sections. At a minimum one typical section for each habitat type to be included in the new channel is required. This section should extend from top-of-bank to top-of-bank and should include details related to substrate type, intended slopes, location of features (*i.e.,* baseflow channel) and proposed vegetative treatment of the channel and banks. Generalized locations of specific habitat features will also be shown (*e.g.,* fish spawning and nursery habitats). These plans will ensure that an integrated approach to channel modifications is taken at the EIR stage. Again, other factors such as hydraulics, geomorphology, and servicing must also be taken into account. These plans will provide the basis for more detailed plans to be completed at the site plan/draft plan stage.

At the draft plan stage, details will be required to obtain permits (such as permits under the Fisheries Act). Any watercourse realignment will require a permit in accordance with Ontario Regulation 162/06, through the appropriate Conservation Authority. The details required must be determined in consultation with the pertinent agencies. The work completed at the EIR stage will provide a conceptual basis for the preparation of plans at the draft plan stage. This could include, but not be limited to, detailed plan views of the relocated channel demonstrating the extent and relative extent of each habitat type is required. This plan view should also show the location of specific habitat structure features to be included in the new channel. It must also show locations of any habitats to be created to provide for a specific life stage activity *(i.e.,* spawning or nursery habitat). A vertical profile of the new channel should also be included to demonstrate how the channel will be built to accommodate the inverts at the upstream and downstream end of the new channel. In addition to the plan views, cross-sections and other landscaping plans should be provided.

Low Constraints (Green Streams) – Green streams are to be maintained as part of an open corridor (greenway) but do not require rehabilitation as a natural stream corridor. Its primary function is to provide open drainage system characteristics to downstream receiving watercourse (either blue or red streams). A SWM pond is acceptable as part of a green stream. The green stream should therefore be a grassed waterway and could take the form as a grassed swale through an easement or roadside ditch. As an open channel, it would provide open channel flow characteristics, by providing sediment and/or potential food source to downstream aquatic habitat reaches. Green streams are to be used to meet the drainage density targets set out in this subwatershed study. If the red and blue stream (and combined or special categories, such as red or blue hatched) in a stream network meet the required target, green streams do not need to be added.

Requirements

There are three distinct flow conditions/functions that must be mimicked or preserved. They are:

- Seasonal or ephemeral flow conditions that provide feeding and refuge migration from the main channel during flood events, refuge pools, and spawning;
- Semi-permanent (or intermittent) conditions that flow in response to most rain events and support some permanent refuge pools; and
- Permanent flow that supports multiple life stages of fisheries resources.
- Technical studies will be required to support these conditions through SWM techniques as follows for each respective flow condition*:*
  - **Seasonal Flow** – Through extended detention outlet connections;
  - **Intermittent Flow** – Through extended detention outlet connection and baseflow protection techniques; and
  - **Permanent Flow** – Through protection of all reaches downstream of two combined tributaries with flow conditions, or any reach with multiple extended detention outlets and baseflow protection techniques that result in permanent flow.

7.4.4 Stormwater Management

The following section presents a summary of the EIR and FSS requirements to ensure that the management strategy is correctly employed for the development of Vision Georgetown with respect to the SWM component of the Natural Heritage/Open Space System. The specific SWM component targets for water quantity, water quality, erosion, and infiltration are summarized below and outlined in the following sections. Refer to **Section 6.3.5.2** for detailed analysis. In addition, the importance of volume control for water quality (particularly phosphorus) has been evaluated in this report and is discussed in **Section 7.4.4.3.**

Water Quantity:	• 2-year to Regional peak flow control required, with no overtopping of emergency spillway
Water Quality:	• Enhanced (Level 1) protection corresponding to 80% of suspended solids removal is required for all lands subject to future land use change • Thermal control for fisheries protection • Salt management to meet source protection requirements
Erosion Control:	• 300 m^3/ha minimum storage for Tributary A, C, D (Sixteen Mile Creek) • 40 m^3/ha minimum storage for Tributary B (Silver Creek)
Infiltration/Retention:	• 10 mm LID unit area retention volume for neighbourhood commercial, institutional, mixed use-mainstreet, mixed use and open space (parks) landuses. • 5 mm LID unit area retention volume along ROWs.
Temperature:	• Coldwater targets for Tributaries A and B, warm water for Tributary C.

SWM Implementation Guidelines

SWM facilities and enhancement techniques will be required to ensure that hydrologic characteristics of the watersheds are maintained and ecological resources are protected. The approximate locations of SWM facilities are shown on **Figure 6.3.8**. A SWM plan must be prepared and included as part of the EIR. The SWM plan must demonstrate that the requirements of the subwatershed plan have been met.

The SWM approach should follow the intent of the revised *Stormwater Management Guidelines* (MOECC, 2003) and the proposed Source Water Protection Act and the SWM requirements in CVC *Stormwater Management Criteria (2012)* in developing an approach for erosion protection and maintaining the flow regime conditions in the catchments. This follows the same principle in the proposed protection of headwater streams. The distributed runoff control (DRC) outlined in the draft guidelines provide the principles for a SWM approach.

The following information will be provided:

- Identification of management objectives and sizing criteria from the Subwatershed Plan;
- Identification of management practices and design considerations necessary to ensure that the subdivision plan conforms to the Subwatershed Plan;
- Identification, screening and design of alternative management practices, based on guidelines provided in *Stormwater Management Planning and Design Manual* (MOECC, 2003);
- Follow SWM requirements in CVC *Stormwater Management Criteria (2012)*;
- Confirm floodplain limits based on detailed site topography and incorporate into survey base plan;
- Identify opportunities to maintain overland drainage to compliment woodlot protection or watercourse enhancement objectives;
- Define major/minor system drainage patterns and contributing areas. Address post development servicing area for the SWM facilities, as well as objectives for minimizing the number of ponds, while achieving practical development timing;
- Confirm that quantity and erosion controls are in place and functioning as required to ensure no adverse downstream impacts. Demonstrate achievement of quantity and erosion controls through the refinement of the post development watershed model on the basis of the conceptual stormwater management strategy advanced in the EIR/FSS. The model is to be updated based on constructible rating curves consistent with the proposed design advanced by the EIR/FSS;
- Confirm thermal mitigation measures to be used to meet thermal targets set regarding downstream watercourse;
- Undertake site specific soil and groundwater investigations to assess the potential for infiltration/groundwater recharge and identify appropriate, feasible Best Management Practices. Identify and determine the relative benefits of other measures, such as lot level measures that could be implemented (i.e. LID practices). The investigation should determine the relative benefits and assess the impacts on the overall water budget and local groundwater conditions (*e.g.,* effects on water table position);
- Documentation in the EIR should address pre and post development conditions, proposed major and minor system patterns, selected SWM technique(s), locations of ponds, preliminary design including outlet characteristics and controls to reduce thermal impacts, outfall locations and relationship to the stream and riparian habitats, erosion, and channel stability with proposed release rates;
- Confirm volume of storage and tributary drainage area, conceptual design of ponds, and pond outlet locations;
- Watershed targets must be met using overall watershed wide criteria, but the local effect events must also be evaluated to ensure that the ponds are designed so that they will not be at risk due to locally intense events (*i.e.,* AES Chicago events). Unit area flow targets are summarized in **Table 7.4.3**.

- Demonstrate how storm sewers work in conjunction with pond operating characteristics;
- Demonstrate that development conforms to criteria established for quantity control;
- Identification of a monitoring program necessary to demonstrate that the SWM facilities are performing as designed and the water quality and quantity targets are being met;
- Provide for innovative SWM (including source control and protection of headwater swale systems, LID principles) to protect headwater stream functions and infiltration to meet LID retention target;
- Demonstrate infiltration management, particularly in areas that are highly pervious, for protection of flow regime conditions, and fisheries protection (*i.e.,* baseflow);
- Documentation on adherence to criteria related to fish habitat, extended detention, infiltration, erosion and sedimentation control, regional storm flood control and use of swales and artificial wetlands for water quality enhancement;
- Sediment and erosion control plans; and
- Operation and maintenance manual for proposed facility.

