MORRISON HERSHFIELD

FINAL REPORT

Eastern Subwatersheds Stormwater Management Retrofit Study

Ottawa, Ontario

Presented to:

Laurent Jolliet, P.Eng.
Planning Infrastructure & Economic Development
Infrastructure Services Department
City of Ottawa

Final Report December 21, 2018

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Eric Emery, P.Eng, MBA
Morrison Hershfield Ltd.

Dave Maunder, P.Eng,
Aquafor Beech Ltd.

December 20, 2018
Date:

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Executive Summary

Eastern Subwatersheds Stormwater Management Retrofit Study

When rainwater falls on paved surfaces, it carries pollutants to natural streams and the Ottawa River. Instead of being absorbed by the soil and vegetation, the runoff from paved surfaces is conveyed directly to the environment, leading to erosion, poor water quality and greater potential for flooding. This problem is addressed through the application of stormwater management (SWM) practices, which consist of technologies designed to mimic the natural response of watersheds to rainfall, as much as possible.

In older established communities, originally built without the infrastructure needed to mitigate the impacts of uncontrolled runoff, retrofit measures can be implemented to restore a more natural hydrologic cycle. Unlike Greenfield development, where SWM measures are incorporated as a matter of course, the challenge of SWM retrofit is to identify effective measures that can be implemented after the fact, i.e. when there is limited land available to implement conventional SWM facilities. These SWM measures are categorized by the location where they operate within the drainage system and include:

- Lot level: These measures are located at the source of runoff, i.e., "on the lot." They function to reduce the amount or volume of rainfall that runs off and prevent pollutants from being picked up and conveyed off the lot. Lot level measures are therefore considered to be the first line of protection in maintaining or rehabilitating the health of a watershed. Though each lot (public or private) may be relatively small in size, the use of lot level practices on the sheer number of lots and properties in urbanized areas can combine to provide a positive cumulative effect. Typical lot level measures include: rain barrels or cisterns that harvest rainfall for later use on the property; rain gardens and other absorbent landscaping measures that capture and infiltrate or evapotranspirate runoff; the use of various pervious or permeable materials for the construction of driveways and parking lots; green roofs, etc.

- Conveyance: Conveyance measures provide the means by which stormwater runoff is transported from one location to another. These measures collect and accumulate runoff from individual lots and convey it to the drainage system's outlet, typically the closest stream or river. Conveyance measures include drainage ditches and swales, storm sewers and the right-of way itself which conveys flows that exceed the capacity of the storm sewer system.

- End-of pipe: End-of-pipe measures are larger scale facilities that receive the accumulated runoff collected by the conveyance system. End-of-pipe facilities can provide treatment to improve the quality of runoff before it is discharged to the receiving watercourse and/or can reduce the rate at which runoff is discharged to reduce or avoid flooding impacts. End-of-pipe measures include both surface and subsurface facilities.

- Stream rehabilitation: When the implementation of retrofit measures within the watershed is not sufficient to address erosion and stability impacts, it may be necessary to undertake stream rehabilitation measures. Such measures are undertaken to improve the stream's ability to withstand urbanized flows while maintaining or improving its natural features and functions. In other words, stream rehabilitation is not intended to provide hardened erosion protection (although sometimes that is unavoidable to protect existing infrastructure that was built too close to the stream or in inappropriate locations) but to improve the stream's overall resiliency. Such measures can include re-building sections of the stream, creating off-line pools for floodplain storage, cutting down banks to re-connect a downcut or eroded channel with its floodplain, etc.

On February 24, 2010 City Council adopted the Ottawa River Action Plan (ORAP). One of the key objectives of ORAP is to maintain a healthy aquatic ecosystem and to reduce beach closures due to water quality issues. Of the 17 separate projects that comprise ORAP, two include the development of SWM retrofit plans for areas of the City that were developed with little or no stormwater management. The first of these studies, the Pinecrest Creek/Westboro SWM Retrofit Study, has been completed and identifies a long-term plan composed of a range of retrofit programs/capital projects, monitoring and outreach efforts aimed at reversing or partially reversing the historical impacts of development on the Creek and local reach of the Ottawa River. The second study identified by ORAP is the Eastern Subwatersheds SWM Retrofit Study.

The overall purpose of the Retrofit Study is to develop a long-term Retrofit Plan to apply stormwater management within urban areas to improve water quality, and achieve a sustainable flow regime in the watercourses. Related key objectives are as follows:

- Reduce erosion impacts;
- Preserve and re-establish the natural hydrologic cycle in the stream;
- Improve water quality;
- Reduce impacts to the beach at Petrie Island; and
- Reduce flooding and minimize risk to human life and property due to flooding.

To develop the Retrofit Plan, the following key steps were undertaken:

- Setting the stage: existing conditions and SWM retrofit potential;
- SWM retrofit: selection of the preferred scenario;
- Public consultation and communications; and
- Preparation of an implementation plan.

The study was conducted as a Master Plan per the Municipal Class Environmental Assessment process.

The study area described as the Eastern Subwatersheds covers an area close to 15,000 hectares within the urban boundary of the City of Ottawa. It includes 5 different subwatersheds in the east part of the City of Ottawa, extending from the urban tributaries to Green's Creek to the east boundary of the Taylor Creek subwatershed at Trim Road. The lands within the study area are characterized by deep deposit of clay, a very low permeability and a tendency to generate fine sediments in the streams. Land use in the developed subcatchments range from 45 to 85% urban. The study area contains 14 separate outfalls to the Ottawa River and includes over 50 kilometers of natural streams, much of which have been impacted by urban development. There is limited stormwater management facilities within the Eastern Subwatersheds. An existing condition hydrology and water quality model was developed to enable the testing of the effect of alternative stormwater management retrofit strategies. Hydraulic analysis of streams and fluvial geomorphology were also completed to understand flooding constraints and an inventory of erosion sites and relative priority. Terrestrial and aquatic habitat were assessed.

Three retrofit scenarios were developed using different combinations of lot level, conveyance, and end-of-pipe measures. Each scenario was evaluated based on criteria related to technical, economic, environmental and social factors. The preferred Retrofit Plan is composed of:

i. Lot level measures: 30% of private properties (industrial, commercial, institutional and residential) will be retrofitted with Low Impact Development (LID) measures.

ii. Conveyance measures: 50% of the Right-of-Ways (ROW) will be retrofitted with LID measures. The majority of the streets within the Eastern Subwatersheds contain underground infrastructure that is in relatively good condition. Some of the oldest infrastructure in the study area was constructed in the early 1960s. Therefore, widespread road re-construction is not expected to be required in the study area until beyond 2060.

iii. Remediation of priority erosion sites: three medium to high priority sites and 9 medium priority sites were identified.

An extensive screening process was conducted for the selection of potential locations for end-of-pipe measures. Given the limited captured drainage area and the extent of local constraints (e.g. high groundwater level, land ownership, depth of facility), end-of-pipe measures were eliminated as a viable strategy. Therefore, the focus of the preferred approach is on lot-level and conveyance measures. An initial implementation plan to achieve lot-level controls on residential properties and City owned facilities is included in the report.

The water quality modeling results for the existing condition confirm Baird & Associates (2011) conclusion that Bilberry, Green's and Voyageur Creeks are significant contributors of bacterial contamination to Petrie Island. This is reinforced by the results of the Ottawa River water quality modeling for the retrofit scenarios, completed by Baird & Associates in 2018. A 43% reduction of bacterial loads to the river could be achieved with the preferred retrofit scenario.

The total 50-year lifecycle cost for the implementation of 30% lot-level controls and 50% conveyance controls is estimated to be $221.3 million, including $13.7 million to be allocated for stream restoration and erosion sites.

Public consultation included a virtual open house presented in 2013 through the City of Ottawa website. A second open house was conducted in 2014 as part of the Environmental Round Table session that took place at the time. A third and final open house was held in 2018 to present the final recommendations from the study.

1 INTRODUCTION

The City of Ottawa contains within its boundaries a rich resource of rivers, shorelines water ways and their tributaries. These waterways and tributaries to the Rideau and Ottawa Rivers, had historical and economic significance for Ottawa. Sustaining the natural resources of these watersheds over time is an important element of the City of Ottawa's goal to be a livable and vibrant City.

Over the past 30 years, the City of Ottawa has progressively invested in stormwater management to protect water quality, control erosion and prevent flooding due to impacts from urban development. These practices have evolved and continue to evolve over time with new technology, policies and approaches to improve water quality, preserve watercourses, and manage flooding.

Stormwater management is intended to maintain the natural hydrologic balance as much as possible. In undeveloped watersheds, most of the rainfall is intercepted by vegetation and soil and is either lost to evaporation, absorbed by vegetation, or infiltrated into the ground. In this case, little runoff flows directly to watercourses and rivers. Development changes this water balance so that most of the rainfall is conveyed to streams as runoff which carries pollutants associated with the urban environment. The result is rapid enlargement of stream channels, bank erosion, loss of in-stream habitat, and increased peak flows resulting in flood damage.

In 2002, the City of Ottawa worked with the Rideau Valley Conservation Authority (RVCA) and others to develop the Lower Rideau River Watershed Strategy. This effort provided a framework to update the City of Ottawa stormwater management policies to emphasize a more holistic approach to watershed protection.

The result of the Lower Rideau Watershed Strategy was to develop new policies to guide the future of stormwater management. One of the key strategies was to initiate a retrofit stormwater management program to address stormwater issues in the developed, existing urban areas of the City where stormwater management was not generally applied.

The Pinecrest Creek and Westboro Stormwater Management Retrofit Study was completed in 2011 and was a pilot study to assess what specific measures could be practically implemented to improve the health of the Creek and local reach of the Ottawa River, and to restore the natural water balance in the receiving streams.

At the same time, concerns about the water quality in the Ottawa River prompted the City of Ottawa to launch the Ottawa River Action Plan (ORAP). This initiative resulted in 17 specific projects aimed at improving the health of the Ottawa River and its many urban tributaries, one of the 17 projects identified is the current study. Some of those initiatives involved stormwater management and the development of a plan to retrofit, or implement stormwater management in the Eastern Subwatersheds.

1.1 Study Objectives and Purpose

The urban watercourses within the Eastern Subwatersheds study area in the City of Ottawa are exhibiting poor water quality, degraded aquatic habitat and on-going bank erosion. This is due to the relatively rapid urbanization of the watersheds since the 1970s, prior to the implementation of stormwater management for water quality and quantity control.

To improve water quality and to establish a sustainable flow regime in the urban watercourses in the Eastern Subwatersheds, an analysis of the implementation of possible stormwater management retrofit scenarios was completed with the objective of determining an optimal combination of lot level controls, conveyance controls and end-of-pipe facilities.

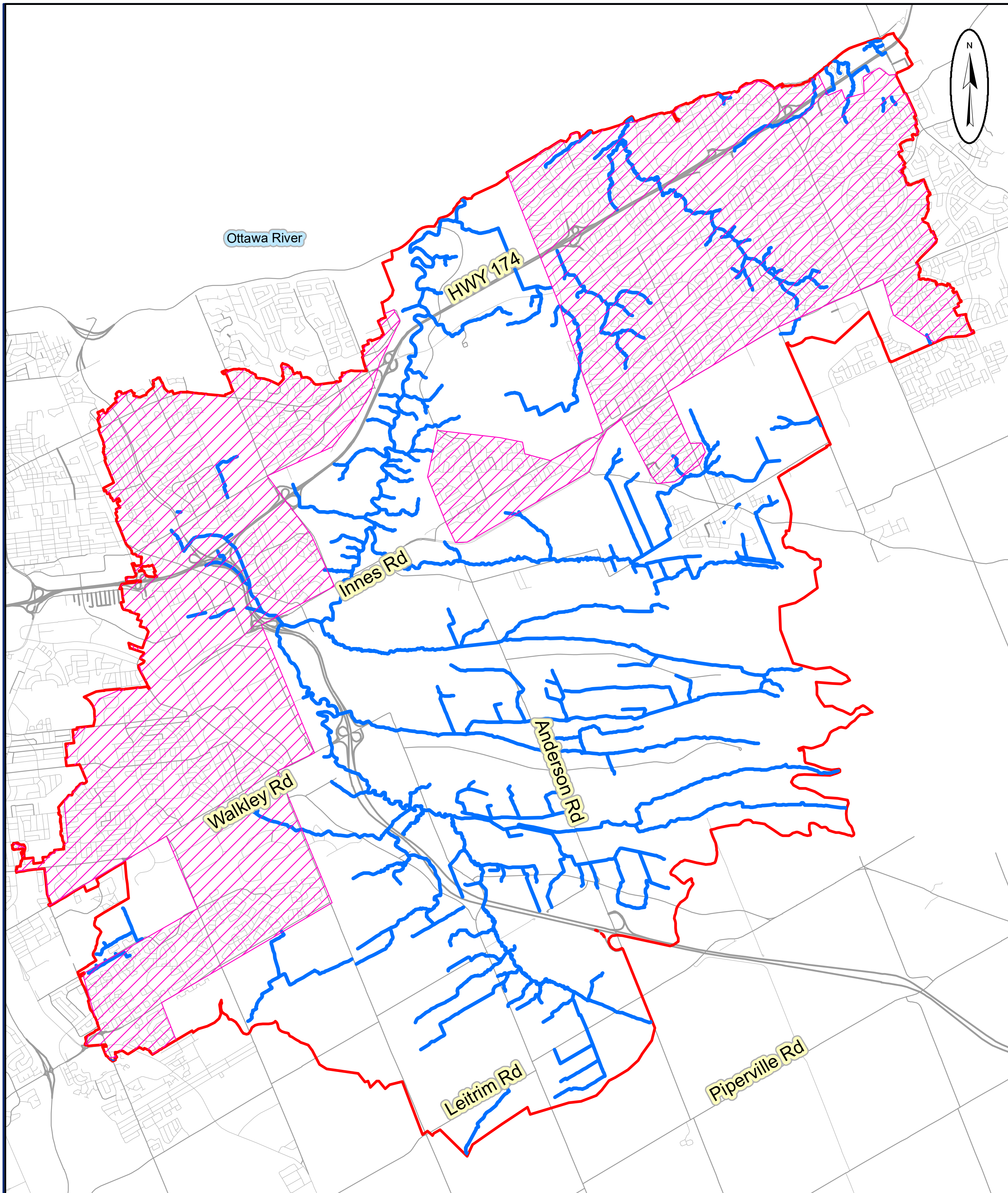
The Eastern Subwatersheds Stormwater Management Retrofit Study area is shown on Figure 1.1. The entire Eastern Subwatersheds covers an area close to 15,000 hectares and extends east from the urban tributaries to Green's Creek to the east boundary of the Taylor Creek subwatershed close to Trim Road. The study area is within the urban boundary of the City of Ottawa.

The study is intended to develop a long-term plan to implement stormwater management applications within existing urban areas of the Eastern Subwatersheds in order to achieve improvements to water quality and a more sustainable flow regime in the various watercourses within the Eastern Subwatersheds. Most of the urban development within the study area took place prior to the general current application of stormwater management practices and policy.

The Environmental Assessment Act was legislated by the Province of Ontario in 1980 to ensure that an Environmental Assessment is conducted preceding to the onset of development and development related (servicing) projects. Depending on the individual project or Master Plan to be completed, there are different processes that municipalities must follow in order to meet Ontario's Environmental Assessment requirements.

This report provides a strategy for implementing a large number of projects of a similar nature with differences being primarily due to site specific conditions. For this reason, the Municipal Class Environmental Assessment Master Planning process, as described by the Municipal Engineers Association (MEA) (2000, as amended 2007) will be followed.

Class Environmental Assessments (Class EA) are prepared for approval by the Minister of the Environment. A Class EA is an approved planning document that defines groups of projects and activities and the environmental assessment (EA) process which the proponent commits to for each project undertaking. Provided the process is followed, projects and activities included under the Class EA do not require formal review and approval under the EA Act. In this fashion the Class EA process expedites the environmental assessment of smaller recurring projects.



Legend

- Urban Areas
- Watercourse
- Study Area

Eastern Subwatersheds Stormwater Management Retrofit Study

Study Area

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Figure 1.1

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Km

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O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 1.1 - Study Area.mxd

The following information in this section is a brief summary from the Municipal Engineers Association document (Municipal Class Environmental Assessment, October 2000, as amended 2007). The Municipal Class Environmental Assessment Master Planning process to be followed is illustrated in Figure 1.2, and may involve up to five phases of assessment. These phases include:

Phase 1: Establish the Problem or Opportunity

Phase 2: Identify and Assess Alternative Solutions to the Problem, and Select a Preferred Alternative

Phase 3: Identify and Asses Alternative Design Concepts for the Preferred Solution, and Select a Preferred Design Concept.

Phase 4: Prepare an Environmental Study Report

Phase 5: Proceed with Design and Implementation.

Public and agency consultation is also an important and necessary component of the five phases.

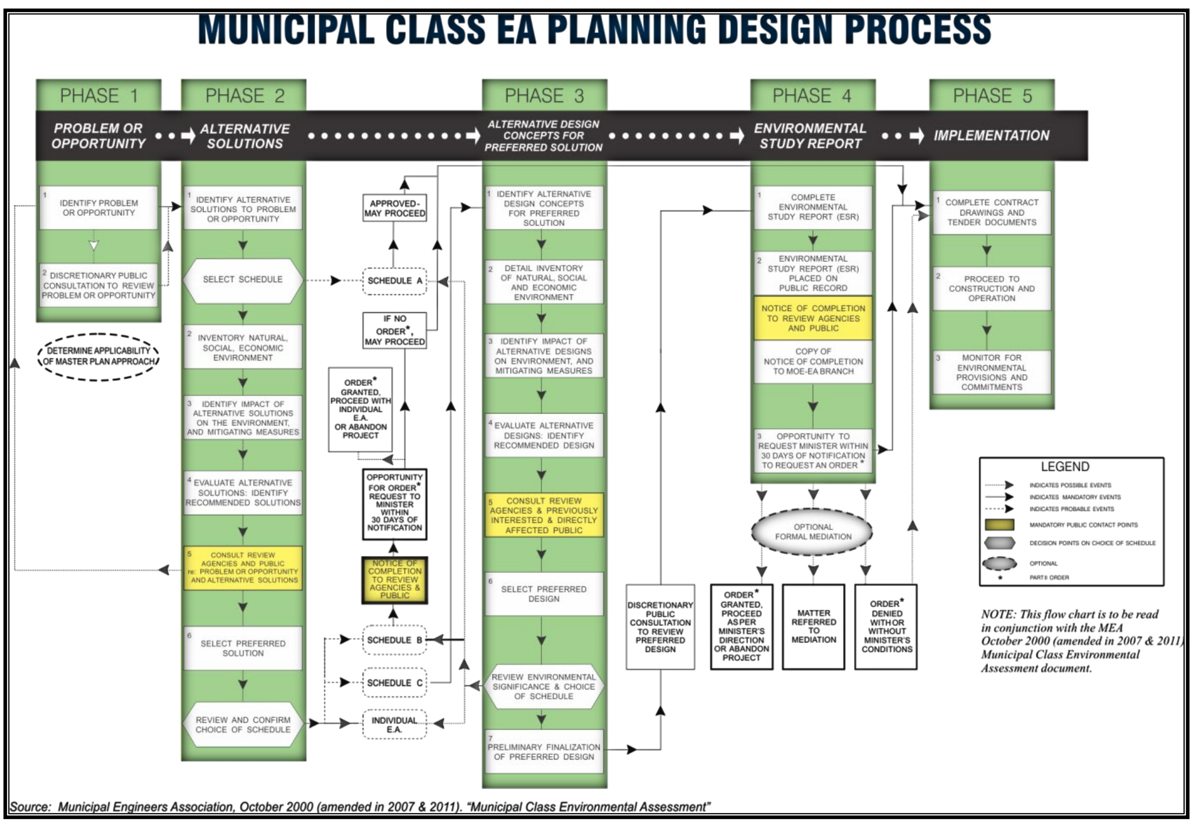


Figure 1.2: Municipal Class EA Process (Source: *Municipal Engineers Association – Municipal Class Environmental Assessment (October 2000, as amended 2007*))

In partial fulfillment of Ontario's Environmental Assessment requirements, a Master Plan must satisfy at least the first two phases of the Class Environmental Assessment process. Depending on the type of Master Plan to be completed, Phases 3 and 4 may also be required.

The Municipal Engineers Association's Class EA document also classifies projects as Schedules A, A+, B or C depending on their level of environmental impact and public concern. Any project identified in this Master Plan must be classified as to their level of complexity and potential level of environmental impact, which will in turn decide which Schedule process needs to be followed.

- Schedule 'A' projects are generally routine maintenance and upgrade projects; they do not have the potential for significant environmental impacts or need public input. Schedule 'A' projects are pre-approved without any further public consultation.

- Schedule 'A+' projects, introduced in 2007 by the Municipal Engineers Association, are pre-approved; however, the public is to be advised prior to the project implementation. Per Appendix I – Project Schedules of the Municipal Class Environmental Assessment (2000, as amended in 2007), wastewater management projects that are intended to "modify, retrofit, or improve a retention/ detention facility including outfall or infiltration systems for the purposes of stormwater quality control" including "biological treatment through the establishment of constructed wetlands" are pre-approved under Schedule A+ of the Municipal Engineers Association.

- Schedule 'B' projects have more environmental impact and do have public implications. Examples would be stormwater ponds, river crossings, expansion of water or sewage plants beyond up to their rated capacity, new or expanded outfalls and intakes, and the like. Schedule 'B' projects require completion of Phases 1 and 2 of the Class EA process.

- Schedule 'C' projects have the most major public and environmental impacts. Examples would be storage tanks and tunnels with disinfection, anything involving chemical treatment or expansion beyond a water or sewage plants rated capacity. Schedule 'C' projects require completion of Phases 1 through 4 of the Class EA process, before proceeding to Phase 5 implementation.

- The Municipal Engineers Association's Class EA document also identifies four different approaches to completing Master Plans corresponding to different levels of assessment. Regardless of the approach selected, all Master Plans must follow at least the first two phases of the Class Environmental Assessment process.

- Approach 1, the most common approach, is to follow Phases 1 and 2 as defined above, then use the Master Plan as a basis for future investigations of site specific Schedule 'B' and 'C' projects. Any Schedule 'B' and 'C' projects that need specific Phase 2 work and Phases 3 and 4 work, usually have this Phase 2, 3 and 4 deferred until the actual project is implemented.

- Approach 2 is to complete all the work necessary for Schedule 'B' site specific projects at the time they are identified. Using this approach, a municipality would identify everything it needed in the first five years and would complete all the site-specific work required, including public consultation to meet Class EA requirements. The Master Plan in such cases should be completed with enough detail so that the public in site specific locations can be reasonably informed, and so that the approving government Agencies (Conservation Authorities, Natural Resources, Federal Department of Fisheries and Oceans, Transportation Canada etc.) can be satisfied, in principal, that their concerns will be addressed before construction commences.

- Approach 3 is to complete the requirements of Schedule 'B' and Schedule 'C' at the Master Plan stage.

- Approach 4 is to integrate approvals under the EA and Planning Acts. For example, the preparation of new or amended Official Plans could be undertaken simultaneously with Master Plans for water, wastewater and transportation, and approval for both sought through the same process.

The City of Ottawa is proceeding with Approach 1 for undertaking this Master Plan.

1.2 Problem Identification

Servicing of urban development over the past 60 years has involved a wide range of stormwater management practices. Prior to the 1980s, stormwater was simply collected and disposed of with the construction of storm sewers and conveyance systems designed to transport runoff away from the source as quickly and efficiently as possible. The main concern at that time was providing adequate drainage for the development, with little regard to the consequences downstream. As a result, increased peak flows and runoff volumes occurred downstream, along with the related problems of erosion and flooding.

Beginning in the 1980s, new development began to include stormwater management practices intended to limit the impact of increased peak flows downstream — mainly to address riparian law, and potential damages that could occur to property. In the 1990s, data on the impact on water quality from the wash off of contaminants from urban areas became a concern. Stormwater management approaches were adjusted to meet water quality objectives as well as flood and erosion control downstream.

The result of all of this historical change in stormwater management is the current situation where there is a combination of large developed areas with no stormwater management, with other, isolated areas containing various types of stormwater management facilities.

The Eastern Subwatersheds Stormwater Retrofit Study is intended to review the current situation in the subwatersheds and develop a coordinated long-term plan to implement stormwater management measures to mitigate the on-going impacts of uncontrolled stormwater runoff.

1.3 Description of the Study Area

Most of the Eastern Subwatersheds study area contains the Green’s Creek watershed. The Green’s Creek watershed covers approximately 12,000 hectares, or about 80% of the study area. The headwaters of Green’s Creek is in the predominantly rural areas of southeast Ottawa, and includes the Pine Grove Forest Reserve, south of Hunt Club Road, and the western portion of the wetland complex known as Mer Bleue. Most of the main channel of Green’s Creek is within the Greenbelt which is managed by the National Capital Commission. The Greenbelt is a significant open space land area which contains natural areas, recreational pathways, agricultural lands and institutional facilities.

The urban subwatershed tributaries to Green’s Creek include the Cyrville Drain, McEwan Creek, the Mather Award Drain, Mud Creek and Green’s Creek main branch. There are also smaller, unnamed tributaries which flow into Green’s Creek which have also been affected by land development.

The other, significant portion of the study area includes the four predominately urbanized subwatersheds located east of Green’s Creek. These are known as Voyageur Creek, Bilberry Creek, the Queenswood catchments, and Taylor Creek. Each of these subwatersheds has one or more outlets to the Ottawa River. Figure 1.3 shows the subwatersheds, the watercourses, and the corresponding outlets to the Ottawa River.

The focus of the study is on the existing urban subwatersheds which include the urban tributaries to Green’s Creek, Cyrville Drain, the Mather Award Drain, McEwan Creek, Voyageur Creek, Bilberry Creek, the Queenswood Catchments, and Taylor Creek. These urban subwatersheds make up about 78% of the entire study area. Table 1-1 summarizes the contributing area and the City of Ottawa Official Plan urban area within each subwatershed. The City of Ottawa is conducting studies of the Mud Creek Subwatershed separately.

There are three mostly rural subwatersheds which drain into Green's Creek. These include Borthwick Creek, Black Creek and Ramsay Creek. These subwatersheds are located completely outside of the urban boundary. Table 1-2 summarizes the contributing areas of the rural subwatersheds.

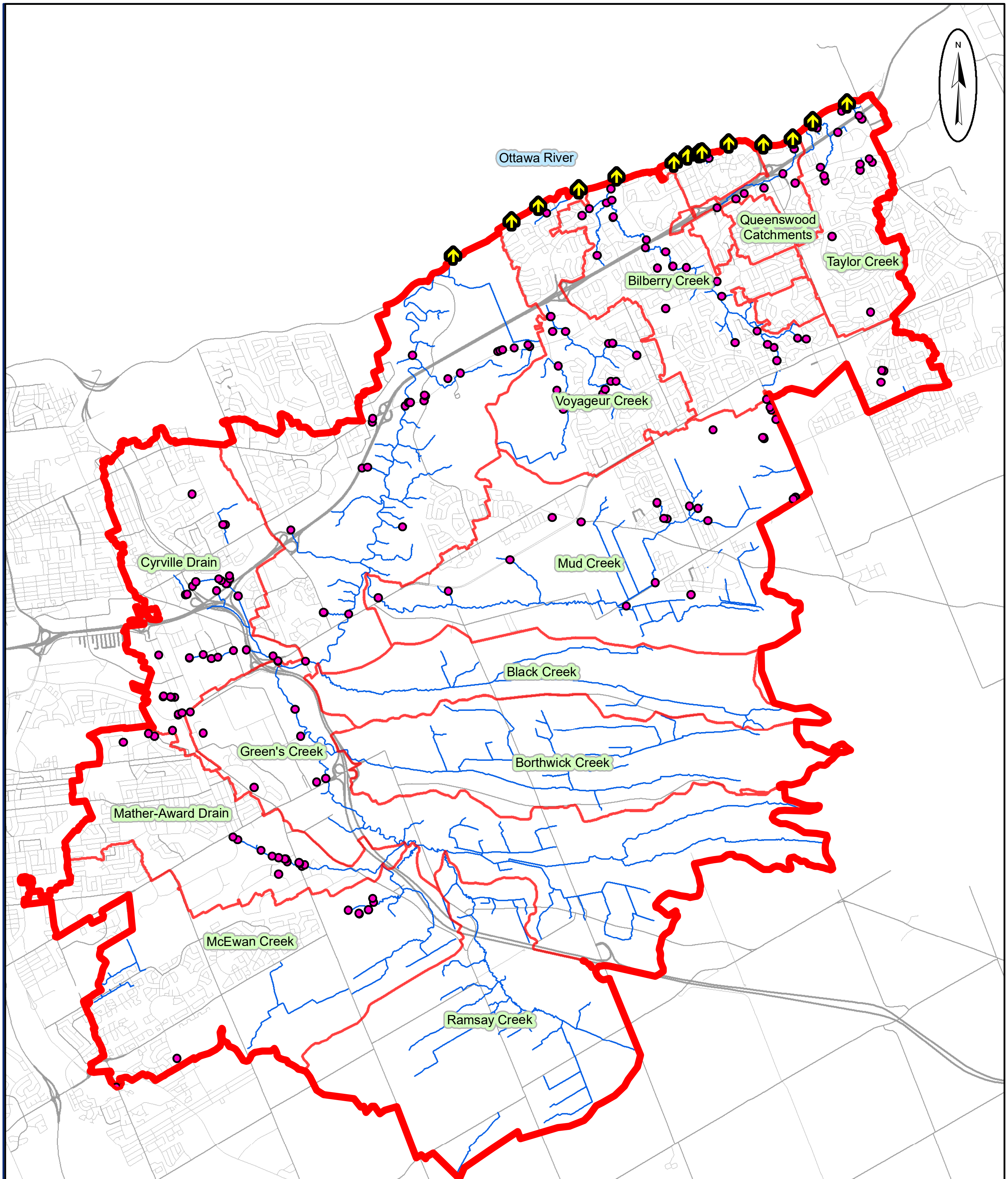
The streams and watercourses that are the focus of this study have been affected by land development in various ways. There are numerous uncontrolled storm sewer outfalls, channelization, enclosure of former open watercourses in storm sewers, loss of buffer areas, as well as crossings of watercourses for roads and major transportation links and interchanges.

Table 1-1: Summary of the Urban Subwatersheds

Subwatershed	Area (ha)	Percentage of Study Area (%)	Area Within Urban Boundary (ha)
McEwan Creek	1,559	10.4	650 (42%)
Mather Award Drain	806	5.4	700 (87%)
Cyrville Drain	962	6.4	950 (99%)
Green's Creek	3,558	23.8	810 (23%)
Voyageur Creek	828	5.5	620 (75%)
Bilberry Creek	1,109	7.4	960 (86%)
Queenswood Catchments	263	1.8	260 (99%)
Taylor Creek	665	4.4	580 (88%)
Mud Creek	1,851	12.4	280 (16%)
Total	**11,602**	**77.5**	**5,810 (50%)**

Table 1-2: Summary of Rural Subwatersheds

Subwatershed	Area (ha)	Percentage of Study Area (%)
Black Creek	809	5.4
Borthwick Creek	1,114	7.4
Ramsey Creek	1,458	9.7
Total	**3,381**	**22.5**



Legend
- Outfalls to Ottawa River
- Storm Sewer Outlets
- Study Area
- Subwatersheds
- WaterCourses

Ottawa

Eastern Subwatersheds Stormwater Management Retrofit Study

Eastern Subwatersheds Outlets and Ottawa River Outfalls

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Figure 1.3

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O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 1.3 - Eastern Subwatersheds Outlets and Ottawa River Outfalls.mxd

1.4 Urban Subwatersheds

1.4.1 Taylor Creek

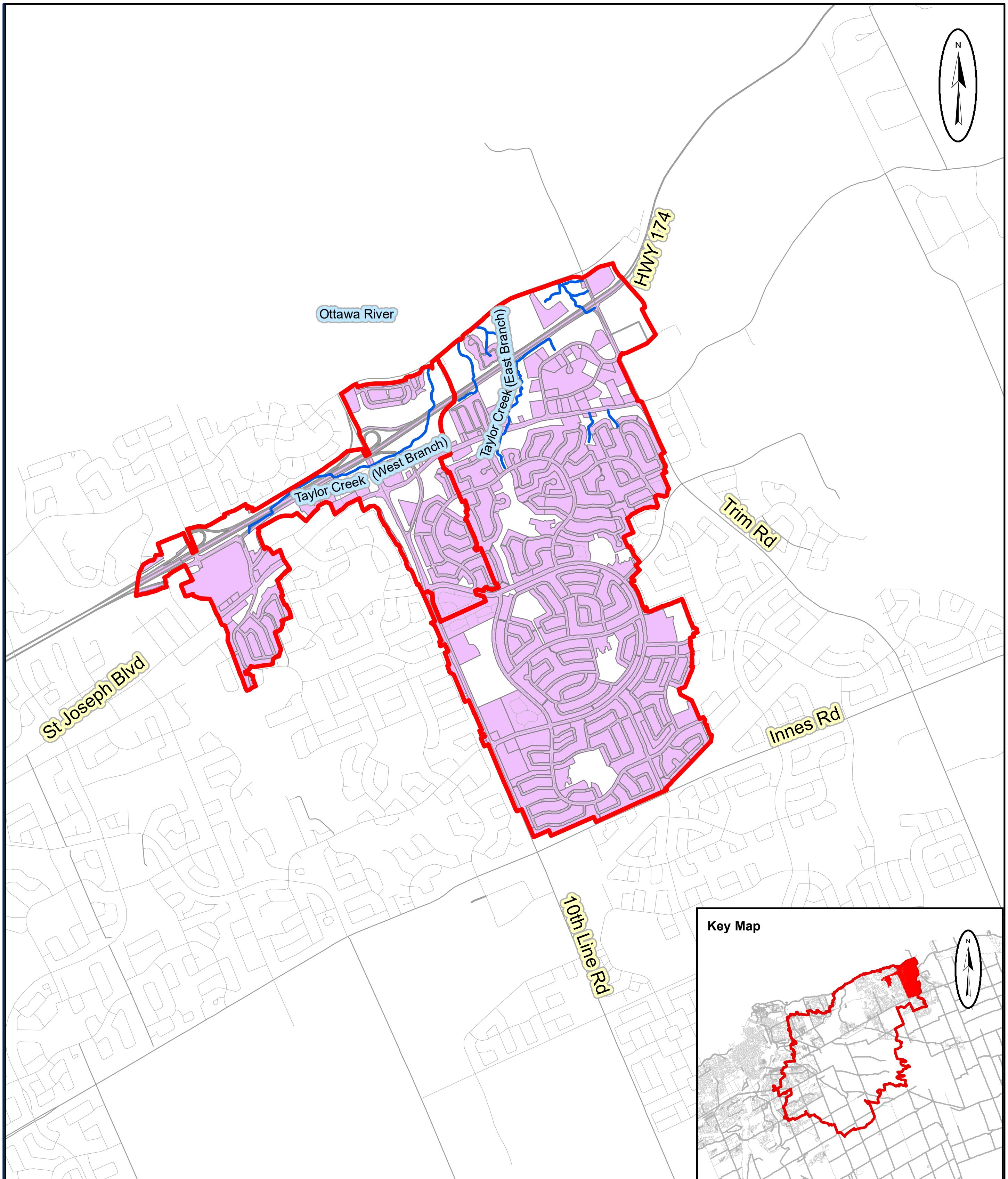
Figure 1.4 shows the Taylor Creek subwatershed which contains the Queenswood and Fallingbrook communities located near the east limit of the study area. The Taylor Creek subwatershed covers 665 hectares and is divided into two distinct parts — Taylor Creek West Branch and Taylor Creek East Branch.

Photo 1: Princess Louise Falls on the Main Branch of Taylor Creek

Taylor Creek East Branch contains the main Taylor Creek watercourse which begins at a waterfall south of St. Joseph Boulevard. The waterfall feature is known as the Princess Louise Falls (also called Taylor Falls). An unnamed tributary near the east limit of the subwatershed drains the Taylor Creek Business Park, and begins at the outlet of a water quality stormwater management treatment facility at the southwest corner of Trim Road and the Highway 174. There is also another minor tributary known as Bellevue Creek which is located just west of the main branch.

Taylor Creek West Branch contains a watercourse known as Brisebois Creek which originates just east of the Place D'Orleans Shopping Center/Orleans Town Center area. All three of the tributaries have separate outlets to the Ottawa River, between the south shore and Petrie Island.

The Taylor Creek subwatershed has been almost completely developed, however the area between the Queensway and the North Service Road continues to develop with commercial and higher density residential developments.



Legend
- Taylor
- Water Courses
- Developed Areas

Eastern Subwatersheds Stormwater Management Retrofit Study

Taylor Creek Subwatershed

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Figure 1.4

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1.4.2 Queenswood Catchments

The area known as the Queenswood Catchments is 265 hectares in size. It does not contain a defined watercourse, and is completely developed and drained by storm sewers. Figure 1.5 shows the Queenswood catchments located between Taylor and Bilberry Creek subwatersheds.

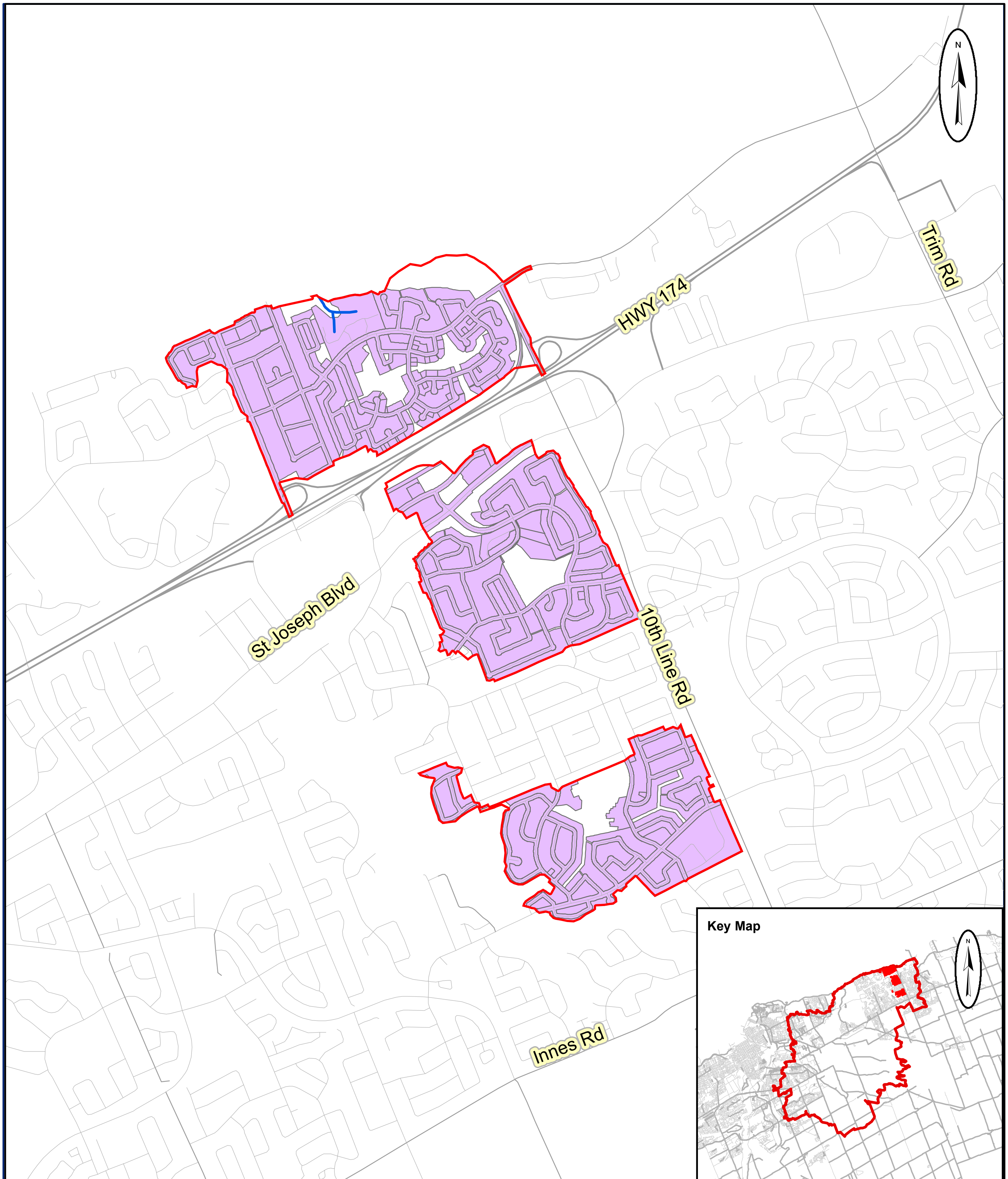
The Queenswood Catchments are three distinct catchment areas linked together by a storm sewer system that outlets to the Ottawa River. There are five storm sewer outlets from the Queenswood Catchments to the Ottawa River, with one main trunk sewer outlet and minor outlets.