7.4.4.1 Water Quantity

Runoff peak flow rate attenuation will be required on all new development. New development shall not increase the risk to public safety or increase the risk to property damages. Public safety refers to the risk to the loss of life and the loss of property from floodwaters and erosion.

New development (without SWM) increases the volume and peak flow rate of runoff while reducing the amount of infiltration and evapotranspiration. Increases in peak flow rates, if unattenuated, will increase the frequency of road/rail crossing overtopping, increase flood levels along the watercourses, and increase flood damages. Runoff increases resulting from new development must be attenuated to prevent increases to the risk of life and property damages.

Runoff attenuation will be required for all frequency events including the 2 through 100-year return periods and the Regional storm. Peak flow rates for each event will be calculated using an unit area flow rate approach. The allowable release rate from a new development for a particular return period will be determined by multiplying the drainage area by a unit area flow rate. **Table 7.4.3** summaries the unit area flow rates (L/s/ha) for the regional SWM facility control area catchments, based on the current proposed development concept plan. All new developments within the upstream watershed will use the same unit area flow regardless of the location within the watershed. Existing condition unit flow rates (L/s/ha) are also provided in **Table 7.4.3**. The post-development conditions for the final SWM servicing strategy (including regional SWM facility control areas, uncontrolled development areas, natural corridor areas, and external areas) must not exceed existing unit flow rates (L/s/ha).

Table 7.4.3 Unit Area Flow Targets (L/s/ha)

Contributing Catchment	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	Regional Storm
Post-Development Conditions Unit L/s/ha Rate - Regional SWM Facility Control Areas							
A	2.4	12	23	42	49	50	53
B	1.6	1.7	13	23	23	24	27
C	1.7	4.0	13	30	36	37	41
D[2]	6.6	20	37	38	39	40	43
E[3]	3.5	9	9	10	10	10	11
Existing Condition Unit L/s/ha Rate – Total Area							
A	4.5	9	16	25	33	41	90
B	1.0	7	16	30	*37*[1]	*43*[1]	54

Contributing Catchment	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	Regional Storm
C	2.8	10	19	32	43	55	82
D	12	31	47	70	89	109	116
E	11	28	42	63	80	98	112

1. *CVC's GAWSER existing condition unit flows from CVC Peak Flow study (2003), applied were Gawser flows are less than SWMM5 modelled existing flows.*
2. *Pond D1 has been controlled to the assumed allowable release rate to the downstream by-pass pipe of the Fernbrook Phase 3 development, at 0.47 m^3/s*
3. *Pond E1 has been controlled to the assumed allowable release rate to the existing culvert crossing of Side Road 10 (Structure #22) at 0.16 m^3/s*

Allowable peak flow rates for the Regional SWM Facility Control Areas is based on maintaining downstream peak flow rates, and accounts for the timing and peak flows from uncontrolled areas, natural corridors, and external areas as shown on the current concept plan (**Figure 6.3.8**).

Due to capacity constraints in existing downstream infrastructure, provided through the Fernbrook Phase 3 development, it is noted that for Tributary D, Catchment D-1 and D-2 (10.6 ha) have been controlled to the assumed allowable release rate to the downstream by-pass pipe of 0.47 m^3/s, and Catchment D-3 (19.0 ha) has been diverted to Tributary A, via discharge to the regional SWM facility PondA1. It is also noted that Tributary E (Catchment E-1) has been controlled to the assumed capacity of the existing culvert crossing of Side Road 10 of 0.16 m^3/s. Diversions from one watershed to another will not be allowed unless there are equal offsetting diversions.

It is noted that uncontrolled development areas have been delineated based on the condition that not all areas of the proposed development can be serviced by a regional facility due existing grade constraints. Refer to **Figure 6.3.8**. For Tributary A and C, minimum capture facilities are required for catchment A-5_Unc2 (2.3 ha) and C-1_Unc1 (2.4 ha) to control to the 5-year storm event. For Tributary B, a minimum capture facility is required for catchment B-1_Unc1 (5.2 ha) to control to the 10-year storm event to meet pre-development flows. Runoff from this catchment area may be controlled through enhancements to the existing filter bed SWM facility located in the southeast corner of Eighth Line and 15th Side Road. Future servicing studies may investigate other quantity/quality control facilities to manage runoff from uncontrolled areas using source controls, small scale BMPs and potential diversions to a Regional SWM facility.

The EIR will document existing conditions peak flow rates using the unit area flow rate approach, unattenuated peak flow rates based on new development, and peak flow rates from the proposed mitigation measures.

7.4.4.2 Water Quality

Maintenance of a healthy aquatic ecosystem requires that predevelopment water quality be maintained or enhanced. Water quality treatment to achieve Enhance (Level 1) protection corresponding to 80% of suspended solids removal is required for all lands subject to future land use change to maintain the existing receiving water aquatic habitat.

The modelling is carried out in **Section 6.3.5** demonstrates that, for the most part, an enhanced level of control will meet the water quality targets for TP and SS. TP is exceeded for two of the catchments. However, the modelling does not take recommended LID applications into account. At the Master Drainage and SWM Plan stage, and use will have been further defined and LID can then be considered in more detail. A that stage, the application of LID, should be analysed in more detail to ensure that water quality targets are being met.

Hierarchy of SWM Measures

The implementation of SWM measures should be done in a sequence that recognizes the hierarchy of preferred measures. The hierarchy is based on the following principles:

- Preference for measures located at the source on the lot level (LID) for quantity controls and that incorporate pollution prevention concepts for quality control;
- Preference for measures that satisfy more than one objective, such as infiltration and baseflow protection, as well as flow reduction and quality control;
- Preference for measures at source and in the conveyance system that take advantage of natural systems that reduce flow volume and filter out pollutants such as surface detention (i.e. bioretention, bioinfiltration, rain gardens); and
- Preference for measures that reduce the size of end-of-pipe structural measures.

Meeting Total Suspended Solids and Total Phosphorus Targets

The TSS and TP targets should be considered together, along with infiltration goals. The preferred approach is to consider source controls first, then conveyance, and finally end-of-pipe controls.

A step-by-step procedure for calculating targets for a developing area, and evaluating the degree to which control measures meet targets, is presented in **Appendix T**.

Summary of Step-by-Step Procedure

1. Establish phosphorus target for the area beings developed:
   - Step 1 – Calculate runoff volume for the undeveloped area;
   - Step 2 – Calculate TP target based on the pre-development load;
   - Step 3 – Calculate post development runoff volume and TP load;
2. Account for infiltration measures at source (LID) and in conveyance system and the degree they meet infiltration targets (Step 4);
3. Account for surface retention measures that reduce overall flow and TP load reduction (Step 5);
4. Account for end-of-pipe stormwater ponds to meet TSS targets (sized for the reduced runoff) for the watershed, and account for the TP load reduced as well (Step 6);
5. If TP targets are not met with the combined measures, repeat the process with additional control (Step 6 plus):
   - Upgrade the end-of-pipe pond to remove more TSS and TP;
   - Add additional infiltration or surface retention measures; and
   - Add additional structural measures to remove TSS and TP, either in the conveyance system or end-of-pipe.