The Queenswood community contains some of the oldest residential developments in the eastern suburban communities of Ottawa between the Greenbelt and the City limit.

Photo 2: Typical Street in Queenswood Heights Neighbourhood (Source: Google Street View Image)

1.4.3 Bilberry Creek

The Bilberry Creek subwatershed covers almost 1,110 hectares and is located just to the west of Taylor Creek and the Queenswood Catchments. Figure 1.6 shows the extent of the Bilberry Creek subwatershed which is characterized by an extensively forested and relatively deep ravine system extending from St. Joseph Boulevard to a point just north of Innes Road. Within the City of Ottawa, the Bilberry Creek valley is second only to the Green’s Creek ravine in terms of overall height. The valley is over 8 kilometers in length with an average grade of close to 0.6%. The main branch is joined by two other minor tributaries at a location north of Jeanne D’Arc Boulevard, before it meanders through the wetland shoreline area of the Ottawa River.



Legend
Queeswood
Water Courses
Developed Areas

Eastern Subwatersheds Stormwater Management Retrofit Study

Queenswood Catchments

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Figure 1.5

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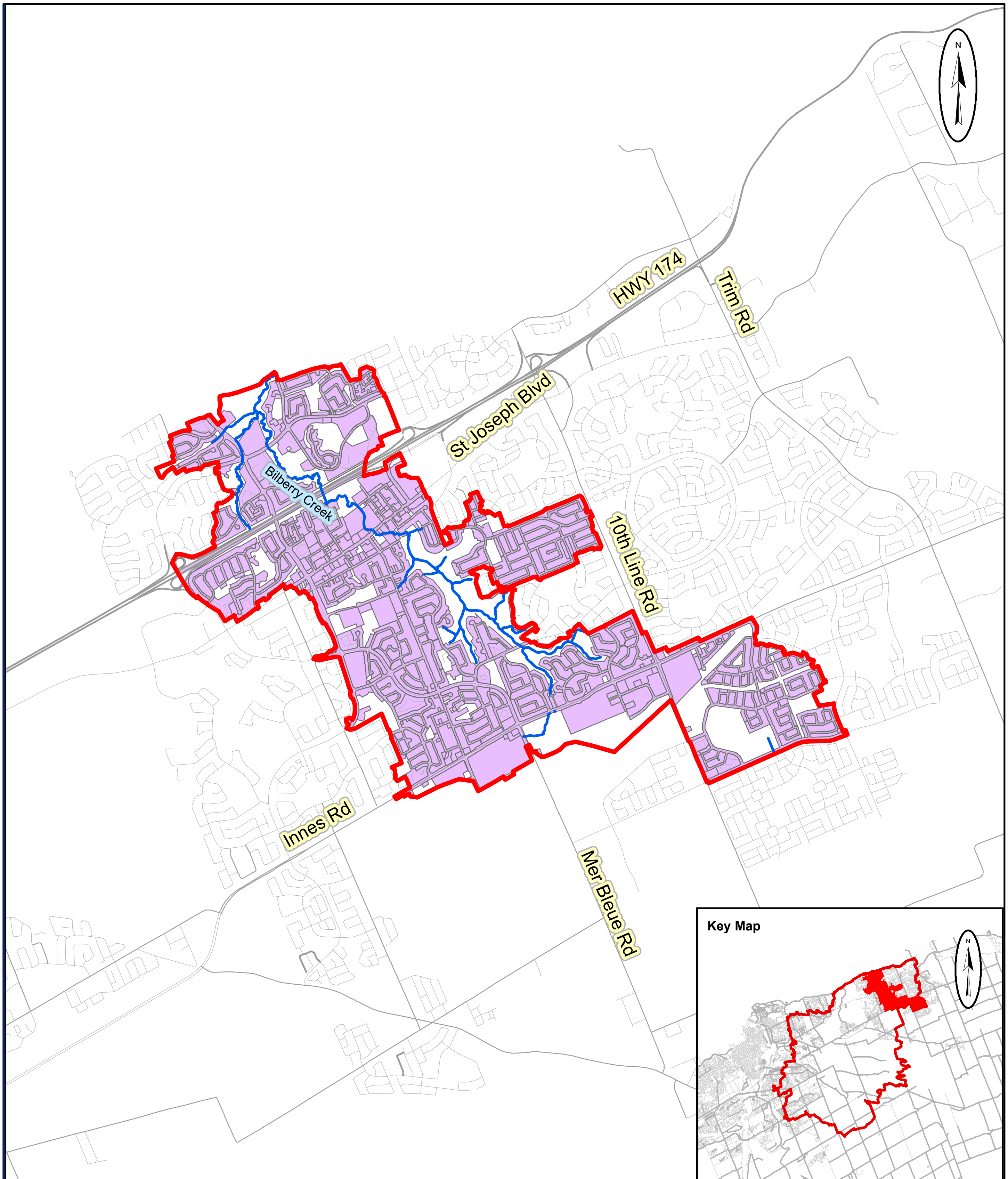

O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 1.6 - Bilberry Creek Subwatershed.mxd

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Legend

- Bilbery
- Water Courses
- Developed Areas

Eastern Subwatersheds Stormwater Management Retrofit Study

Bilberry Creek Subwatershed

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Figure 1.6

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Km

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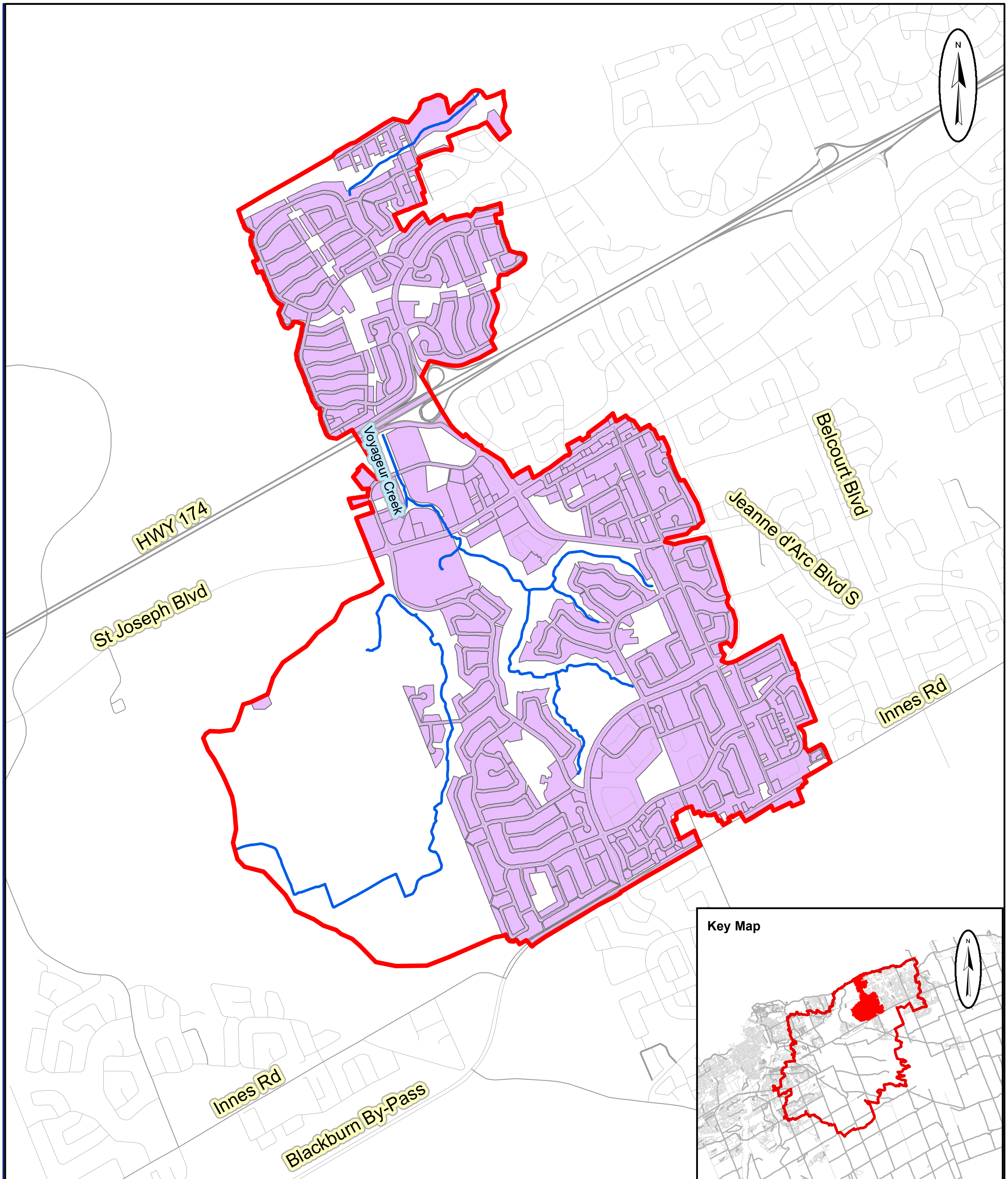
Photo 3: The Upper Reach of Bilberry Creek

The Bilberry Creek subwatershed is completely developed with residential housing except for the ravine itself, and an area of commercial development along the St. Joseph Boulevard corridor.

1.4.4 Voyageur Creek

Figure 1.7 shows the Voyageur Creek subwatershed. Voyageur Creek, also known as Bilberry West Creek, covers a total area of approximately 830 hectares. Similar to Bilberry Creek to the east, Voyageur Creek is characterized by a deep and well-defined ravine system south of St. Joseph Boulevard. There are two main ravines. Based on a review of historical air photos, the west tributary previously flowed to Green's Creek across what is now the NCC Greenbelt. The east branch was originally a tributary that flowed in a north-easterly direction to Bilberry Creek. There is also remnant tributary to Bilberry Creek near the Ottawa River shoreline that is now within the Voyageur Creek subwatershed.

Photo 4: Typical Forested Ravine in the Upper Reach of Voyageur Creek



Legend

- Voyageur
- Water Courses
- Developed Areas

Eastern Subwatersheds Stormwater Management Retrofit Study

Voyageur Creek Subwatershed

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Figure 1.7

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O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 1.7 - Voyageur Creek Subwatershed.mxd

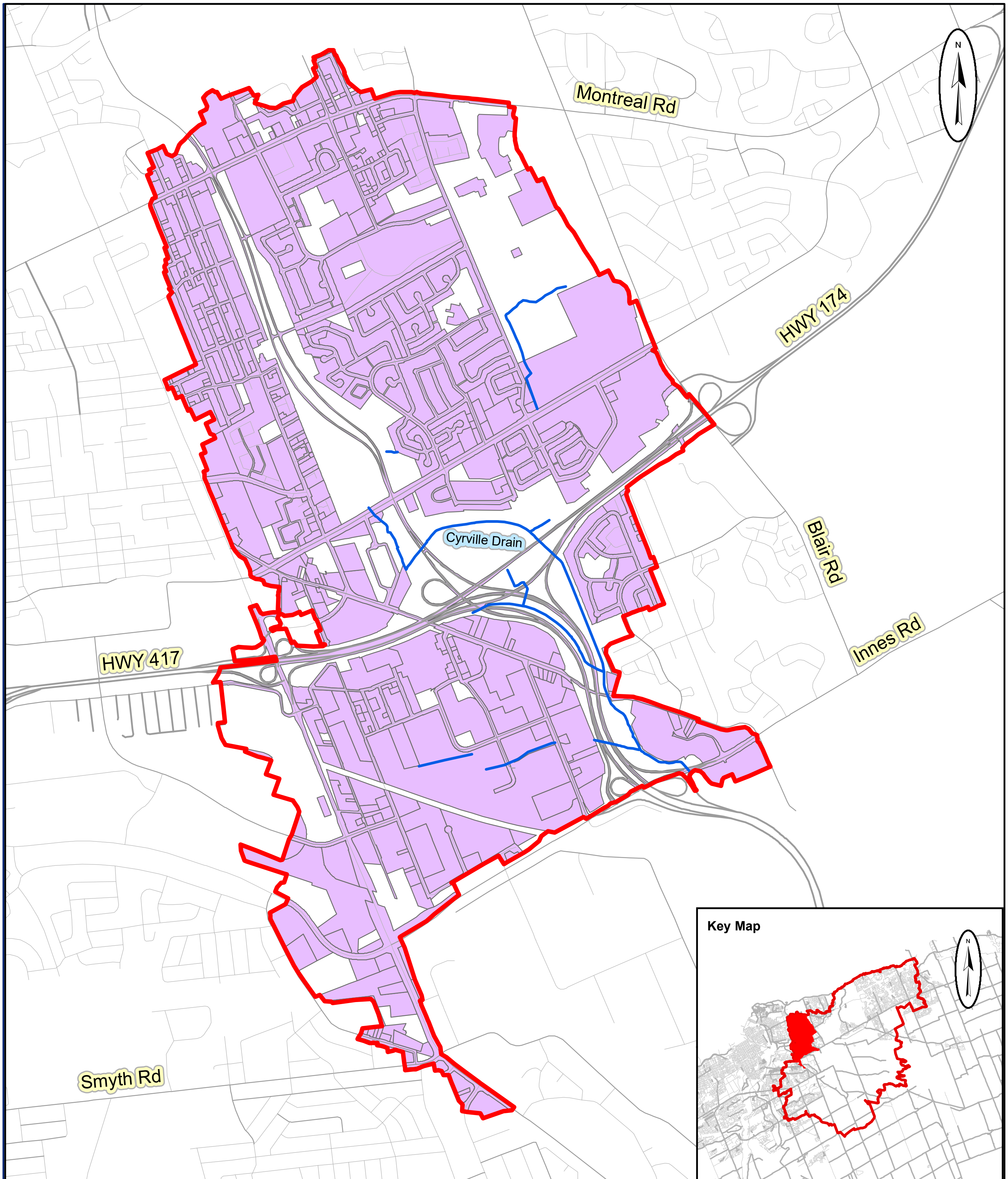
North of St. Joseph Boulevard, Voyageur Creek has been greatly modified by channelization and enclosure. In 1976, the watercourse was constructed as a trapezoidal shaped channel with gabion drop structures. These drop structures, or weirs, experienced damage from erosion and were repaired in the early 1980s. South of the Queensway, Voyageur Creek enters a large diameter trunk storm sewer which continues to the outfall at the Ottawa River. The 3.6m diameter trunk sewer was originally constructed to divert flows from the south side of Highway 174 to the Ottawa River — a length of over 1.5 km. The sewer diversion was constructed in the mid-1970s within a pedestrian pathway and green corridor through the residential community north of the Queensway.

Photo 5: The Channelized Section of Voyageur Creek in the Youville Industrial Park

The catchment area for the west branch includes lands within the Greenbelt containing part a Department of National Defense facility and a large tract of forested lands. The east branch is entirely developed except for the ravines. The land use is mostly residential with an area of commercial/ industrial development in the Youville Industrial Park located between St. Joseph Boulevard and the Queensway.

1.4.5 Cyrville Drain

The Cyrville Drain subwatershed, shown on Figure 1.8, covers an area of approximately 960 hectares. Historically, Cyrville Drain has undergone significant change and impact from development, including extensive channelization and realignment. Cyrville Drain has been impacted by encroachment from development and major transportation improvements. The watercourse is no longer a natural watercourse, and can be described as a wide and straight channel, lacking significant riparian area.



Legend

- Cyrville
- Water Courses
- Developed Areas

Eastern Subwatersheds Stormwater Management Retrofit Study

Cyrville Drain Subwatershed

Morrison Hershfield | Aquafor Beech Limited

Figure 1.8

0 0.25 0.5 1 Km

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O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 1.8 - Cyrville Drain Subwatershed.mxd

Photo 6: South Cyrville Drain

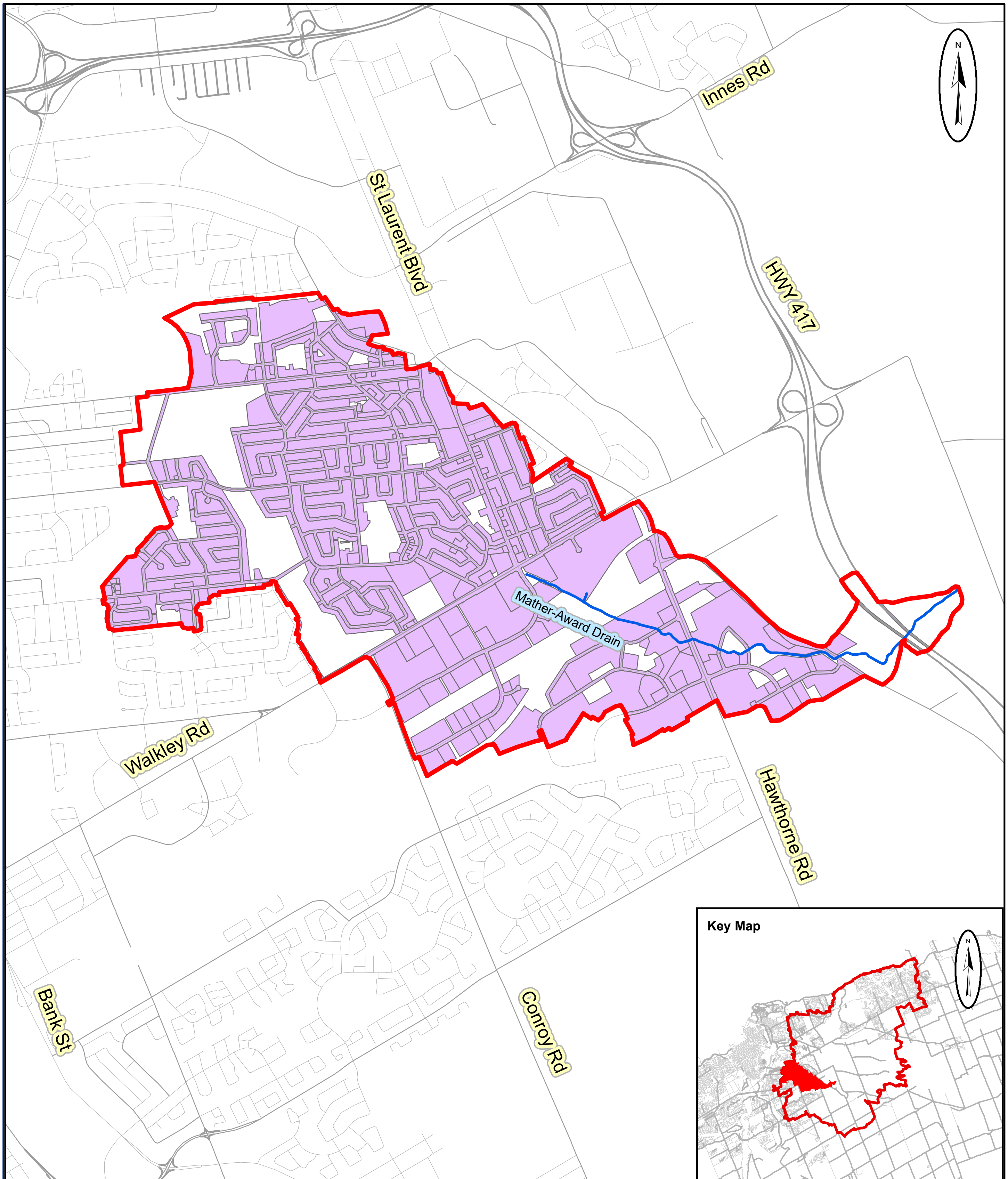
Cyrville Drain has a north and south branch which join north of Innes Road and the Highway 417 interchange, before flowing into Green's Creek. The North Cyrville Drain is also known as Cummings Creek.

In 1946, the former Township of Gloucester adopted a bylaw for drainage improvements on what was known as the Choquette Award, which was constructed approximately 40 years previously. The Choquette Award drain became the South Cyrville (Municipal) Drain.

The land use in the south branch is predominately long standing industrial and commercial development. The channel is within a corridor less than 10 meters in width, and has been enclosed with lengthy sections of storm sewers in various locations.

1.4.6 Mather Award Drain

The Mather Award Drain is located south of the Cyrville Drain catchment, and covers about 810 hectares. Figure 1.9 shows the Mather Award Drain subwatershed. A dense network of storm sewers, serving the Elmvale and Alta Vista residential neighbourhoods, combine together just upstream of the outfall to the Mather Award Drain, located just south of Walkley Road, east of St. Laurent Boulevard. The channel runs in a southeast direction for about 2 kilometers before joining with the lower reach of McEwan Creek and flowing directly east to Green's Creek.



Legend

- Mather Award Drain
- WaterCourses
- Developed Areas

Eastern Subwatersheds Stormwater Management Retrofit Study

Mather Award Drain Subwatershed

MORRISON HERSHFIELD

Aquafor Beech Limited

Figure 1.9

0 0.25 0.5 1 1.5 Km

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O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 1.9 - Mather Award Drain Subwatershed.mxd

Photo 7: Photo of Lower Reach of Mather Award Drain

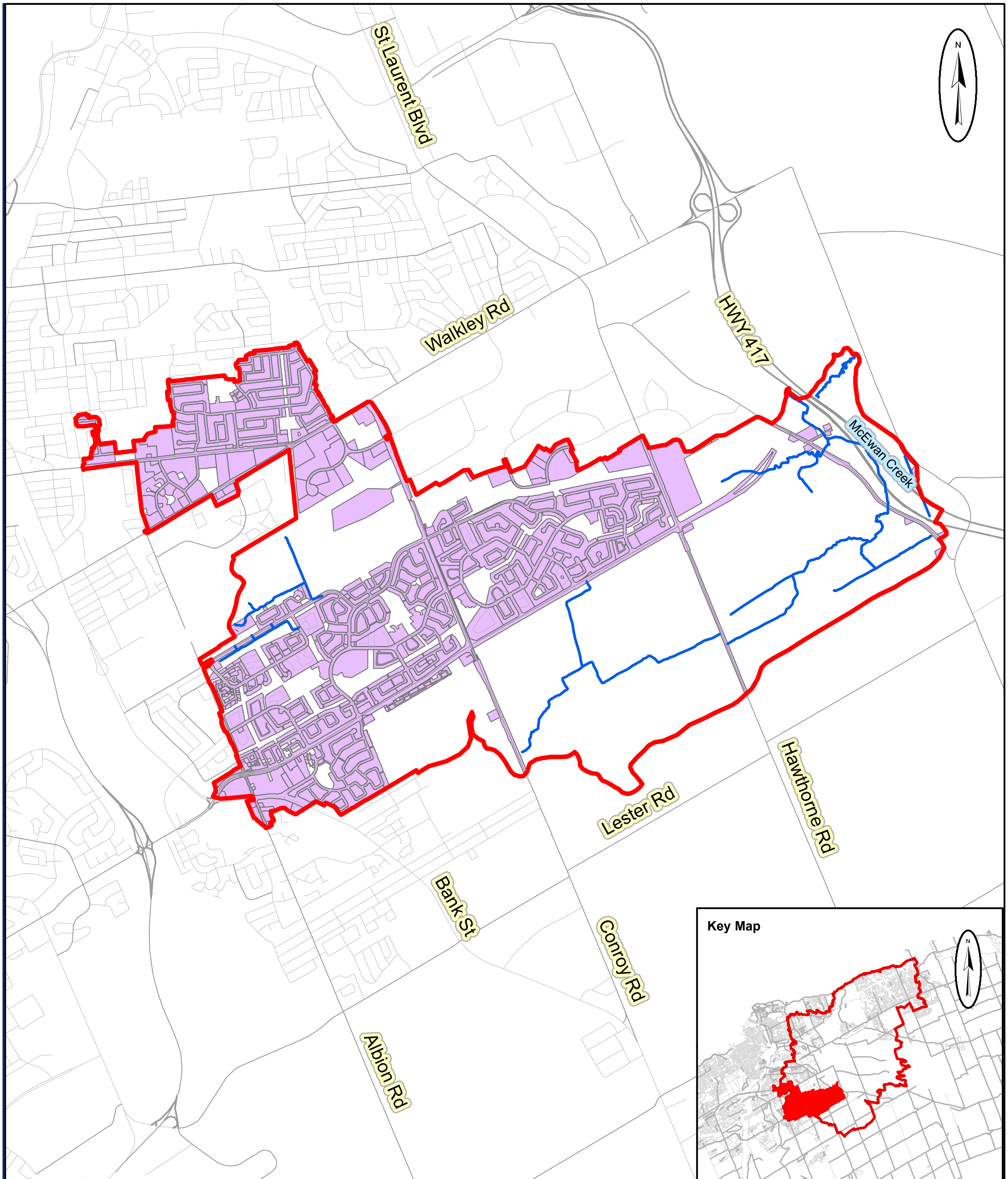
The catchment areas are completely developed, except for a significant Hydro corridor south of Walkley Road, and an undeveloped corridor extending north from Walkley Road and Conroy Road, which is planned for a future arterial road. The reach of the Mather Award Drain downstream of Russell Road goes through agricultural lands. There are several culvert crossings of the Mather Award Drain.

A trunk sewer on Walkley Road diverts high flows directly to an outlet on Green's Creek, near Highway 417. The tributary area to the trunk sewer is a significant portion of the subwatershed area north of Walkley Road. The 2400mm diameter trunk sewer follows Walkley Road to the outfall on the west bank of Green's Creek. There is an additional 1500mm trunk sewer which drains Sheffield Road and a portion of the industrial commercial lands north of Walkley Road. A study in 1993 recommended the diversion of flows from the 1500mm diameter trunk sewer to the 2400mm diameter sewer to balance capacity.

The channel is relatively straight with limited riparian area, similar in characteristics to the neighbouring Cyrville Drain to the north. The banks are sparsely vegetated and maintained for access and maintenance.

1.4.7 McEwan Creek

Figure 1.10 depicts the extent of the McEwan Creek subwatershed. The McEwan Creek subwatershed covers an area of approximately 1,560 hectares, and is located at the south boundary of the Eastern Subwatersheds Study Area. McEwan Creek is made up of a north and south branch, each having markedly different characteristics.



Legend
- McEwan
- Water Courses
- Developed Areas

Ottawa

Eastern Subwatersheds Stormwater Management Retrofit Study

McEwan Creek Subwatershed

MORRISON HERSHFIELD

Aquafor Beech Limited

Figure 1.10

0 0.25 0.5 1 1.5 2
Km

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O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 1.10 - McEwan Creek Subwatershed.mxd

Photo 8: Remnant Channel of McEwan Creek at Hawthorne Road

The catchment areas of the north branch have been extensively developed with a combined commercial/ industrial and residential land use. Most of the original watercourse has been replaced with a trunk storm sewer with an outfall located east of Hawthorne Road. A recently constructed stormwater management facility exists just downstream of the outfall. The watercourse continues easterly and is being affected by the recently completed Hunt Club Road extension and Highway 417 Interchange project.

Photo 9: McEwan Creek Stormwater Management Facility North of Hunt Club Extension under Construction April 2012

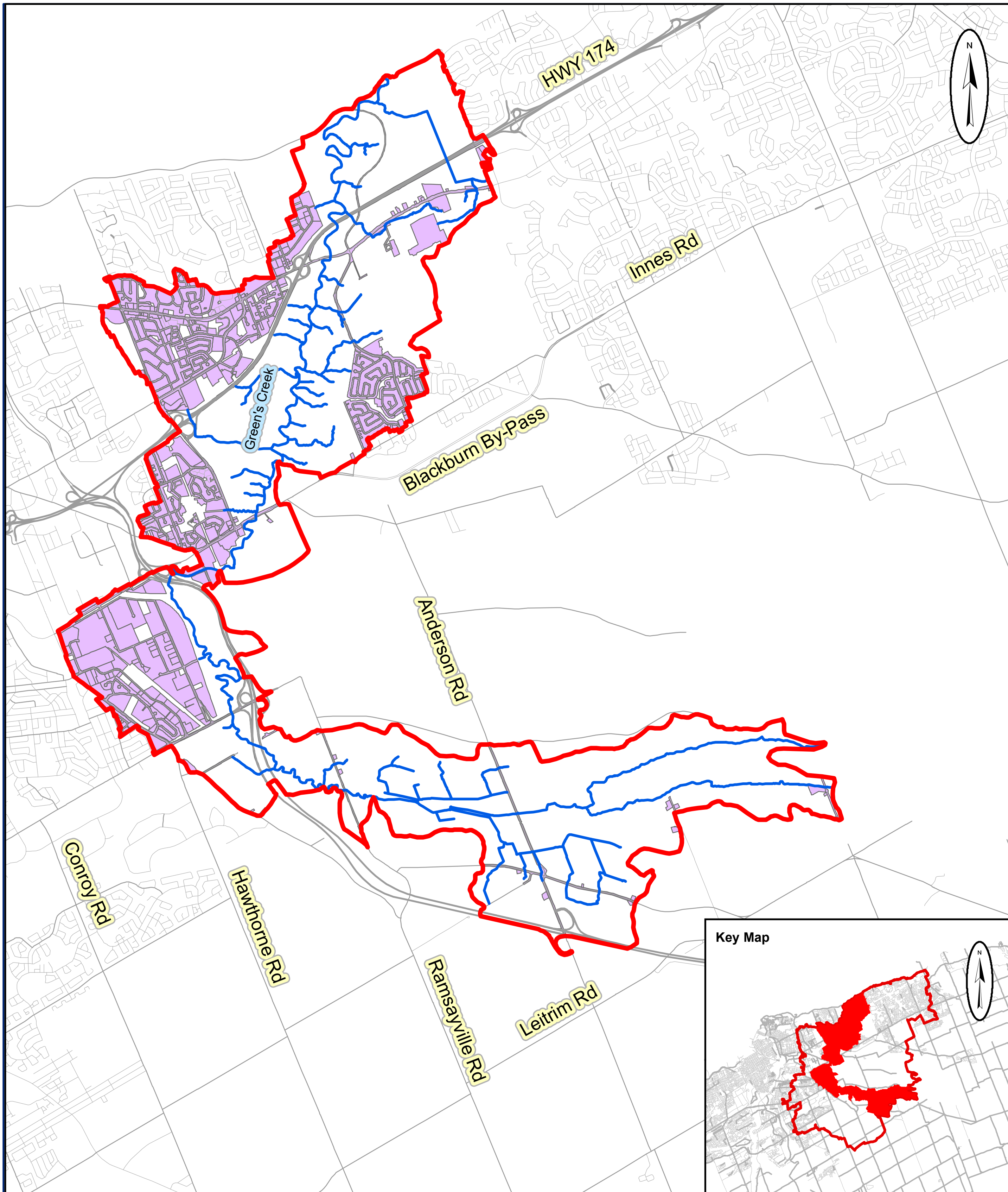
The south branch catchment area is completely undeveloped. It begins within the Greenbelt and drains a portion of the Pine Grove Forest reserve, south of Hunt Club Road. The south branch crosses Russell Road and the east bound lanes of Highway 417 before flowing north between the east and west bound lanes of Highway 417. This branch is mostly in a natural state and largely unaffected by development.

The north and south branch join just west of Highway 417. It appears that McEwan Creek was, at some time, diverted north to join with the Mather Award Drain before going through a single crossing of the Highway 417. This diversion left a remnant meandering stream channel which runs east from Highway 417 before entering Green's Creek.

1.4.8 Green's Creek Catchments

There are a number of developed catchment areas that drain to very small tributaries of Green's Creek or directly to the main branch of Green's Creek. These catchment areas are shown on Figure 1.11. The total area of these catchments is approximately 1290 hectares.

Photo 10: Green's Creek at Cyrville Road



Legend

- Green Creek
- Water Courses
- Developed Areas

Ottawa

Eastern Subwatersheds Stormwater Management Retrofit Study

Green's Creek Subwatershed

Morrison Hershfield

Aquafor Beech Limited

Figure 1.11

0 0.25 0.5 1 1.5 2 2.5 3 Km

August, 2018

Project No. 2124041

O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 1.11 - Greens Creek Subwatershed.mxd

2 BACKGROUND REVIEW

2.1 Information Sources

2.1.1 Reports and Studies

The City of Ottawa provided a data base of all the known previous reports and studies that have relevance to the Eastern Subwatersheds study. Appendix A contains summaries of the purpose and subject of the reports and studies that were determined to have some direct relevance to the current study.

There are a number of ongoing studies that have relevance to Eastern Subwatersheds Stormwater Management Retrofit Study. These include the following:

- Green's Creek Subwatersheds: Constraints and Opportunities for Rehabilitation Projects (NCC);
- Joint Study to Assess Cumulative Effects of Transportation Infrastructure on the National Capital Greenbelt (City of Ottawa/ NCC);
- Capital Urban Lands Master Plan (NCC).

2.1.2 Physical Inspections

Field inspections were carried out from July 16th to July 20th, 2012 to characterize the existing municipal infrastructure, outfalls, fluvial geomorphology, and general conditions in the urban areas of the urban subwatersheds. An inventory of all outfalls and photographs taken during the field investigations is provided in Appendix B.

The City of Ottawa completed and provided a desktop analysis to identify the estimated depth of cover of existing infrastructure crossing the watercourses. Analysis calculations indicated exposure of the sanitary trunk crossing the Bilberry Creek; however, the field crew were unable to observe the exposure on the site. Furthermore, a number of the infrastructure crossings within the Eastern Subwatersheds were identified by field crew as to be exposed in the near future. The list and the figure showing the location of the infrastructure crossings were included in Appendix B1.

2.1.3 GIS and Mapping Information

The City of Ottawa provided Geographical Information System (GIS) data which contained information on the physical characteristics and land use across the study area. This data was extensively used in all of the analysis, including the hydrology modelling.

In addition to the GIS data, the City provided LiDAR (Light Detection and Ranging) data which covered most of the study area. This data enabled the generation of a very accurate digital elevation model (DEM) of the study area.

2.1.4 Hydrologic Models

Hydrologic models provide a means to understand the existing flow regime and response to rainfall events. The models can be used to estimate the effect of different management approaches on the flow regime and water quality in the individual watercourses and outlets to the Ottawa River.

There are numerous hydrologic models associated with separate design studies related to development projects, as well as stormwater management facility design and planning. There has been no comprehensive hydrology model developed for the Eastern Subwatersheds that is available to the current study.

In 2012, Baird and Associates completed hydrologic modelling of the Eastern Subwatersheds, specifically, Green's Creek, Bilberry Creek and Taylor Creek. The purpose for this modelling effort was to build on the screening level analysis that was done as part of the Ottawa River Water Quality Model Study. The P8 Urban Catchment Model was applied for that study (http://wwwalker.net/p8/).

2.2 Natural Environment

The study area is relatively gently sloped towards the Ottawa River, and has an elevation difference of about 50 meters from the highest land elevation to the shore of the Ottawa River.

The Eastern Subwatersheds contain a few well defined, incised ravines such as Green's Creek, Voyageur Creek and Bilberry Creek. The Bilberry Creek ravine has a length just over 8 kilometers and an elevation change of about 46m with an average gradient approaching 0.6% (Characterization of Ottawa's Watersheds, 2011).

Generally, most of the study area consists of clay and till plains, characterized by deep deposits of clay over bedrock generated from glacial and post glacial marine deposits. In portions of the upper reaches of Voyageur Creek subwatershed the surficial geology is predominantly sand.

The Eastern Subwatersheds contain intact and mature forested areas. These include the Green's Creek, Voyageur Creek and Bilberry Creek ravines, as well as the south portions of the McEwan Creek subwatershed.

The area has a unique geological history. The last period of glaciation took place between 20,000 and 11,000 years ago. Once the glacier retreated about 12,000 years ago the area became covered by a deep freshwater lake. The lake became inundated with seawater from the Atlantic Ocean for a period of about 2,000 years after a glacial ice barrier disappeared. This was known as the Champlain Sea. Once the lands rebounded from the effect of the retreat of the glaciers, the sea disappeared. The seawater left marine clay deposits renowned as Leda clay, which is known to be unstable and subject to liquefaction.

With the exception of the upper portion of the Voyageur Creek, the combined overburden depth and clay deposits predominate most of the Eastern Subwatersheds.

A limestone escarpment exists near the Ottawa River shoreline in the eastern portion of the study area — located just south of St. Joseph Boulevard in the Taylor Creek and Queenswood subwatersheds.

A significant shoreline wetland exists along the Ottawa River near the outlets of Taylor Creek, Queenswood catchments and Bilberry Creeks. There are remnant wetland areas in the headwaters of Cyrville Creek. The Mer Bleue is an extensive and very significant wetland complex located at the upper reach of Mud Creek, Black Creek, Borthwick Creek and Green's Creek.

Figure 2.1 shows the key natural features of the Eastern Subwatersheds.

2.3 Built Environment

The Eastern Subwatersheds study area covers a diverse area within the City of Ottawa. It includes the eastern portion of the City's urban core inside the greenbelt, and more recently developed suburban neighbourhoods outside of the greenbelt. The urban core areas contain older residential areas, including extensive industrial and commercial development. Most of the City of Ottawa's inventory of industrial lands is located in the eastern urban area of the City.

The study area includes the former municipalities of Cumberland, Gloucester, and portions of the City of Ottawa mature neighbourhoods of Alta Vista, Elmvale, Carson Grove and Hawthorne Meadows. The former municipalities were amalgamated to the current City of Ottawa in 2001.

The study area contains extensive recreational facilities, natural areas, schools, and other services close to major transportation routes to downtown. Suburban areas outside of the greenbelt have experienced extensive growth over the last 30 years.

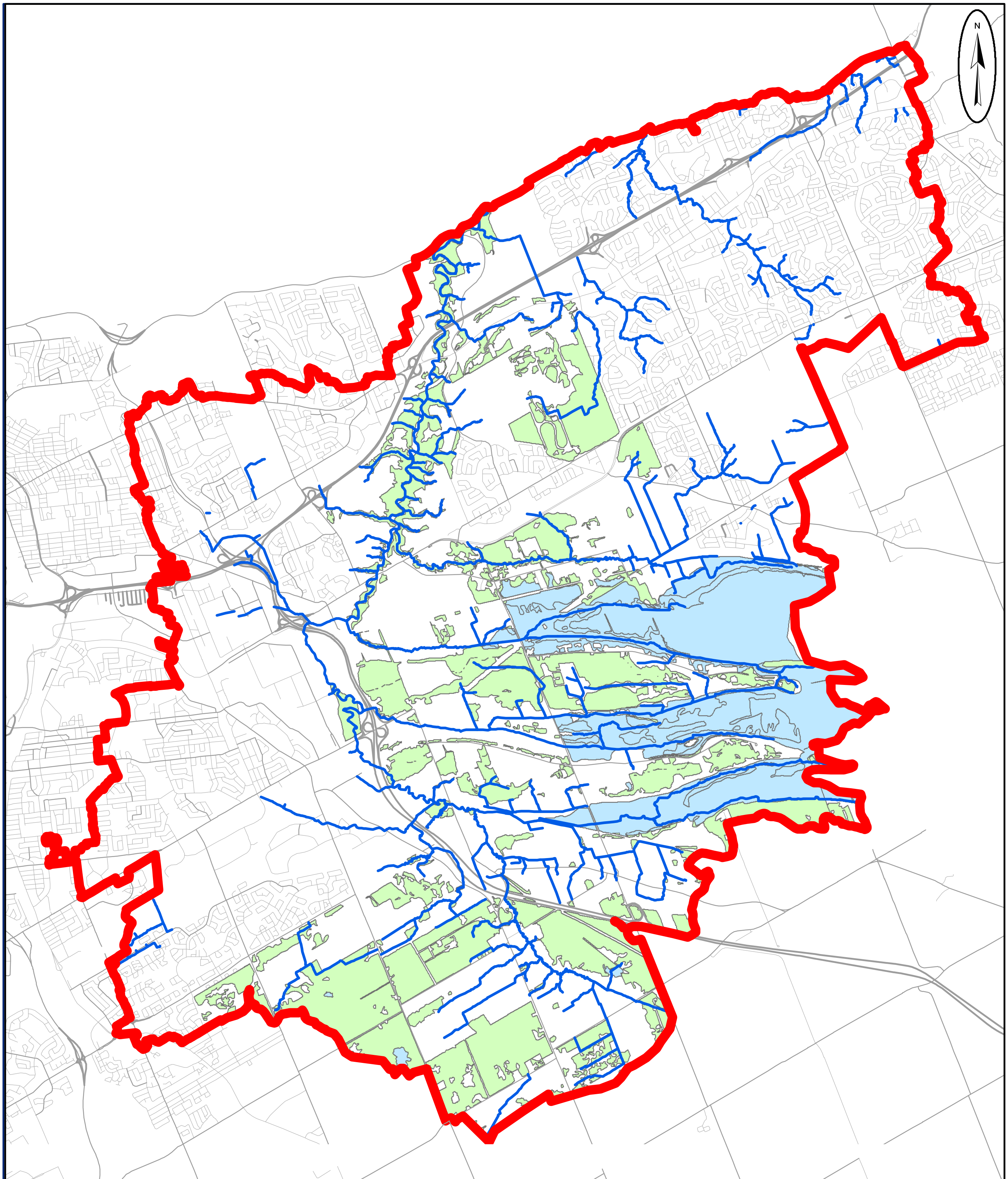
Most of the area contains residential communities and neighbourhoods. The main places of employment are located either along the Walkley/Hawthorne corridor, or around the Orleans Town Center, Innes Road, north of Montreal Road, and east of Sheridan Road.

A main commercial town center is situated on the north side of St. Joseph Boulevard, between Place D'Orleans Drive and Tenth Line Road. This area contains a major shopping center (Place D'Orleans), a community center (Peter D. Clark Place), a performing arts theatre (Shenkman Arts Centre), and numerous commercial businesses.

Other main commercial districts within the study area are located at Blair Road near the Queensway, the interchange between the Queensway and Highway 417.

Major highways such as the Queensway and Highway 417 transect the study area. The proposed Ottawa light rail transit (OLRT) Phase 1 line is currently being constructed along the north side of the Queensway, and with OLRT Phase 2 will extend to the Tenth Line.

Figure 2.2 shows the key features of the built environment within the Eastern Subwatersheds.



Legend

- Study Area
- Water Courses
- Forested Area
- Wetland

Ottawa

Eastern Subwatersheds Stormwater Management Retrofit Study

Natural Environment

Morrison Hershfield

Aquafor Beech Limited

Figure 2.1

0 0.5 1 2 3 4

Km

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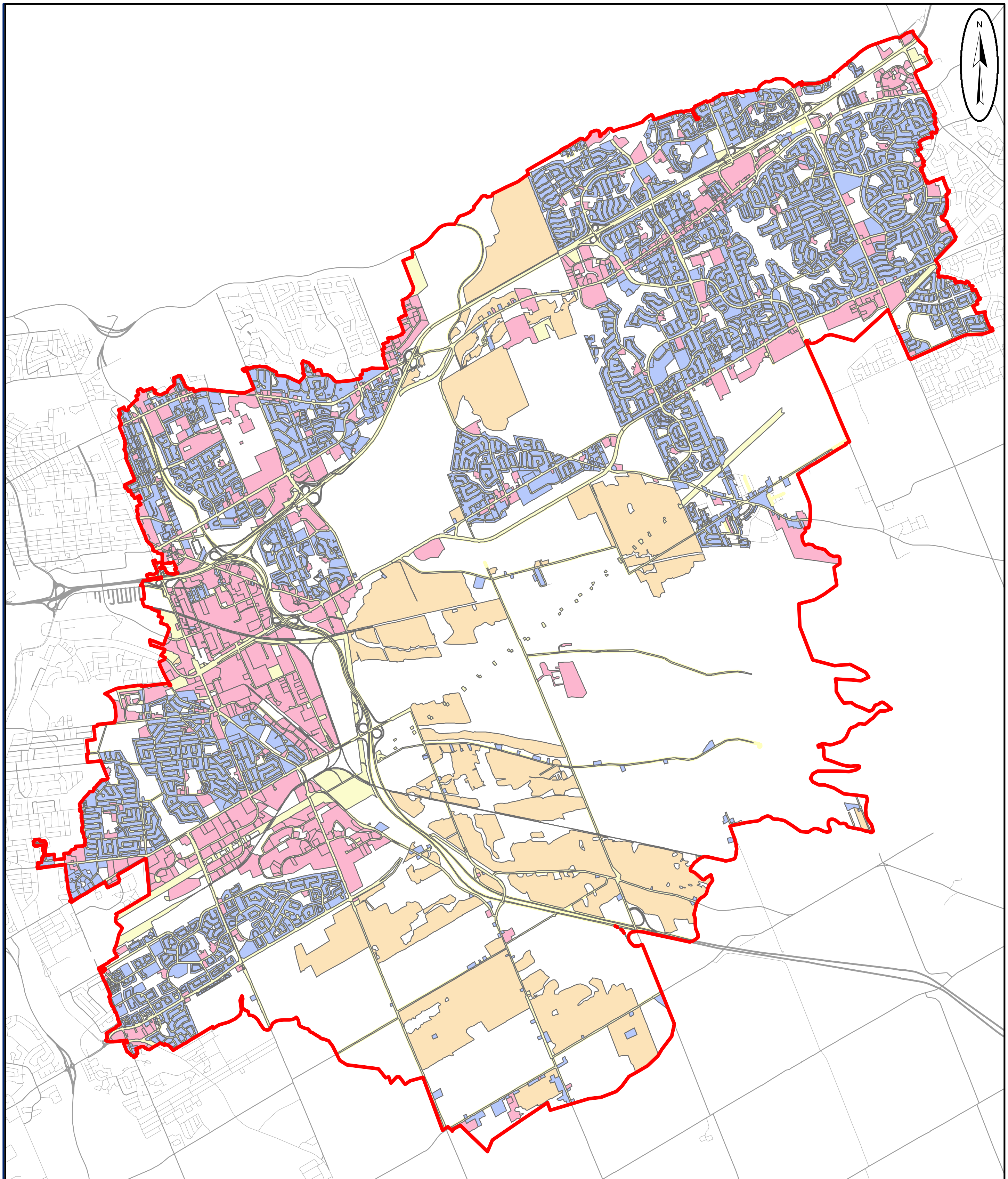
O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 2.1 - Natural Environment.mxd



Ottawa

Legend

- Study Area
- Other
- Commercial/Industrial/Institutional
- Transportation Utility Communication
- Residential

Eastern Subwatersheds Stormwater Management Retrofit Study

Built Environment

Morrison Hershfield

Aquafor Beech Limited

Figure 2.2

0 0.5 1 2 3 4
Km

August, 2018

Project No. 2124041

O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 2.2 - Built Environment.mxd

3 CHARACTERIZATION OF THE SUBWATERSHEDS

The following sections describe the existing conditions of the various individual subwatersheds within the study area, including the natural environmental conditions related to terrestrial and aquatic habitat and fisheries. The effort applied to the characterization was a desktop exercise using available reports and sources of information to summarize known habitat values and conditions.

The information sources used for the description of aquatic and terrestrial habitat includes the Natural Heritage Information Center (NHIC). The NHIC is a joint effort by the Ontario Ministry of Natural Resources and the Nature Conservancy of Canada, the Natural Heritage League, and the Nature Conservatory. The NHIC provides information on natural species, plant communities and spaces of conservation concern in Ontario.

Other information sources were available reports as well as sampling studies either by the City of Ottawa or the Rideau Valley Conservation Authority. A list of the information sources is provided in the list of references. The City Stream Watch program provides valuable information on watercourses within the City of Ottawa. The program is run by a partnership of six groups from the Ottawa area, and seeks to obtain, record and manage information on the physical and biological characteristics of streams in the City of Ottawa.

A document entitled *Characterization of Ottawa's Watersheds,* produced by the City of Ottawa in March of 2011, provided a key source of information pertaining to the Eastern Subwatersheds.

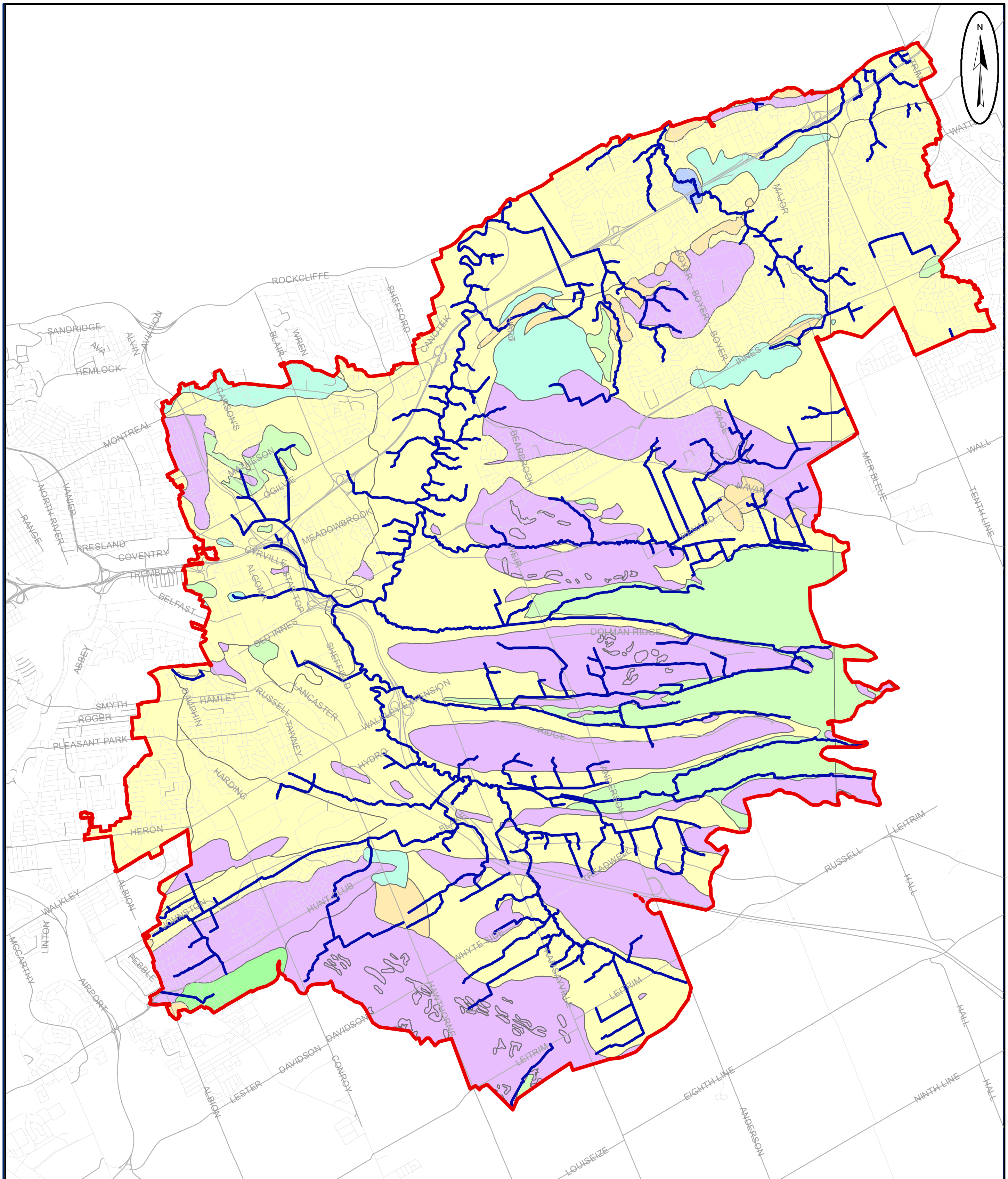
3.1 Surficial Geology

The surficial soil information in the study area taken from the City of Ottawa GIS is shown on Figure 3.1. Generally, the Ottawa River valley is dominated by silty clay deposits, and sand left from the ancient Champlain Sea (Ministry of Agriculture and Food, 1987). Extensive periods of glaciation followed by inundation with freshwater and seawater have resulted in widespread and relatively deep deposits of clay throughout most of the study area.

There are some exceptions to this, however, the upper reaches of Mud Creek, Borthwick Creek and Green's Creek contain organic materials associated with the Mer Bleue wetland. There are also areas of extensive sand deposits located along the south and southeast portions of the study area, associated with old shoreline deposits from the historical locations of the Ottawa River and post-glacial lakes.

There are isolated deposits of poorly graded sediments, and an extensive deposit of sand/ silt and gravel in the Voyageur Creek, the east slope of Green's Creek, and the southern portion of the McEwan Creek subwatershed.

The surface geology indicates that the lands have a low permeability with a propensity to generate a source of very fine sediments in the streams.



Legend

Study Area

Watercourse

Surficial Geology

- Clay/Silt
- Clay/Silt/Sand
- Diamicton
- Organic Deposits
- Paleozoic Bedrock
- Sand
- Sand/Gravel

Eastern Subwatersheds Stormwater Management Retrofit Study

Surficial Geology

Figure 3.1

0 0.5 1 2 3 4

Km

August, 2018

Project No. 2124041

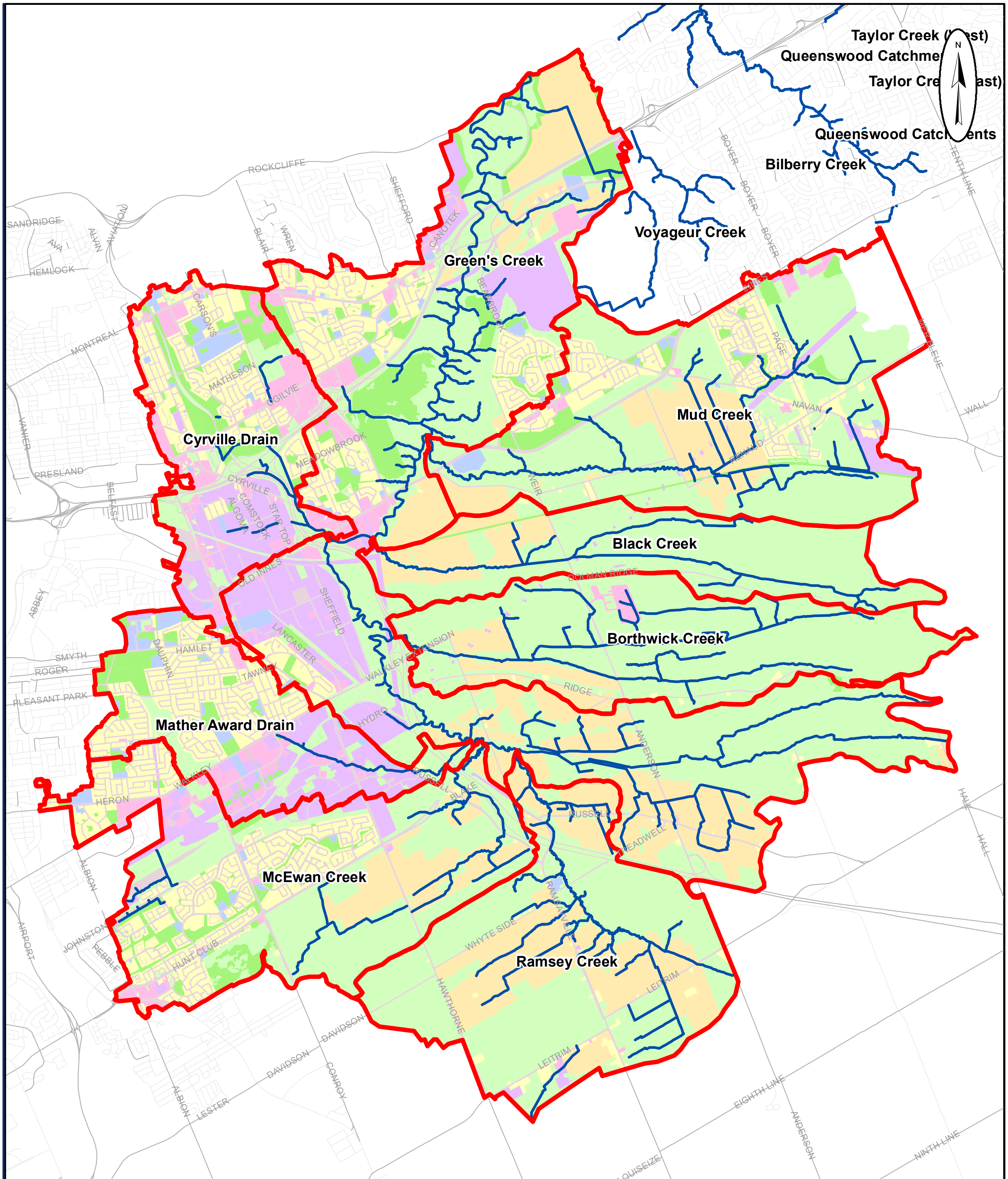
O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 3.1 - Surficial Geology.mxd

3.2 Land Use

Figure 3.2 and Figure 3.3 indicate the land use throughout the study area. Information on the existing land use was extracted from the City of Ottawa GIS data which includes a data layer described as the 2010 land use. The layer 2010 land use was re-categorized and consist of:

- Residential,
- Commercial,
- Industrial,
- Institutional,
- Major Transportation and Utility Corridors,
- Recreational,
- Natural Environment,
- Agricultural, and
- Arterial, Collector and Local Roads.

Table 3-1 summarizes the proportion of land use within each of the subwatersheds in the study area. The land use in the urban subwatersheds is between 45 and 85% urban. The highest proportion of urban land use is in the Queenswood Catchments. The lowest proportion is the main branch of Green's Creek at 29% and McEwan Creek at 44%. This is due to the fact these subwatersheds include a large rural catchment within the Greenbelt. For the entire Green's Creek watershed, 29% of the area is urban land use. For the Ottawa River subwatersheds, the proportion of urban land use ranges from 61% (Voyageur Creek) to 85% (Queenswood). Taylor Creek and Bilberry Creek are about 75% urban.



Legend

- Subwatershed
- Watercourse

Land Use

- Agriculture
- Commercial/Office Space
- Industrial
- Insititutional
- Natural Environment
- Residential
- Recreational
- Roads/Transportation

Ottawa

Eastern Subwatersheds Stormwater Management Retrofit Study

Land Use - Green's Creek

MORRISON HERSHFIELD

Aquafor Beech Limited

Figure 3.2

0 0.5 1 2 3
Km

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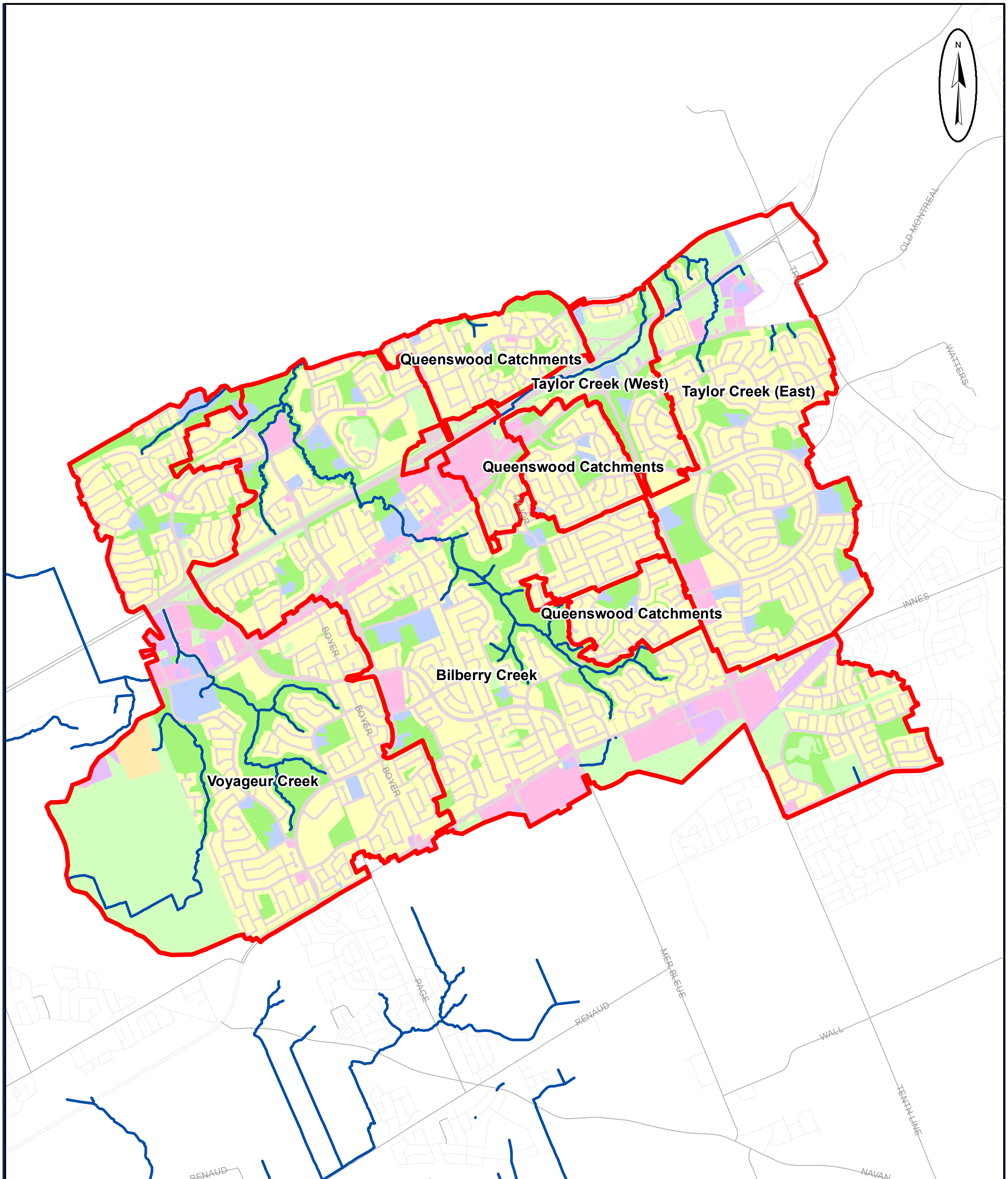
O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 3.2 - Land Use - Green's Creek.mxd



Legend

- Subwatershed Boundary
- Watercourse

Land Use

- Agriculture
- Commercial/Office Space
- Industrial
- Institutional
- Natural Environment
- Residential
- Recreational
- Roads/Transportation

Ottawa

Eastern Subwatersheds Stormwater Management Retrofit Study

Land Use - Ottawa River Subwatersheds

Morrison Hershfield

Aquafor Beech Limited

Figure 3.3

0 0.25 0.5 1 1.5 2
Km

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O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 3.3 - Land Use - Ottawa River Subwatersheds.mxd

Table 3-1: Summary of Land Use for the Eastern Subwatersheds

Subwatershed	Area (ha)	Land Use / Land Cover (%)									Total (%)
		Residential	Commercial/ Office	Industrial	Institutional	Recreational	Major Transportation Utility Corridors	Agriculture	Collector Arterial, and Local Streets	Natural Environment	
Urban Subwatersheds											
Taylor Creek	665	39.5	5.6	2.6	4.0	12.1	0.0	0.0	22.3	13.9	100.0
Queenswood Catchments	263	55.2	1.7	0.2	2.2	13.3	0.0	0.0	26.1	1.3	100.0
Bilberry Creek	1,109	40.8	8.6	0.8	3.1	16.7	0.7	0.0	21.2	8.1	100.0
Voyageur Creek	828	36.1	3.0	0.8	3.7	16.0	0.7	1.6	16.5	21.6	100.0
Cyrville Drain	962	21.2	15.3	16.9	4.2	11.4	0.9	0.0	17.1	13.0	100.0
Mather Award Drain	806	27.6	6.9	18.2	5.6	10.0	3.3	0.3	16.4	11.7	100.0
McEwan Creek	1,558	21.1	2.6	4.9	1.3	7.2	1.6	11.2	13.1	37.0	100.0
Mud Creek	1,851	11.4	1.3	2.2	1.0	5.5	1.6	13.5	7.3	56.2	100.0
Green's Creek (Main Branch)	3,558	9.2	3.2	5.7	1.3	7.3	2.2	18.3	7.4	45.4	100.0
Urban Sub-total	**11,600**	**21.1**	**4.7**	**5.7**	**2.3**	**9.5**	**1.6**	**9.4**	**12.8**	**32.9**	100.0
		Rural Subwatersheds									
Black Creek	809	0.2	0.0	0.3	0.0	1.0	.9	16.7	1.0	79.9	100.0
Borthwick Creek	1,113	0.6	1.8	0.0	0.0	0.1	0.2	9.2	2.1	86.0	100.0
Ramsay Creek	1,457	1.9	0.1	0.6	0.3	0.0	0.0	33.5	3.3	60.3	100.0
Rural Sub-total	**3,379**	**1.1**	**0.6**	**0.3**	**0.1**	**0.3**	**0.3**	**21.5**	**2.4**	**73.4**	100.0
TOTAL	**14,979**	**16.6**	**3.8**	**4.5**	**1.8**	**7.4**	**1.3**	**12.1**	**10.5**	**42.0**	100.0

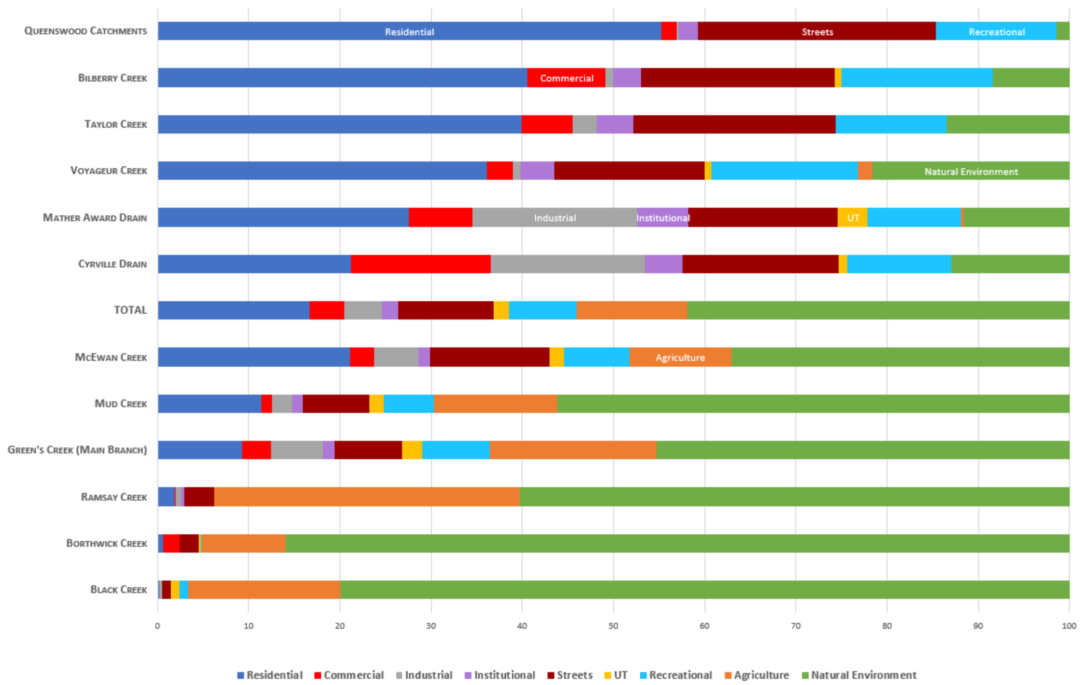
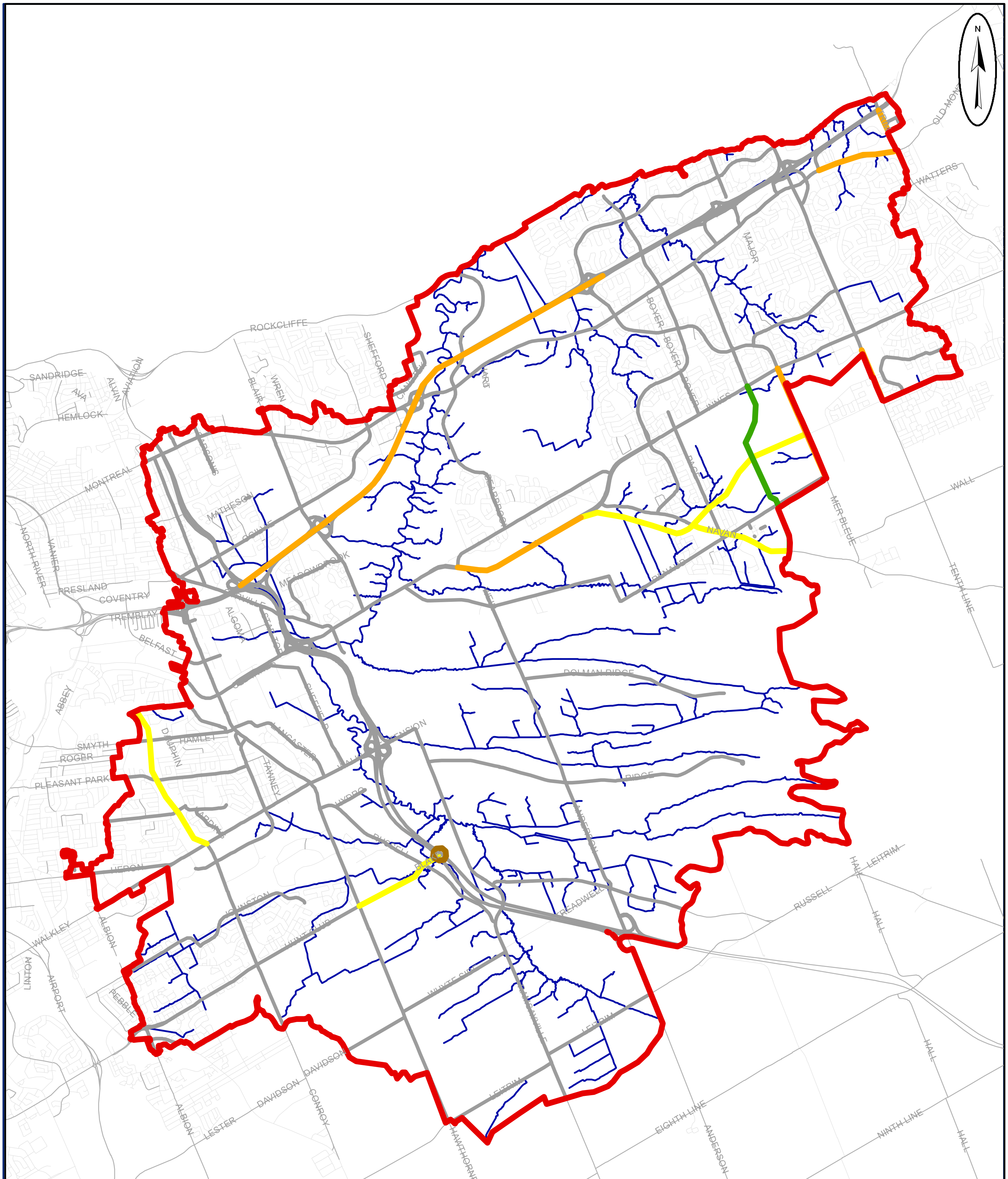


Figure 3.4: Land Use Breakdown for Eastern Subwatersheds Study Area

3.2.1 Transportation Network

The road and transportation network is a significant contributor to stormwater discharges to the natural streams. Figure 3.5 shows the existing and future major transportation routes in the study area, along with future, planned projects. Transportation routes include multi-use pathways, the arterial road network, major highways, and transit ways. There are several planned transportation projects that have the potential for significant stormwater impact to the receiving water. These future transportation projects include:

- The Alta Vista Transportation Corridor is a 5.5 km, 4-lane arterial road with a multi-use pathway and bus lanes between the north end of Conroy Road to Nicholas Street;
- The Highway 417 Hunt Club Interchange and Extension and the Innes Road-Walkley-Hunt Club link which includes a phased 4 lane road from the Hunt Club/Highway 417 interchange to Innes Road, west of Blackburn Hamlet
- Trim Road Widening to 4 lanes from the North Service Road to the future extension of the Blackburn Hamlet Bypass/Brian Coburn Road;
- Queensway Widening from the 417 Interchange to Blair Road and Blair Road to Jeanne D'Arc Boulevard;
- The LRT to Blair Station and eventual extension along the north side of the Queensway to Trim Road; and St. Joseph Boulevard widening east and west of Trim Road.



Legend

- Study Area
- Watercourse
- Existing Major Transportation Route

Proposed Major Transportation Route

- Arterial Widening
- New Arterial
- New Collector/Widening
- New Interchange

Ottawa

Eastern Subwatersheds Stormwater Management Retrofit Study

Major Transportation Routes

MORRISON HERSHFIELD

Aquafor Beech Limited

Figure 3.5

0 0.5 1 2 3 4
Km

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3.2.2 Recreational and Natural Areas

Recreational lands are shown on Figure 3.6. The natural areas include Green's Creek, Mer Bleue conservation areas, Petrie Island, and the Ottawa River shore wetlands area. In terms of recreational areas, there are numerous multi-use pathways that connect through City and NCC parklands as well as City of Ottawa neighbourhood parks.

3.2.3 Institutional Lands

There are several large properties that have institutional type land use. This includes the National Research Council, of which a portion drains south to the Cyrville Drain. The area includes campus style developments with significant open space areas.

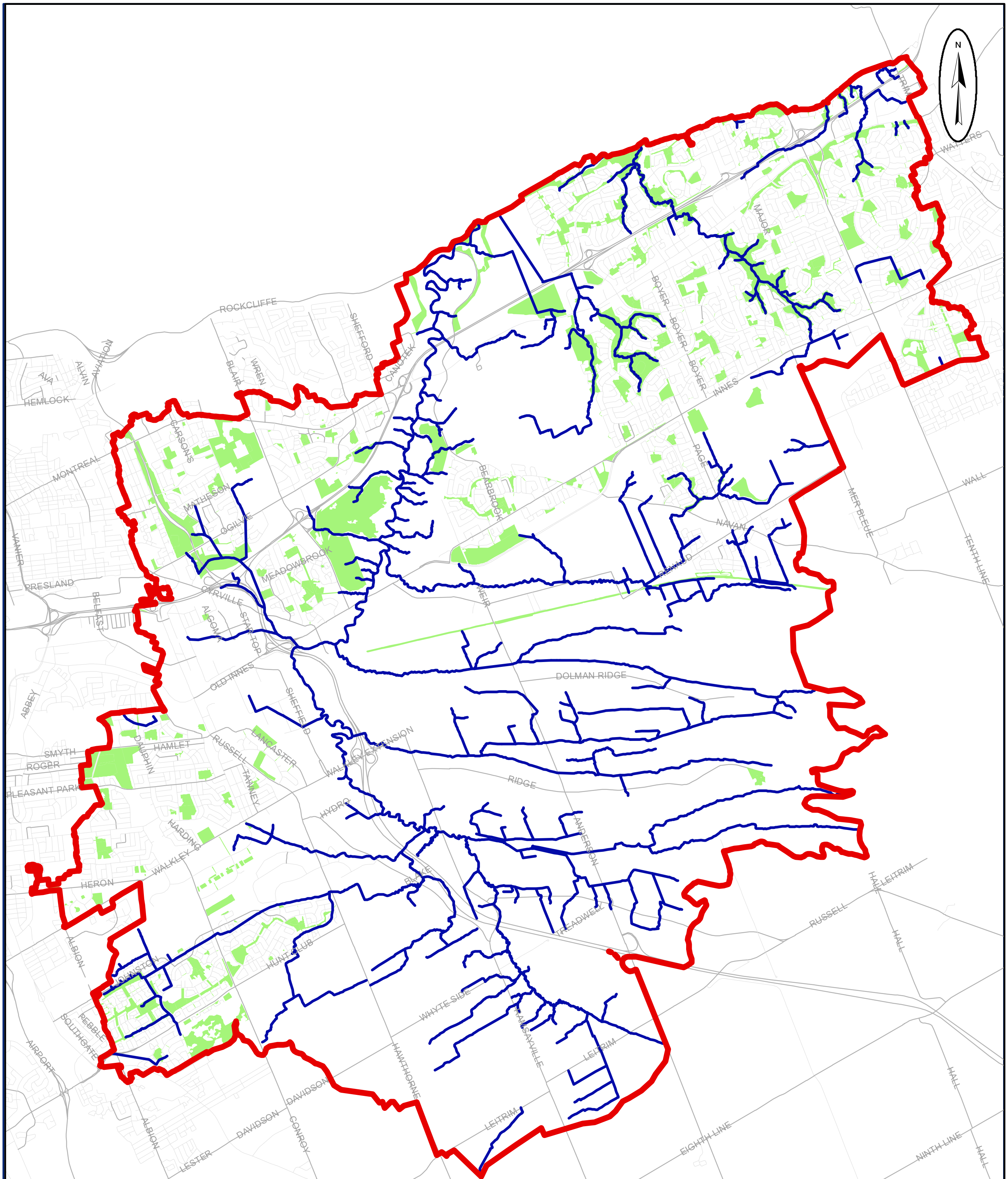
A National Defense facility is located in the NCC Greenbelt. This large property drains west to Green's Creek and east to the east branch of Voyageur Creek.

In addition to the above, the Greenbelt contains various pockets of land use apart from main natural resource area of Green's Creek. Included in this is a significant area of land that was used as a nursery by the NCC located just west of Blackburn Hamlet.

3.3 Municipal Outfalls and Stormwater Management Facilities

A field investigation was undertaken to confirm outfalls and structures in the vicinity of the watercourses in the study area. Photographs from this field investigation are documented in Appendix B. The photographs were geo-referenced. Figure 3.7 and Figure 3.8 show the existing storm sewer outfall locations relative to the watercourses in the Eastern Subwatersheds.

Locations of existing municipal stormwater management facilities are also shown on Figure 3.7 and Figure 3.8. The stormwater management facilities include dry detention ponds, designed to contain excess surface runoff resulting from major storms, and wet ponds designed for both peak flow control and water quality treatment. The Bilberry Creek infrastructure was not included in this inventory as it is covered by a separate study.