7.4.4.3 Erosion Control

In order to ensure that stormwater flows post-development are controlled and released in such a manner that existing channel erosion or aggradation is not exacerbated by land use change, all proposed development areas need to incorporate the recommended erosion control volumes identified in **Section 6.3.5.2** and summarized below**.**

- Tributary A, C, D and E: 300 m3/ha minimum storage (Sixteen Mile Creek), released over 24 – 48 hours
- Tributary B: 40 m3/ha minimum storage (Silver Creek), released over 24 – 48 hours

Further analysis carried out at either the Master Planning or EIR stage should confirm that quantity and erosion controls are in place and functioning as required to ensure no adverse downstream impacts. Demonstrate achievement of quantity and erosion controls through the refinement of the post development watershed model on the basis of the conceptual stormwater management strategy advanced in the EIR/FSS. The model is to be updated based on constructible rating curves consistent with the proposed design advanced by the EIR/FSS. This analysis is required to confirm and mitigate erosion impacts of potential diversions of Tributary D to Tributary A, upstream of Eighth Line.

7.4.4.4 Hydrogeological

One of the stated goals for the subwatershed study is to develop a plan that guides the planning of future land use planning, infrastructure, and resource development while protecting and enhancing the environment. From a hydrogeological perspective, the goal is to protect and enhance groundwater quantity and quality in the Study Area.

Within the Natural Heritage System areas and other features such as Public Parks, it is expected that there will be little to no impact on infiltration quantity after development of the surrounding areas. In areas where infiltration will be reduced, it is recognized that, because of the low hydraulic conductivity of the soils in the area, the goal of maintaining pre-development infiltration may not be met. To mitigate the recharge deficit and provide partial erosion control the following LID controls are recommended:

- 10 mm LID unit area retention volume for neighbourhood commercial, institutional, mixed use-mainstreet, mixed use and open space (parks) landuses.
- 5 mm LID unit area retention volume along ROWs.

It is noted that additional retention targets may be required to mitigate erosion impacts due to potential stormwater diversion from Tributary D to Tributary A, and is subject to the servicing design advanced by the EIR/FSS.

LID options are available (TRCA, 2013) and best efforts must be used to achieve this goal. The proposed LID controls are recommended along non-residential lands to ensure the long term operation, maintenance, and replacement of LIDs. LIDs on private residential properties are encouraged but have conservatively been omitted for the purpose of the SWM strategy impact analysis.

Future development in WHPA-Q1/Q2 will be subject to, for example, measures to mitigate or compensate recharge reductions (i.e., LID, off-site compensation, storm water controls) or additional hydrogeological study (at the site plan stage) to demonstrate that site recharge function, surface water flows and permitted municipal water takings can be maintained.

To achieve the stated objectives, the following steps must be taken:

- Confirm existing hydrogeological conditions in each subwatershed/catchment area, including the stratigraphy, the estimated infiltration, the depth to water table, local groundwater flow direction, and areas of recharge and discharge.
- Develop a local water balance and determine acceptable and achievable local infiltration and recharge targets.
- Specifically address groundwater quantity and quality within the WHPA, WHPA-Q1/Q2 and ICA (chloride), where applicable.
- Use the site specific details to determine the opportunities and measures within each catchment and/or subwatershed for maintaining and enhancing infiltration. In the analysis, special consideration is to be given to the site specific areas that have been identified as either observed or potential seepage (or

creek discharge) areas, as illustrated on **Figure 4.4.6** and **Figure 4.4.7** and recharge areas in **Figure 5.4.5**.

- Infiltration measures could include the use of various area wide measures such as infiltration along the alignment of storm sewers and enhanced infiltration techniques at SWM facilities or lot level measures such as the discharge of roof leaders to lawns and gardens.
- If infiltration within a specific catchment area cannot be maintained, identify other areas in the subwatershed where measures can be taken to augment or enhance infiltration to, at least in part, make up the infiltration deficit. Determine related changes in the groundwater flow regime and how the changes will affect stream flow, the local water table, and groundwater quality.
- If the impact assessment indicates that recharge in a significant groundwater recharge area will not be maintained, amend the development plan to address this assessed impact (this requirement is subject to review of the final Source Water Protection Policies).

Should infiltration targets not be maintained, the impact on the Study Area baseflows and the local water table must be predicted and mitigation measures suggested, if warranted.

Approved Source Protection Plans may include revised threat areas and policies that necessitate different interpretations. It is recommended that the most up-to-date versions of policy documents be consulted on the Source Protection Region websites for requirements on land use planning.

7.4.5 Servicing Studies

Overall master planning is being carried out as part of the Secondary Plan to provide direction as to the overall servicing approach (Roads, Water, Sanitary, Stormwater Drainage, and Management) including layout of a master planning level. These studies are intended to provide overall direction in carrying out Draft Plan preparation and detailed servicing design.

During the preparation of an FSS and detailed design, consideration must be given to the objectives, targets and intent of the management strategy. The items to be included in servicing studies include:

- Any underground services must consider hydrogeologic functions/characteristics and must preserve and enhance these functions and characteristics as follows:
  - Protection of groundwater source to terrestrial features;
  - Protect and enhance wetland features (*i.e.,* maintain groundwater levels);
  - Protect and enhance baseflow to streams;
  - Protect groundwater quality;
  - Enhance groundwater recharge (*i.e.,* use of perforated storm sewers);
  - Dewatering measures will require a water taking permit (registration in the Environmental Activity and Sector Registry or Permit to Take Water) when volumes are greater than 50,000 L/day;
- It is recognized that some stream systems (blue and green) will need to be lowered to provide for servicing. This should be designed to meet the aquatic/stream objectives for protection and enhancement;
- Road designs should be developed in a manner to meet any site specific wildlife linkage objectives. This should include consideration of road cross-sections that will provide for wildlife crossing objectives;
- Any road design should minimize the road length parallel to the NHS and to cross any watercourse of right angles wherever possible;
- Any SWM facility design should facilitate the proposed monitoring plan; and

- Designing servicing to result in a “no net change” to the hydrological and hydrogeological conditions within the Subcatchment Area.

7.5 Monitoring Strategy

7.5.1 Principles of Monitoring Program

Traditional master drainage planning has evolved since the 1970's into the comprehensive subwatershed planning now practiced. The concerns addressed have increased the complexity and scope of the studies from quantity control for flood and erosion protection, with the addition of many issues such as water quality, aquatic biota and habitat, and geomorphology. Monitoring has been included in the more recent studies as an integral part of implementation. The *Subwatershed Planning Report* (MOECC and MNR, 1993) stated the following:

“A subwatershed plan cannot be considered complete until its monitoring program is established. Monitoring programs should be designed to assess environmental changes in the subwatershed, to evaluate compliance with the plans, goals and objectives, and to provide information which will assist custodians of the plan to implement it and update it. The monitoring program should be presented as part of the subwatershed implementation plan.”

Monitoring is now considered as a necessary continuation of the subwatershed plan, designed to evaluate the need to review or update subwatershed plans, or to trigger the implementation of contingency plans that may include remedial measures needed to achieve the subwatershed goals and objectives. The following principles are proposed as the basis of the monitoring framework.

1. Monitoring must be directed at fulfilling one or more objective sets, be subject to analysis and lead to potential actions.
2. Monitoring of receiving streams should be for identifying problems, establishing a background reference, and evaluating the effectiveness of controls.
3. Technology performance monitoring should be to confirm that SWM facilities operate as designed, and if not, determine if remedial design improvements or maintenance are needed. This will assist in improving future designs.
4. An ideal monitoring program should be directed at connecting receiving stream impact analysis with technology performance assessment in a watershed context.
5. The strategy should recognize and incorporate existing monitoring programs, for example protocols already in use by Conservation Halton for monitoring ecological parameters.
6. Reporting on results and taking appropriate follow up action is a key component that fulfils due diligence expectations.

7.5.2 Erosion and Sediment Control (ESC) Planning

Future construction activities taking place in Vision Georgetown will require clearing of vegetation, topsoil stripping and earth grading that leaves exposed soils vulnerable to wind and water erosion. Stringent sediment and erosion control measures will need to be implemented to ensure that the adjacent natural heritage system is not negatively impacted by construction practices. Sediment release due to construction activities is not only detrimental to the health of the receiving NHS but will also result in costly future maintenance work of the existing downstream drainage infrastructure.