Legend

Recreational Lands

Study Area

Water Course

Ottawa

Eastern Subwatersheds Stormwater Management Retrofit Study

Recreational Lands

MORRISON HERSHFIELD

Aquafor Beech Limited

Figure 3.6

0 0.5 1 2 3 4

Km

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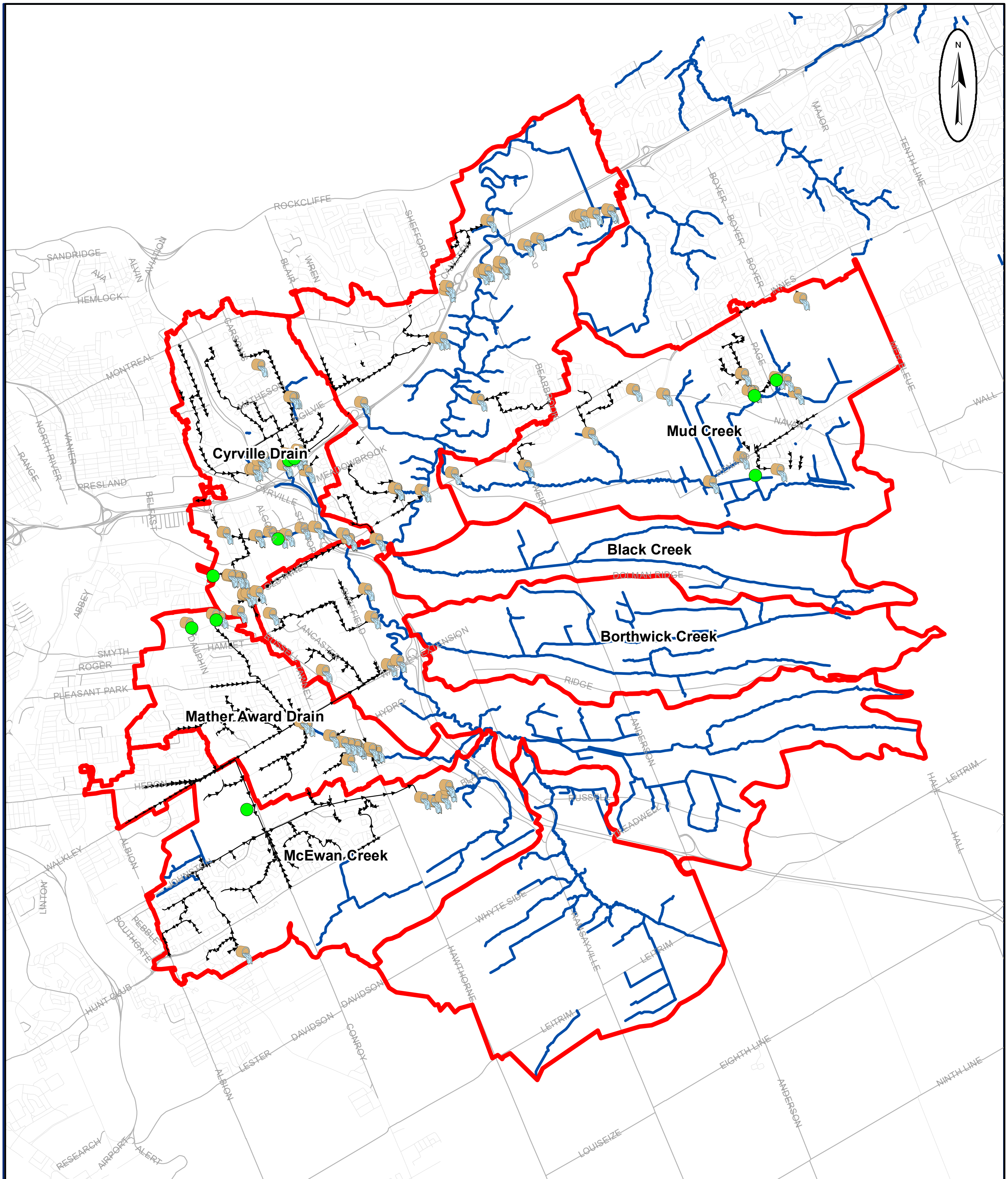


Legend
- SWM Facility
- Storm Sewer Outlet
- Storm Sewer (Diameter > 900mm)
- Watercourse
- Subwatershed

Ottawa

Eastern Subwatersheds Stormwater Management Retrofit Study

Storm Sewer Trunks, Outlets & Stormwater Management Facilities - Green's Creek

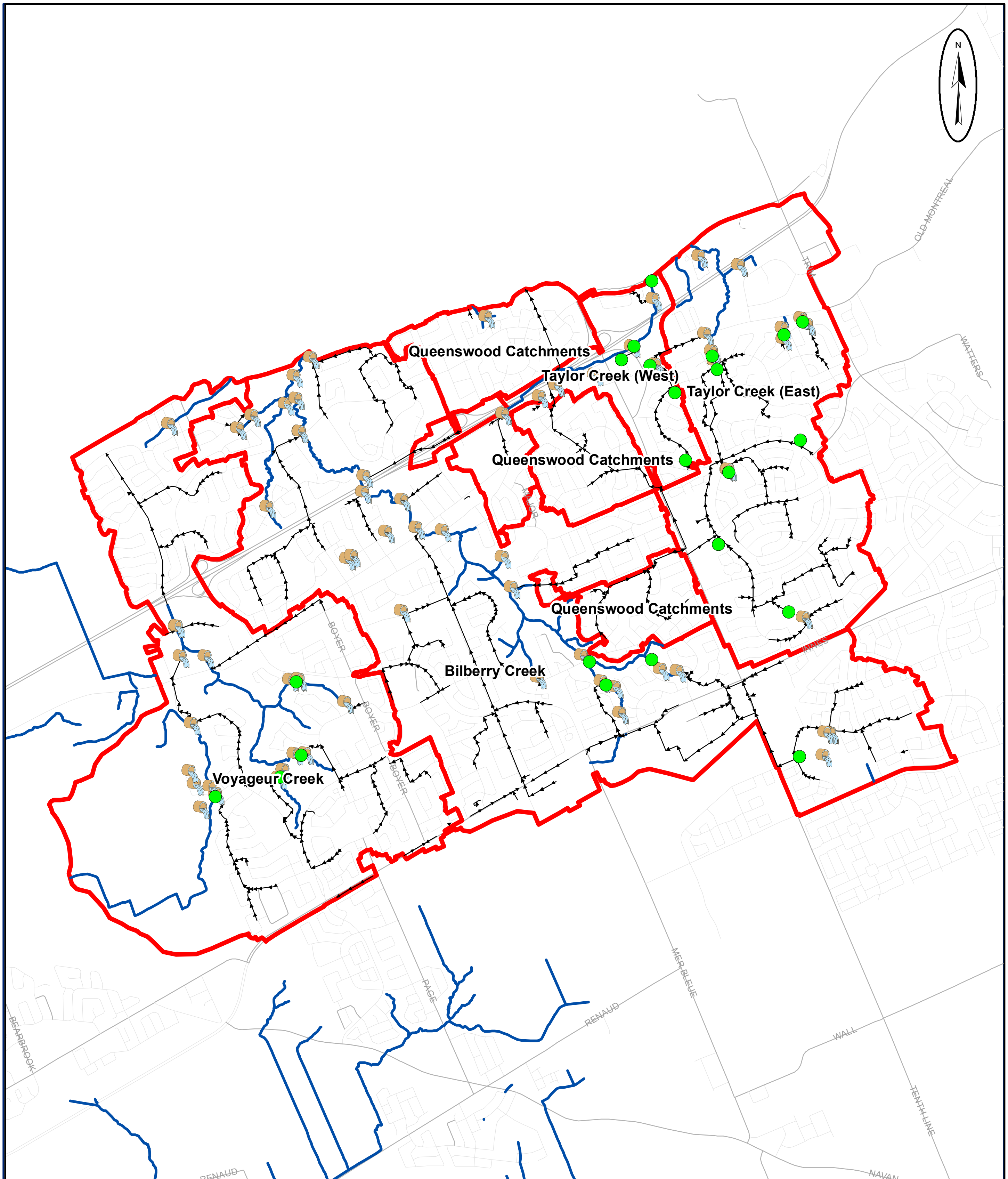
Morrison Hershfield | Aquafor Beech Limited

Figure 3.7

0 0.5 1 2 3
Km

August, 2018 | **Project No. 2124041**

O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 3.7 - Storm Sewer Outfalls & SWM Facilities - Green's Creek.mxd



Legend

- Storm Sewer Outlet
- SWM Facility
- Storm Sewer (Diameter > 900mm)
- Watercourse
- Subwatershed Boundary

Ottawa

Eastern Subwatersheds Stormwater Management Retrofit Study

Storm Sewer Trunks, Outlets & Stormwater Management Facilities - Ottawa River Subwatersheds

Morrison Hershfield

Aquafor Beech Limited

Figure 3.8

0 0.5 1 2
Km

August, 2018 | Project No. 2124041

O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 3.8 - Storm Sewer Outfalls & SWM Facilities - Ottawa River Subwatersheds.mxd

3.4 Surface Water

The existing condition surface water conditions or hydrology needed to be represented by a model which will generate peak flows and volumes in the various watercourses and represent the existing flow regime. The following section provides a description of the modelling approach and development.

The study area is focused on the urban catchments only. The majority of the tributary area to Green's Creek is rural, or open space, containing predominantly clay, silty and sandy soil. Approximately 17% of the entire Eastern Subwatersheds area is residential, 4% commercial, 4% industrial, 2% institutional, 42% open space, 11% streets, 7% recreational, 1% utility corridor, and 12% agriculture. The study area has fourteen (14) separate outfalls to the Ottawa River, including (one (1) from Green's Creek, three (3) from Voyageur Creek, one (1) from Bilberry Creek, five (5) from Queenswood Catchments, and four (4) from Taylor Creek). Table 3-2 summarizes creek lengths and slopes.

Table 3-2: Creek Characteristics

Subwatershed	Creek Length (km)	Slope (%)
Bilberry Creek	7	0.62
Black Creek	8	0.13
Borthwick Creek	7	0.10
Cyrville Drain	3.5	0.43
Green's Creek	26	0.13
Mather Award Drain	2.3	0.35
McEwan Creek	3.2	0.50
Mud Creek	5.7	0.26
Queenswood Catchments	N/A	N/A
Ramsay Creek	5.3	0.26
Taylor Creek	3.1	0.6
Voyageur Creek	4.3 + 1.4 (piped)	0.70

3.4.1 Modelling

The existing condition Eastern Subwatersheds hydrology was modelled using PCSWMM (Version 7.1.2480 with SWMM 5.1.010), a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. PCSWMM built on EPA-SWMM engine is capable of accounting for various hydrologic processes which produce runoff and runoff quality simulations from urban areas, including time-varying rainfall, evaporation, snow accumulation/melting, rainfall interception, infiltration, groundwater flow, reservoir routing, channel routing, and simulation of various hydraulic structures. Typical applications include design and sizing of drainage system components for flood control, sizing of detention facilities and their appurtenances for flood control and water quality protection, and evaluating the effectiveness of best management practices (BMPs) for reducing wet weather pollutant loadings.

3.4.1.1 Methodology

The subwatersheds are represented within the model by defining boundary conditions and various physical hydrologic parameters calculated from land use and other topographical data obtained from the City of Ottawa, and processed into a GIS database. PCSWMM utilizes the EPA-SWMM approach where important model parameters for runoff estimation include subcatchment width, slope, imperviousness, storage depth for pervious and impervious areas, and method of infiltration.

The following steps were applied to develop the hydrologic model:

1. Background review of previous studies;
2. Collection and analysis of input data;
3. Development of model parameters;
4. Development and analysis of the base models; and
5. Evaluation of the model results.

3.4.1.2 Assumptions

The model was setup based on the following assumptions:

- The boundary condition at the downstream end of each catchment was taken as normal flow depth;

- The effect of groundwater was not taken into consideration in the model;

- Subcatchments were connected via links (i.e. pipes or open channels) and nodes (i.e. maintenance holes or dummy nodes) where zero head loss was assumed in all open channels and related nodes;

- PCSWMM offers three (3) alternatives for subarea routing of runoff in the subcatchment level: (a) runoff flows from pervious area to impervious area, (b) runoff flows from impervious area to pervious area, and (c) runoff flows from both areas directly to the outlet. For the existing condition model, it was assumed that subcatchment runoff flows are directly connected to the outlet, therefore the third routing option was used; and

- For catchments within proximity to more than one rain gauge station, rainfall data used in the continuous models was averaged from data collected from each of those gauge stations using the Thiessen Polygon Method. Then, the average rainfall was assumed to be distributed evenly across each subwatershed.

3.4.1.3 Previous Studies

Hydrologic models of Green's Creek, Bilberry Creek, and Taylor Creek subwatersheds were previously developed by Baird & Associates using the P8 stormwater and water quality model. Model results were summarized in the report entitled Hydrologic Model Development of Eastern Subwatersheds (2012). Electronic copies of the P8 models were obtained from the City of Ottawa, upon which model parameters and pond data were reviewed for incorporation into this study's SWMM models.

3.4.2 Digital Elevation Model (DEM)

Light Detection and Ranging (LiDAR) data was obtained from the City of Ottawa and used to generate a DEM layer (see Appendix C1). This layer, along with topographic mapping, was used to create surface flow paths for the delineation of the subcatchments. The generated DEM was found to have a number of locations with missing elevation data which limited the accuracy to which subcatchments could be defined. However, the effect of the missing elevation data was minimal on the development of the SWMM models since the subcatchments were delineated primarily using the storm sewer system and land use.

3.4.3 Geographic Information System (GIS) Data

GIS data for air photos, catchments, hydrography, infrastructure, land use, geology, monitoring, topography and parcels was provided by the City of Ottawa. A list of the data is provided in Appendix C1 along with an electronic copy of the GIS layers.

3.4.4 Rainfall

SCS storms (MTO type) with 12-hour were used for 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year design events. The design rainfalls were adapted from the Pinecrest Creek Cumulative Impacts Study (2016).

Rainfall data from five (5) gauge stations in the proximity of the Eastern Subwatersheds was also obtained from the City of Ottawa. These stations include Avalon, Hawthorne, Lee's, ROPEC, and Trim (see Appendix C1). Gauged rainfall for the analyzed time period (May 1st to October 31st), for Bilberry Creek subwatershed for example, was determined to be comparable to the total annual rainfall values obtained from Environment Canada's website for the Ottawa MacDonald-Cartier International Airport for both 2010 and 2011, as summarized in Table 3-3.

Table 3-3: Gauged Rainfall Volumes between May 1 and October 31

Year	Rainfall Volume (mm)		
	Thiessen Polygon	Ottawa MacDonald-Cartier International Airport	Normals (1971-2010)
2010	585	604	501
2011	474	483	501

Continuous 2010 rainfall data from the five rain gauge stations was used to determine seasonal and cumulative rainfall for each subwatershed. For subwatersheds within proximity to more than one rain gauge station, data was averaged into one complete data set using the Thiessen Polygon Method. Design and continuous rainfall data is included in Appendix C1. The PCSWMM model files are provided electronically in Appendix C2.

3.4.5 Flow Monitoring Data

The knowledge of the hydrology of the Eastern Subwatersheds has recently been augmented with the establishment of flow monitoring stations. Since 2008, flow monitoring stations have been put in place at nine (9) locations throughout the study area. These stations are shown in Figure 3.9.

Flow data was provided in 15-minute intervals and included base flow. To determine the contribution of storm runoff to the receiving watercourses, base flow was separated from the observed flow data (McCuen, 1998, McCuen et al. 2002). This was done using the BFI+ tool in the program HydroOffice 2010 (Gregor, 2012). The program used a Local Minimum Method as an initial filter, while further filtering was performed manually using Excel to check flows during peak events. Continuous observed flow data and base flow separation for 2010 for Bilberry Creek's monitoring station (CK22-008) is provided in Appendix C1.

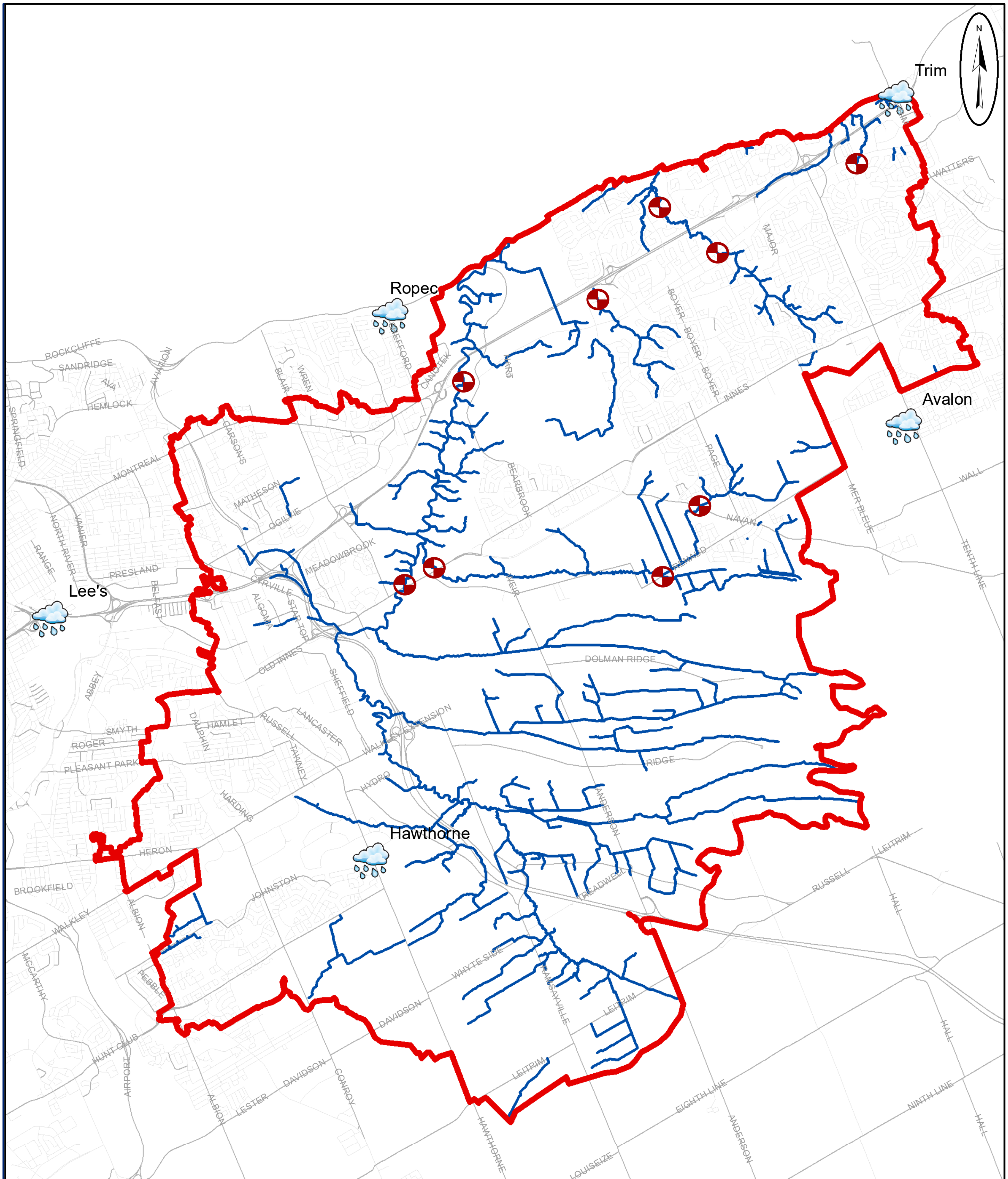
Although model calibration was attempted, it was determined the available flow data was insufficient at the time of modelling. Model calibration may be completed in the future when additional flow data becomes available.

3.4.6 Evaporation

The evaporation loss factor was also considered in the PCSWMM model. This factor can be included various ways. For the models, monthly average evaporation values from Pinecrest Creek Cumulative Impacts Study PCSWMM model (2016) were used to account the evaporation losses as shown in Table 3-4. The evaporation values for the Pinecrest Creek Cumulative Impact Study were obtained from a QUALHYMO model of Huntley Creek (personal communication with JFSA, March, 2018).

Table 3-4: Monthly Evaporation (mm/day)

January	February	March	April	May	June
0.0	0.0	0.0	1.13	2.52	3.93
July	**August**	**September**	**October**	**November**	**December**
4.52	3.87	2.37	1.39	0.20	0.0



Legend

- Flow Monitoring Station
- Rain Gauge Station
- Study Area
- Water Course

Eastern Subwatersheds Stormwater Management Retrofit Study

Flow Monitoring & Rain Gauge Stations

MORRISON HERSHFIELD

Aquafor Beech Limited

Figure 3.9

0 0.5 1 2 3 4
Km

August, 2018

Project No. 2124041

O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 3.9 - Flow Monitoring & Rain Gauge Stations.mxd

3.4.7 Infiltration

The Horton Method was used to determine infiltration as it is the most widely applied method for computer modelling of urban drainage basins and recommended by the City of Ottawa Sewer Design Guidelines (2012). The suggested values of 76.2mm/hr, 13.2mm/hr, and 4.14hr^{-1} were used, respectively, for initial infiltration rate (f_o), final infiltration rate (f_c), and decay coefficient (k).

3.4.8 Stormwater Infrastructure and Facilities

The study area consists of a total of 179 storm sewer system outlets, 33 SWM facilities, 11,173 pipe segments, and 11,146 maintenance holes, which are shown in Appendix C1. This data, along with the DEM and aerial photos, was used to confirm pipe connectivity, overland flow routes, subwatershed boundaries, and subcatchment delineation.

A number of on-line wet ponds were included in the model. The remaining wet, semi-dry, and dry ponds were not included in the model since they are small and would have a negligible effect on model results. These ponds are possible locations for retrofit actions.

Table 3-5: Existing Stormwater Management Facilities included in Hydrologic Model

No.	Description	Subwatershed	Reference
1	Aquaview Pond	Bilberry Creek	SWM Plan Neighbourhood 2 Upper Bilberry Creek Watershed, East Urban Community Expansion Area, February 2000 by Cummings Cockburn Limited (CCL)
2	CMHC Pond	Cyrville Drain	CMHC Stormwater Management Pond-Cyrville Drain, City of Gloucester, November, 1991 by Paul Wisner & Associates Inc. and Andrew Brodie Associates Inc.
3	McEwan Pond	McEwan Creek	McEwan Creek Stormwater Management Facility Design Brief, November 2009 by IBI Group.
4	Pond #1	Mud Creek	Servicing Report for Trails Edge and Orleans Business Park Minto Developments Inc., Richcraft Group of Companies, March 2013 by DSEL.
5	Pond #3	Mud Creek	East Urban Community, City of Ottawa (Gloucester) Stormwater Management Facility #3 Design Brief Update, August 2005 by Stantec.
6	Gardenway Park	Taylor Creek	Drawings: 1) Minto Construction-Queenswood Lands Neighbourhood IV-Township of Cumberland, December 1987 by CCL; 2) Gardenway Park Grading and Facilities-Township of Cumberland, April 1991 by McNeely Engineering Ltd.
7	Apollo Crater Park	Taylor Creek	Data taken from Oliver Mangione McCalla & Associates Ltd. Drawings dated as Jan 1984

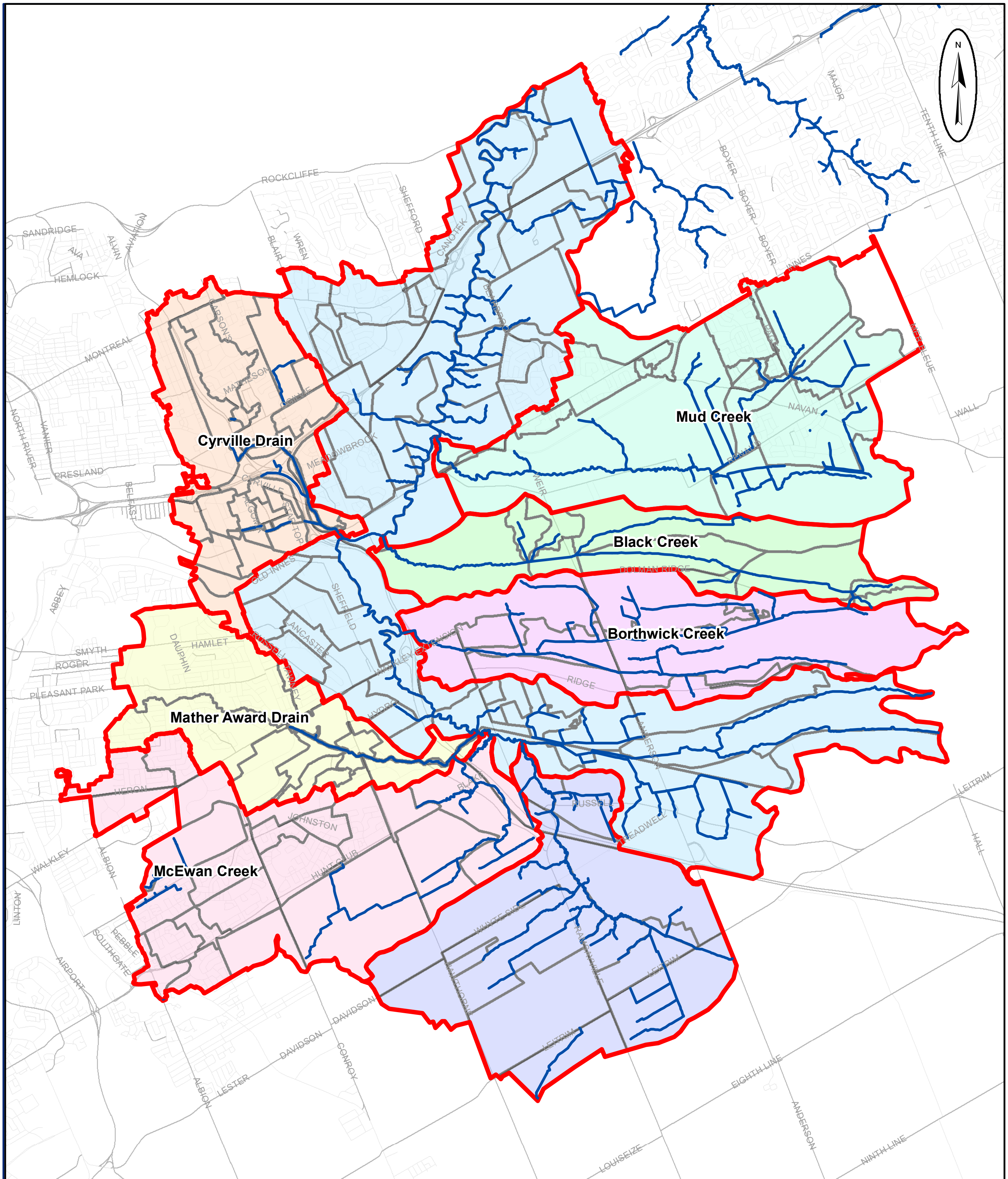
3.4.9 Subcatchment Delineation

For the delineation of catchments, the City of Ottawa provided GIS catchment data which were revised in particular locations as necessary. Each subwatershed was subdivided into subcatchments based on the storm sewer system, DEM, land use, imperviousness and hydrography data. Subcatchments were assigned an ID using the first two letters of the first word in the subwatershed's name plus the first letter of the second word, followed by a two-digit numerical value (i.e. Bilberry Creek subcatchment 1 = "BIC01"). Where possible in urban areas, subcatchments were delineated based on enclosing storm sewer networks with a downstream pipe with a maximum diameter of 1200mm. For rural areas, subcatchments were delineated based on land use and the DEM. The delineated subcatchments for Green's Creek are shown in Figure 3.10, and the Queenswood Catchments, Voyageur, Bilberry, and Taylor Creek subcatchments are shown on Figure 3.11. Figure 3.12 shows the PCSWMM model schematic of the study area.

The City of Ottawa sub-catchment delineation was applied to the study. Some modifications were made to the boundaries in consultation with the City of Ottawa.

PCSWMM is compatible with GIS data therefore models were created by importing GIS subcatchment data into PCSWMM models. The nodes and linkages (i.e. storm sewer, watercourse) between subcatchments were constructed and parameterized based on input data in the PCSWMM environment. Storm sewer linkages were modelled using the largest upstream pipe diameter for that segment, and open channels were modelled using PCSWMM's transect tool which created cross-sections based on the DEM.

The models do not distinguish between the major and minor system flows, thus stormwater is modelled assuming 100% captured.



Legend

Watercourse

Subwatershed

Eastern Subwatersheds Stormwater Management Retrofit Study

Subcatchment Delineation - Green's Creek

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Figure 3.10

0 0.5 1 2 3

Km

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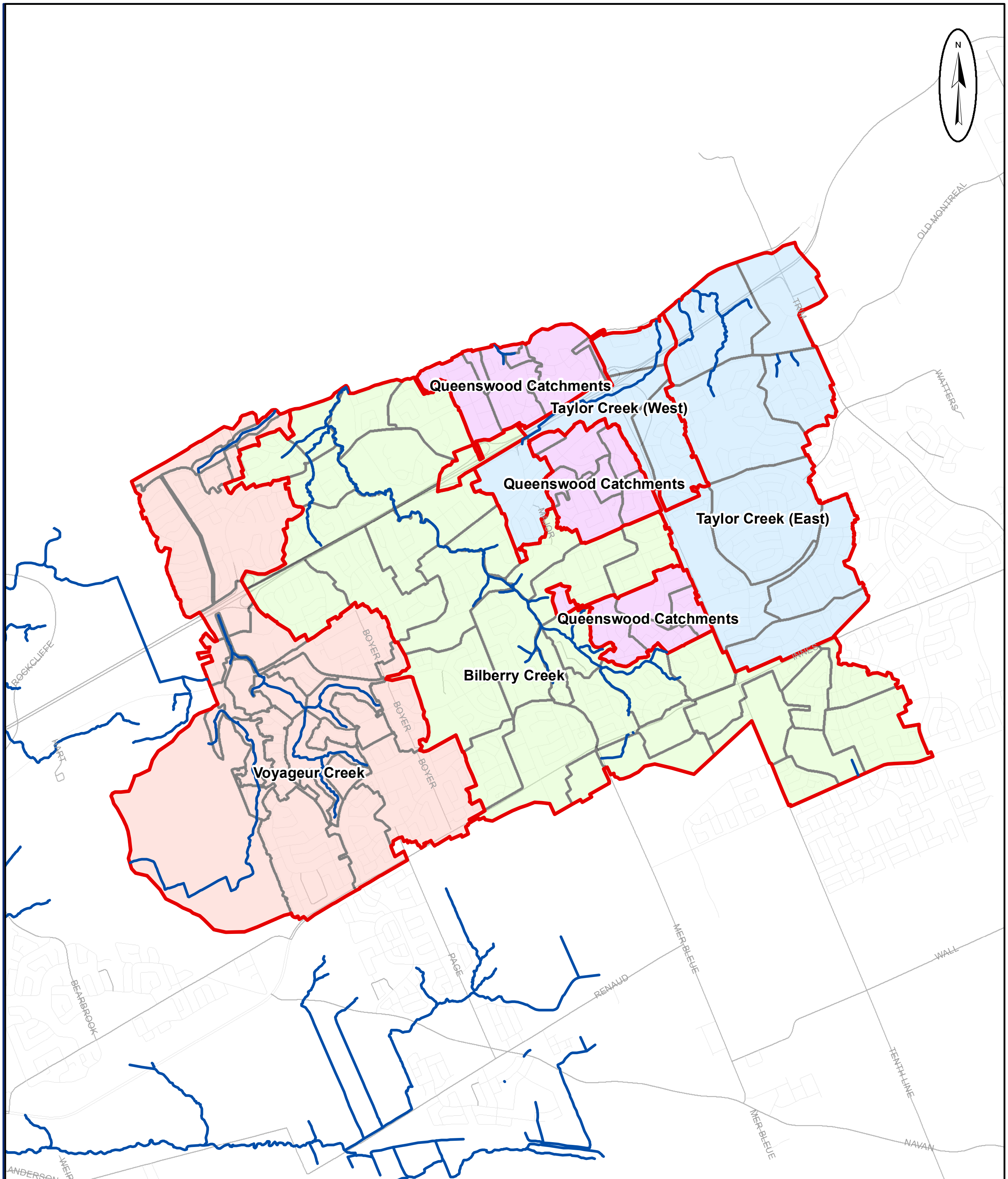

Ottawa

Legend
- Watercourse
- Subwatershed

Eastern Subwatersheds Stormwater Management Retrofit Study

Subcatchment Delineation - Ottawa River Subwatersheds

MORRISON HERSHFIELD

Aquafor Beech Limited

Figure 3.11

0 0.25 0.5 1 1.5 2
Km

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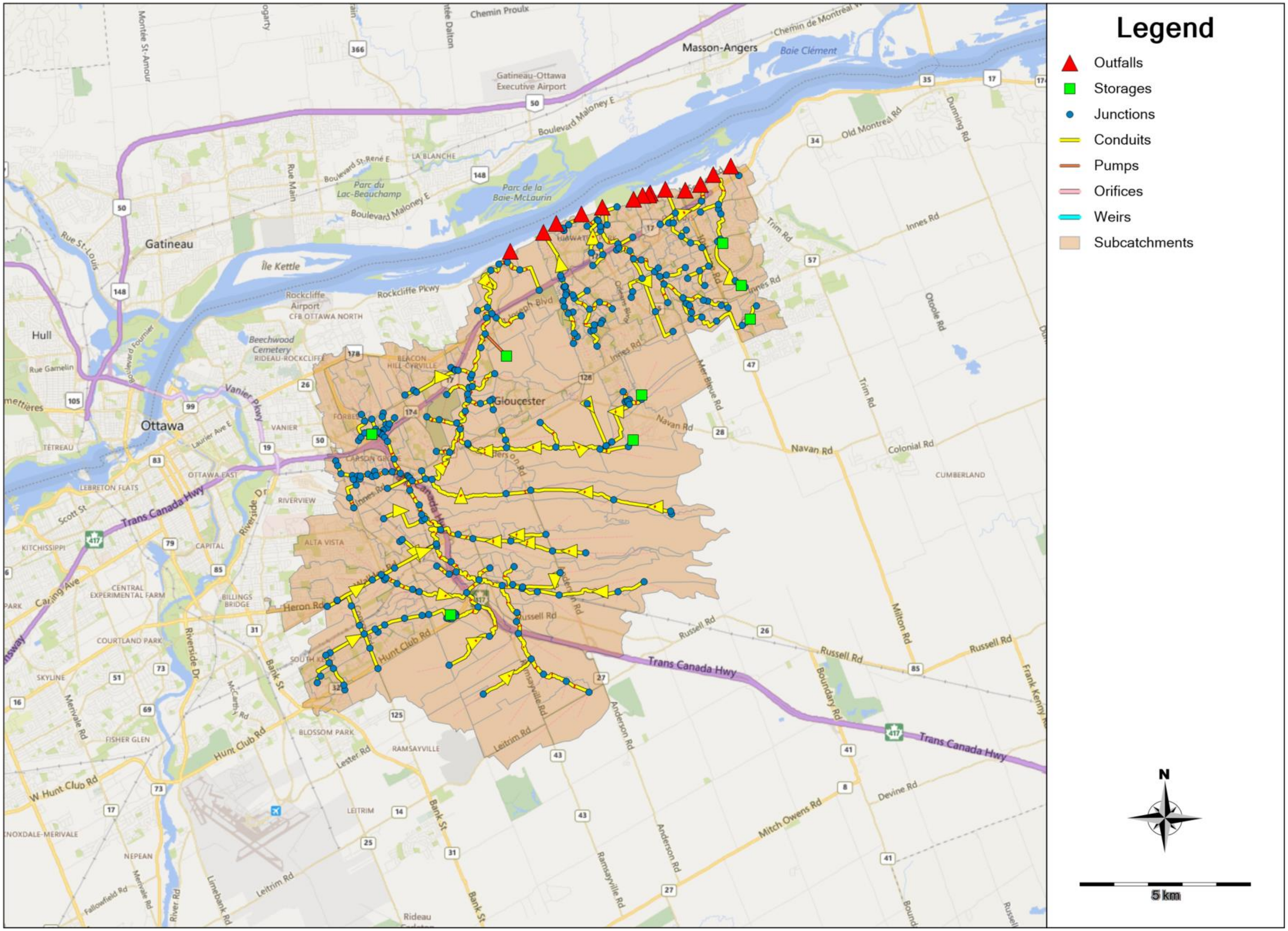


Figure 3.12 : PCSWMM Schematic

3.4.10 Model Parameters

The following base characteristics in Table 3-6 were defined and input into the model for each subcatchment based on the stated assumptions, where applicable:

Table 3-6: Model Parameters

Parameter	Value
Area (ha)	N/A
Width (m)	Subcatchment area / length of longest overland flow path
Slope (%)	Average slope across the subcatchment
Total Percent Impervious (%)	Impervious area / total area
N-Imper (Manning's n for overland flow over impervious surfaces)	0.013
N-Perv (Manning's n for overland flow over pervious surfaces)	0.2
Dstor-Imperv (mm) (depth of depression storage on impervious surfaces)	1.57
Dstor-Perv (mm) (depth of depression storage on pervious surfaces)	4.67
% Zero-Imperv (%) (percent of the impervious area with no depression storage)	25 (EPA SWMM default value)
Subarea Routing	Outlet (runoff from both pervious and impervious surfaces flows directly to outlet)[1]

[1] This was done in order to be able to simulate the effect to LID measures in the model. For example, the routing runoff from impervious areas over pervious areas replicates the effect of LID measures in the subwatershed.

3.4.10.1 Event-based Model

After simulating the 24-hr SCS and 3-hr Chicago storms, it was confirmed that the governing storm would be 12-hour MTO-SCS design storm. The 2-, 5-, 10-, 25-, 50-, and 100-year 12-hour MTO-SCS design storms with a 15-minute time step were used for the event based modelling. Modelled peak flows are shown in Table 3-7. From the urban subwatersheds, Green's Creek demonstrated the highest peak flows, with a value of 94.3 m^3/s for the 100-year storm event. The lowest peak flows were present in Queenswood Catchments, with a 100-year peak flow of 15.9m^3/s. For the rural subwatersheds, peak flows were much lower than flows from the urban subwatersheds.

3.4.10.2 Volume based model Analysis

Continuous 2010 rainfall data was used in the volume-based model to assess the evaporation, infiltration, and surface runoff volumes as percentages of the total annual precipitation. Target percentages of the total precipitation were taken from the Federal Stream Corridor Restoration Handbook (2001), developed by the U.S. Federal Interagency Stream Restoration Work Group (FISRWG). The handbook relates ranges of total imperviousness to water budget percentages, as seen in Figure 3.13. Based on the subwatershed's total imperviousness of 35%-50%, target percentages were estimated to be approximately 35% for evapotranspiration, 35% for infiltration, and 30% for surface runoff.

PCSWMM calculates evaporation as a separate loss, and does not provide a clear indication of the total amount of transpiration that occurs during a simulation. Since runoff losses were found to generally correspond with the target percentage while infiltration loss values were generally higher than target percentages, it was assumed that transpiration and other losses (i.e. groundwater recharge) are included in the generated infiltration loss.

Volume-based model results yielded highest infiltration losses (plus additional losses) in Green's Creek due to larger pervious areas, whereas the lowest infiltration losses the urban Queenswood and Bilberry Creek subwatersheds. Conversely, surface runoff was highest in the Queenswood and Bilberry Creek subwatersheds, and lowest in Green's Creek. Evaporation ranged from 6 to 12% for all subwatersheds, which was much lower than the target percentage of 35%. This may be due to the fact that transpiration is not included in PCSWMM's calculation of the evaporation volumes. The volume-based model results are presented in Figure 3.14.

3.4.11 Future Land Use Scenario

The City of Ottawa provided GIS information on the future development (build out) of the study area. The existing conditions hydrology model was updated to reflect the change in land use. This model was used to evaluate the future conditions, uncontrolled scenario, for comparison purposes.

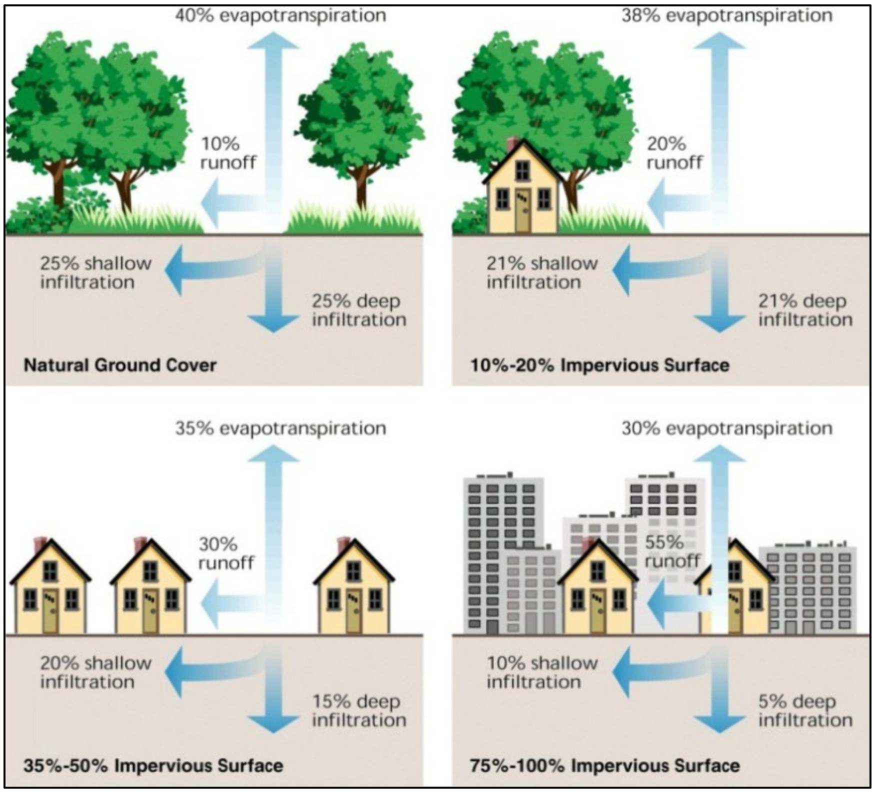
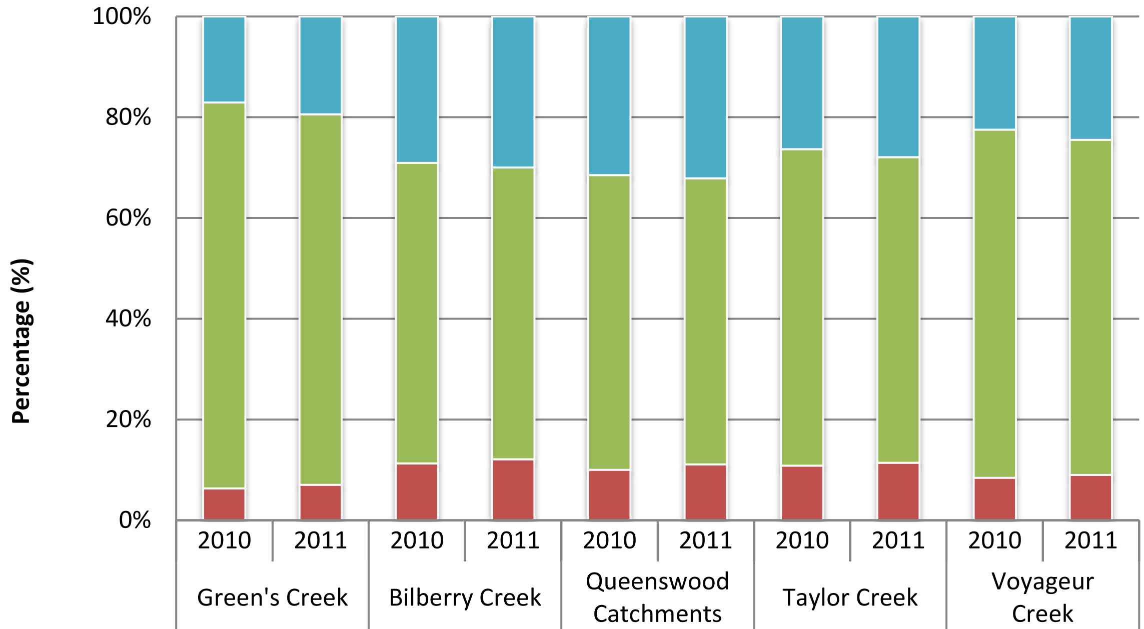


Figure 3.13: Water Budget Percentages for Varying Impervious Surface (Source: FISRWG, 2001)

Table 3-7: Event based Model Results (Peak Flows)

Catchment Name	Catchment ID	Number of Sub-catchments	Catchment Area (ha)	Imperviousness (%)	Peak Flow (m^3/s)					
					2 year	5 year	10 year	25 year	50 year	100 year
Green's Creek (total)	GRC	192	12,114	19	23.5	37.6	48.9	65.9	79.6	94.3
Voyageur Creek	VOC	34	828	31	20.2	29.8	36.5	45.2	51.0	56.4
Bilberry Creek	BIC	40	1,109	39	15.7	21.6	32.3	45.3	56.7	66.1
Queenswood Catchments	QUC	17	263	39	7.9	11.6	13.4	14.2	15.1	15.9
Taylor Creek (total of three outlet peak flows)	TAC	13	665	39	18.8	27.5	33.8	42.5	48.9	55.2

Note: Flows are based on the SCS 12-Hour Storm Distributions.