Prior to construction, comprehensive erosion and sediment control (ESC) plans must be submitted to the Town and Conservation Authority detailing the methods that will be used to prevent the release of sediment laden runoff from the construction site. There are extensive sediment and erosion control guidelines available that describe the design considerations, application and function, implementation procedures, maintenance procedures and removal procedures for a wide variety of sediment and erosion control measures for construction sites. The following is a list of existing guidelines currently used in Ontario:

- *MOECC Stormwater Management Planning and Design Manual (2003);*
- *CVC Stormwater Management Criteria (2012);*
- *MNR Technical Guideline: Erosion and Sediment Control;*
- *MTO Drainage Management Manual (1995 – 1997);*
- *Erosion and Sediment Control Guidelines for Urban Construction (2011); and*
- *TRCA Perserving and Restoring Healthy Soil: Best Practices for Urban Construction (2012); and*
- *MTO Highway Drainage Design Standard (2008).*

The *Erosion and Sediment Control Guidelines for Urban Construction* has been prepared by Greater Golden Horseshoe Conservation Authorities. In order to develop the most effective ESC plans for Vision Georgetown, these guidelines must be consulted before submission of an ESC plan. The comprehensive checklists provided in these guidelines are specifically designed to assist developers, contractors and inspectors with developing and implementing effective ESC plans.

Typical sediment and erosion control best management practices currently in use today include but are not limited to:

- Sediment traps, dewatering traps;
- Compost filled filter socks;
- Sediment control fencing;
- Check dams;
- Inceptor swales and ditches;
- Temporary stabilization measures of exposed soils (erosion control matting, seeding, hydro seeding, and mulches);
- Construction mud mats;
- Protecting surface inlets with filter cloth; and
- Applying water to control dust and wind erosion.

In order for these measures to be truly effective, they will need to be monitored regularly by the contractor to ensure that these measures are maintained in proper working order throughout the construction phase and until the site has become fully stabilized.

7.5.2.1 ESC Inspection

Section 6.4 provides details of the inspection requirements for during construction monitoring. **Appendix U** provides sample checklist style report that the contractor can fill out and submit the Town of Halton and Conservation Authorities as part of the inspection and monitoring program.

7.5.2.2 ESC Monitoring

Section 6.4 provides details of the water quality monitoring and reporting required during construction. Monitoring data will be submitted to the Town as hard copy and digital format. The data will be inputted into a database that will provide details regarding construction start and end dates, construction site area, what watercourse(s) to which the site drains, date when the construction site has become 100% stabilized, number of rainfall events, types of BMP's used, frequency of maintenance.

The database will be used to monitor construction activities and to help set targets that will trigger inspections and when maintenance is required. The data collected will be used to measure the effectiveness of different BMP practices.

7.5.2.3 Construction Site Dewatering

Typically, after heavy rainfall events construction sites require dewatering in order to proceed with work. Dewatering measures will require a water taking permit (registration in the Environmental Activity and Sector Registry or Permit to Take Water) when volumes are greater than 50,000 L/day. Dewatering may involve pumping water or constructing scratch ditches or channels to drain water away from construction areas. It will be very important to ensure that sediment laden water will not be released into the receiving NHS as a result of dewatering operations. Energy dissipation, large particle sedimentation and filtration of finer materials will be required through the use of effective measures. Water quality samples will be required during dewatering operations to measure the TSS concentrations of runoff leaving the site and evaluate the effectiveness of the dewatering measures.

7.5.3 Monitoring Parameters

A major component of a subwatershed plan is SWM. It usually results in the construction and operation of built works such as stormwater ponds, conveyance features, and infiltration facilities. These facilities are typically designed to meet some receiving water objectives such as flood control, channel erosion control, water quality protection/improvement, habitat protection, and protection of biota, including fish. Therefore, monitoring may involve biological, physical habitat, and water quality and quantity parameters that may be in-stream or at other locations.

In-stream monitoring parameters can be either specific constituents or surrogates. The specific parameters are typically related directly to the objective or use being protected, whereas, for SWM facilities, indirect parameters or surrogates are often used as indicators when monitoring system performance. In other words, different parameters will have to be identified and monitored to evaluate the system effectiveness in-stream and performance in the facility. The effectiveness is measured by comparing the monitoring results to the targets established for the parameters for each objective. **Table 7.5.1** illustrates this point. Monitoring in a watershed for the facility and watercourse elements will take advantage of the common elements for all objectives (*i.e.,* rain, flow, water quality, and toxicity data). Objective specific data will have to be collected for erosion control, and aquatic habitat and biota.

For the Southwest Georgetown Subwatershed, two types of monitoring programs are proposed:

1. Performance assessments of SWM facilities, and
2. Watershed effectiveness assessment.

Table 7.5.1 Monitoring Parameters for Stormwater Management Objectives

Objectives	Flood Control	Channel Erosion Control	Water Quality Improvement	Habitat/Biota Protection
SWM Facility	Rainfall, peak flow rate, water level, flood flow routing, draw down time	Rainfall, flow rate and duration, water level	Pollutant removal efficiency, sediment accumulation, temperature	Discharge water quality, toxicity, temperature
Watercourse	Peak flow rate, water	Flow rate and duration,	Water quality improved?	Habitat parameters

Objectives	Flood Control	Channel Erosion Control	Water Quality Improvement	Habitat/Biota Protection
	level, property damage	water level, bank erosion, channel modifications stable, velocity, bed substrate, bank recession, down cutting of channel, bank vegetation	Provincial Water Quality Objectives met? Subwatershed targets met?	/indices (including physical parameters), toxicity, macro invertebrate indices/fish health indices, and biomonitoring.

7.5.4 Performance Assessment Monitoring for Stormwater Facilities (Table 7.5.2)

Objectives

- Determine whether performance of control facility meets design objective.
- Can facility be assumed from developer?
- What level of continued monitoring and maintenance are needed?

Following construction, each facility should be inspected and compared to the design by Municipal staff to ensure compliance and a monitoring policy should be implemented. The facility should be monitored for compliance during construction for a minimum period of five years following complete build-out under the ownership of the developer. A monitoring report should be provided to the Town, Region, and Conservation Authority (two per year) for the five-year period. Responsibility for, and ownership of, facilities would be assumed by the Town of Halton Hills after a period of five consecutive years of monitoring that confirms the targets and objectives have been met.

Should the monitoring show non-compliance, the developer would be responsible for implementing the contingency plan/remedial measures and continued monitoring until the monitoring confirms compliance for three consecutive years.

A protocol for monitoring that could be followed by the developer is attached (**Appendix U**). It is recommended that the Town of Halton Hills require the protocol be followed by developers prior to the Town assuming the ownership and operation of the end-of-pipe SWM facilities).

Analysis

- Operations Monitoring
  - Compare infiltration, flood control and quality control pond hydraulics to design specifications for flow splitting, volume controlled, drawdown time, and released flow rates. Compare total capture to expected volumetric control level. Compare quantity control hydrology to what was expected as the modelled performance. May need to apply models for some analysis steps. Calculate removal rate efficiency of parameters and compare to established targets.
- Maintenance Monitoring
  - Observe or measure sedimentation in channels, sediment build-up in ponds, berm erosion, litter build-up, clogging of inlet and outlet structures, free operation of moveable control elements, health of wetland plants, pond security, and gratings.

Contingency Plan/Remedial Action

Table 7.5.2 Performance Assessment Monitoring for Stormwater Facilities Contingency Plan/Remedial Action

Result	Remedial Action
• Facility built and functioning as designed.	• Town assumes facility from developer.
• Facility outflows and drawdown rates not as specified.	• Modify pond hydraulics – continue monitoring until facility meets flow targets and can be assumed from developer.
• Litter build-up; shore erosion.	• Maintain pond.
• Sediment build-up greater than 5%.	• Remove sediment build-up.
Result	**Remedial Action**
• Performance less than specified.	• Retrofit additional controls in pond or upstream in drainage area – continue monitoring until facility meets targets and can be assumed from the developer; modify design and/or targets for future similar cases.

7.5.5 Effectiveness Assessment Monitoring (Table 7.5.3)

Proposed Program

Following stream modification and land development construction period, each stream course should be inspected by Municipal staff to determine whether targets are being met. The stream should be monitored for compliance during construction and for a minimum period of five years following complete build-out by the developer. A monitoring report should be provided to the Town, Region, and Conservation Authority twice per year for the five-year period. Responsibility for future monitoring would be assumed by the agencies after five consecutive years of monitoring confirms the targets and objectives have been met. Should the monitoring show non-compliance, the developer would be responsible for implementing the contingency plan/remedial measures and continued monitoring until the monitoring confirms compliance for three consecutive years.

Objectives

- Determine effectiveness of measures (upstream control facilities) in-stream.
- Flow rates not increased over pre-development (flood and erosion objective).
- Flow velocities (impulse) not increased (erosion control objective).
- Maintenance of baseflows.
- Channel and bank erosion not increased.
- Water quality maintained or improved.
- Aquatic habitat conditions acceptable.
- Biota diverse and healthy.
- SWM discharge meets various specified standards as listed in **Table 6.3.21**.

Analysis

- Compare observed conditions to Subwatershed Study results. Reference can be to upstream control, or pre-development conditions at the same site or to a parallel site. Also compare to published standards, (*i.e.,* PWQO), or chronic toxicity criteria. Finally, compare to Subwatershed targets.

Contingency Plan/Remedial Action

Table 7.5.3 Effectiveness Assessment Monitoring Contingency Plan/Remedial Action

Result	Action
• Flow targets not met.	• Apply remedial measures in stream to modify channel to handle higher flows; additional controls on flow for SWM ponds.
• Water quality targets not met; signs of toxicity in biota.	• Apply additional controls upstream by retrofitting measures at existing sites; add SWM measures to uncontrolled drainage; add pollution prevention measures to control specific parameter not meeting targets
Result	**Action**
• Habitat degraded.	• Improve stream habitat; consider if source of the problem is flow related and modify flows.

7.5.6 Monitoring Program

7.5.6.1 Hydrology

Performance targets from the monitoring should include minimal reduction in the entrenchment ratio to ensure the channel does not become incised and functionally removed from its floodplain. Bank erosion or migration should not exceed a rate of 10cm/yr and cross-sectional areas should experience no more than a 10% increase over the annual monitoring period. Additionally, substrate sizes should not vary more than half a standard deviation from the current D50.

Flood Protection

The monitoring strategy is to measure streamflow on a continuous basis at two locations within the study area. The streamflow measurements will be located along Eighth Line for Tributaries A, B and C.

Streamflow measurements will allow the calculation of annual peak flow rates as development progresses within the study area. Peak flow rates will determine if the *Implementation Strategy* has been successful. If peak flow rates increase, modifications may be required to the outlet works of the SWM facilities. In addition, continuous streamflow measurements will allow the determination of flow duration curves, baseflows, and annual runoff volumes.

Table 7.4.2 provides the target unit area peak flow rates for the existing land use.

7.5.6.2 Hydrogeology – Groundwater Monitoring

Changes to the groundwater regime are usually difficult to observe and quantify. The impact assessment completed for the Study Area indicated that future development could result in a reduction in baseflow/groundwater support to Tributaries A, B and C. Groundwater contributions to these features are an important factor in their ecological health and function. Therefore, for stream reaches where there is currently an observed or interpreted groundwater discharge, future monitoring should be done as an overall measure of stream health. This would focus on stream flow and the aquatic habitat function of the reach. No specific groundwater monitoring is proposed.

Because year to year variations in the condition and function of these tributaries are expected, the tracking and comparison of long term observations to both historical observations and predicted changes will enable a determination of the overall success of the management plan. Should significant variations occur that affect the health and function of the tributaries, opportunities for implementing alternative mitigation measures can then be explored.

In addition to the stream/habitat monitoring, the water table elevation should also be monitored. This could be accomplished by a continuation of the regional monitoring program currently conducted by Halton Region, which includes monitoring wells in the Study Area. These wells should be monitored at least semi-annually during periods of high and low water table (after spring melt and in late summer). As there are relatively large seasonal and year to year fluctuations in the water table, collected monitoring data should be compared to the existing baseline data to evaluate these fluctuations before conclusions are made regarding long term water level impacts, related to development in the Study Area.

In addition, it is recommended that Halton Region review the monitoring program established for the Georgetown Municipal wells WHPA sentry wells as it relates to development in the study area. Water quality monitoring at these wells should be conducted to identify any impacts to water quality, particularly chloride, which has been identified as an issue for the Cedarvale municipal wells.

7.5.6.3 Water Quality Monitoring

The water quality monitoring program is to be based upon the objectives and targets established, and management approach for water quality conditions as outlined in **Section 6.3.5.** The parameters to be included are:

- Chloride;
- Total Phosphorus;
- Metals (cadmium, copper and zinc);
- Nitrates;
- Total Suspended Solids;
- Dissolved oxygen;
- Conductivity; and
- Water temperature and pH.

It is recommended that water quality be monitored at the proposed streamflow monitoring sites, i.e., the main branch of Silver Creek at Eighth Line Street and 16 Mile Creek at Eighth Line Street, tributaries monitored in the 2013 study (SWG-B1 on Silver Creek, and SWG-A3 and SWG-C1 on 16 Mile Creek), as well as downstream of stormwater management ponds.

Monitoring should be initiated at least one-year prior to land use changes to ensure that representative baseline information is obtained. The monitoring program should include nine rainfall events for the first year (to collect additional base information and establish event mean concentrations), followed by three rainfall events per year for each consecutive year. It is recommended to use automated flow-weighted samplers for monitoring of rainfall events at the two main stations. A temperature probe should be used to record water temperature at regular intervals (15-30 minutes). Other stations may be monitored using grab samples. Three dry weather events should also be monitored by collection and analysis of grab samples in each year including the first year.
The recommended plan provides a framework for carrying out monitoring, however further details could be developed as implementation is carried out. The monitoring plan should be linked to the current monitoring program for the Town and Conservation Halton.

The agency monitoring responsibilities are outlined in **Section 7.7.**

7.5.6.4 Terrestrial

The terrestrial monitoring program discussed in **Section 6.4** of the management strategy is focused on detecting potential changes in habitats as well as plant and wildlife populations in the study area. Since natural systems are dynamic, the monitoring program will seek to identify a range of changes in the system. These will include:

- Maintenance of existing natural habitats, such as mature woodlands and swamp communities, and wildlife populations;
- Successional changes in habitats, especially early and mid-successional stages;
- Changes in species occurrence and/or composition (i.e. invasive species); and
- Success of restoration measures including natural vegetation on abandoned agricultural lands.

The natural systems in the Southwest Georgetown area are described in detail in the Subwatershed Study. From this characterization it is clear that there is a diversity of species and habitats that limit the ability to undertake monitoring of all components. Therefore the monitoring is focused on a number of factors/features that:

- Are readily measurable;
- Are sensitive to changes; and
- Have accepted, standardized monitoring methodologies.

This latter item allows the monitoring within the area to be integrated with other monitoring programs that are widespread throughout Ontario, and can therefore be used to compliment these growing provincial databases and can draw on the results of these widespread monitoring programs to assist with interpreting local changes.