	Green's Creek 2010	Green's Creek 2011	Bilberry Creek 2010	Bilberry Creek 2011	Queenswood Catchments 2010	Queenswood Catchments 2011	Taylor Creek 2010	Taylor Creek 2011	Voyageur Creek 2010	Voyageur Creek 2011
Runoff Depth	17.1	19.4	29.0	30.0	31.4	32.2	26.3	27.9	22.4	24.5
Infiltration	76.5	73.5	59.6	57.9	58.4	56.8	62.7	60.7	69.1	66.6
Evaporation	6.3	7.0	11.3	12.1	10.0	11.1	10.8	11.4	8.4	9.0

Figure 3.14: Volume based Model Results (Percentages of Total Precipitation)

3.5 Fluvial Geomorphology

This chapter provides an overview of the methods, analysis and results of the fluvial geomorphology component of the Eastern Subwatersheds SWM Retrofit Study. More Additional detailed information is provided within Appendix D. Fluvial geomorphology is the study of the processes associated with streams and rivers, including stream hydraulics and sediment movement. Variables that influence the morphology of a stream include discharge, velocity, sediment load and size, channel slope, and the width and depth of the channel. A change in one of these variables will eventually alter another variable causing the channel to adjust. Land-use changes within a watershed can alter the amount of surface runoff and the amount of sediment reaching a stream. This can result in erosion and flooding problems, as well as degraded aquatic habitat. Channel restoration works can mitigate the impacts of land-use change, through natural channel design or other river engineering approaches.

The geomorphic investigation extended through five (5) subwatersheds, which include Taylor Creek, Voyageur Creek, Cyrville Drain, Mather Award Drain, and McEwan Creek. Taylor and Voyageur Creek flow in a northerly direction and outlet into the Ottawa River. Geomorphic investigation on Bilberry Creek was conducted in a separate study. Whereas Cyrville Drain, Mather Award Drain, and McEwan Creek are urban tributaries of Green's Creek. Review of the historical development indicates these subwatersheds have become increasingly urbanized which in turn has altered the hydrologic regimes, confined some of the watercourses within limited corridors, removed headwater channels, and in some areas, has created a network of underground storm sewers. The objective of the fluvial geomorphology component is to characterize the watercourses, particularly with respect to channel form and function, and their capacities to convey flows through the urbanized sections of the Eastern Subwatersheds extents.

3.5.1 Methodology

The geomorphic investigation and assessment was completed as per the methodology defined in Table 3-8.

Table 3-8: Summary of Fluvial Geomorphic Investigation

Phase	Approach	Parameters	Purpose
Phase 1: **Desktop Analysis and Background Review**	• Summarize background data using various base mapping layers • Historic aerial photograph analysis • Development of standard forms for synoptic field assessment	• Identify the physical characteristics of the subwatersheds and compute reach and valley gradient, channel length, sinuosity, and stream order • Initial reach break delineation • Physiography and surficial geology were identified for each subwatershed • Identify land-use and drainage network modification within the subwatershed • Historic erosion / mitigation rate analysis • Used to identify geomorphic and hydraulic parameters within each reach	• Watercourse parameters are used to delineate stream reaches, as well as in empirical formulas to calculate the hydraulic properties, such as flow conveyance • The channel is spatially grouped so that each reach displays similar channel characteristics, functions, and processes. Reaches are delineated by key factors such as hydrology, channel gradient, geology, valley setting, and sinuosity • The boundary materials of a channel (i.e. bed and banks) are influenced by local geology and contributions of sediment from upstream • Land-use and drainage network change within a watershed can significantly influence the rate and method of water and sediment routing to a watercourse • Assess channel adjustment and migration along the watercourse • Ensure that field collected data meets the project requirements

Continued - Table 3 8: Summary of Fluvial Geomorphic Investigation

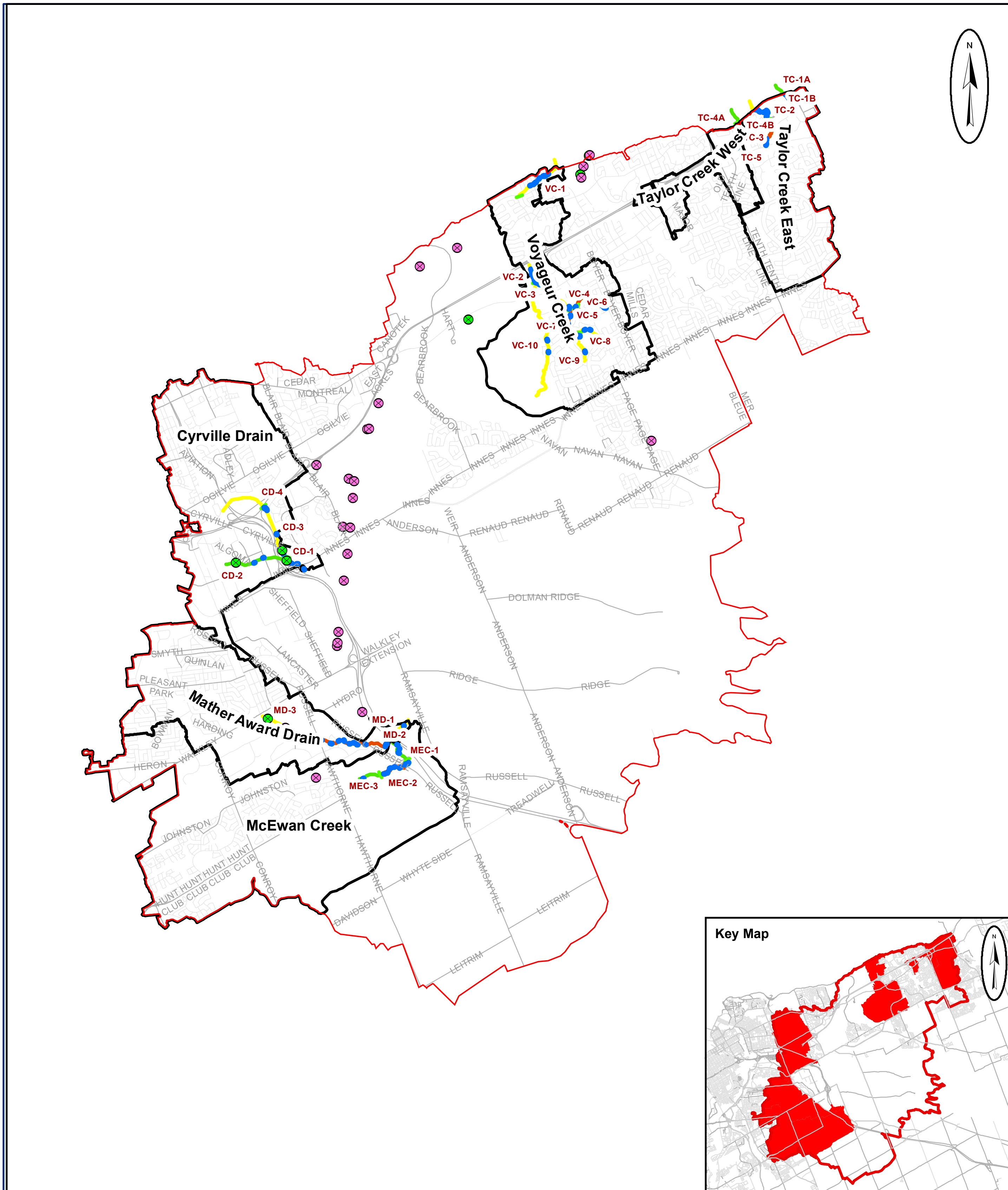
Phase	Approach	Parameters	Purpose
Phase 2: **Field Investigation**	• Rapid Geomorphic Assessments (RGA) (MOE, 1999) and Rapid Stream Assessments (RSAT) (Galli, 1996) of each reach • Photographic inventory by reach • Erosion and slope hazard identification • Representative channel morphometrics (width, depth, substrate)	• Assessment of channel stability using rapid assessment protocols during synoptic field assessment • All photographs taken during synoptic field assessment are geo-referenced • Field reconnaissance identified, mapped, and photographed erosion sites along the watercourses • Rapid geometric measurements were conducted within each reach at representative cross sections during the synoptic field assessment	• The RGA uses visual indicators to determine whether a channel is stable or in-adjustment. The RSAT also evaluates channel conditions using visual indicators • Photographs illustrate the typical conditions along each of the defined reaches • Erosion sites that pose a risk to public health and safety, as well as the environment are identified • These values can be used in empirical formulas to determine erosion and depositional properties of the watercourse
Phase 3: **Erosion and Tractive Force Analysis**	• Assessment of flows (bankfull, effective, and channel discharge) • Tractive force and permissible velocity analysis	• Use of background data and field data to calculate flow properties of each reach • Use of background data and field data to calculate tractive force properties for each reach	• Determine erosion and depositional properties of each reach • Determine erosion and depositional properties of each reach
Phase 4: **Flow and Sediment Transport Analysis**	• Determine sediment transport potential based on flow and channel characteristics	• Use of background data and field data to calculate transport potential for each reach	• Determine erosion and depositional properties of each reach
Phase 5: **Restoration Concepts and Cost Estimates**	• Prioritize erosion sites for restoration based on levels of risk	• Qualitative characteristics identified during field reconnaissance classify each site as low, medium, or high	• Sites that are in close proximity to infrastructure, private property, roads etc. were identified as higher priority sites depending on distance from erosion. Extent of erosion, impacts to aquatic habitat, and environmental land classification surrounding the site were also considered

3.5.2 Reach Descriptions

Within each subwatershed, channels were delineated into reaches based upon form, function, gradient, geology, sinuosity, and valley setting. In total, 27 reaches were delineated for detailed study with location and extents shown on Figure 3.15. Reach characteristics were identified through a synoptic level field investigation which documented channel morphology, prominent channel processes, and channel stability. Refer to Appendix D for reach descriptions, including photographs illustrating typical conditions along each reach.

3.5.2.1 Taylor Creek

The location of the Taylor Creek subwatershed is generally bound by Innes Road to the south, Tenth Line Road to the west, Trim Road to the east, and the Ottawa River to north the which the watercourses drain into. A total of seven (7) stream reaches were delineated within this subwatershed with a total length of 3170m assessed. This subwatershed has become increasingly urbanized since 1976 with the watercourse dominantly channelized in the lower portion of the subwatershed and some of the headwater reaches disappearing underground through a network of storm sewers. Each of the reaches lies within the clay plains and is dominated by fluvial and glaciomarine deposits consisting of clay, silt, sand, and organics (Ministry of Northern Development and Mines [map], March 2013).



Legend

- Study Area
- Other Infratructure Crossings
- Crossing exposed in near future
- Erosion Sites
- Catchment
- Reach Break
- <all other values>

RGA_Class

- In-adjustment
- Stable
- Transitional

Ottawa

Eastern Subwatersheds Stormwater Management Retrofit Study

Geomorphic Reaches, Erosion Sites and Infrastructure Crossings

Morrison Hershfield

Aquafor Beech Limited

Figure 3.15

0 0.5 1 2 3 4

Km

August, 2018 | Project No. 2124041

O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 3.15 - Geomorphic Reaches.mxd

Representative channel properties for Taylor Creek are described as follows:

- Dominantly entrenched with little access to the floodplain, but closer to the outlet into the Ottawa River some of the reaches are well connected;
- The near bank zone consists predominantly of herbaceous species, both deciduous trees and coniferous trees are also present within the riparian zone;
- Channel substrate consists of fines and small particles with exposed clay. Larger material identified is likely non-native and has transported within the channel from previous restoration works that may also be in disrepair and/or in need of maintenance (i.e. broken gabion baskets).
- Some reaches meander through a wooded valley system and consist of poorly defined riffle-pool morphology;
- Areas exist where channel banks and valley walls run continuously into one another;
- Altered planform exists due to the creation of an on-line storm water pond, as well as channelization due to creation of road networks.
- Results of the RGA show that the reaches are dominantly 'stable' or 'transitional'. Evidence of adjustment within the upper reaches is likely attributed to the boundary material adjacent to the watercourse and the historic changes that have occurred within the subwatershed and along watercourse.

3.5.2.2 Voyageur Creek

The limits of the Voyageur Creek subwatershed are roughly delineated by Innes Road to the north, Bearbrook Road to the west, Boulevard Jeanne D'Arc to the east, and the Ottawa River to the south. Ten (10) stream reaches along Voyageur Creek were identified and documented within the subwatershed, totaling 8212m of watercourse assessed. Urbanization has significantly increased within this subwatershed resulting in portions of the watercourse becoming channelized underground through a series of storm sewers. The majority of Voyageur Creek meanders through a wide valley system located in the upper portion of the subwatershed. The downstream reach is no longer connected to the upper portion of Voyageur Creek due to the fact that the watercourse is piped from Highway 174 to its new outlet location into the Ottawa River. Construction of a new culvert underneath Highway 174 was occurring during the time of field work. The upper reaches of Voyageur Creek flow through predominantly sand plains, with the exception of the headwaters of reach VC-9. Surficial geology of this catchment consists of both glaciomarine and colluvial deposits, which range from clay, silt, sand, and diamicton soil types. The lower reaches of this watercourse flow through the clay plains, with clay outcrops only identified within the channelized section of reach VC-2.

Representative channel properties are described below.

- The lower portion of the watercourse (which is no longer connected to the upper reaches) is connected to the surrounding floodplain, whereas the channelized reaches and valley reaches upstream are entrenched to slightly entrenched;
- A mix of herbaceous species, deciduous and coniferous trees dominant the riparian zone within the lower portion and the valley reaches. Channelized reaches largely consist of herbaceous vegetation in the riparian zone;

- Residential property exists at the top of slope along the wide valley systems. Channelized reaches are confined by commercial property;
- Areas exist where the channel banks and valley walls run continuously into one another;
- Channel substrate is composed of poorly sorted fines, gravel, and some cobbles at various locations. Larger, angular cobbles identified along the bed appeared non-native and likely sourced from riprap deposited at storm outlet channels, as well as existing restoration measures that are in disrepair (i.e. broken gabion baskets). Exposed clay was also identified within this watercourse;
- Three (3) reaches are separated by on-line storm water management areas;
- Grade control structures were identified along the bed in reach VC-10;
- Results of the RGA show that Voyageur Creek is predominantly classified as a transitional system, with evidence of adjustment present within 8 of the 10 reaches. This subwatershed has undergone a significant increase in urbanization within the past 30 years which can increase runoff magnitude and frequency resulting in channel enlargement and bed degradation.
- Straightening and channelizing of the watercourse through some reaches has prevented flood flows from dissipating onto the floodplain, and therefore impacted flow diversity and natural sediment transport processes through the reach, contributing to the adjustment processes identified.

3.5.2.3 Cyrville Drain

The boundaries of Cyrville Drain generally consist of Montreal Road to the north, St. Laurent Boulevard to the west, Blair Road to the east, and Green's Creek to the south, which Cyrville Drain outlets into. Cyrville Drain has been delineated into four (4) stream reaches within the study area for a total of 3790m of watercourse assessed. Historical aerial photographs show that the subwatershed was once dominated by agricultural land-use and that Cyrville Drain was a series of straightened drainage features. As urbanization increased within the subwatershed the watercourse was further channelized and altered to construct new transportation corridors and urban development. This watercourse currently consists of two (2) defined channels that have been modified by human interaction and are confined by urbanization. The subject reaches of Cyrville Drain flow within an urbanized area through both till plains (drumlinized) and clay plains to its outlet into Green's Creek.

Representative channel properties are summarized within **Section 3.5.3**. Reaches within this subwatershed are described below.

- The watercourse is generally well connected to the floodplain, but there are areas where limited access to a floodplain is present;
- Near bank and riparian zones are dominated by herbaceous, deciduous, and coniferous species, providing a fairly dense root system and therefore some erosion control along the banks;
- Fine material, cobbles, and platy particles can be found along the channel bed, as well as exposed shale within portions of the watercourse. Coarser material may have transported from non-native stone mixtures deposited at storm sewer outlets and restoration works.

- Channel banks consist of alluvial material and shale layers which are contributing to the platy material found along the bed. A portion of this watercourse has been channelized with engineered revetments and long culverts;
- Areas exist where the channel banks run continuously into the valley/channelized slope;
- Approximately 150m upstream of Highway 174 a concrete weir structure spans the channel width and no low flow notch was identified; and
- The Rapid Geomorphic Assessment classifies this watercourse as predominantly transitional, with the only stable reach modified with armourstone walls. Evidence of adjustment can be attributed to the fact that the confined, partially straightened channel is adjusting its boundaries in an attempt to regain some meandering form.

3.5.2.4 Mather Award Drain

Mather Award Drain flows eastward to outlet into Green's Creek and is roughly bounded by Walkley Road to the north, Conroy Road to the west, and Stevenage Drive to the south. A total of three (3) reaches were identified and documented on Mather Award Drain to total approximately 3340m of watercourse assessed. This watercourse is a channelized system that is confined by the valley/channelized slopes. Increases in urbanization have occurred since 1965, but few adjustments to the channel planform were identified during this period. At the time of the study, construction for the extension of Hunt Club Road was occurring within this subwatershed and includes bridge structures over the watercourse. This watercourse flows through clay plains that consist of clay and silt geologic material that was deposited during the Wisconsin glacial retreat.

Representative properties are summarized within **Section 3.5.3** and watercourse characteristics are described as:

- Having few to no natural bends and poorly defined riffle-pool morphology, except a portion downstream of Russell Road which is a low to moderate sinuous channel;
- Where the watercourse is channelized, the channel banks run continuously with the valley/channelized slopes, therefore providing little to no access to the floodplain;
- The near bank zone consists predominantly of herbaceous species and the riparian buffer consists of both deciduous and herbaceous species;
- The lower and upper reaches have banks composed of fine material and exposed clay. Through the middle portion, shale layers are exposed along the base of the banks contributing to the coarser material found along the bed;
- Channel substrate consists of poorly sorted material ranging in size from fines to small pebbles, as well as exposed clay and shale. Larger material found along the bed appears to be non-native and may have been transported from riprap mixtures deposited along drainage channels entering the watercourse;
- The Rapid Geomorphic Assessment classifies this watercourse as predominantly 'transitional. Straightening of the watercourse and no access to the floodplain to dissipate flow energy can contribute to the instability identified within the reach. The channel is likely adjusting to regain some meandering form through its channelized reaches.

3.5.2.5 McEwan Creek

The limits of the McEwan Creek subwatershed are roughly delineated by Stevenage Drive to the north, Albion Road South to the west, Whyte Side Road to the south, and Green's Creek to the east. McEwan Creek has been divided into three (3) stream reaches totaling 1949m of watercourse assessed. This watercourse is a channelized system that has undergone significant planform changes since 1965. The headwaters are partially channelized through a series of underground storm sewer networks, as well as along the surface through wooded and vegetated fields. The lower portion of McEwan Creek no longer outlets into Green's Creeks, as seen in the 1965 historic aerial photograph, but has been channelized and shortened to outlet into Mather Award Drain. At the time of the study, road construction involving the extension of Hunt Club Road was occurring within this reach and includes bridge structures over the watercourse. A large storm water pond exists to the left of the channel (looking upstream) in the upper reach and the outlet channel for the pond is present near the downstream end of the reach. The subject reaches within the McEwan Creek subwatershed flow through clay plains with glaciomarine deposits consisting of both clay and silt.

Representative channel properties are summarized in **Section 3.5.3**. Reaches within this subwatershed are described below.

- The upper and lower reaches have been straightened and are moderately entrenched, but the middle reach is sinuous with numerous meander bends present;
- Poorly developed riffle-pool morphology is present along the watercourse;
- The near bank and riparian zone contain both herbaceous and deciduous species;
- The channel banks consist of fine material with exposed shale present within the upper reach;
- Evidence of channel restoration is present in the upper reaches through identification of larger roundstone at the toe of the banks and vegetative plantings in the near bank zone;
- Poorly sorted material exists along the channel bed, consisting of clay, fines, and coarser material. The majority of the coarser material likely transported downstream from the locations where it was placed along the bank toe; and
- Results of the RGA show that the upper reach is classified as stable likely due to the surrounding bedrock limiting channel adjustment and may also be due to recent plantings and hardening of the bank toe with larger rock in the downstream end. The lower portion of this watercourse is showing some evidence of adjustment likely due to the straightened and channelized planform. The middle reach is classified as 'in-adjustment' and could be attributed to the altered reaches directly upstream and downstream.

3.5.3 Representative Channel Properties

Channel geometric parameters (width and depth) and substrate characteristics were defined at representative channel cross sections within each subwatershed reach during the field assessment. The substrate characterization through grain size sampling (Wohlman pebble count) was completed along riffle features where the width and depth measurements were taken. The results of the Wohlman pebble count were tabulated and a particle size distribution was generated. Reaches where bed material was too small to measure using the pebble count method were defined as consisting of fine bed material. Table 3-9 provides a summary of the subwatershed geomorphic characteristics. Refer to Appendix D for channel properties defined by subwatershed reaches.

Table 3-9: Subwatershed Geomorphic Summary Characteristics

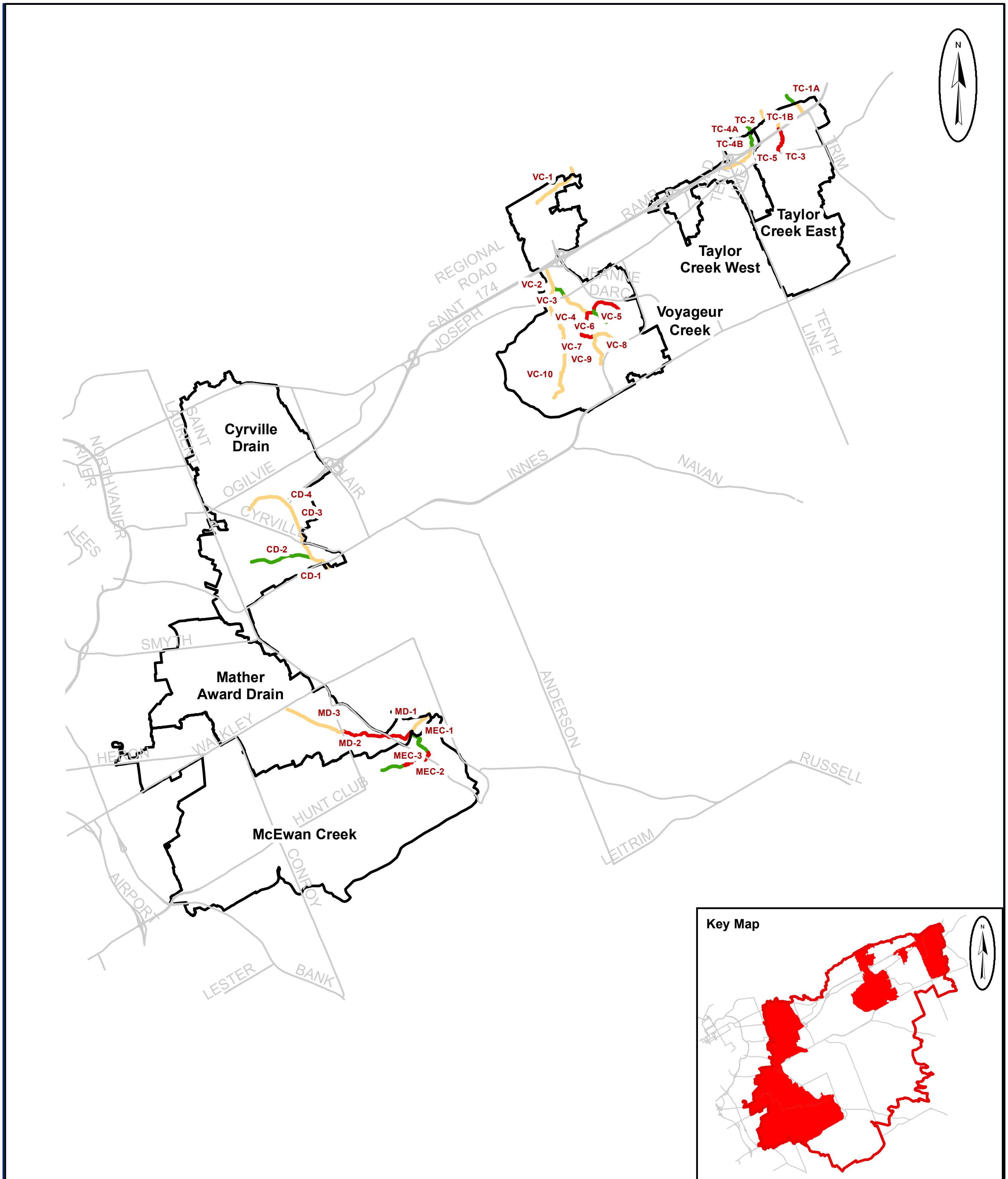
Subwatershed	Channel Width, Range (m)	Channel Depth, Range (m)	Bed Material (m)		Channel Gradient, Range (%)
			D50	D84	
Taylor Creek	1.50 - 8.00	0.35 - 2.00	Clay, Fines, 0.008 - 0.015	Clay, Fines, 0.010 - 0.020	0.4 - 1.9
Voyageur Creek	2.65 - 5.40	0.15 - 1.10	Clay, Fines, 0.0005 - 0.06	Clay, Fines, 0.005 - 0.09	0.3 - 2.3
Cyrville Drain	3.40 - 8.50	0.50 - 0.60	Fines, Shale, 0.008 - 0.024	Fines, Shale, 0.02 - 0.09	0.05 - 0.4
Mather Award Drain	9.00 - 15.00	2.78 - 8.00	Fines, 0.012	Fines, 0.06	0.02 - 0.5
McEwan Creek	5.00 - 9.60	1.0 - 2.5	Clay, 0.001 - 0.04	Clay, 0.01 - 0.09	0.2 - 0.4

3.5.4 Subwatershed Data Analysis

Data collected during the reach characterization and the synoptic level field assessment was used in the tractive force analysis to provide insight into erosional processes and threshold values. Grain size sampling was completed using the Wohlman pebble count methodology at representative cross sections within each reach. Therefore, these samples were not conducted in areas where non-native material existed along the channel bed. Based on the measured channel parameters within each reach segment empirical formulas were used to determine threshold values. Some of the results show that the D50 particle size will become mobile at depths less than top of bank as determined by the critical depth value. These values are based on representative bed material that largely consists of small pebbles to silt sized particles. These values do not take into account the areas where riprap and coarser material were identified, nor do they account for bedrock exposed areas, low gradient reaches, grade control structures, or resistance provided by vegetation. These factors will all result in lower shear stresses and velocity values. Areas where none of these parameters are present may result in channel degradation and widening processes. Refer to Appendix D for the detailed tractive force analysis.

3.5.5 Erosion and Maintenance Issues

As part of the field assessment of the watercourses in March of 2013, erosion sites along each of the studied reaches was identified, mapped, and photographed. The location of erosion sites are shown in Appendix D. The sections below provide a summary and description of the erosion and maintenance issues as they were identified in 2013. A detailed inventory of erosion sites and their relative priority are provided in Appendix D.



Legend	
Greens_Primary Roads	
Catchment	
Greens_Primary Roads	
RGA Classification	
Stable	
Transitional	
In-adjustment	

Eastern Subwatersheds Stormwater Management Retrofit Study

Rapid Geomorphic Assessment (RGA) Classification

Morrison Hershfield

Aquafor Beech Limited

Figure 3.16

0 0.5 1 2 3 4 Km

August, 2018

Project No. 2124041

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3.5.5.1 Taylor Creek

Eighteen (18) erosion sites were identified along Taylor Creek. The sites include:

- Minor slumping and undercutting;
- Exposed root systems, and leaning/fallen trees contributing to large woody debris found within the channel (refer to Photo 11: Typical Erosion Conditions within Taylor Creek Consisting of Steep Banks with Exposed Roots and Fallen Vegetation.);
- Erosion impingement into the valley wall;
- Broken gabion baskets, and an undercut armourstone wall, as well as mobilization of riprap at storm sewer outlets and culverts (refer to Photo 12: Priority Erosion Site within Taylor Creek, Undercut Armourstone Wall and Steep Valley Slope.);
- Knickpoints identified at exposed clay bed locations; and
- Erosion protection, likely implemented by landowners, in the form of concrete rubble and debris discarded along the channel/valley slopes.

Of the eighteen (18) sites identified ten (10) were classified as low priority, five (5) classified as low to medium, and three (3) sites as medium priority. The low priority sites were largely identified as bank/ valley wall erosion with no infrastructure or private property risks close by. These sites do have the potential to impact aquatic habitat due to the extent of the erosion and the additional sediment entering the watercourse.

Photo 11: Typical Erosion Conditions within Taylor Creek Consisting of Steep Banks with Exposed Roots and Fallen Vegetation.

Photo 12: Priority Erosion Site within Taylor Creek, Undercut Armourstone Wall and Steep Valley Slope.

3.5.5.2 Bilberry Creek

In 2006 Geomorphic Solutions completed a geomorphic assessment of Bilberry Creek on behalf of the City of Ottawa. In May of 2014, GHD completed the Geomorphic Systems Master Implementation Plan for Bilberry Creek. The purpose for this study was to provide an updated characterization of existing watershed conditions, to identify areas of concern, and to predict future adjustments in channel form based on underlying geomorphic controls. The study produced a prioritized list of restoration projects emphasizing infrastructure protection.

3.5.5.3 Voyageur Creek

Forty-two (42) erosion sites were identified along Voyageur Creek which consist of:

- Areas of bank slumping, steep, undercut and bare banks located along both straight and meandering portions of the watercourse;
- Fallen/leaning trees have created large woody debris jams within the channel. Debris jams have the capability of increasing erosion due to the fact that larger flows may be directed at the channel banks (refer to Photo 13: Typical Erosion Conditions Within Voyageur Creek, Consisting of Bank/Valley Toe Erosion and Fallen Vegetation.);
- Knickpoints identified at exposed clay bed locations;
- Erosion impingement into the valley wall (refer to Photo 14: Priority Erosion Along Voyageur Creek, Fallen Vegetation Along Steep Slopes With Residential Properties At Top Of Slope.);
- Broken gabion baskets identified, and in some cases are spilling the cobble sized material onto the bed;
- Broken storm sewer outlets, concrete ramp, and a small diameter pipe with a constant flow of water exiting the pipe were identified; and
- Erosion protection in the form of discarded riprap and concrete pieces were identified along the channel banks.

Twenty-seven (27) of the total erosion sites have been classified as low priority sites, ten (10) as low to medium, and five (5) as medium priority within this subwatershed. The higher priority classification is based on the proximity to infrastructure and private property, as well as the extent of the erosion site. The lower priority sites are typically bank/valley erosion that could potentially impact aquatic habitat due to the additional sediment entering the watercourse. These sites also included maintenance issues with no immediate risks identified (i.e. broken storm sewer outlets).

Photo 13: Typical Erosion Conditions Within Voyageur Creek, Consisting of Bank/Valley Toe Erosion and Fallen Vegetation.

Photo 14: Priority Erosion Along Voyageur Creek, Fallen Vegetation Along Steep Slopes With Residential Properties At Top Of Slope.

3.5.5.4 Cyrville Drain

Eleven (11) erosion sites were identified along the channelized reaches of Cyrville Drain and consist of:

- Steep banks resulting in exposed soil and vegetative roots, slumping, and undercutting (refer to Photo 15: Typical Erosion Conditions Identified Along Cyrville Drain Consisting Of Steep Banks And Exposed Roots.);
- Erosion impingement into the valley wall;
- Knickpoints identified along the bed; and
- Maintenance sites that include a broken grate across a storm sewer inlet, storm sewer outlet with a ~2.0m drop to channel bed (refer to Photo 16: Priority Erosion Site Along Cyrville Drain Consisting Of ~2.0m Drop To Channel Bed Due To A Broken Storm Sewer Outlet Structure.), as well as a concrete bed structure that is partially undercut due to a 0.15m drop from the structure to the channel bed.

Of the eleven (11) erosion sites identified within this subwatershed, seven (7) have been classified as low priority, two (2) as low to medium, one (1) as medium, and one (1) as medium to high. Lower priority sites largely are bank/valley erosion issues with no infrastructure or private property located in close proximity. The higher priority sites are maintenance issues identified along existing infrastructure, or erosion sites identified closer to private property.

Photo 15: Typical Erosion Conditions Identified Along Cyrville Drain Consisting Of Steep Banks And Exposed Roots.

Photo 16: Priority Erosion Site Along Cyrville Drain Consisting Of ~2.0m Drop To Channel Bed Due To A Broken Storm Sewer Outlet Structure.

3.5.5.5 Mather Award Drain

Nineteen (19) erosion sites were identified along the Mather Award Drain which consists of:

- Slumped bank material, as well as steep, undercut, and/or bare banks (refer to Photo 17: Typical Erosion Conditions Along Mather Award Drain Consisting Of Slumped Bank Material. and Photo 18: Priority Erosion Site Along Mather Award Drain Due To Steep Banks Identified At Newly Constructed Road Bridge.);
- Erosion impingement into the valley wall; and
- A broken storm sewer outlet and gabion basket within the upstream reach, as well as the culvert located under the railway which is angled upwards creating a 0.30m drop to the plunge pool.

Eleven (11) of the total erosion sites identified have been ranked as low priority sites, seven (7) as low to medium, and one (1) as medium to high. The higher priority sites have been identified due to the proximity and risk of impacting infrastructure, private property, roads etc. The lower priority sites were identified largely as bank/valley erosion issues that may impact aquatic habitat due to the extent of the erosion.

Photo 17: Typical Erosion Conditions Along Mather Award Drain Consisting Of Slumped Bank Material.

Photo 18: Priority Erosion Site Along Mather Award Drain Due To Steep Banks Identified At Newly Constructed Road Bridge.

3.5.5.6 McEwan Creek

Eleven (11) erosion sites have been documented along McEwan Creek which consist of:

- Steep banks with bare banks and exposed vegetative roots;
- Undercut banks; and
- Slumped bank material along the toe of the channel (refer to Photo 19: Typical Erosion Conditions Along McEwan Creek Consisting Of Slumped Bank Material. and Photo 20: Priority Erosion Site Along McEwan Creek Due To Steep Banks And Slumped Material Identified Upstream Of Newly Constructed Road Bridge.).

The majority of the erosion sites identified along McEwan Creek were classified as low priority (ten sites in total). All of these sites were identified as bank/valley erosion along the watercourse. These sites were not in close proximity to infrastructure or private property but the addition of sediment into the watercourse has the potential to impact aquatic habitat. Only one (1) site was identified as higher priority and this was due to the potential risk to future infrastructure.

Photo 19: Typical Erosion Conditions Along McEwan Creek Consisting Of Slumped Bank Material.

Photo 20: Priority Erosion Site Along McEwan Creek Due To Steep Banks And Slumped Material Identified Upstream Of Newly Constructed Road Bridge.

3.5.6 Priority Erosion Sites

A summary of all of the priority erosion sites is provided in Table 3-10.

Table 3-10 Summary of Priority Erosion Sites – Eastern Subwatersheds

Photo No.	Reach	Erosion Site No.	Description	Risk	Priority
21	TC-3	1	Failure of armourstone wall at upstream end of structure, structure is undercut	Private / Commercial Property	Medium - High
22	VC-1	4	~5cm diameter pipe with constant flow of water exiting pipe, water flow down the bank slope as well	Municipal Infrastructure Failure	Medium – High (Investigation Required)
23	VC-2	1	Concrete ramp is undercut and broken causing drop into pool, knickpoints present ~5-6m downstream from ramp	Culvert under Youville Road Upstream	Medium
24	VC-2	6	Erosion scar extends to toe of bank, riprap and concrete have been dumped on slope, exposed storm sewer outlet, broken gabion baskets upstream, riprap and small knickpoints on bed	Parking lot less than 10m from top of scar	Medium
25	VC-5	5	Steep valley slope, properties less than 5m from top of slope; large woody debris in channel causing right bank to be undercut	Private property less than 5m from top of slope	Medium
26	VC-9	3	Gabion baskets have detached from banks, riprap and gabion in channel, geotextile material exposed	Culvert upstream	Medium
27	CD-1	2	Concrete portion along bed drops into plunge pool to native bed, is undercut, riprap exposed underneath	Gabion baskets line channel baskets, storm sewer outlet downstream	Medium
28	CD-3	4	~1200 storm sewer outlet, baffles, ~2m drop to channel bed, exposed stone all the way down, creation of plunge pool	Storm sewer outlet	Medium to High
29	MD-2	3	Meander bend at location of newly constructed road bridge, erosion scars and exposed roots present	Newly constructed bridge	Medium to High
30	MEC-1	2	Bank erosion identified near construction of new road bridge, channel bend is bare, roots exposed, and is slightly undercut	Newly constructed bridge	High
Refer to GHD, 2014 report	B10A		Eroding storm outlet along valley slope, valley wall erosion and undermining of pedestrian crossings. Refer to Geomorphic Systems Master Implementation Plan for Bilberry Creek, GHD, 2014, for details.	Erosion at outlet and valley wall	High
Refer to GHD, 2014 report	B10/B10A*		Woody debris jam and beaver dam upstream of the pedestrian bridge. Require minor realignment downstream of crossing. Refer to Geomorphic Systems Master Implementation Plan for Bilberry Creek, GHD, 2014, for details.	Debris jam and beaver dam combined may restrict the flow	High

Continued - Table 3-10 Summary of Priority Erosion Sites – Eastern Subwatersheds

Photo No.	Reach	Erosion Site No.	Description	Risk	Priority
Refer to GHD, 2014 report	B10/B10B*		Channel degradation and known presence of a sanitary sewer crossing under both reaches. Refer to Geomorphic Systems Master Implementation Plan for Bilberry Creek, GHD, 2014, for details.	Valley wall failure threatens a sanitary manhole along the top of slope	High
31	TC-1B	4	Bank Repair: Exposed material on right bank, 50cm drop on bed, geotextile exposed on bed and banks	Bank failure	Medium
32	TC-3	3	Failure of gabion baskets on bed creating 0.5m drop, exposed geotextile, undercut and broken gabion	Bank failure	Medium

*Reach B10/B10A and B10/B10B have been already scheduled for the implementation.

Photo 21: Erosion site #1 along Reach TC-3

Photo 22: Erosion (Maintenance) site # 4 along Reach VC-1

Photo 23: Erosion site #1 along Reach VC-2

Photo 24: Erosion site #6 along Reach VC-2

Photo 25: Erosion site #5 along Reach VC-5

Photo 26: Erosion site #3 along Reach VC-9

Photo 27: Erosion site #2 along Reach CD-1

Photo 28: Erosion site #4 along Reach CD-3

Photo 29: Erosion site #3 along Reach MD-2

Photo 30: Erosion site #2 along Reach MEC-1

Photo 31: Erosion Site #4 along Reach TC-1B

Photo 32: Erosion Site #3 along Reach TC-3

3.6 Hydraulic Analysis

3.6.1 Overview of Existing Conditions

Background information regarding surface water features, crossings, and conveyance issues were reviewed. Data gaps including as-built drawings, dimensions, and locations of crossings in addition to cross sections were communicated with the City, and addressed in order to develop a HEC-RAS model for five (5) watercourses: Voyageur, Taylor, McEwan, Mather Award, and Cyrville.

HEC-RAS was selected for this study as it is the conventional modelling tool for open-channel hydraulics. This approach is consistent with other City studies.

Floodplain mapping from the RVCA is not available for any of the subwatersheds within the study area.

3.6.2 Modelling Approach

The HEC-RAS modelling platform was used to assess the hydraulics under existing conditions. Information concerning cross sections and crossings were provided by the City, reviewed for data gaps, and subsequently refined and updated. Five (5) watercourses were evaluated, namely Voyageur, Taylor, McEwan, Mather Award, and Cyrville.

Peak flow values at identified crossings were extracted from the hydrologic model and applied to the HEC-RAS model. The flows represented surface runoff rates that were generated from design storms ranging from 2-year to 100-year storms. The model included the following number of roadway crossings:

(1) Voyageur Creek: 2 crossings
(2) Taylor Creek: 5 crossings
(3) McEwan Creek: 7 crossings
(4) Mather Award: 8 crossings
(5) Cyrville Creek: 12 crossings

Flood elevations were estimated for each crossing and compared to road top elevation. Each crossing was considered below capacity if the flood elevation was higher than road top elevation. Results were summarized in Appendix I.

3.7 Water Quality

3.7.1 Background

Two key objectives of the Ottawa River Action Plan (ORAP) are to maintain a healthy aquatic ecosystem (with a focus on addressing challenges presented by existing infrastructure), and to optimize recreational use and economic development of the Ottawa River (with a focus on reducing beach closures at Petrie Island.)

As part of this Plan, a hydrodynamic model to assess bacterial inputs to the Ottawa River model was developed by Baird & Associates (2011), extending from the Chaudière Dam downriver to Masson-Cumberland, past Petrie Island. The model incorporated all significant point source inputs to this river reach, including, flows from twenty-nine combined sewer overflows (CSOs), twenty-eight stormwater outfalls, twenty-two tributaries and two wastewater treatment plants. One of the main findings was that the Ottawa River tributaries, in particular, Green's, Bilberry, and Voyageur Creeks, were key contributors of bacterial contamination at the Petrie Island beach. The study also recognized the deficiencies associated with the empirical approach that was used to develop wet weather flows for the two larger subwatersheds: Bilberry and Green's Creeks.

The objective of this section is to quantify the water quality impact from stormwater runoff to the four (4) largest Eastern Subwatersheds tributaries to the Ottawa River. The concentrations of key pollutants in the streams due to stormwater runoff were estimated, as well as the loads discharged to the Ottawa River.

The findings and conclusions of this chapter are based on the following assumptions:

- Synthesizing and analyzing recent water quality field observations at the outlets of the four subwatersheds to the Ottawa River including dry weather and wet weather data;
- Comparing field data and assembled Event Mean Concentrations (EMCs) with the findings of previous studies (i.e. Baird & Associates, 2011);
- Comparing recent field observations with federal and provincial water quality standards;
- Identifying and selecting Event Mean Concentrations to be used for the water quality model;
- Water quality modelling using EPA SWMM; and
- Water quality model calibration using field data synthesized and organized earlier.

3.7.2 Scope and Approach

The Study Area includes four (4) relatively large subwatersheds, namely Green’s Creek (12,007 hectares), Bilberry Creek (1,116 hectares), Voyageur Creek (828 hectares) and Taylor Creek (658 hectares). Green’s Creek includes a number of smaller tributary watercourses. There are 3 segments to Green’s Creek: the Green’s Creek headwaters (2% impervious), Green’s Creek Mid-Reach (28% impervious) and the Green’s Creek Downstream Reach (19% impervious). Green’s Creek tributaries are Mud Creek, Black Creek, Borthwick Creek, Ramsay Creek, McEwan Creek, Mather Award Drain and Cyrville Drain. The study area also includes the smaller catchments that drain directly to the Ottawa River within the eastern and western limits of the above 4 subwatersheds.

The City of Ottawa provided a database of flow records and water quality sampling of watercourses discharging to the Ottawa River. The data was collected between April and November (no sampling was done in winter). In 2009, 2010 and 2011, hourly water quality samples were collected from the four major streams during 7 to 12 storm events. Flow data for the same watercourses were simultaneously collected a short distance upstream.

The water quality monitoring data sources were merged to derive Event Mean Concentrations (EMCs) of selected pollutants for the monitored storm events in Green's, Bilberry, Voyageur and Taylor Creeks. This effort provides a representative estimate of the concentrations and loads of pollutants discharged to the Ottawa River during storm events, covering 6-8 months of the year (early summer to fall). The average of a series of grab samples of the same streams collected during baseflow conditions was used to represent dry-weather EMCs.

The wet-weather and dry-weather flow data were pooled and their derived EMCs were combined to calculate the total in-stream loads of pollutants discharged to the Ottawa River. The load is defined as the flow (in cubic metres) multiplied by the derived EMC (in milligrams per litre [mg/L] = grams per cubic metre [g/m^3]).

The resulting loads in the streams represent the sum of dry- and wet-weather contributions of pollutants from all the land uses and non-point sources upstream for the 6-8 months of monitoring.

3.7.3 Selection of Key Pollutants

The key pollutants affecting the recreational enjoyment of water and its overall ecosystem health are bacteria (specifically E.coli), sediment (as total suspended solids or TSS), nutrients (especially total phosphorus or TP) and metals (particularly metals often associated with development, such as copper and zinc).

Escherichia coli (E.coli) is the indictor of choice for a host of pathogenic (illness-causing) bacteria, as they are excreted in the feces of all warm-blooded animals. The main concern is that swimming becomes unsafe and beaches are posted when concentrations of E.coli in water exceed 100 colony-forming units per 100 milliliters (CFU/100mL).

Total suspended solids (TSS) are solid particles (organic and inorganic) that are suspended in water. High concentrations of TSS in water have a several undesirable impacts:

- TSS lowers water quality by absorbing light. Hence, warmer water loses the ability of the water to hold dissolved oxygen levels necessary for aquatic life. Photosynthesis in aquatic plants decreases and less oxygen is produced;

- Elevated TSS clogs fish gills, reduces growth rates and can smother fish eggs. The material that settles to the bottom fills the spaces between rocks and makes these microhabitats unsuitable for various aquatic insects, such as mayfly nymphs, stonefly nymphs and caddisfly larva; and

- TSS derived from eroded soil is also a vector for the transport of nutrients, bacteria and metals.

The Canadian Council of Ministers of the Environment (CCME) provides two TSS guidelines for the protection of aquatic life: for clear flow in streams, the maximum increase in TSS is 25 mg/L from background levels for any short-term exposure (e.g., 24-h period), with a maximum average increase of 5 mg/L from background levels for longer term exposures (e.g., inputs lasting between 24 h and 30 d). Under high flow conditions, the maximum increase is 25 mg/L from background levels at any time when background levels are between 25 and 250 mg/L. The TSS concentrations should not increase more than 10% of background levels when the background concentration exceeds 250 mg/L (CCME).

Phosphorus is the rate-limiting nutrient for aquatic and terrestrial life, but an excess can lead to the proliferation of nuisance algae, oxygen depletion and dead zones in water, resulting in fish kills and foul odours. Although commonly associated with fertilizers and agricultural runoff, phosphorus is present in soils at an average concentration of 0.8 mg/l in Ontario, such that soil erosion is a significant source of phosphorus to receiving waters[2].

The CCME Canadian Guidance Framework for Phosphorus provides Trigger Ranges for Total Phosphorus (mg/L) that range from 0.004 – 0.010 in oligotrophic water bodies and >0.035 for eutrophic water bodies. The PWQO for rivers and streams is 0.03 mg/L total phosphorus (TP) (PWQO, 1994).

Copper and zinc are commonly associated with development. Copper sources include brake dust, wood preservatives, pool algaecides, and copper piping in household drains. High concentrations of dissolved copper are toxic to aquatic organisms. Zinc sources are galvanized metals, tire wear and oil drip and high concentrations in water can impair the growth of invertebrates. These metals are also essential micro-nutrients in soils, with average Ontario concentrations of 10 ppm (Cu) and 60 ppm (Zn) in rural parkland soils. As with phosphorus, soil erosion can be a significant source of copper and zinc to streams along with entrained soil as TSS.

The CCME guideline and PWQO for zinc are both at 0.030 mg/L. The CCME guideline for copper is 0.002 mg/L, whereas the PWQO for copper is 0.005 mg/L (PWQO, 1994; CCME).

3.7.4 Event Mean Concentrations (EMC) and Stream Loads

The Event Mean Concentration (EMC) is the average concentration of a given pollutant during a period of flow, usually a storm event, where it is defined as the total pollutants mass divided by the total runoff volume.

The EMC is the preferred measure of pollutants because the concentrations of pollutants in stormwater vary tremendously between watersheds and, within any given watershed. The concentrations of most pollutants also change significantly from beginning to end within any single storm event. That is why most studies attempt to derive an EMC that is representative of the entire storm event.

The concentration of each pollutant reflects its source and supply during a storm event. There are three pollutant responses that affect concentrations in stormwater runoff.

A "First Flush" response is characterized by wash-off of fine-grained material that accumulated on directly-connected impervious surfaces during dry periods. The material is easily transported because of its fine-grained nature and it is concentrated at the start of a relatively high-energy flow episode. However, the supply of material is limited and it is quickly washed off, resulting in a decrease in concentrations through the course of the event. The concentration of pollutants in the "First Flush" response is generally a function of the duration of the antecedent dry period, the rate of build-up of the pollutant (including atmospheric fallout), the grain size of the pollutant, the mode of entrainment and the distance between the source and the point of measurement.

[2] As an example, the mean concentration of phosphorus in Ontario rural parkland soils is 800 mg/kg (ppm). A soil containing the 800 mg/kg of phosphorus, if eroded and suspended in flowing water to a TSS concentration of 38 mg/L, will also have a total phosphorus concentration of 0.03 mg/L, thereby exceeding the Provincial Water Quality Objective.

From the National Stormwater Quality Database (NSQD), TSS, COD, TDS, total metals (including copper, lead and zinc) had “first flush” concentrations that were significantly higher (up to 3X) when compared to the composite sample concentrations in urban areas.

A “dilution” behaviour reflects a constant supply of material containing the pollutant prior to, during, and after the flow event. For example the supply of Total Kjeldahl Nitrogen (TKN) and E.coli from a leaking sanitary sewer into a flowing creek would result in high concentrations during the dry-weather flows, which would decrease by dilution as the flow rate increases during the rising limb of the storm hydrograph. The concentrations of organic nitrogen and bacteria will then increase as the flow decreases in the recession limb to baseflow conditions.

A “proportional” behaviour is typical of an unlimited but energy-related supply of material containing the pollutant of interest. For example, the supply of suspended solids (as TSS) derived from stream erosion increases with flow rate in most systems which have a virtually unlimited supply of material to erode. Along with the sediment, the concentrations of some pollutants (such as entrained phosphorus and metals in the eroded soil) will also increase as the flow rate increases.

These behaviours illustrate why it is important that water quality studies be designed to capture the variability of pollutant concentrations as the flow rates change and to represent this variability as a single number for the entire storm event. This is the concept of the EMC.

Numerous studies conducted since the 1980s have determined EMCs for different land uses, providing a useful tool to predict water quality impacts related to different land uses. This helps to establish ranges of EMCs as functions of land uses, from which one can calculate the loadings of selected pollutants to receiving waters. This information is essential for planning, phased development, stormwater management and adaptive management.

With regard to determining reliable EMCs, there are three major considerations:

1. How many samples (or sub-samples for a composite) should be collected during each storm event to determine the EMC?

2. When multiple samples are collected, should they be based on intervals of flow (flow-proportional), time (time-weighted) or can a series of grab samples be sufficient?

3. How many storm events should be sampled to obtain a reliable average EMC?

The number of samples collected during a given storm event is best determined by initiating a sampling event for every increment of flow (flow-proportional) over the entire duration of a large storm event. In this case, each sub-sample represents the same unit volume of flow (as illustrated in Figure 3.17). Time-weighted sampling may miss peak flows altogether, particularly in urbanized areas where runoff can be “flashy”.

The third consideration is the number of storm events that should be monitored to establish an EMC. Since no two storms will be alike, at least 8 storm events should be sampled before a representative EMC or Average Event Mean Concentration (AEMC) is determined (see Figure 3.18). Below this number, the variance in the results can render results virtually meaningless.

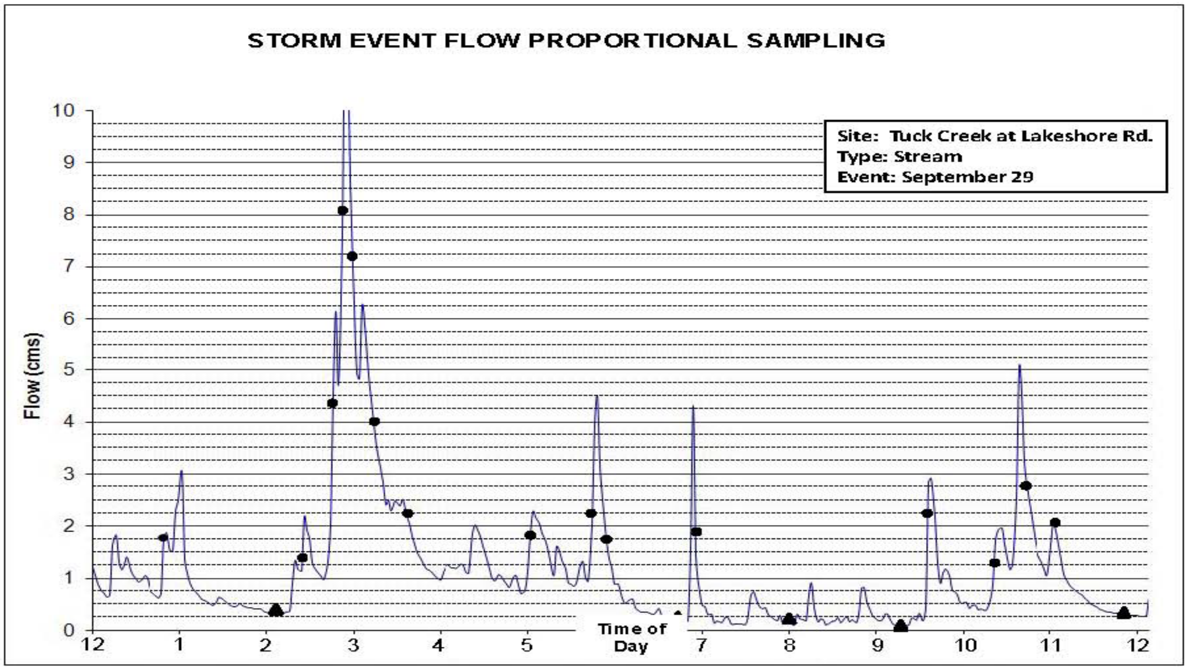


Figure 3.17: Example of Flow-proportional Sampling During a 12-hour Period.

The filled circles represent individual flow-proportional sub-samples. The filled triangles represent individual grab samples during baseflow conditions. (Source: Aquafor Beech Limited, 2005)

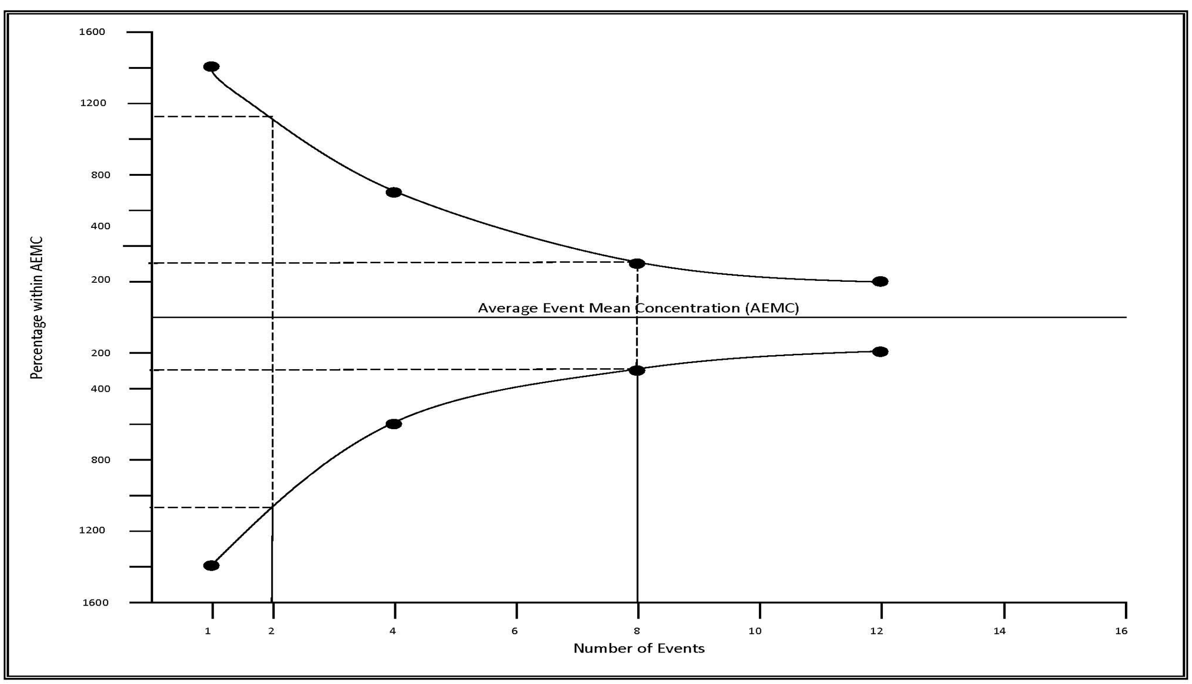


Figure 3.18: Illustrative Figure Showing Expected Variability of Individual Storms as a Function of the Number of Storms Monitored (Source: Aquafor Beech Limited, 2006)

From a statistical perspective, when the sample population is lower than 30 and the Student's t-test is applied to the population, the greater the population of events, the narrower the confidence interval. This is illustrated in the nomogram in Figure 3.19, where the acceptable variance (± X%) of the 95% confidence interval and an acceptable variance of the result (as a fraction of the mean) will show the number of storms that are required to achieve this. In the example shown, a 15% variance of the 95% confidence interval for a 25% variance in the resulting mean would require 12 events to be monitored.

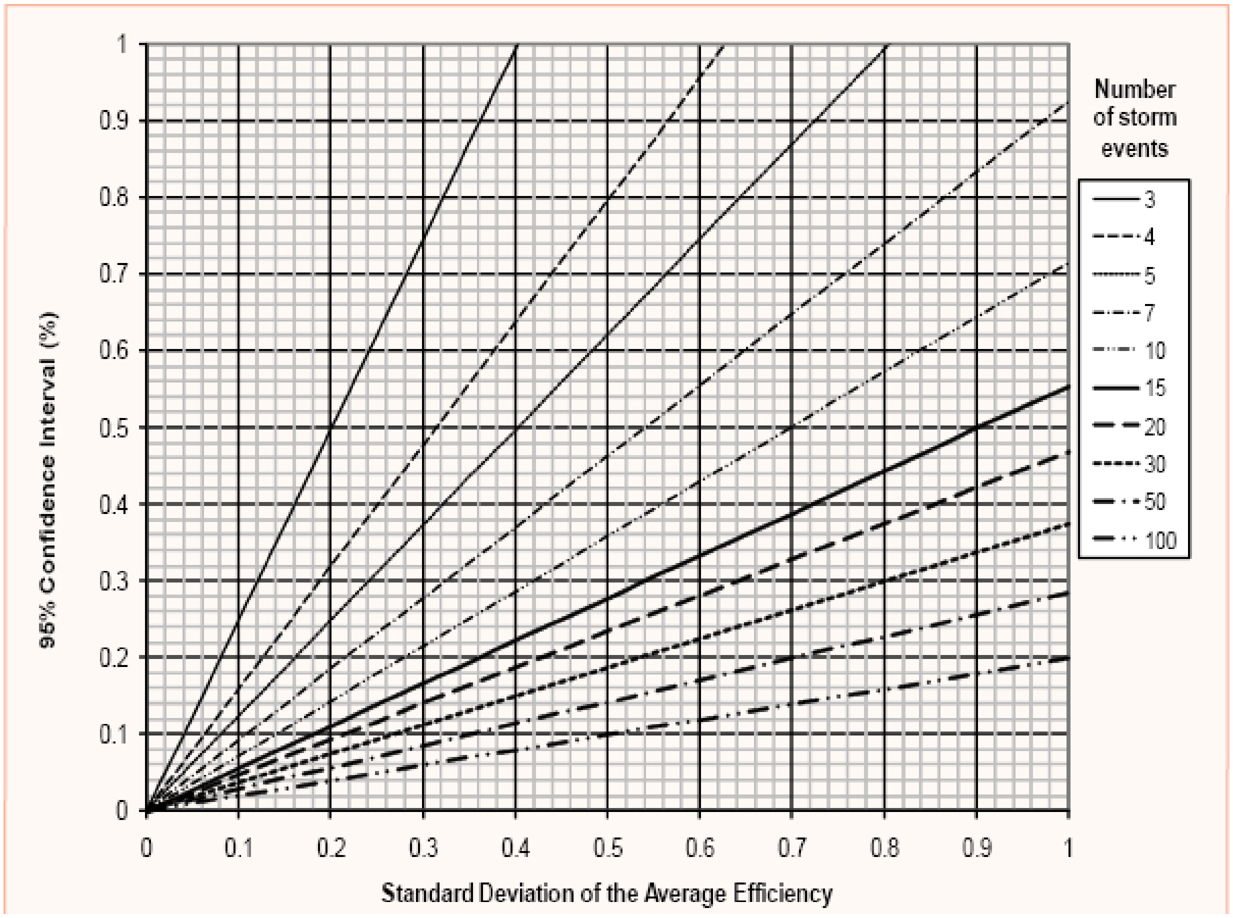


Figure 3.19: Relationship between the Number of Storm Events and Standard Deviation for a 95% Confidence Interval

In this case, a confidence interval of ±15% and standard deviation of 25% would require 13 storm events to be monitored (Source: A.J. Erikson, P.T. Weiss, J.S. Gulliver and R.M. Hozalski, 2010).

3.7.5 Results

The database provided by the City of Ottawa (2009-2011) allowed the determination of in-stream wet-weather EMCs for 4 streams (Green's, Voyageur, Bilberry and Taylor Creeks). These were derived from 7 to 12 separate hourly storm sampling intervals. Flow data were compiled from upstream locations on the same streams. The sampling was done over an 8-9 month period, from April to October.

Although the water quality samples were collected hourly (and thus not truly flow-proportional), it was noted that combining these sampling intervals with the flow data produces a reasonable surrogate of a storm event. Having a dozen such events is considered to be a representative Event Mean Concentration for storm events. An example from Green's Creek is shown in Figure 3.20.

For dry-weather EMCs, the means of 4-12 dry-weather grab samples taken during baseflow conditions were used. The selected wet- and dry-weather means, medians and EMCs are presented in Table 3-11. The averages of the EMCs (AEMCs) are also summarized in Table 3-11. The total flows during the sampling periods are shown in Table 3-12 and the total loads carried to the Ottawa River are presented in Table 3-13.

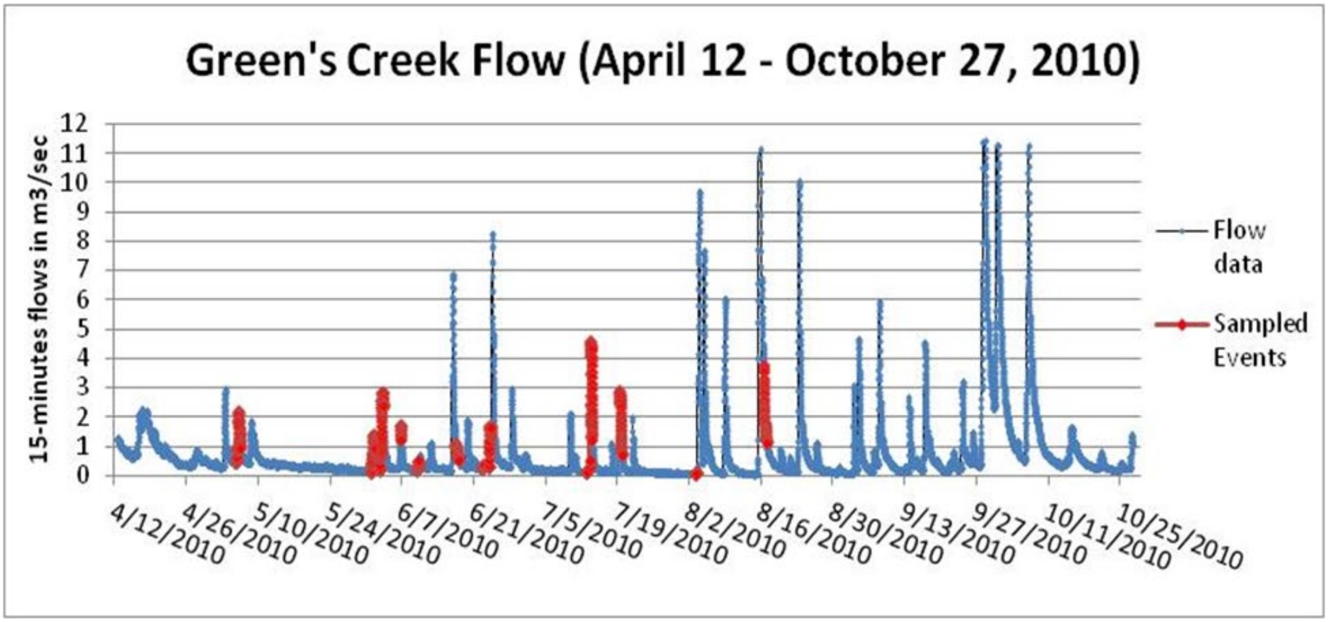


Figure 3.20: Wet-Weather Sampling Intervals Superposed on the Hydrograph for Green's Creek (May-August, 2010)

Table 3-11: Wet-Weather and Dry-Weather Event Mean Concentrations (EMCs) – Eastern Subwatersheds

Year	Creek	Months	Dry TSS (mg/L)	Dry E.Coli (CFU/100mL)	Dry TP (mg/L)	Dry Cu (mg/L)	Dry Zn (mg/L)	Wet TSS (mg/L)	Wet E.Coli (CFU/100 mL)	Wet TP (mg/L)	Wet Cu (mg/L)	Wet Zn (mg/L)
1998	Green's	May - Oct	23.4	195	0.06	0.0062	0.0093	179.1	1,125	0.14	0.0137	0.0445
2009	Bilberry	Apr - Nov	21	504	0.07	0.0084	0.011	-	1,600 – 2,600*	-	-	-
	Green's	Estimated	-	-	-	-	-	-	2,200*	-	-	-
	Taylor	Apr - Nov	29	1,438	0.087	0.011	0.026		2,600*			
	Voyageur		-	-	-	-	-	-	2,600*	-	-	-
	Mud	Apr - Nov	8	247	0.051	0.047	0.005	-	-	-	-	-
2010	Bilberry	Mar - Nov	22	50	0.064	0.0107	0.008	742	4,740	0.332	0.023	0.066
	Mud	May - Nov	7	254	0.039	0.0054	0.003	-	-	-	-	-
	Green's	May - Aug	-	-	-	-	-	317	804	0.198	0.015	0.037
	Taylor	Apr - Nov	5	3,124	0.046	0.0099	0.009	-	-	-	-	-
	Voyageur	March - Nov	11	348	0.040	0.0109	0.006	239	3,446	0.268	-	-
2011	Green's	Apr - Nov	24	289	0.091	0.0099	0.014	92	1,623	0.206	0.013	0.189
	Bilberry	Mar - Nov	22	209	0.061	0.0088	0.009	270	8,138	0.187	0.019	0.035
	Mather	Apr - Nov	12	1,147	0.058	0.009	0.016	-	-	-	-	-
	Mud	May - Nov	5.4	933	0.037	0.0053	0.005	-	-	-	-	-
	Taylor	Apr - Nov	5	597	0.052	0.073	0.011	104	6,237	0.087	0.014	0.036
	Voyageur	Mar - Nov	8	323	0.036	0.0216	0.015	371	7,295	0.145	0.025	0.084

*Data from Baird & Associates (2011). Ottawa River Water Quality Model Improvement Study (Draft).

Table 3-12: Dry-Weather Flows, Wet-Weather Flows and Total Flows Monitored – Eastern Subwatersheds

Stream	Year	Date	Stream	Dry-Weather Flow – Baseflow (m^3)	Wet-Weather Flow (m^3)	Total Flow (m^3)	Wet Flow (%)
Green's Creek	1998	May 9 – October 14	Green's Creek	1,219,211	3,571,211	4,790,422	75
Bilberry Creek	2009	April 1 – November 12	Bilberry Creek	1,005,781	821,930	1,827,711	45
Taylor Creek	2009	April 15 – November 12	Taylor Creek	380,223	640,468	1,020,691	63
Mud Creek	2009	April 9 – November 10	Mud Creek	1,801,797	5,788,813	7,590,610	76
Bilberry Creek	2010	March 17 – November 10	Bilberry Creek	1,264,046	816,401	2,080,447	39
Mud Creek	2010	April 16 – November 24	Mud Creek	1,419,463	9,056,903	10,476,366	86
Taylor Creek	2010	March 17 – November 10	Taylor Creek	348,856	514,971	863,827	60
Voyageur Creek	2010	March 19 – November 10	Voyageur Creek	470,640	582,381	1,053,021	55
Green's Creek	2010	March 10 – October 27	Green's Creek	3,037,280	7,559,154	10,596,434	71
Green's Creek	2011	April 19 – November 15	Green's Creek	471,813	5,701,911	6,173,724	92
Bilberry Creek	2011	March 8 – November 17	Bilberry Creek	851,147	1,743,583	2,594,730	67
Mather Award Drain	2011	April 12 - November 14	Mather Award Drain	674,393	78,537	752,930	10
Mud Creek	2011	May 12 – November 25	Mud Creek	1,066,005	14,146,165	15,212,170	93
Taylor Creek	2011	April 15 – November 16	Taylor Creek	318,081	481,718	799,799	60
Voyageur Creek	2011	March 9 – November 16	Voyageur Creek	685,326	1,328,676	2,014,002	66

Table 3-13: Dry- and Wet-Weather Loadings for Streams – Eastern Subwatersheds

Year	Creek	Months	Dry TSS (kg)	Dry E.coli (CFU)	Dry TP (kg)	Wet TSS (kg)	Wet E.coli (CFU)	Wet TP (kg)	Total TSS (kg)	Total E.coli (CFU)	Total TP (kg)
1998	Green's	May - Oct	28,530	2.38E+12	73.2	639,586	4.02E+13	500.0	668,116	4.26E+13	573.2
2009	Bilberry	Apr. – Nov.	21,121	5.07E+13	87.5						
	Taylor	Apr. – Nov.	11,026	5.47E+12	91.9						
	Mud	Apr. – Nov.	14,414	4.45E+12	26.6						
2010	Bilberry	Mar. – Nov.	27,809	4.42E+12	80.9	605,770	3.87E+13	271.0	633,579	4.3E+13	351.9
	Mud	May – Nov.	9,936	3.61E+12	55.4						
	Green's	Mar. – Oct.				2,393,969	6.07E+13	1,495	2,393,969	6.08E+13	1,495
	Taylor	Apr. – Nov.	1,744	1.09E+13	16.0						
	Voyageur	Mar. – Nov.	5,177	1.64E+12	18.8	139,189	2.01E+13	156.1	144,366	2.2E+13	174.9
2011	Green's	Apr. – Nov.	11,324	1.36E+12	42.9	524,576	9.25E+13	1,174.6	528,351	9.4E+13	1,201.9
	Bilberry	Mar - Nov	18,725	1.78E+12	51.9	470,767	1.42E+14	326.1	489,492	1.4E+14	378.0
	Mather	Apr - Nov	8,093	7.74E+12	39.1						
	Mud	May – Nov	5,756	9.95E+12	39.4						
	Taylor	Apr. – Nov.	1,590	1.90E+12	16.5	50,099	3.00E+13	41.9	51,689	3.2E+13	58.4
	Voyageur	Mar. – Nov.	5,483	2.21E+12	24.7	492,939	9.69E+13	192.7	498,422	9.9E+13	217.4

3.7.6 Water Quality Modeling

Water quality modelling is applied to estimate and analyze water quality characteristics within a watershed which are undergoing change, such as urban growth, and system wide application of stormwater management. The water quality characteristics include pollutant concentrations and loading. In this study, quality models were developed to quantify the impact of stormwater runoff to the four (4) largest Eastern Subwatersheds tributaries that flow to the Ottawa River, namely Green's Creek, Taylor Creek, Voyageur Creek, and Bilberry Creek. The concentrations of key pollutants in the streams due to stormwater runoff were modelled, as well as the loads they carry to the Ottawa River. The water quality models were calibrated using field measurements and observations tabulated earlier.

3.7.7 Modelling Approach

PCSWMM software was used to model water quality characteristics within the study area. The model has been used globally to model the buildup, washoff, transport, and treatment of many water quality constituents. Through the implementation of several build up and washoff functions over multiple land uses, PCSWMM is capable of simulating a variety of modelling scenarios and conditions to provide baseline conditions for stormwater management studies. In addition, treatment also available through the application of Best Management Practices and LID measures that can be simulated using the model.

Hydrological analysis (see **Section 3.5**) provides the foundation of the water quality model by delivering surface runoff rates and volumes needed for the assessment of pollutant concentrations and loads through the study area, and the pollutants are delivered to the Ottawa River.

3.7.8 Discussion of In-Stream Results

The following are observations and conclusions drawn from the in-stream EMCs, and from a comparison between the loads carried by dry-weather (baseflow) and wet-weather (storm flow):

1. The EMCs for all pollutants under wet-weather conditions are significantly greater than the values under dry-weather conditions, ranging from 2X for metals, 5X for phosphorus and often more than 10X for TSS and E.coli. High flows of storm runoff appears to concentrate those pollutants, not dilute them;

2. The wet-weather EMCs are significantly greater than the averages of wet-weather grab samples for the same parameters and for the same storms in 2010 and 2011. Grab samples in wet-weather flows significantly underestimate true concentrations;

3. The wet-weather EMCs for E.coli in Bilberry, Voyageur and Taylor Creeks are more than 2X higher than those used by Baird & Associates (2011) for the same creeks. Green's Creek concentrations were marginally lower than Baird's value;

4. None of the Eastern Subwatersheds streams meet the Health Canada recreational water quality criterion of 100 E.coli/100 mL. Wet-weather loads of E.coli are 10X greater than the dry-weather loads;

5. None of the Eastern Subwatersheds streams meet the PWQO of 0.03 mg/L for phosphorus under both dry and wet-weather conditions. Green's Creek exported more than 1 tonne of phosphorus to the Ottawa River in 2011. It is likely that eroding soils is a major source of phosphorus entrained in the suspended solids (TSS);

6. Stormwater flow comprises more than half (sometimes up to 90%) of the total flow during the 8-9 months of flow monitoring; and

7. The pollutant loads carried by stormwater constitutes more than 90% of the entire loads carried by the streams.

3.7.9 Pollutant Characteristics

Field data was synthesized and analyzed in order to assess the existing conditions for four (4) subwatersheds. Five (5) pollutants, namely E.coli, TP, TSS, Copper, and Zinc were defined in the model water quality routine.

Pollutant concentrations were initially applied to the water quality model on a lumped basis, representing concentrations that are expected based on a comprehensive literature review of the range of pollutant concentrations encountered in previous studies covering North America and Europe depending on the land use encountered.

Decay coefficient, which is a component of the EPA SWMM water quality model that accounts for the kinetics of decay, was used for E.coli washoff only. A higher decay coefficient was used for rural subwatersheds making up Green's Creek subwatershed (i.e. first order decay coefficient =1.4/ day), and a lower rate (0.2/ day) for urban subwatersheds except for Taylor Creek, where decay was assumed to be negligible because of the dominance of storm sewers and the lack of a natural channel system except for a short segment downstream Apollo Park.

This can be justified by slower die-off rates encountered within urban areas due to the following:

- The predominance of storm sewer systems in urban streams. Research has reported that sunlight is the most important factor affecting die-off of E. coli with 90% concentration reductions within about 1 hour (Canteras et al., 1995); and

- Impervious surfaces prevent E.coli from dissipating through natural processes provided by pervious areas (e.g. adsorption and settling).

3.7.10 Land Use and Washoff Characteristics

Pollutant buildup and washoff parameters were defined based on a recommended range of Event Mean Concentrations (EMCs) for seven (7) land uses (Table 3-14). These land uses represent the major land uses that exist within the Eastern Subwatersheds, and they are:

- Residential (all residential from single family homes to high-rise apartments);
- Commercial (retail stores and shopping centres);
- Industrial (industries and industrial malls); Institutional (schools, hospitals, nursing homes and campus residences);
- Open Space (streets, parks, sports fields, vacant property, shrub land, wetland);
- Agriculture (all agricultural uses); and
- Forest.

The percentages of land use cover for the seven (7) land uses were obtained using GIS analysis, and plugged into the water quality model with washoff characteristics that agree with the suggested range of EMC values shown in Table 3-14. The ranges of EMC values were extracted from stormwater sampling in catchments representing the listed land uses from North America and Europe. These EMC values were used in the water quality model and calibrated against observed field data to arrive to the best fit between modelled and observed data.

Sampling of stormwater in small catchment areas characterized by single land uses was initiated in the 1970s with the purpose of deriving EMCs. In the United States, this effort was prompted by the National Pollutant Discharge Elimination System (NPDES), a federal program to regulate the quality of the nation's water bodies. Although initially applied to discharges from industry and municipal sewage treatment plants, the NPDES was expanded in 1987 to include stormwater runoff. Municipalities were obliged to prepare pollution prevention plans and stormwater controls to prevent the degradation of receiving waters.

Considerable efforts were made in both North America and Europe over the past 30 years to measure the impacts of specific (existing or planned) land uses on the quantity and quality of stormwater runoff. Knowledge of the land uses, their respective EMCs and the rainfall/runoff characteristics allows a reasonable calculation of the impacts to receiving waters.

In this case, there is a good understanding of the existing in-stream impacts in the four streams of the Eastern Subwatersheds. The pollutant loads are significant and mostly carried by uncontrolled stormwater runoff.