Vegetation Communities

Vegetation monitoring can occur at two levels: (1) at the species composition level and (2) at the community level. Numerous vegetation monitoring programs are in place throughout Ontario which use species composition. In many cases these protocols rely on extensive species level assessments and repeated sampling of plots over time. The ultimate interpretation of the changes in species composition can be cumbersome and in some cases less sensitive to changes in the characteristics of the habitat in question. This can be due to a number of factors such as wide species tolerances, and variation in growing season characteristics. Typically this type of monitoring would be focused on restoration or sensitive systems as identified as part of detailed environmental analyses at the EIR or Draft Plan stages.

On the other hand, monitoring changes in general vegetation community composition and boundaries will assist in detecting changes as a result of natural succession, as well as potential impacts as a result of development. The use of the standardized Ecological Land Classification (ELC) system allows for the review and monitoring of vegetation community composition and boundaries over time. This approach has been used in a number of similar studies in which the extent of vegetation communities has been monitored using field surveys and/or aerial photography. This level of monitoring can be readily completed at a subwatershed level as part of an overall performance monitoring program or at the EIR or Draft Plan stage.

Wildlife

Wildlife monitoring is recommended to consist of breeding bird surveys as well as amphibian monitoring. These two groups of species are fairly readily monitored and are sensitive to changes in habitats and potential impacts of development. Standard monitoring protocols are in use throughout southern Ontario and can be used to track changes in species overtime.

- **Birds –** The Ontario Breeding Bird Atlas protocol should be used to monitor breeding birds at strategic locations in the study area.
- **Amphibians –** Early spring call surveys following the standard Marsh Monitoring protocol should be conducted at strategic wetland areas.

The need for monitoring terrestrial features could be triggered at a number of levels, as summarized in **Table 7.5.4**.

7.5.6.5 Fisheries

The fisheries monitoring program is to be further refined based on the management requirements that were established in **Section 6.3**. As identified in **Section 6.4** the following components should be included in the on-going monitoring program for the study area:

- Riparian vegetation
- Water temperature
- Suspended solids
- Biodiversity
- Aquatic habitat

The monitoring components identified in **Section 6.4** will overlap with several other disciplines including terrestrial, water quality, hydrogeology and fluvial geology. As such, while the fisheries monitoring program is refined during future stages of the planning process there will need to be coordination with related disciplines to ensure a fulsome program is developed and to minimize overlap.

The recommended monitoring should be used a framework to develop a detailed monitoring plan and will require refinement as the process moves forward. Generally, all components of the fisheries monitoring program should be carried out on an annual basis with baseline monitoring being conducted one year prior to development at a minimum. Depending on the component and final monitoring program design, the frequency of monitoring events could be continuous, seasonal or event based. The exact location of monitoring will need to be identified once a development plan has been created but should be strategically selected to confirm the function of the recommended target and objectives.

As discussed by the terrestrial component the need for monitoring has the potential to be triggered throughout the planning process and is discussed in **Table 7.5.4**.

Table 7.5.4 Summary of Terrestrial Vegetation and Wildlife Monitoring

Level		Woodlands	Wetlands	Hydrologic Features	Linkages	Riparian Habitats	Successional Habitats	Trigger or Focus	Frequency
Subwatershed	Vegetation	• Use of air photos and ELC mapping to determine the extent of woodland cover and composition	• Use of air photos and ELC mapping to determine the extent of wetland cover and composition	• N/A (may be covered by wetlands monitoring)	• Use of air photos and ELC mapping to determine the extent of vegetation cover and composition within linkage area (see riparian habitats)	• Use of air photos and ELC mapping to determine the extent of vegetation cover and composition within linkage area (see linkages habitats)	• Use of air photos and ELC mapping to determine the extent of vegetation cover and composition	• This monitoring would be based on the generation of current air photos. Normally this monitoring would be completed at regular intervals for large portions of the subwatershed area. • Generally the focus of this level of monitoring would be to detect overall habitat at a coarse scale one-year (minimum, or see below).	5 years
	Wildlife	• Use of standardized breeding bird and amphibian monitoring protocols	• Use of standardized breeding bird and amphibian monitoring protocols	• N/A (may be covered by wetlands monitoring)	• Use of standardized breeding bird and amphibian monitoring protocols	• Use of standardized breeding bird and amphibian monitoring protocols	• Use of standardized breeding bird and amphibian monitoring protocols	• A regular wildlife monitoring program at the subwatershed level is not anticipated. Use of volunteers or organizations to conduct periodic monitoring could occur or monitoring via province-wide breeding bird or marsh monitoring programs is encouraged.	5 years
EIR	Vegetation	• Use of air photos, groundtruthing, staking of existing dripline, with ELC mapping to determine the extent of woodland cover and composition • Photographic inventory of edge conditions recommended.	• Use of air photos, groundtruthing, staking of existing edges, with ELC mapping to determine the extent of wetland cover and composition. • Photographic inventory of edge conditions recommended	• See wetlands	• Groundtruthing, and ELC mapping to determine the extent of vegetative cover and composition. • As these are likely to be predominantly restoration or successional areas, establishment of monitoring plots or photographic inventory is recommended.	• Groundtruthing, and ELC mapping to determine the extent of vegetative cover and composition. • As these are likely to be predominantly restoration or successional areas, establishment of monitoring plots or photographic inventory is recommended	• Groundtruthing, and ELC mapping to determine the extent of vegetative cover and composition. • As these are likely to be predominantly restoration or successional areas, establishment of monitoring plots or photographic inventory is recommended	• This monitoring should be based on subwatershed level monitoring results and integrated with above. • Monitoring would be triggered by land use changes, proposed modification/relocation of streams/linkages, as well as proposed restoration.	• Linked to the timing of the EIR, generally one year pre and two years post development
	Wildlife	• Use of standardized breeding bird and amphibian monitoring protocols. • Establishment of sample stations at strategic locations to be selected at the EIR	• Use of standardized breeding bird and amphibian monitoring protocols. • Establishment of sample stations at strategic locations to be selected at the EIR	• See wetlands	• Use of standardized breeding bird and amphibian monitoring protocols	• Use of standardized breeding bird and amphibian monitoring protocols	• Use of standardized breeding bird and amphibian monitoring protocols	• Focused wildlife monitoring is recommended to occur at this stage, triggered by land use changes, proposed modification/relocation of streams/linkages, as well as proposed restoration.	• Will depend on the timing of the EIR, generally one year pre and two years post development • Predominantly in the spring
Draft Plan	Vegetation	• Staking of existing dripline, with ELC mapping to determine the extent of woodland cover and composition • Photographic inventory of edge conditions	• Staking of existing wetland edge, with ELC mapping to determine the extent of wetland cover and composition • Photographic inventory of wetland edge. • Monitoring of water regime to be integrated with monitoring of SWM,	• See wetlands and/or restoration/riparian areas. • As these are likely to be predominantly restoration areas, establishment of monitoring plots or photographic inventory is recommended.	• Field surveys, and ELC mapping to determine the extent of vegetative cover and composition. • As these are likely to be predominantly restoration or successional areas, establishment of monitoring plots or photographic inventory	• Field surveys, and ELC mapping to determine the extent of vegetative cover and composition. • As these are likely to be predominantly restoration or successional areas, establishment of monitoring plots or photographic inventory is recommended.	• Field surveys, and ELC mapping to determine the extent of vegetative cover and composition. • As these are likely to be predominantly restoration or successional areas, establishment of monitoring plots or photographic inventory is	• This monitoring should be based on EIR level and subwatershed level monitoring results. • Monitoring would be triggered by land use changes, proposed modification/relocation of streams/linkages, as well as proposed restoration.	• Linked to the timing of the EIR (may overlap with or replace EIR monitoring, generally one year pre and two years post development