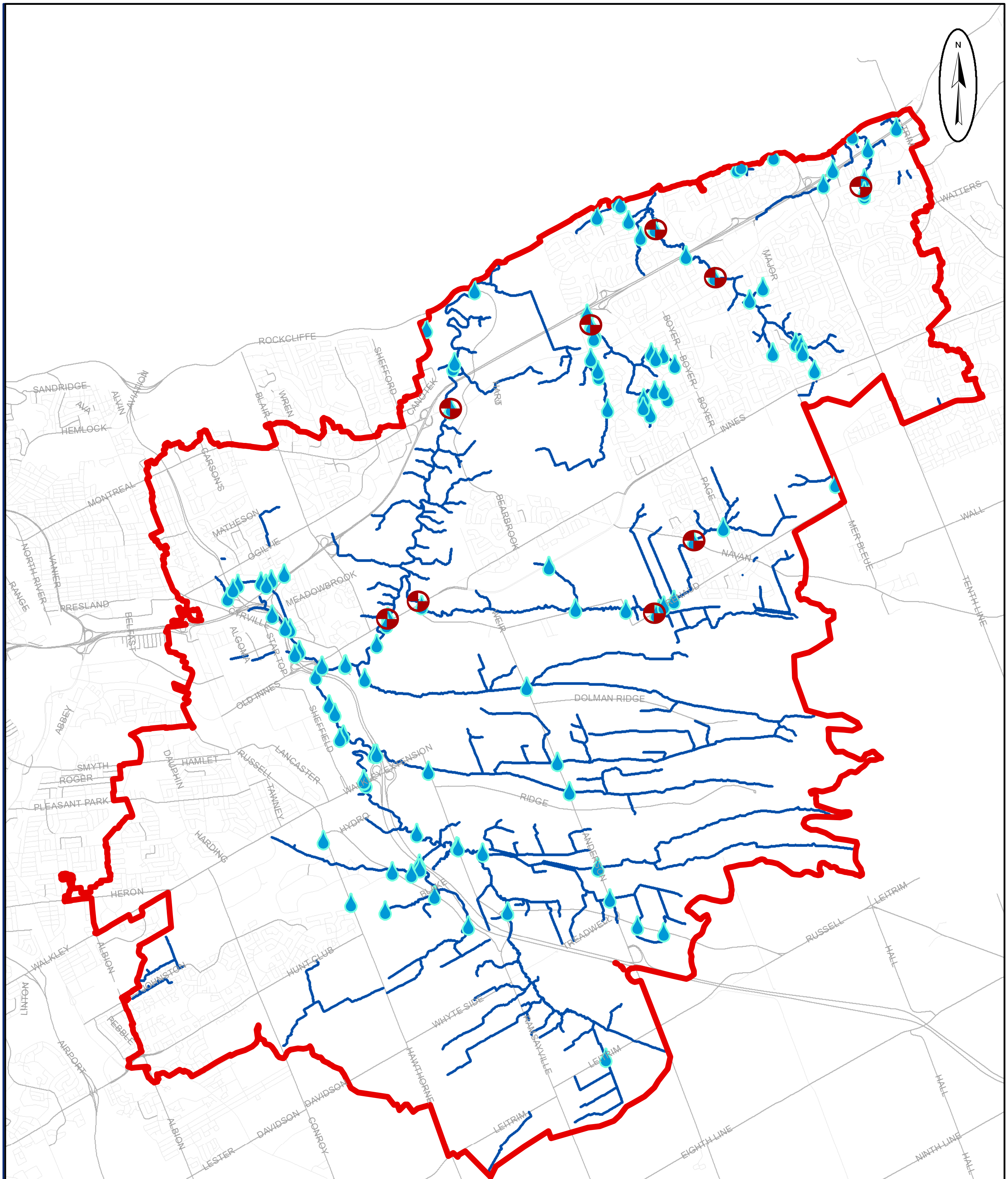
Table 3-14: Suggested Ranges of EMCs for the Five Pollutants Used in the Study

Land Use	Suggested Range of E.coli EMC Values (Counts/100mL)	Suggested Range of TP EMC Values (mg/L)	Suggested Range of TSS EMC Values (mg/L)	Suggested Range of Copper EMC Values (mg/L)	Suggested Range of Zinc EMC Values (mg/L)
Residential	8,180 – 1,081,000	0.20 – 0.79	49 – 273	0.012 – 0.045	0.080 – 0.296
Commercial	5,000 – 1,071,000	0.20 – 0.35	43 – 210	0.0145 – 0.032	0.0127 – 0.397
Industrial	1,100 – 653,000	0.23 – 0.63	60 – 404	0.020 – 0.031	0.016 – 0.629
Education/Institutional	8,400 – 8,500	0.18 – 0.36	17 – 164	0.010 – 0.025	0.113 – 0.140
Open Space	4,100 – 5,370	0.10 – 0.31	48 – 216	0.004 – 0.038	0.020 – 0.040
Agricultural	26,000 – 40,500	0.19 – 3.52	6 – 1,768	0.0015 – 0.008	0.017 – 0.140
Forest	NA	0.10 – 99	0.15 – 99	NA	NA

3.7.11 System Representation

The water quality for the four (4) subwatersheds was modelled based on the system and parameters specified in the hydrological model including physiographical characteristics, geometric characteristics, and climate data. In addition to that, land uses and pollutant event mean concentrations were added to each subcatchment in each subwatershed within the study area. The concentration and load of each pollutant was assessed for each subwatershed for the time period between May and October 2010, except for Taylor Creek where the year 2011 data was used since wet weather data was not available for the year 2010. Pollutant concentrations were compared with concentrations at water quality monitoring stations shown in Figure 3.21. Pollutant loads were assessed for each subwatershed system and not based on the flow volumes from one single monitoring stations because most of the subwatersheds within the study area have more than one watercourse (e.g. Taylor Creek, Voyageur Creek).

Except for the decay rate assumptions for the E.coli, no stormwater quality treatment was assumed throughout the study area.



Legend	
	Flow Monitoring Station
	Water Quality Monitoring Station
	Study Area
	Watercourse

Eastern Subwatersheds SWM Retrofit Study

Water Quality Monitoring Stations

MORRISON HERSHFIELD

Aquafor Beech Limited

Figure 3-21

1:125,000

0 0.5 1 2 3 4 Kilometers

October, 2018 | Project No. 2124041

O:\Ottawa\proj\2124041\14 Reports\Final Report June 2017\Figures\Figure 3.21 - Water Quality Monitoring Stations.mxd

3.7.12 Water Quality Modelling Results

Table 3-15 shows pollutant concentrations (modelled and observed) and pollutant loads at the outlets of each of the four subwatersheds modelled in this study. Green's, Bilberry, Voyageur and Taylor Creeks do not meet CCME guidelines for TSS under wet-weather conditions nor the PWQO of 0.03 mg/L for Total Phosphorus. Heavy metals are also above the PWQO standards, and none of the Eastern Subwatersheds streams meet the Health Canada recreational water quality criterion of 100 E.coli/100 mL.

Figure 3.22 through Figure 3.26 illustrate the magnitude of pollutant load and the difference in pollutant load among the four subwatersheds. It can be noticed that Green's Creek subwatershed is the major contributor of all pollutants except for E.coli load where Taylor Creek subwatershed contributes the greatest load. This may be linked to the high E.coli concentration at the outfall of Taylor Creek (almost eight (8) times the concentration at Green's Creek outfall). According to

Table 3-15, Green's Creek subwatershed delivered close to 2 tonnes of phosphorus and around 2,600 tonnes of total suspended solids to the Ottawa River in 2010. It is likely that eroding soil is a major source of phosphorus entrained in the suspended solids (TSS).

The modelled results are reasonably close to the observed results. A discussion of the calibration process used to better match observed data is presented in the next section.

Table 3-15: Pollutant Concentrations and Loads to the Ottawa River (All Subwatersheds)

Subwatershed	Pollutant	Pollutant Concentration at Outfall (mg/L) (Modelled)	Pollutant Concentration at Outfall (mg/L) (Observed)[3]	Pollutant Load (Tonnes) (Colonies for E.coli) (Modelled)
Green	E.coli (Counts /100mL)	822	804	1.73E+14
	TP	0.208	0.198	1.77
	TSS	333	317	2,636.4
	Copper	0.012	0.015	0.114
	Zinc	0.036	0.037	0.311
Bilberry	E.coli (Counts /100mL)	5,077	4,741	1.05E+14
	TP	0.360	0.332	0.650
	TSS	393	742	721.8
	Copper	0.024	0.023	0.045
	Zinc	0.066	0.066	0.122
Voyageur	E.coli (Counts /100mL)	3724	3446	9.71E+13
	TP	0.290	0.268	0.535
	TSS	246	239	527.3

[3] Data is based on 2010 monitoring data except for Taylor Creek which was based on the 2011 data

Continued - Table 3-15: Pollutant Concentrations and Loads to the Ottawa River (All Subwatersheds)

Subwatershed	Pollutant	Pollutant Concentration at Outfall (mg/L) (Modelled)	Pollutant Concentration at Outfall (mg/L) (Observed)[4]	Pollutant Load (Tonnes) (Colonies for E.coli) (Modelled)
	Copper	0.017	0.023	0.038
	Zinc	0.068	0.066	0.171
Taylor	E.coli (Counts /100mL)	6,529	6,237	2.17E+14
	TP	0.094	0.087	0.379
	TSS	99	104	475.1
	Copper	0.009	0.014	0.031
	Zinc	0.037	0.036	0.145

[4] Data is based on 2010 monitoring data except for Taylor Creek which was based on the 2011 data

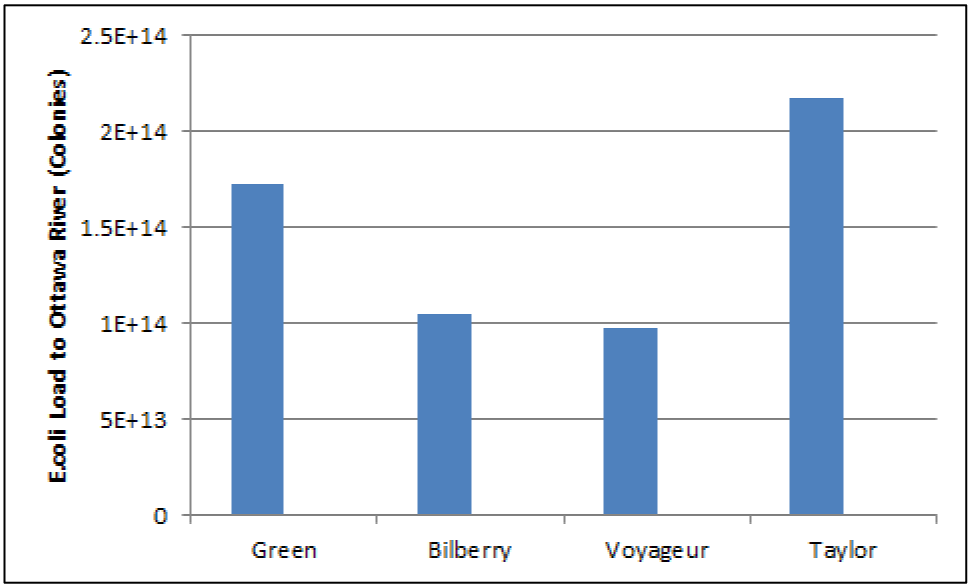


Figure 3.22: Estimated E.coli Load to Ottawa River

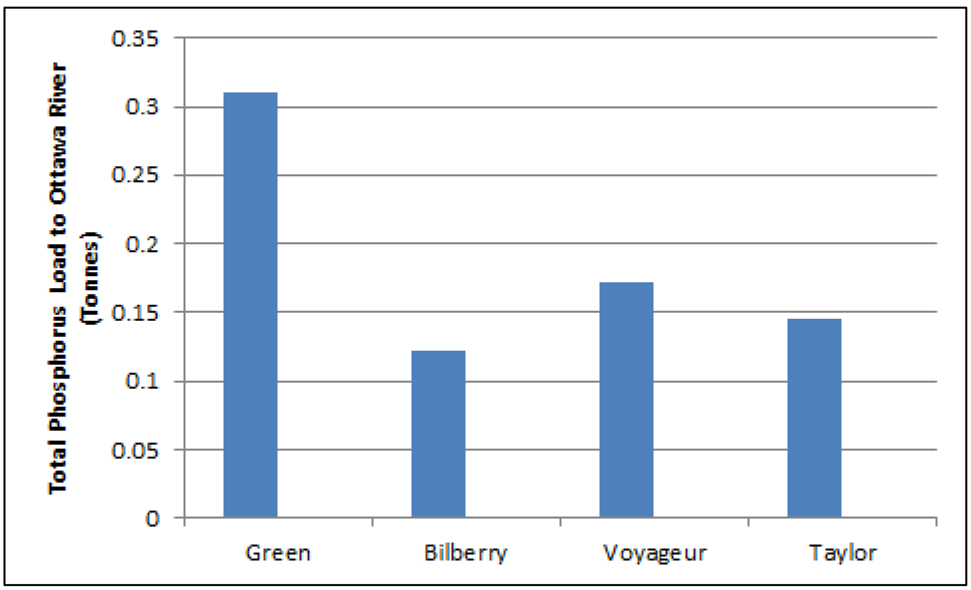


Figure 3.23: Estimated TP Load to Ottawa River (All Sources)

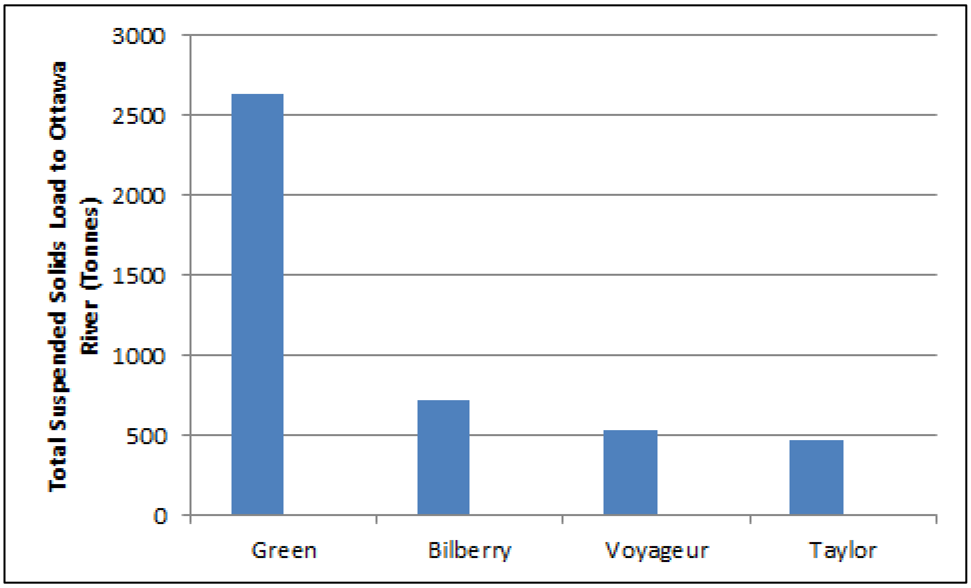


Figure 3.24: Estimated TSS Load to Ottawa River (All Sources)

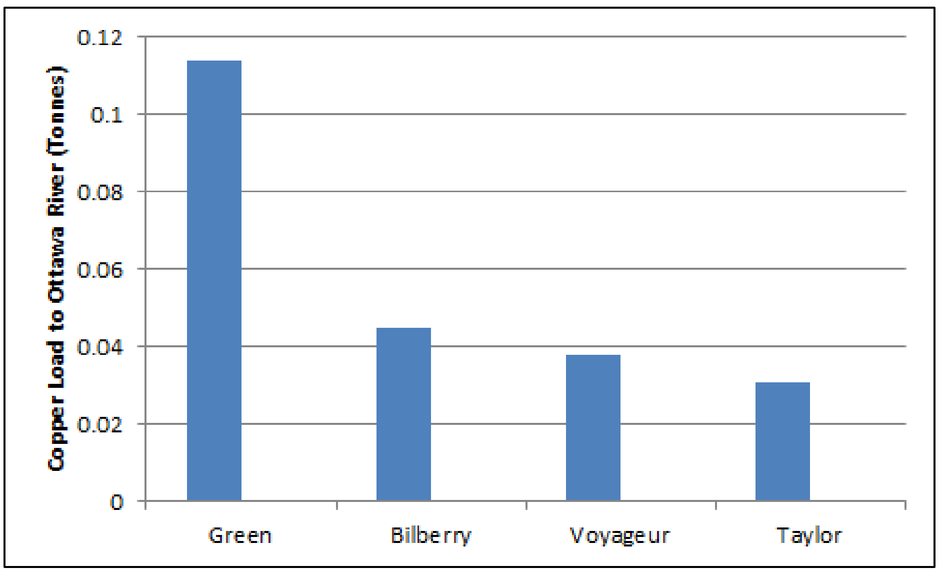


Figure 3.25: Estimated Copper Load to Ottawa River (All Sources)

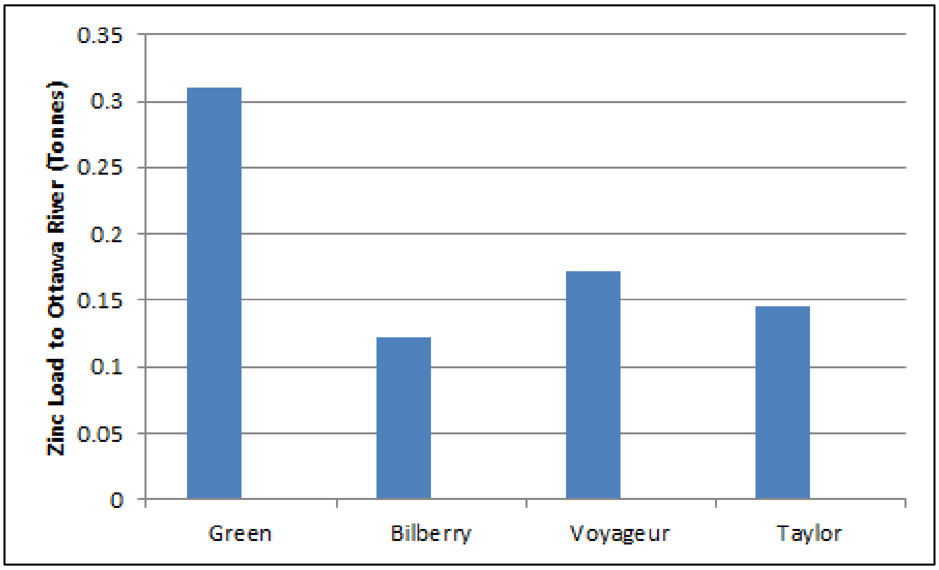


Figure 3.26: Estimated Zinc Load to the Ottawa River (All Sources)

3.7.13 Model Calibration

For water quality calibration, climate data including precipitation and evaporation were simulated for the year 2010 for all subwatersheds except Taylor Creek. Taylor Creek was simulated for the year 2011 since no wet weather quality data was available for 2010. EMC values for the five pollutants within the suggested range (

Table 3-16) were applied to the model to obtain reasonable results that are close to the field observations.

Considerations applied throughout the water quality calibration included:

- Urban vs. rural subwatersheds; where the effect of heavy metals was simulated by adjusting the EMCs for Copper and Zinc to account for the greater impact of heavy metals within urban subwatersheds;

- E.coli decay coefficient; where a decay coefficient of 0.2/day was used for urban streams except for Taylor Creek, and 1.4/day for rural streams to account for faster decay rates in natural landscapes (wetlands, vegetation, soil) and sunlight vs. slower rates on impervious areas and closed storm sewers found in urban subwatersheds;

- Stream erosion input; which is not one of the inputs of the model, therefore the contribution of land uses had to be adjusted. More specifically, the effect of stream erosion in increasing the TSS load in streams was accounted for by adjusting the TSS EMC value for the Open Space land use to account for overland and stream erosion. This procedure was successful in all cases except for the TSS concentration at the Bilberry outlet where the procedure of increasing the EMC value of TSS could not help in matching the observed TSS concentration, which was very high (742 mg/l) relative to historical TSS measurements at the same location. This occurrence of very high TSS concentration is considered to be an anomaly in the data set. Overall, the calibration was concluded to agree with the range observed in previous measurements.

The EMCs used for different land uses in the model were within the suggested range of EMCs from the literature, except for the EMC value for TSS which had to be adjusted in order to account for stream erosion processes. Decay coefficients were also adjusted to account for faster attenuation of E.coli within rural subwatersheds.

For demonstration purposes, the results of the calibration of two water quality models (i.e. Green's Creek subwatershed (predominantly rural) and Voyageur Creek subwatershed (predominantly urban)) for E.coli concentrations between May and October 2010 are shown in Figure 3.27 and Figure 3.28. It can be noted that the fluctuation of modelled data converges towards observed data as also seen in

Table 3-15, where average concentrations at the designated outfalls are reasonably close.

Modeled and observed TSS concentrations from Green's Creek and Voyageur Creek during a storm event in June 2010 are shown in Figure 3.29 and Figure 3.30. It can be noticed that most of the samples lie within the range of the model and follow the same pattern. Accordingly, the water quality model performs reasonably in long term and short-term simulations. The same can be said about the model performance in urban and rural contexts.

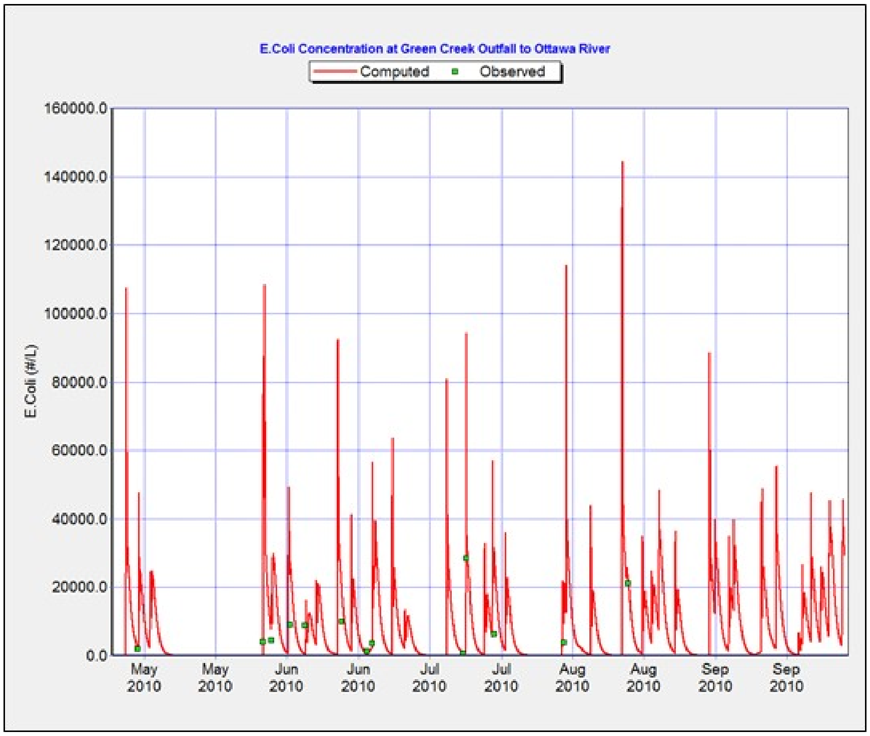


Figure 3.27 Modeled and Observed TSS Concentrations at Green's Creek Outfall to the Ottawa River (May-October, 2010)

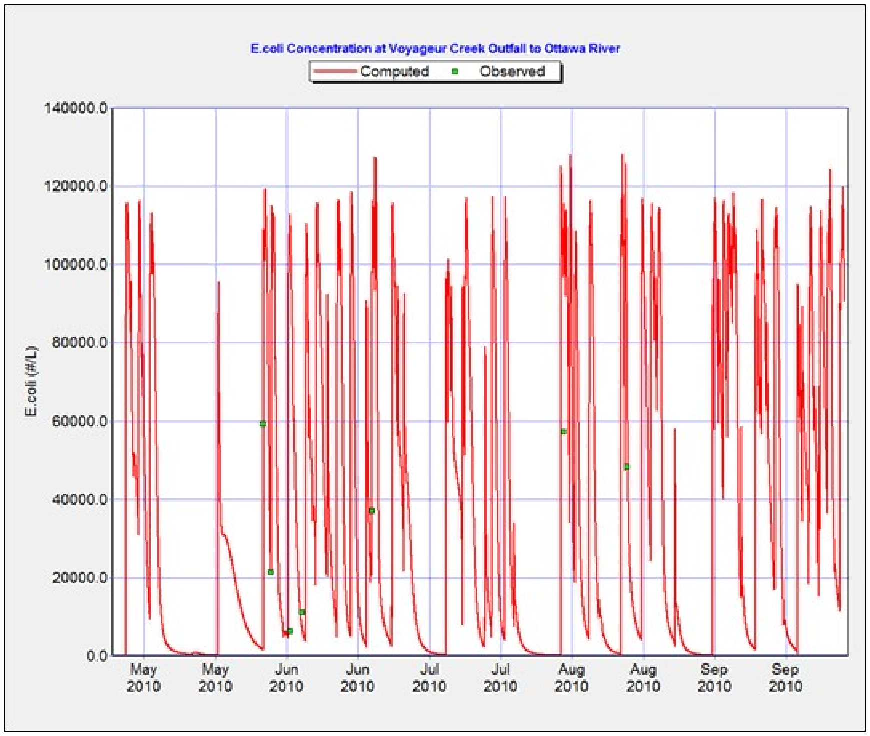


Figure 3.28: Modeled and Observed E.coli Concentrations at Voyageur Creek to the Ottawa River (May-October, 2010)

Table 3-16: Calibrated EMC Values Used in the Water Quality Model

Land Use	Pollutant	Suggested Range of EMC Values	Model EMC Values (Green's Creek)	Model EMC Values (Bilberry Creek)	Model EMC Values (Voyageur Creek)	Model EMC Values (Taylor Creek)
Residential	E.coli (Counts 100 mL)	8,180 – 1,081,000	8,180	8,180	15,000	55,000
Commercial		5,000 – 1,071,000	5,000	5,000	10,000	20,000
Industrial		1,100 – 653,000	1,100	1,100	2,000	4,000
Institutional		8,400 – 8,500	8,400	8,500	8,500	8,500
Open Space		4,100 – 5,370	4,100	4,100	5,000	5,000
Agricultural		26,000 – 40,500	26,000	30,000	30,000	30,000
Forest		N/A	10	100	100	100
Residential	TP (mg/L)	0.20 – 0.79	0.20	0.50	0.79	0.50
Commercial		0.20 – 0.35	0.20	0.35	0.35	0.35
Industrial		0.23 – 0.63	0.35	0.60	0.60	0.60
Institutional		0.18 – 0.36	0.25	0.36	0.36	0.36
Open Space		0.10 – 0.31	0.25	0.30	0.30	0.30
Agricultural		0.19 – 3.52	0.35	0.35	1.5	0.35
Forest		0.10 – 99	0.30	0.30	2.0	0.30
Residential	TSS (mg/L)	49 – 273	200	273	273	273
Commercial		43 – 210	150	210	210	210
Industrial		60 – 404	300	404	404	404
Institutional		17 – 164	164	164	164	164
Open Space		48 – 216	1,000	1,000	1,000	600
Agricultural		6 – 1,768	500	500	500	500
Forest		0.15 – 99	99	99	99	99
Residential	Copper (mg/L)	0.012 – 0.045	0.02	0.015	0.045	0.045
Commercial		0.0145 – 0.032	0.02	0.03	0.03	0.03
Industrial		0.020 – 0.031	0.02	0.031	0.031	0.031
Institutional		0.010 – 0.025	0.01	0.025	0.025	0.025
Open Space		0.004 – 0.038	0.004	0.038	0.038	0.038
Agricultural		0.0015 – 0.008	0.004	0.004	0.008	0.004
Forest		N/A	0.001	0.001	0.001	0.001
Residential	Zinc (mg/L)	0.080 – 0.296	0.10	0.10	0.29	0.29
Commercial		0.0127 – 0.397	0.0127	0.05	0.39	0.39
Industrial		0.016 – 0.629	0.016	0.05	0.62	0.62
Institutional		0.113 – 0.140	0.113	0.140	0.140	0.140
Open Space		0.020 – 0.040	0.02	0.03	0.04	0.04
Agricultural		0.017 – 0.140	0.017	0.05	0.05	0.05
Forest		N/A	0.011	0.011	0.011	0.011

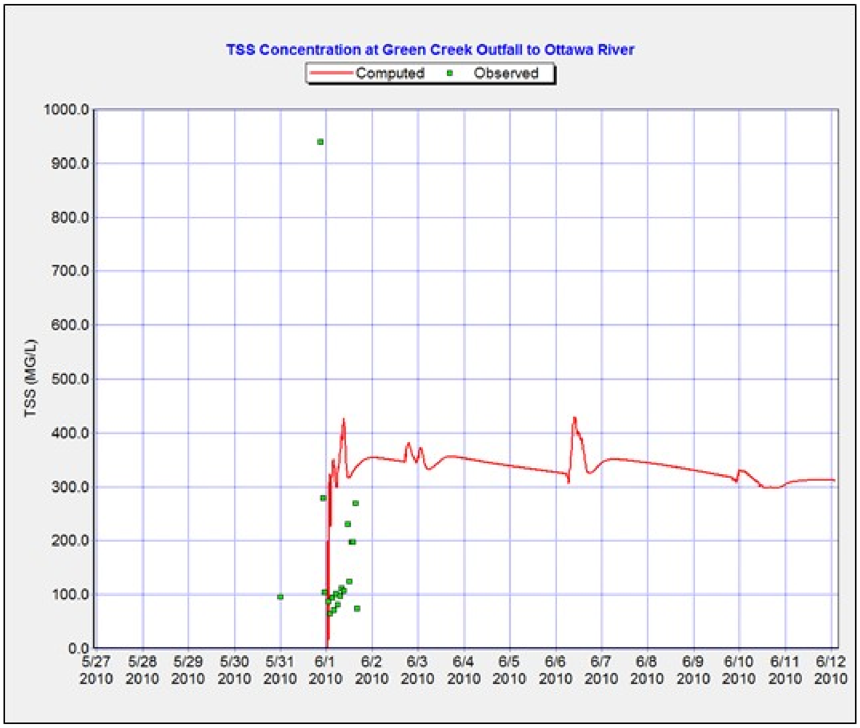


Figure 3.29: Modeled and Observed TSS Concentrations at Green's Creek Outfall to the Ottawa River (June 1, 2010 Storm)

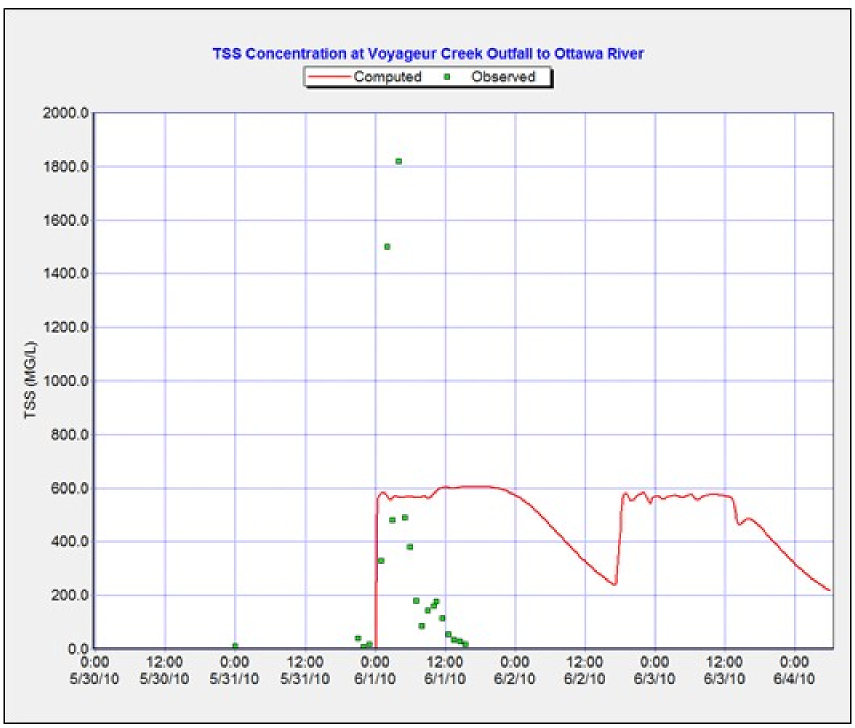


Figure 3.30: Modeled and Observed TSS Concentrations at Voyageur Creek Outfall to the Ottawa River (June 1, 2010 Storm)

3.7.14 Ottawa River Model Results

The Ottawa River Water Quality Model (ORWQM), prepared by Baird and Associates, was used to compare the changes in water quality in the Ottawa River at Petrie Island for the various stormwater management scenarios considered. The results of the summary report on the modeling is included in Appendix H. The indicator E.coli was used to determine the relative impact of each SWM retrofit control scenario on the receiving water at Petrie Island Beach.

The baseline model was updated to include recent infrastructure improvements related to the removal of combined sewer overflows. A total of sixteen simulations were completed covering four reference rainfall events from 1980 – representing an average rainfall year. The findings show a reduction in bacterial levels from 14% to 43%, with the highest reduction occurring as a result of the combined lot level and conveyance control retrofit strategy.

3.8 Aquatic Resources

The aquatic resources in the Eastern Subwatersheds are summarized according to aquatic habitat, buffer area, and fish species.

The aquatic habitat is evaluated and classified according to key factors. Among them is the type of instream morphology, or the proportion of the stream that exhibit particular physical characteristics such as pools, riffles and runs. Another factor is the type of instream substrate. A diverse substrate is beneficial for fish and benthic invertebrates by providing spawning conditions, over wintering habitat, and refuge areas for a varied species of fish. The extent of instream vegetation, or the presence of vegetation within the stream, offers opportunities for contaminant removal, higher levels of oxygen, and habitat for fish and other aquatic species. Vegetation can be affected by the frequency of high flow, and the loss of substrate material that can provide nutrients and anchorage for plants.

Buffer areas, or the extent and quality of the riparian buffer is a significant determinant on the health of a stream in terms of shading to limit the temperature of the water, and sources of food.

Sampling studies reveal the type of fish species and provide an indication of the population of fish that live in the streams. The fish community in the Eastern Subwatersheds is limited either by access to and from the Ottawa River/Green’s Creek, or by the physical limitations in the stream structure, a general lack of instream vegetation, and poor water quality. Generally low numbers of fish have been collected in sampling studies.

3.8.1 Fish Species

Fish sampling data relevant to the study was obtained from the Rideau Valley Conservation Authority and the City of Ottawa. Information on the types of fish present was also obtained through communications with City of Ottawa and RVCA staff. For some of the subwatersheds such as the Mather Award Drain and Voyageur Creek, there is little or no documented information available on fish and aquatic resources.

3.8.1.1 Taylor Creek

Taylor Creek is classified as a cool water system with cold water reaches according to City of Ottawa and RVCA data. Relatively low numbers of fish have been collected indicating that the fish community of Taylor Creek is limited. City of Ottawa collection data from 2006 confirm the presence of creek chub and brook stickleback, two cool water bait/forage fish. Fish community sampling of Taylor Creek by RVCA was conducted in 2012 and a number of cool and warm water fish species were collected including pumpkinseed, white sucker, creek chub, brook stickleback and central mud minnow. White sucker is a migratory species which indicates that reaches of Taylor creek, below the escarpment/waterfall may be used as spawning and nursery areas.

3.8.1.2 Bilberry Creek

Bilberry Creek is a cool water stream with some cold water reaches as reported by the RVCA and the City of Ottawa. A total of 25 fish species are known to be present within Bilberry Creek at various times of the year and the community as a whole is moderately tolerant of sediment and turbidity (RVCA, 2009 and City of Ottawa, 2006, 2010, 2011). The fish community throughout the system consists of warm and cool water bait and forage fish as well as some sportfish which include largemouth bass, smallmouth bass, black crappie, yellow perch and Burbot. Burbot is a coldwater species, confirming that coldwater reaches are present within the system. White sucker, a migratory species, was also present throughout the system (RVCA, 2009 and City of Ottawa, 2006, 2010, 2011). The RVCA Species at Risk (SAR) mapping indicates that there is potential for channel darter, an aquatic SAR, to be present in the lower reach of Bilberry Creek in the vicinity of the Ottawa River. Fish were generally found in areas where cover was present including woody debris, overhanging vegetation from the bank and areas with rocky structure including boulders, cobble, and gravel where stream morphology varies.

3.8.1.3 Voyageur Creek

Very little information is known about the fish community or habitat usage in Voyageur Creek. It is likely that fish species present in Voyageur Creek migrate into the watercourse from adjoining headwater tributaries and do not use Voyageur Creek as a migratory channel from the Ottawa River. Fish collection data from City of Ottawa in 2011 shows the presence of creek chub, a cool water bait fish. This collection record was taken at the culvert inlet area of Highway 174. The RVCA plans to perform stream habitat assessments including fish surveys on this system in the summer of 2013.

3.8.1.4 McEwan Creek

McEwan Creek was extensively studied and sampled under the 2010 City Stream Watch program. A total of five sites along McEwan Creek were sampled for fish which revealed mostly cool water species with one cool/warm water fish. Most of the species were found at a site upstream of the Russell Road crossing. A total of eight different fish species were collected including a variety of baitfish. The species of fish found in McEwan Creek include the following:

- Central Mud Minnow
- Brook Stickleback
- Creek Chub
- Blacknose Dace
- White Sucker
- Longnose Dace
- Etheosioma spp (Johnny Darter or Tessellated Darter)
- Lepomis spp (sunfish - pumpkinseed or bluegill)

3.8.1.5 Cyrville Drain

In 2000, the South Cyrville drain was considered a moderate quality fish habitat, or classified as an MNR Type 3 (TSH 2000). There is no recent documented fishery data related to the Cyrville Drain.

3.8.1.6 Mather-Award Drain

There is no available data on fish species in the Mather-Award Drain.

3.8.1.7 Green's Creek (Main Branch)

As reported by the City of Ottawa Green's Creek is a cool water stream. According to RVCA SAR mapping, there is potential for channel darter, an aquatic SAR, to be present in Green's Creek near the shore of the Ottawa River.

The fish community throughout the system consists of warm and cool water bait and forage fish as well as sportfish which include walleye, northern pike, bluegill, largemouth bass, smallmouth bass, black crappie, yellow perch, channel catfish, and burbot. Additional species of interest are the presence of trout-perch, freshwater drum, longnose gar, quillback, shorthead redhorse, silver redhorse, and white sucker (RVCA 2005, 2006, 2010 and City of Ottawa 2000, 2005, 2006, 2007, 2010, 2011).

Burbot and trout-perch are coldwater species which may indicate that there are coldwater reaches present within the system, or influence of the Ottawa River on the lower reach of Green's Creek.

A total of 41 fish species are known to be present within Green's Creek at various times of the year however diversity seems to be higher, especially for sportfish species, near the Ottawa River and becomes less diverse further upstream.

3.8.2 Aquatic Habitat

3.8.2.1 Taylor Creek

Taylor Creek is approximately 1.5 km in length and flows from Fallingbrook Community into the Ottawa River at Petrie Island. The headwater of Taylor Creek, upstream of Princess Louise Drive, has been replaced with storm sewers, although there is no historical evidence that a defined watercourse ever existed beyond this transition point.

There are waterfalls at the limestone escarpment, known as Taylor Falls or Princess Louise Falls, present immediately upstream (south) of St. Joseph Blvd which is not passable by fish. Much of the area downstream of Highway 174 remains natural and undisturbed however the area upstream has been completely developed with residential housing.

Taylor Creek flows into a large wetland area along the Ottawa River which provides diverse habitat for a number of species.

Instream vegetative cover within Taylor Creek is low to rare throughout much of the channel. In 2007 RVCA found that 87% of Taylor Creek had little to no instream vegetation. However adequate vegetation growth is present where Taylor Creek flows into the Ottawa River.

3.8.2.2 Bilberry Creek

Bilberry Creek headwaters originate just south of Innes Road. A forested buffer surrounds most of the Bilberry Creek ravines. Bilberry Creek morphology consists primarily of runs and flats with only a small percentage of pools and riffles. Significant riffle areas which are utilized by the local fish community exist upstream of the mouth of the Ottawa River and upstream of St. Joseph Blvd (RVCA, 2009).

The instream substrates within Bilberry Creek consist of primarily clay and were mainly homogenous however a small diversity of other substrates beneficial to fish and aquatic invertebrates (food for fish) exist including boulder, cobble, gravel, sand, and detritus (RVCA, 2009).

Due to clay and silt substrates which result in turbidity throughout much of the Bilberry stream channel, and potential lack of nutrients, little instream vegetation cover exists within the channel. According to City Stream Watch data in 2009, about 67% of the watercourse had very little to no instream vegetation.

3.8.2.3 Voyageur Creek

Voyageur Creek, also referred to as the West Bilberry Creek by RVCA, is enclosed in a large diameter trunk sewer from the Queensway to the outfall to the Ottawa River. It is unlikely that fish can migrate from the Ottawa River into the natural channel located upstream of the Queensway, mainly due to frequent high flow and velocity which create a swimming barrier to most fish species. Voyageur Creek between the Queensway and St. Joseph Blvd is open watercourse but it has been channelized and flows through a highly developed business park area.

The headwaters area of Voyageur Creek, upstream of St. Joseph Blvd. branches off in multiple directions and flows through residential neighbourhoods however the natural buffer has been left largely intact. The watercourse flows through a valley which is bordered by forest and likely offers adequate habitat for bait and forage fish species.

3.8.2.4 Green’s Creek

The Green’s Creek headwaters is fed primarily by Borthwick, Mud, Black and Ramsay Creek which all flow from Mer Bleue wetland complex or bog. Green’s Creek provides an important link between the Mer Bleue and the Ottawa River. Much of the valley along Green’s Creek from Innes Road to Ottawa River is considered a Life Science Area of Scientific Interest (ANSI) (RVCA, 2010).

The morphology for much of Green’s Creek consist primarily of runs however pool and riffle areas exist in low frequencies (RVCA, 2010).The instream substrate within Green’s Creek consist primarily of clay, sand and silt and were mainly homogenous. A diversity of other substrate beneficial to fish and aquatic invertebrates including muck, gravel, cobble, boulder, and detritus are also exhibited. Areas which had course substrate (cobble, boulder, gravel) had been covered in layers of fine material including sand and silt (RVCA, 2010). Due to clay and silt substrates, which results in high turbidity throughout much of the stream channel and potential lack of nutrients, very little instream vegetation cover exists within the channel. According to RVCA (City Stream Watch) data in 2010, 71% of the watercourse had very little to no instream vegetation.