Level		Woodlands	Wetlands	Hydrologic Features	Linkages	Riparian Habitats	Successional Habitats	Trigger or Focus	Frequency
			etc at this stage.		is recommended.	• Monitoring to be integrated with monitoring of other stream corridor parameters.	recommended		
	Wildlife	• Use of standardized breeding bird and amphibian monitoring protocols. • Establishment of sample stations at strategic locations to be selected at the EIR	• Use of standardized breeding bird and amphibian monitoring protocols. • Establishment of sample stations at strategic locations to be selected at the EIR	• See wetlands and/or restoration/riparian areas. • As these are likely to be predominantly restoration areas, establishment of monitoring plots is recommended.	• Use of standardized breeding bird and amphibian monitoring protocols. • Establishment of sample stations at strategic locations to be selected at the EIR	• Use of standardized breeding bird and amphibian monitoring protocols. • Establishment of sample stations at strategic locations to be selected at the EIR	• Use of standardized breeding bird and amphibian monitoring protocols. • Establishment of sample stations at strategic locations to be selected at the EIR	• Focused wildlife monitoring is recommended to continue at this stage based on the results of EIR and subwatershed level monitoring results. • Monitoring triggered by land use changes, proposed modification/relocation of streams/linkages, as well as proposed restoration.	• Linked to the timing of the EIR (may overlap with or replace EIR monitoring, generally one year pre and two years post development

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Linkages

As noted above, recommendations are provided for the establishment of native woody species along stream corridors. Much of this is anticipated to occur by natural regeneration. Monitoring the establishment of these plantings is recommended.

7.6 Long-Term Management of the Natural Heritage System

7.6.1 Core Areas

Based on these recommendations, **Table 7.6.1** and **Figure 7.3.1** were developed to indicate the generalized character of the management of the Core Areas and NHS.

Table 7.6.1 Summary of Core Area Themes and Management (see Figure 7.3.1)

Name	Themes	Management
Block Area A:	**Significant Natural Heritage Features**: significant woodland, wetlands of significant, habitat of threatened species and habitat of special concern species. **Linkage**: existing corridor provides a connection along Tributary A to link significant woodland and riparian wetland along a watercourse with direct, seasonal fish habitat. **Wildlife**: presence of two species at risk, Barn Swallow (Threatened) and Wood Thrush (Special Concern).	• Enhancement and restoration of vegetation communities for maintaining and improving habitat for flora and fauna. • Maintain and enhance hydrological requirements of riparian wetland as part of natural channel design. • Local linkage enhancements through wetland restoration, buffer and infill plantings with increased forest cover. The local linkage will provide connection to areas adjacent to the study area.
Block Area B	**Significant Natural Heritage Features**: significant woodland and habitat of special concern species. **Connection**: general connection along Tributary C between subwatersheds (Silver Creek headwater and Sixteen Mile Creek headwater). **Wildlife**: presence of two species at risk, Wood Thrush (Special Concern) and Eastern Wood-Pewee (Special Concern).	• Enhancement plantings and edge management of woodland to maintain forest breeding bird community. Management of trees damaged by ice storm. • Management and enhancement of breeding amphibian habitat. • Greenway along Tributary C to provide for general connection between Block B and C while allowing for accessory uses such as surface water infiltration, and a trail with landscaping plantings to support recreational uses.
Block Area C	**Significant Natural Heritage Features**: significant woodland, significant wildlife habitat, and habitat of special concern species. **Connection**: general connection along Tributary C between subwatersheds (Silver Creek headwater and Sixteen	• Enhancement plantings and edge management of woodland to support functions of woodland. Active management and enhancement (removal of invasive shrubs and sapling under-planting) of thicket to increase extent of forest cover. • Management and enhancement of breeding amphibian habitat including maintaining

Name	Themes	Management
	Mile Creek headwater). Enhance existing local linkage between Block C and D. **Wildlife**: presence of one species at risk, Eastern Wood-Pewee (Special Concern).	hydrological requirements of vernal pool complex. • Greenway connection along Tributary C to provide for general connection between subwatersheds. Enhancement of existing link between Block C and D to further buffer breeding amphibian habitat and maintain hydrological link between subwatersheds.
Block Area D	**Significant Natural Heritage Features**: significant woodland, wetlands o significant, significant valleyland, significant wildlife habitat and habitat of special concern species. **Linkage**: enhance existing local linkage between Block C and D. Maintain existing linkage function along Tributary B valleyland. **Wildlife**: presence of one species at risk, Eastern Wood-Pewee (Special Concern).	• Enhancement plantings and edge management of cultural meadow and thicket on perimeter of woodland. Vegetation community restoration and enhancement in areas of localized erosion at valley inflow locations. • Invasive species control and management of Black Locust through implementation of Block D woodland management and enhancement plan. • Enhancement and management to maintain forest breeding bird community. Wetland replication feature relocated into NHS/linkage to provide functional breeding amphibian habitat. Semi-open areas for reptile habitat to be integrated into buffer restoration design. • Enhancement of existing link between Block C and D to further buffer breeding amphibian habitat and maintain hydrological link between subwatersheds.

7.6.2 Linkages

Many of the aspects of the management of linkages are discussed in the Subwatershed Study (**Section 6.3.3** of the management strategy).

The recommended linkages capture the key features of woodlands and wetlands for incorporation into the NHS. In many cases the proposed linkages cross lands where existing vegetation is limited or not existent. Therefore the issue of protecting the vegetation is not as important as encouraging the establishment of vegetation in these areas.

7.6.3 Riparian Corridors

The management of the corridor will be closely related to the management of the stream corridors and the many other factors that must be considered (*i.e.,* aquatic habitats, hydrology, and geomorphology).

The preferred management of the corridors from a linkage perspective would be to retain existing woody and wetland vegetation associated with the corridors, and allow for the establishment of woody vegetation within the stream corridors. This is consistent with the management recommendations from an aquatic perspective (see

below). In some cases, pockets of woodland and wetland are found associated with these stream corridors and these existing vegetation features should be incorporated into the corridor where possible.
It may occur that the existing riparian vegetation found within stream corridors is limited or not existent. Therefore the issue of protecting the riparian vegetation is not as important as encouraging the establishment of vegetation in these areas.

Broad level management recommendations have been discussed to achieve certain targets on a system wide basis. Recommendations fall into the following broad categories:

- Plant woody vegetation to supplement existing herbaceous vegetation where an herbaceous cover is well established;
- Allow vegetative succession of woody vegetation to continue undisturbed. In these cases woody vegetation is far enough advanced that natural succession should be left alone;
- Bank revetment required to repair bank erosion problems. Very site specific areas where advanced erosion is evident;
- Movement of channel recommended to remove it from negative land use practices (*e.g.*, moving a channel out of a road ditch);
- Leave undisturbed, existing vegetation community is doing well and should not be disturbed. This applies mainly to heavily wooded reaches, or reaches where shrubs and herbaceous vegetation are very well established;
- No management required applies mainly to reaches which have been designated as supporting no in-situ aquatic habitat.

7.6.4 Stormwater Management Facilities

The permitting of SWM facilities within the NHS has been described in the management report. Maintenance of these facilities must take into account the management recommendations of the NHS. When providing for future maintenance work access to the facility must be via a public ROW. For example, SWM facilities located within linkages must be maintained from the road or through public lands and not directly through the NHS.

7.6.5 Rehabilitation Measures

Streams requiring rehabilitation have been identified in the management strategy and are illustrated in **Figure 5.9.1** and **Figure 7.3.1.**

It is recommended that the stream and riparian corridor enhancement works be carried out as development proceeds since it provides increased resiliency in the stream system, particularly headwater streams. Since some headwater streams are not identified for protection, enhancement of the balance of the streams will serve to protect the overall watershed functions. It is further recommended that these works be completed as a requirement of land development. Additional site level enhancements, such as fish barrier removal, would be carried out by public agencies.

7.7 Agency Responsibilities

The implementation of the subwatershed plan leads to responsibilities for the various agencies involved. The components of the plan have been identified and summarized in **Table 7.7.1** along with the responsibilities of the various agencies.

Table 7.7.1 Responsibilities for Implementation of Management Strategy

Management Recommendation	Purpose (Why)	Responsibilities (Who)	Timing (When)	Other Considerations (How)
Stormwater Management				
Quantity Control - Infiltration - Peak Flow - Extended Detention - Erosion Control	• Duplicate runoff conditions to protect creek. • Protect supply to groundwater.	• Incorporate in Municipal and Conservation Authority policies.	• Immediately.	• Change municipal policies as necessary.
Infiltration - Provide infiltration to meet targets set. - Provide as close to at-source as possible where possible.	• Maintain baseflow • Potential to enhance baseflow during low periods. • Maintain recharge to municipal water supply aquifer.	• Municipality and Conservation Authority.	• Immediately. • Policy in Official Plan.	• Implement policies.
SWM plans to be established for proposed developments.	• Identify details of SWM plans and requirement for at-source controls to meet water balance targets(i.e. rain gardens, bioretention, etc.).	• Incorporate in Municipal and Conservation Authority policies.	• Draft Plan Stage • Official Plan	• SWM Plans to be submitted to demonstrate compliance. • Policies for development in Local Recharge Area
Quality Control - Provide Level 1 Control as a minimum; consider new technologies for higher removal efficiencies and thermal train approach. - Phosphorus to existing levels. - Certain land use activities are restricted by Source Water Protection Policy and Region Official Plan.	• Protect water quality and fish habitat. • Protect groundwater quality.	• Municipality and Conservation Authority.	• Draft Plan Stage.	• Change policies as necessary.
Non-point source controls - Property owners should conduct an environmental practice assessment.	• Minimize excess chemical loadings to the groundwater system.	• Municipality and individual owners.	• Immediately.	• Work co-operatively to develop an environmental assessment for individual property owners if no property

Management Recommendation	Purpose (Why)	Responsibilities (Who)	Timing (When)	Other Considerations (How)
				assessment has been done.
Encourage pollution prevention Measures.	• Protect water quality.	• Municipality, Subwatershed Implementation Committee.	• Immediately.	• Initiate programs to encourage pollution prevention (i.e. social marketing). • To be incorporated in SWM plans by developers.
Natural Heritage System				
Protect significant stream corridors – main branch and tributaries. Protect floodplain, fill line.	• Protect life and property • Water quality buffer • Preserve hydrologic functions • Habitat protection • Provide wetland and stream protection and facilitate engagement.	• Municipality, Conservation Authority, Landowners and Community.	• Develop and adopt policies immediately • Implement at draft plan stage.	• Designate greenspace • Implement flood and fill line regulations • SWM design • EIR for adjacent developments • SWM, trail and greenspace to be interface between wetland and development.
Protect woodlots with significant wildlife habitat Protect and enhance supporting areas.	• Wildlife habitat. • Landscape ecology and aesthetics.	• Landowners, Municipality, MNRF, Conservation Authority. • Municipality, landowners, community groups, Conservation Authority.	• Change Official Plan as necessary. • EIR at draft plan stage • Ongoing Management.	• Designate greenspace • EIR for adjacent developments. • SWM, trail and interface between greenspace and development.
Require EIR for development in adjacent lands and/or category two areas	• Protect and enhance function of Natural Heritage System, develop amenity benefit for human residents	• Conservation Authority, Region, Municipality to review Developer EIR.	• Draft plan stage. • Policy in Official Plan.	• Refer to specific features and function laid out.
Aquatic Management and Restoration				
Carry out riparian enhancement and stream rehabilitation.	• To improve aquatic habitat and increase resiliency of stream	• Municipality, conservation authority and developers.	• Prior to development.	• Include as a condition for development.

Management Recommendation	Purpose (Why)	Responsibilities (Who)	Timing (When)	Other Considerations (How)
	system to permit future urban development.			
Monitoring				
Inspect SWM facilities following construction.	• Ensure compliance*	• Developer (prior to assumption) • Municipality (after assumption).	• Following construction and after assumption.	• Include in subdivision agreements.
Monitor SWM facilities.	• Ensure long-term function. *	• Developer, Municipality	• Every year for first two-years from when the subdivision has been assumed.	• Developer responsible for first three-years, City thereafter.
Aquatic species monitoring and stream water quality	• Monitor stream health.	• Municipality, Conservation Authority.	• Annually with baseline monitoring beginning at minimum one year before development •	• Town responsibility with costs passed on to developers?
• Require compliance and performance monitoring as part of the development review process.	• To ensure that mitigation measures are properly built and maintained and that they perform as intended.	• Development proponents under the direction of Municipalities, eventually transfer responsibility for long term inspection to Implementation Committee.	• As part of the draft plan process to continue on a volunteer basis after completion of the development.	• Build on existing site inspection and monitoring requirements • Regular inspection and repair if needed of fences buffers trails.
• Effectiveness Monitoring	• Ensure targets are met.	• Municipality, Conservation Authority.	• Immediately, annually.	• At specified.
Implementation				
Assign a staff member to coordinate implementation - Environmental Coordinator.	• Consistent implementation • Efficient use of money, staff resources, and community volunteers.	• City and/or Conservation Authority.	• Immediately and ongoing.	• Permanent half time staff commitment. • Create a new position or reorganize staff priorities and work load.
Use Implementation committee for special projects, fund raising, volunteer coordination etc.	• Cost savings • Civic pride • Peer enforcement of protection measures.	• Municipality.	• As needed.	• Environmental Coordinator to coordinate and support community committees.

Management Recommendation	Purpose (Why)	Responsibilities (Who)	Timing (When)	Other Considerations (How)
Require EIR for new development proposals and subject them to normal review process involving the public and committees as appropriate.	• Site specific implementation of policies.	• Municipality, Conservation Authority.	• Part of Draft plan process.	• Use EIR guidelines to scope studies
Develop a Terrestrial Monitoring Strategy.	• Identify and respond to negative changes.	• Municipality. • Community volunteers. • Implementation committee.	• Immediately.	• Regular inspection of buffers, fences, trails, state of the watershed reporting, on a periodic basis.
Treat the strategy as a "living document" implement it on an interim basis in advance of land use policy changes and apply all relevant federal, provincial and municipal policies as they are amended.	• To keep up with changing science and social priorities.	• Approval Authorities.	• Immediately.	• Regular review and approval process.
Use interpretive signage at SWM facilities, trails and other mitigation measures.	• Public education and expanded Stewardship.	• Municipality Development Proponents.	• As they are built.	• Conditions of Draft Plan Approval or Site Plans. • Municipal projects funded by implementation budget.

** Servicing studies subsequent to this report (including EIR/FSS stage) should develop further monitoring and evaluation details including contingency plans if facilities do not meet targets set.*

Approvals of stream works are also the responsibility of the Conservation Halton. Any watercourse work (including Medium Constraint – Blue streams) will require approval of the respective Conservation Authority.

7.8 Administration Issues

7.8.1 Subwatershed (Environmental) Engineering Co-ordinator

The subwatershed plan will be implemented by the Town of Halton Hills in co-ordination with the governing agencies. It is recommended that a staff position as an Environmental Co-ordinator be provided at the Municipality and/or Conservation Authority. This will likely require the commitment for a half-time position. Previous experience with watershed studies across the province has shown that dedicated staff time is absolutely necessary to ensure that the report recommendations and monitoring tasks are implemented. Experience has also shown that a great deal of valuable implementation work can be accomplished by volunteers, if there is a person to co-ordinate and support the work. In order to ensure consistency and efficient progress towards subwatershed goals, this responsibility should be assigned to one person. The person in this position should be responsible for ensuring the implementation of this management strategy, including input to the budget setting process. The position should be co-ordinated with the Conservation Authorities and the MNR stewardship program, as well as volunteer efforts from local interest groups.