3.8.2.5 McEwan Creek

The City of Ottawa has reported that McEwan Creek exhibits a low quantity and range of instream vegetation. The sampling report indicates that only 32 percent of the reach was considered to have common or normal levels of instream vegetation. The only type of vegetation observed was algae. Close to 40 percent of the instream substrate in McEwan Creek is clay, making it difficult for instream vegetation to establish itself. In addition, frequent high flow and water level fluctuations also pose a constraint to establishing instream vegetation.

3.9 Terrestrial Resources

Terrestrial resources are summarized for each subwatershed in the following sections, based on a review of available information. The resources are summarized according to natural areas, urban natural areas, and potential species at risk that may be dependent on the existing terrestrial habitat.

3.9.1 Taylor Creek

Taylor Creek has two main distinguishing characteristics — a significant shoreline wetland where the multiple outlet channels flow into the Ottawa River, and an exposed limestone escarpment south of St. Joseph Boulevard. The existence of the escarpment results in a waterfall feature along the east branch known as the Princess Louise Falls.

The limestone escarpment is part of what is known as the St. Martin/ Rockcliffe formations which are Paleozoic age limestone outcrops — unique to the Ottawa River valley.

The terrestrial features of the Taylor Creek subwatershed were identified in the City of Ottawa Urban Natural Areas study. The following urban natural sites are located within the Taylor Creek subwatershed:

- St. Joseph Blvd Woods (88) – not evaluated in 2003; full evaluation required
- Taylor Creek Valley (93) – not evaluated in 2003; full evaluation required

The identified areas include the surrounding lands of the extensive wetland and marsh at the Ottawa River — known as the Petrie wetland. A feature, known as the Taylor Creek valley, located along the east branch, between the Ottawa River and the Princess Louise Falls was identified as an Urban Natural Area (UNA)

The St. Joseph Boulevard Woods covers a narrow area between St. Joseph Boulevard and the top of the Limestone escarpment. This area has stands of mature trees, and is connected to the Taylor Creek Valley. This area was also identified as requiring a full assessment.

A Master Drainage Plan (McNeely Engineering Consultants, 1995) included a description of the various vegetation zones and significant species of plants and birds found in the Petrie wetland.

The following Species at Risk may be found within the Taylor Creek subwatershed:

- Snapping Turtle – Provincially and Federally species of Special Concern
- Milksnake – Provincially and Federally species of Special Concern
- Barn Swallow – Provincially and Federally Threatened species
- Chimney Swift – Provincially and Federally Threatened Species
- Butternut – Provincially and Federally Threatened species
- Monarch – Provincially and Federally species of Special Concern

3.9.2 Queenswood Catchments

The area known as the Queenswood Catchments does not have a defined watercourse within its boundaries. It is drained by storm sewers with an outlet directly to the Ottawa River. The terrestrial features in Queenswood include a narrow strip of forest along the limestone escarpment — or the north edge of the Queenswood heights, and the Queenswood forest near the Ottawa River shoreline.

The Petrie Islands Management Plan (Phase 1) — Natural Environment Assessment was completed by Brunton Consulting Services in March of 2010. The report refers to a mature woodland area near the Queenswood subdivision. There are references to the Queenswood forest as a sugar maple — Hemlock forest occupying the clay/silty sand areas of the Queenswood Forest.

Most of the mainland areas are described as regenerating pasture land. The Petrie Island Study area has been designated a Provincially Significant ANSI (Area of Natural and Scientific Interest). Much of the existing wetland was enhanced by the 1964 construction of the Carillon Dam on the Ottawa River.

The following Species at Risk may be found within the Queenswood Catchment subwatershed:

- Barn Swallow – Provincially and Federally Threatened species
- Chimney Swift – Provincially and Federally Threatened species
- Butternut – Provincially and Federally Threatened species
- Monarch – Provincially and Federally species of Special Concern

3.9.3 Bilberry Creek

The most notable terrestrial resource within the Bilberry Creek subwatershed is the extensive and forested ravine situated south of St. Joseph Boulevard. Although there is no identified NHIC (2012) natural area within the Bilberry Creek watershed, the Bilberry Creek valley is designated in the City of Ottawa UNA study of 2005 as a High environmental rating. It covers an area of close to 50 hectares, and described as extensive forest with deciduous and mixed forest cover over clay substrate along the main (eastern) Bilberry Creek ravine. The lower Bilberry Creek Valley is rated as a moderate environmental designation. It covers less than 10 hectares and is described as upland forest and riparian swamp complex in clay substrate along the lower reach of Bilberry Creek.

The Quarry Woods East area is also rated as moderate value in 2003. The St. Louis Woods, located along the shoreline of the Ottawa River was identified requiring a full evaluation prior to any development or project which may affect the area.

The following Species at Risk may be found within the Bilberry Creek subwatershed:

- Snapping Turtle – Provincially and Federally species of Special Concern
- Milksnake – Provincially and Federally species of Special Concern
- Channel Darter – Provincially and Federally Threatened species
- Barn Swallow – Provincially and Federally Threatened species
- Chimney Swift – Provincially and Federally Threatened species
- Butternut – Provincially and Federally Threatened species
- Monarch – Provincially and Federally species of Special Concern

3.9.4 Voyageur Creek

Voyageur Creek, also known as Bilberry West Creek, covers a total area of 828 hectares. Similar to Bilberry Creek to the east, Voyageur Creek is situated within extensive ravines south of St. Joseph Boulevard. There are two main ravines which may have been historically separated. The western tributary likely flowed to Green's Creek, across what is now the Greenbelt, and the east branch was originally a west tributary to Bilberry Creek.

North of St. Joseph Boulevard, Voyageur Creek was channelized and enclosed. A 3.6m diameter trunk sewer was originally constructed to divert flows from the south side of Highway 174 to the Ottawa River. The sewer diversion was constructed in 1976 within a pedestrian pathway and green corridor through the residential community north of Highway 174. There is a remnant tributary to Bilberry Creek near the Ottawa River shoreline that is within the Voyageur Creek subwatershed.

The key features of Voyageur Creek is the extensively forested network of connected ravines, and the natural forested area in the western areas of the subwatershed, known as the DND forest area — located within the Greenbelt.

The following designated natural areas are located within the Voyageur Creek subwatershed:

- DND Forest (Regional Life Science ANSI)
- DND Woods (Life Science Site)

The following Species at Risk may be found within the Voyageur Creek subwatershed:

- Snapping Turtle – Provincially and Federally species of Special Concern
- Milksnake – Provincially and Federally species of Special Concern
- Barn Swallow – Provincially and Federally Threatened species
- Chimney Swift – Provincially and Federally Threatened species
- Butternut – Provincially and Federally Threatened species
- Monarch – Provincially and Federally species of Special Concern

The City of Ottawa's Urban Natural Areas Environmental Evaluation Study (2005) indicates the following urban natural sites are located within the Voyageur Creek subwatershed:

- Forestglen Park (82) – High Environmental Rating (20.7ha) Extensive, rugged, continuously forested landscape in clay substrate in deep ravines along western bank of Voyageur Creek

- Chapel Hill Park (83) – High Environmental Rating (29.6ha) Extensive but narrow, continuously forested landscape in till deposits over clay substrate in deep ravines along central branch of Voyageur Creek

- Louis Perault Park (84) – Moderate Environmental Rating (2.7ha) Small deciduous woodlot in formerly wet, acidic sand substrate

- Rachette Park (81) – Low Environmental Rating (1.6ha) Fragmented deciduous woodlot in sand substrate

3.9.5 Green’s Creek Tributaries

3.9.5.1 Cyrville Drain

The Cyrville Drain subwatershed covers an area of 962 hectares. Historically, Cyrville Drain has undergone significant changes and impacts from development, including channelization and realignment. Cyrville Drain has been impacted by encroachment from development and major transportation improvements. The watercourse lacks significant riparian area.

Cyrville Drain has a north and south branch which join north of Innes Road and the Highway 417 interchange, before flowing into Green’s Creek. The North Cyrville Drain is also known as Cummings Creek.

In 1946, the former Township of Gloucester adopted a bylaw for drainage improvements on what was known as the Choquette Award, which was constructed approximately 40 years previously. The Coquette Award drain became the South Cyrville (Municipal) Drain.

The remaining natural feature of Cyrville Drain is the complex of wetlands and forest cover located at the headwaters of the north branch, west of the Aviation parkway, and east of Blair Road, north of Ogilvie Road. Most of the catchment areas of the north branch have been fully developed.

The following Species at Risk may be found within the Cyrville Creek subwatershed:

- Snapping Turtle – Provincially and Federally species of Special Concern
- Milksnake – Provincially and Federally species of Special Concern
- Barn Swallow – Provincially and Federally Threatened species
- Chimney Swift – Provincially and Federally Threatened species
- Butternut – Provincially and Federally Threatened species
- Monarch – Provincially and Federally species of Special Concern

According to the NHIC (2012), the following designated natural areas are located within the Cyrville Drain subwatershed:

- Carson Grove Woodland (Life Science Site)
- CMHC National Office Lands/ Carson Grove Wetland (Non-Significant Wetland)

According to the City of Ottawa’s Urban Natural Areas Environmental Evaluation Study (2005), the following urban natural sites are located within the Cyrville Creek subwatershed:

- Carson Grove Woods (173) – Low Environmental Rating. Small, scrubby woodland area of ephemerally wet coniferous swamp forest along southern edge of more extensive deciduous and mixed swamp forest surrounded by residential and institutional development.

- Bathgate Park Woods (174) – Low Environmental Rating. Upland woodlot on till plain in Carson Grove.

- Assaly Woods (172) – Low Environmental Rating. Small remnant woodland over thinly buried limestone bedrock.

- Monfort Hospital Woods (171) – Ecological Condition Check Required

- Aviation Parkway North (67) – Moderate Environmental Rating (20.7ha) Extensive, fragmented swampy woodland area in till and organic substrate divided by a major roadway corridor.

- NRC Woods South (73) – Moderate Environmental Rating (26.8ha) Long and narrow continuous forest area of young to submature deciduous swamp forest in clay substrate; small areas of upland forest on higher knolls; largely isolated from other natural areas and degraded by drainage (flooded in spring only); canopy disturbances concentrated in southern and northern end of woodland, with most mature portions in the small central core.

- Aviation Parkway North (68) – Low Environmental Rating (5.9ha) Young, disturbed upland deciduous forest on sand substrate.

- Eastway Garden Woods (164) – Low Environmental Rating (3.8ha) Narrow band of disturbance young swamp forest in organic substrate on till plain.

3.9.5.2 Mather Award Drain

The Mather Award Drain is located south of the Cyrville Drain catchment, and is about 806 hectares in size. Figure 1.9 shows the Mather Award Drain subwatershed. A dense network of storm sewers, serving the Elmvale and Alta Vista residential neighbourhoods, combine together just upstream of the outfall to the Mather Award Drain, south of Walkley Road, east of St. Laurent Boulevard. The channel extends further in a southeast direction for about 2 kilometers before joining with the lower reach of McEwan Creek and flowing directly east to Green's Creek.

The catchment areas are completely developed, except for a significant Hydro corridor south of Walkley Road, and an undeveloped corridor extending north from Walkley Road, which is planned for a future arterial road corridor. The reach of the Mather Award Drain downstream of Russell Road goes through agricultural lands. There are several culvert crossings of the Mather Award Drain.

The channel is relatively straight with very limited riparian area, similar in characteristics as the neighbouring Cyrville Drain. The banks are sparsely vegetated and maintained for access and periodic maintenance.

According to the NHIC (2012), no designated natural areas are located within the Mather Award Drain subwatershed.

The following Species at Risk may be found within the Mather Award Drain subwatershed:

- Snapping Turtle – Provincially and Federally species of Special Concern
- Milksnake – Provincially and Federally species of Special Concern
- Barn Swallow – Provincially and Federally Threatened species
- Chimney Swift – Provincially and Federally Threatened species
- Butternut – Provincially and Federally Threatened species
- Monarch – Provincially and Federally species of Special Concern

According to the City of Ottawa's Urban Natural Areas Environmental Evaluation Study (2005), the following urban natural sites are located within the Mather Award Drain subwatershed:

- Hawthorne Marsh (157) – Ecological Check Required

- Pleasant Park Woods (159) – High Environmental Rating (8.5ha) Homogeneous deciduous woodlot on low site in till soil in Alta Vista.

3.9.5.3 McEwan Creek

The McEwan Creek subwatershed covers an area of 1,559 hectares, and is located at the south boundary of the Eastern Subwatersheds Study Area. McEwan Creek has a north and south branch, each having substantially different characteristics.

The catchment areas of the north branch have been extensively developed with a combined commercial/ industrial and residential land use. Most of the original watercourse has been replaced with a trunk storm sewer. The outfall of the trunk storm sewer is located east of Hawthorne Road. A recently constructed stormwater management facility is situated just downstream of the outfall. The watercourse continues easterly and is being affected by the Hunt Club Road extension and Highway 417 Interchange project, currently under construction.

The south branch begins within the NCC Greenbelt and drains a portion of the Pine Grove Forest reserve, south of Hunt Club Road. The south branch crosses Russell Road and the east bound lanes of the Highway 417 before flowing north between the east and west bound lanes of Highway 417. This branch is mostly in a natural state and largely unaffected by development.

The north and south branch join together just west of Highway 417. It appears that McEwan Creek was, at some time, diverted north to join with the Mather Award Drain before going through a single crossing of the Highway 417. This left a remnant meandering stream channel which runs east from Highway 417 before entering Green's Creek.

According to the NHIC (2012), the following designated natural areas are located within the McEwan Creek subwatershed:

- Hawthorne Road Quarries (Provincial Earth Science ANSI)
- Pine Grove Forest (Regional Life Science ANSI)

The following Species at Risk may be found within the McEwan Creek subwatershed:

- Snapping Turtle – Provincially and Federally species of Special Concern
- Milksnake – Provincially and Federally species of Special Concern
- Barn Swallow – Provincially and Federally Threatened species
- Chimney Swift – Provincially and Federally Threatened species
- Henslow's Sparrow – Provincially and Federally Endangered species
- Least Bittern – Provincially and Federally Threatened species
- Butternut – Provincially and Federally Threatened species
- Monarch – Provincially and Federally species of Special Concern

According to the City of Ottawa's Urban Natural Areas Environmental Evaluation Study (2005), the following urban natural sites are located within the Mather Award Drain subwatershed:

- McEwan Creek at Hawthorne (156) – Not evaluated in 2003; full evaluation required

- Mather Award Ditch at Russell (111) – Not evaluated in 2003; full evaluation required

- Swansea Woods (155) – Low Environmental Rating (2.1ha) Small, low woodlot in Hawthorne Industrial Park

- Conroy Swamp/ Greenboro Turtlehead Nature Area (151) – High Environmental Rating (28.2ha) Extensive swamp forest and thicket swamp post-glacial drainage channel.

- Conroy Woods (152) – Low Environmental Rating (10.9ha) - Extensive but disturbed upland deciduous forest north of Conroy Swamp.

- Cahill Drive Woods (150) – Not evaluated in 2003; full evaluation required

3.10 Flood Sensitive Areas

Basement flooding has been reported in the older neighbourhoods of Alta Vista/ Elmvale Acres, and Urbandale in the Mather Award Drain subwatershed, as well as in the older residential areas of the Queenswood, Bilberry, and Voyageur Creek subwatersheds. Basement and surface flooding from storm events dating back to 1999 were reported in the area between Innes Road and Highway 174, and west of Tenth Line Road.

The problems in these older residential neighbourhoods were generally caused by the lack of adequate major system to convey runoff from storms exceeding the design capacity of the storm sewers. The result is storm sewer and sanitary sewer surcharge. At the time these areas were originally developed, storm sewers were designed for up to the 1:2-year return period storm, and no accommodation was allowed for to deal with major storms. The Orleans flooding issue has been addressed by a series of design studies in 2007 to implement a system of inlet controls and establishing a major drainage system.

In 1993, Novatech Engineering Consultants Ltd prepared the Urbandale/Elmvale Acres Infrastructure Needs Study. This involved the assessment of the storm and sanitary systems in the Urbandale/ Elmvale Acres area, where there were reports of flooding. The report recommended sanitary sewer relief including temporary increased overflow capacity at the Saunderson pump station, new sanitary sewers, and sewer separation. Recommended storm sewer system relief included flow diversion to the Walkley Road trunk sewer and on-site detention.

About the time of amalgamation in 2000, the City of Ottawa developed options to address inadequate storm sewer servicing.in response to surface flooding on Gladwin Crescent and basement flooding along Saunderson Drive in the Mather Award Drain subwatershed. The report indicated the area north of Pleasant Park Road is known to flood in a 1:2 year frequency storm. The Saunderson Drive storm sewer system is made up of a corrugated steel arch pipe which is now over 50 years old. The report recommended the replacement of the Saunderson Road storm sewer.

There have been no known reported flooding concerns in the Study Area arising from major flows exceeding the banks of watercourses, or culvert crossings. Based on field observation, the most vulnerable areas in terms of flood risk would likely be the older commercial and industrial areas that surround the Mather Award and Cyrville Drains, where the channel is relatively flat, within a relatively narrow corridor.

4 STORMWATER MANAGEMENT RETROFIT EVALUATION

Chapter 4 is a description of the analysis and evaluation of stormwater management retrofit strategies for the Eastern Subwatersheds. The development of objectives and targets was followed by an analysis of the effect of three initial retrofit scenarios. The results of this evaluation were presented to the Technical Advisory Committee and the public as part of the City's Water Round Table event in June of 2014. The results from the 2014 analysis are presented in Appendix E.

Based on the results of the initial evaluation, adjustments were made to the retrofit scenarios to take into account additional local constraints and considerations related to the implementation of retrofit measures. For example, after further detailed screening, end-of-pipe facilities were eliminated as a viable strategy and the retrofit scenarios were re-evaluated. The information presented in this section relates to the latest retrofit scenarios developed for the Eastern Subwatersheds Study.

4.1 Objectives

The development of objectives and targets was completed for this study through a series of discussions and meetings with the City and the Technical Advisory Committee representing relevant stakeholders. More specific and measurable parameters and targets were determined for developing the Evaluation Criteria (Chapter 6) that are used to evaluate the effectiveness of management decisions in achieving the study objectives.

The objective of the stormwater management retrofit measures investigated in this report is to improve water quality and establish sustainable flow regime in the various watercourses within the Eastern Subwatersheds. Related key objectives are as follows:

(1) **Reduce Erosion Impacts:**

a. Maintain, enhance or restore natural stream processes to achieve a balance of flow and sediment transport.

b. Manage stream flow to reduce erosion impacts on habitats and property.

(2) **Preserve and Re-establish the Natural Hydrologic Cycle:**

a. Increase infiltration and evapotranspiration, and decrease surface runoff.

b. Maintain groundwater levels and baseflows (groundwater discharge to streams) to sustain watershed functions and human use.

(3) **Improve Water Quality:**

a. Improve surface runoff water quality and reduce nutrient and contaminant levels through pollution prevention.

b. Maintain or enhance water and sediment quality to achieve ecological integrity.

(4) **Reduce Impact of Runoff on the Beach:**

a. Improve water quality in the Ottawa River and reduce impact of runoff on the beach.

b. Improve water aesthetics including odour, turbidity and clarity.

(5) **Reduce Flooding and Minimize Risk to Human Life and Property due to Flooding.**

4.1.1 Target Setting

A process was developed to translate the above-mentioned objectives into a more detailed and technical set of Indicators, Measurable Parameters and Targets for each of the Objectives. The main purpose of the Target Setting process is to evaluate how successful SWM retrofit opportunities and scenarios are in achieving the stated objectives, and for assessing the health of the study area over the long term.

Indicators: An indicator is a piece of information, clue or attribute of the ecosystem that describes the current condition of the ecosystem, or one of its components. Examples: temperature, total suspended solids (TSS), E.coli, aquatic community abundance, instream erosion potential, forest and wetland cover.

Measurable Parameter: A measurable parameter is a quantitative or qualitative way to measure progress toward achieving the indicator and several measurable parameters may be used for assessing each indicator. Examples: surface runoff volume at outlet, E.coli concentration, probability of exceedance of an extreme flow responsible for stream erosion.

Target: A target is a specific aim that will be achieved in the future. The targets as developed served as a basis for evaluating alternatives. Targets can be set for the short, medium and long term. Targets represent an integrated set of biological, physical and chemical values. A baseline condition needs to be established before targets can be developed. Targets should allow for stepwise improvements to be achieved as interim steps to reaching the ultimate target. Examples: 26°C (for coldwater fish), less than 100 E.coli/100mls, 5,000g fish/100m^2 habitat, reduction of cumulative excess stream power to 25% of current values.

Some targets can be modelled, using various predictive tools, to evaluate the effectiveness of SWM retrofits; others can be monitored, to measure the progress of the implemented strategy towards achieving the stated objective; and still others may be assigned a value representing the progress of a program or policy that is being implemented as part of the overall preferred management strategy.

A challenging task in the Target Setting process is to define the desired ecological state following the implementation of the SWM retrofit opportunities. The following are examples of three "ecological states of health" that are often used for target setting exercises:

- **Status Quo (or short-term targets):** Tells us what is needed to maintain existing conditions — and ensure no further deterioration — in the watershed and its subwatersheds. In some cases, expenditures may be needed to maintain the status quo due to intensification within existing urban areas and/or future development stresses from expanding municipalities. The achievement of these targets is considered to be relatively straightforward using conventional capital works, implementing existing policies and operation/maintenance programs.

- **Moderate Enhancement (or medium-term targets):** Will result in "improved" conditions within the subwatersheds covering the study area.

    - "Improved" water quality conditions mean that nutrient levels would be moderate and there would be fewer occasions when contaminants are present in detectable amounts; conditions would support a more sensitive aquatic community; in non-beach areas, conditions would meet the Provincial Water Quality Objective (PWQO) for swimming beaches 50% of the time;

- "Improved" water quantity conditions mean that dry weather stream flows (i.e. in the absence of a storm), would be higher than existing conditions; wet weather flows would peak at lower levels and be spread out over a longer period of time; stream banks would be more stable, but still subject to some erosion; and

- The achievement of the "Moderate Enhancement" targets is generally considered to be fairly difficult or challenging to meet since it will require commitment of significant funds for capital works, changes to policies and programs, and increases in funding for operations and maintenance budgets to expand programming in non-traditional areas.

- **Significant Enhancement (or long-term targets):** Would mean that Provincial Water Quality Objectives and other regulatory guidelines would be met.

    - Significant water quality enhancement would mean nutrient and contaminant levels would meet provincial guidelines and toxics would generally be undetectable; in non-beach areas, conditions would meet the PWQO for swimming beaches at least 50% of the time;

    - Significant water quantity enhancement would mean that dry weather flow and runoff conditions would be close to historic conditions, resulting in stable stream conditions; and

    - The achievement of these targets is generally considered extremely difficult or challenging to meet for the same reasons described under moderate enhancement, in addition to that the time frames for target achievement are extremely long (decades) making it difficult to demonstrate benefits in the short term.

For each objective, a number of indicators were selected (Table 4-1) that were considered to address all aspects of the objective. For each indicator, measurable parameters were selected based on the following criteria:

- Will the parameter give us meaningful information about the study area?
- Is the information available, retrievable and cost effective to collect?
- Will it give us information about trends over time?
- Do the parameters collectively give us enough information to evaluate the SWM retrofit opportunities?

Table 4-1: Objectives and Targets

Objective	Indicator	Measurable Parameter	Target
(1) Reduce Erosion Impacts	In-stream erosion potential	Flow Duration from Flow Duration Curve (FDC) Analysis	Reduction in time of threshold flow exceedance
(2) Natural Hydrologic Cycle	a. Runoff threshold event[(1)] b. Watershed peakiness[(2)]	a. Hydrologic Cycle Volumes at Outlets to Ottawa River b. Bankfull Flow Compared to Baseflow ($Q_{Bankfull}/Q_{baseflow}$)	a. Decrease surface runoff volume and increase in infiltration + evaporation b. $Q_{Bankfull}/Q_{baseflow} \leq 16$ [(3)]
(3) Improve Water Quality	Total suspended solids (TSS) and Total Phosphorus	TSS and TP Loadings and Concentrations at Outlets to Ottawa River	TSS less than 25 mg/L, (Federal Canadian Council of Ministers of the Environment Guidelines (CCME)) TP less than 0.03mg/L (Pinecrest Creek/Westboro Stormwater Management Retrofit Study (JFSA, 2011))
(4) Reduce impact of runoff on the beach	Instream E.coli at outfall to Ottawa River	E.coli Loadings and Concentrations at Outlets to Ottawa River	PWQO or cts/100mL
(5) Flood Risk	Frequency of overtopping of watercourse crossings	Flow Rate (m^3/s) and Floodline Elevation	Maintain or reduce flood elevations for all storm events from 2- to 100-year
(6) Public awareness of stormwater management and increase public involvement	Public's response to questionnaire	Response indicating awareness of stormwater issues	25% positive response

(1) Runoff Threshold Event is the rainfall event required to generate a runoff response in a watercourse.
(2) Watershed Peakiness is the measure of runoff response to rainfall measured as the ratio of bankfull flow to baseflow.
(3) Source: City of Toronto Wet Weather Flow Master Plan, 2003.

4.2 Retrofit Opportunities and Plan Scenarios

SWM retrofit measures are activities and practices to reduce the volume and magnitude of stormwater runoff, and the pollutant loading to the receiving watercourse. These practices intercept and retain runoff to allow infiltration of runoff from frequent events and provide for the settling and removal of pollutants.

SWM retrofit practices consider impacts to water quality, water quantity, and groundwater recharge. There are three general types of SWM retrofit practices, namely Lot Level Controls, Conveyance Controls and End of Pipe controls. These are described in the following sections.

4.2.1 Lot Level Control Measures

Lot level control measures are small-scale stormwater management measures located at the most upstream point in the drainage system. Stormwater is captured and treated in close proximity to where the rainfall lands. Examples of lot level control on residential lots include redirection of roof and driveway runoff to rain gardens, pervious paver driveways, and landscape design that promotes retention and infiltration of runoff. Lot level control on institutional, commercial and industrial properties typically include bio-retention swales in parking lots, permeable pavers and rain gardens.

Due to the relatively small area treated by individual lot level measures, they must be well distributed to be effective. The advantage of lot level controls is the fact that runoff is intercepted and treated at the source, before the runoff accumulates downstream, and contributes a significant volume to manage, requiring larger and more expensive treatment. It also stems from the concept that water from rainfall is considered a resource, and not simply a waste that must be efficiently removed and transported away.

Lot level control measures are generally installed on individual properties within residential, commercial, industrial and institutional land uses. In residential areas, lot level control measures provide treatment for the stormwater generated from roof and driveway areas. In larger commercial and institutional properties, lot-level controls target roof, access roads, and asphalt parking areas.

Lot level control measures remove pollutants from stormwater through a variety of mechanisms, including mechanical filtration, biological uptake, adsorption, and settling. These measures exhibit a wide variability in their ability to remove pollutants, generally ranging between 40% and 80% in efficiency depending on the particular measure and the type of pollutant.

Despite the emphasis on lot level control in most recent stormwater policy and guidelines documents, systematic and widespread implementation throughout a municipality or an urban watershed has not yet occurred in Canada. The implementation of a variety of lot level control measures has however become more common in the last decade

Examples of lot level control measures range from the simple disconnection of roof leaders, to the application of enhanced landscaping, rain gardens and bio-retention areas. Examples of lot level measures are provided as part of the initial SWM retrofit scenario evaluation completed in 2014 (see Appendix E).

4.2.2 Conveyance Control Measures

Conveyance control measures are designed to treat stormwater during its travel overland, or through sewers upstream of the outlet to the natural stream. Traditional conveyance systems include curb and gutters, and sewer systems in the road network that carry stormwater away from a developed property to a watercourse. Conveyance control measures improve water quality and reduce runoff volume at a lower cost than the typical end-of-pipe type of treatment. This advantage is due to the scale of the measure and the concept that improvements can be made within the existing municipal rights of way, and in conjunction with roadway renewal projects.

Similar to lot level controls, conveyance control removes a portion of the total stormwater volume from entering the storm sewer network, slowing the erosive velocity of stormwater entering watercourses, and filtering out pollutants.

Conveyance control measures can often provide stormwater treatment for the collected drainage concentrated within the right-of-way of a municipal road or provincial highway. Because residential streets account for a significant share of a community's impervious surface, conveyance control measures present an excellent opportunity to improve downstream water quality conditions (e.g. sediment, nutrient, bacteria, oil/grit, thermal impact reduction, etc.), promote groundwater recharge and reduce erosion in natural watercourses.

Examples of conveyance controls include bioretention and perforated pipe systems. Detailed descriptions of conveyance controls are provided in Appendix E.

4.2.3 End-of-Pipe Control Measures

End-of-pipe measures have traditionally been the most commonly applied stormwater management measure in most municipalities. They are typically constructed as part of new developments to provide quality and quantity control stormwater management for entire communities. For existing urbanized watersheds, they can be difficult to implement given the lack of available space and other physical constraints. End-of-pipe measures include ponds (dry or wet), wetlands, hybrid facilities and infiltration basins. Detailed descriptions of end-of-pipe measures are provided in Appendix E.

In wet ponds the permanent pool of water provides water quality treatment through the settling of suspended sediments and pollutants to the bottom of the pond. Provided the facility is functioning properly and is well maintained, a significant proportion of sediments and pollutants will be removed and not be transported downstream of the facility. To optimize pollutant removal capacities, design engineers usually aim to maximize the distance that stormwater must travel through these facilities so that a larger percentage of the suspended solids will fall out of suspension.

The results of many monitoring programs indicate that most engineered wet ponds typically achieve 60-80% suspended solids (SS) removal and 40-50% total phosphorus (TP) removal). In general, a larger volume of water utilized for water quality storage will enhance performance; however, at some point the incremental removal rates of suspended solids diminishes with increasing storage (MOE, 2003).

The ideal situation is to plan and design end-of-pipe measures as large centralized facilities that treat the collected drainage from as much upstream development area as possible. This will optimize the construction, operations and maintenance costs for facilities of this type. In retrofit situations where facilities are being implemented within developed communities, this principle can be difficult to achieve.

4.3 Potential Retrofit Locations and Opportunities

Potential retrofit locations and opportunities for the control measures described above were identified and are discussed in the following sections. Stream restoration opportunities were also been considered.

Combinations of the different types of measures were used to form the proposed SWM retrofit scenarios, at various levels of commitment.

4.4 Lot Level Measure Locations/Opportunities

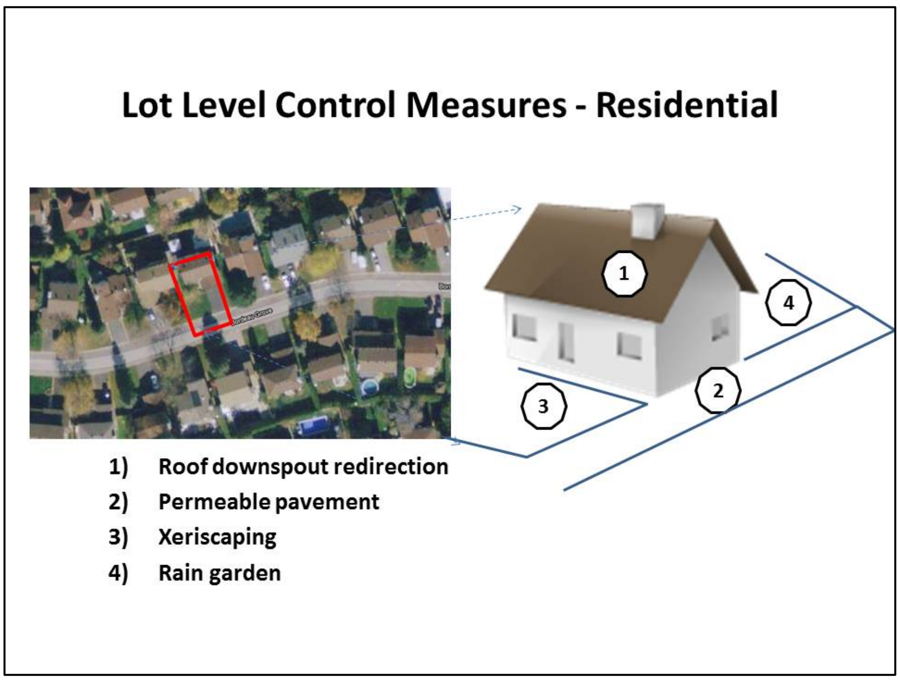
The effectiveness of lot level control measures in achieving municipal and environmental goals and targets primarily depends on the uptake rate for each land use (i.e. percentage of the land use type controlled by lot level measures).

Lot level control measures can be implemented within various land uses including Residential, Commercial, Institutional, and Industrial, and can include one or a combination of the measures. For example, residential land use may include the following lot level measures (Figure 4.1):

1) Roof downspout redirection;
2) Permeable pavement;
3) Xeriscaping; and
4) Rain garden.

Each of these measures provides certain benefit(s) in terms of stormwater quality and quantity management at the lot level, including:

- Decreasing impervious cover;
- Minimizing direct connection to the storm sewer system, resulting in attenuating surface runoff rates;
- Decreasing surface runoff volume; and
- Increasing infiltration and evaporation.



These lot level measures are recommended in general; however, promoting downspout disconnection in some residential neighbourhoods, particularly those that have properties backing onto ravines with steep slopes, may exacerbate existing slope stability issues and contribute to slope failure. This will have to be assessed at a later stage on a case by case.

Figure 4.1: Conceptual Representation of a Combination of Lot Level Measures in a Residential Area

4.5 Conveyance Control Measure Locations/Opportunities

The effectiveness of conveyance control measures in achieving municipal and environmental goals and targets primarily depends on the percentage of implementation (i.e. percentage of the study area captures by conveyance control measures within the right-of-way).

The identification of specific conveyance control measures depends on many factors including environmental and urban planning factors. Environmental factors include major/minor drainage systems, physiographic constraints (i.e. soils and vegetation cover), and location of opportunities within the watershed. Urban planning factors include the City LID preferences (if any), capital planning for road renewal, and operation and maintenance considerations.

Most of the neighbourhoods within the Eastern Subwatersheds study area have roads and sewers that are relatively new. Most of the historical development occurred in the 1970s and 1980s, meaning that the utilities and roads are less than 50 years old. Significant rehabilitation will not take place for a number of decades. Therefore, there is limited opportunity to combine roadway renewal projects with conveyance control retrofit. It is also worth noting that there are some neighbourhoods in Cyrville and Mather Award drains and McEwan Creek that were built in the 1960s. These areas might be candidates for earlier retrofits when infrastructure renewal is needed.

4.6 End-of-Pipe Control Measure Locations/Opportunities

An extensive screening process was conducted for the selection of potential locations for end-of-pipe control measures. The process consisted of the following steps:

1) Step 1: Identification of potential sites;
2) Step 2: Selection of feasible sites

Attempting to retrofit stormwater management end-of-pipe facilities in existing urban areas is challenging due to a number of factors, namely:

- Extended, wet detention facilities require relatively large land areas to provide the necessary stormwater quality and quantity controls for large tributary areas. For example, for a tributary of 400 hectares, a landscaped wet pond will require over 10 hectares of land

- Land ownership, and the availability of land at the outlet of the trunk storm systems that would be suitable for implementation

- Potential conflicts with existing underground and above ground utilities and the logistics and expense of relocating utilities

- Potential conflict with environmentally sensitive areas, particularly near outfalls to watercourses

- Constructability of the facility in terms of access, depth of existing trunk sewers, required earthworks, geotechnical considerations, and the potential for contaminated soils and archaeological significant sites

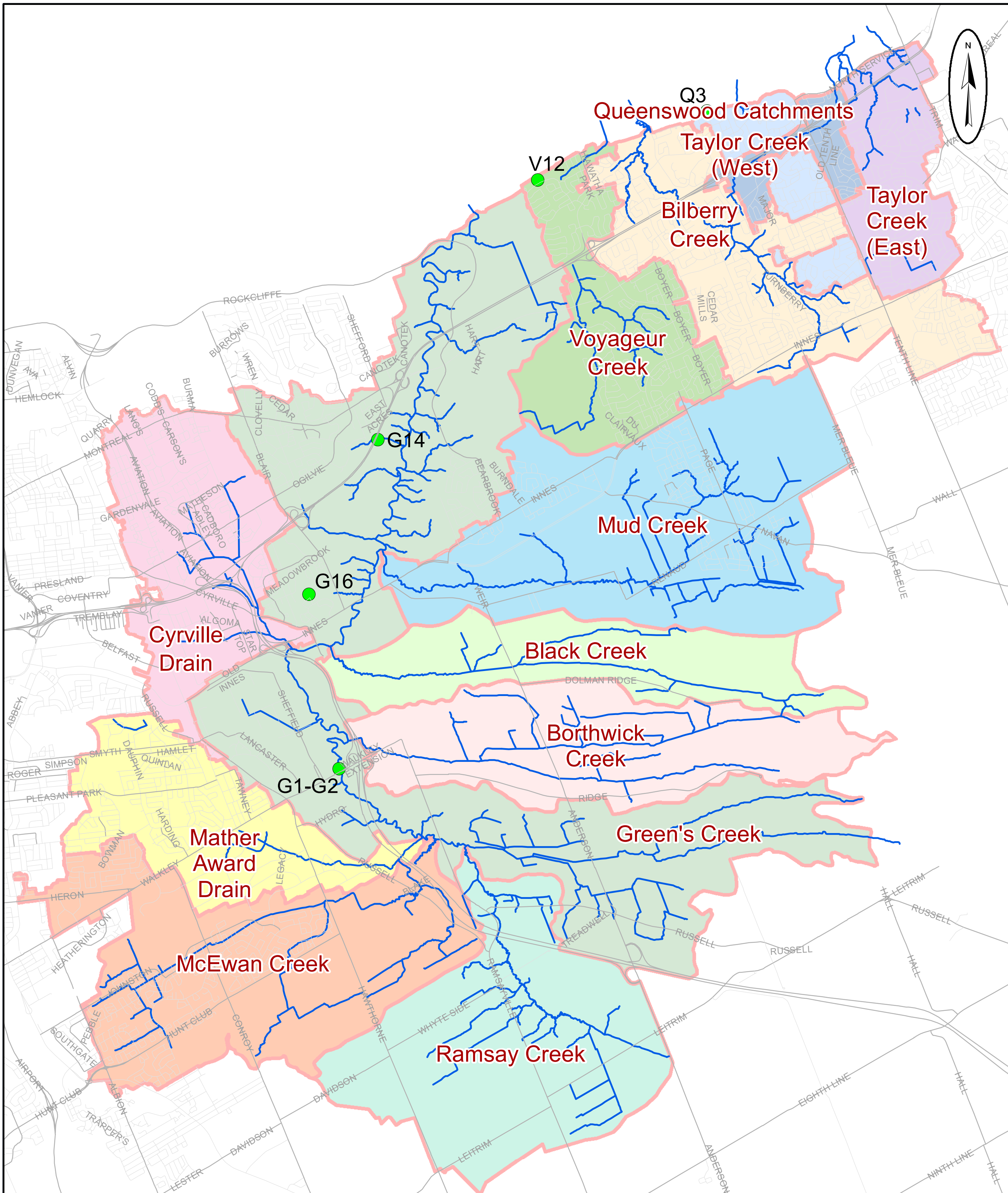
- Impacts on the hydraulic grade line for existing systems and potential impact such as surcharged storm sewers upstream

- Public acceptability and proximity to schools, parks, and impacts on current programs and uses of the property.

From the 130 potential sites identified in Step 1, 39 were further assessed in Step 2 based on the factors noted above including size of land available, topographic constraints, land use, existing infrastructure, and vegetation, size of tributary area, land use, etc.

The final number of feasible sites identified for end-of-pipe facilities was 5. Given the relatively small drainage area that would be treated by these facilities and the potential local constraints (e.g. high groundwater level, land ownership, depth of facility), it was decided to exclude end-of-pipe facilities from the final scenario analyses. Subject to how implementation proceeds in the initial years, these sites may be revisited.

The feasible end-of-pipe facility locations are presented Figure 4.2. Details on the end-of-pipe facilities screening process are provided in Appendix E.



Ottawa

Legend

- Selected EoPs
- Watercourse

Eastern Subwatersheds Stormwater Management Retrofit Study

Feasible EoP Locations

Morrison Hershfield

Aquafor Beech Limited

Figure 4.2

0 0.5 1 2 3 4
Km

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O:\Ottawa\proj\2124041\14 Reports\Final Report August 2018\Figures\Figure 4-2 - Feasible EoP Locations.mxd

4.7 SWM Retrofit Scenarios

Retrofitting stormwater management in existing urban areas presents a significant challenge in terms of the areas that can be treated and the combination of the measures described in the previous section. The stormwater collection systems in these areas were originally designed to efficiently remove stormwater to limit ponding (maximize conveyance) and provide flood control. This history results in extensive municipal conveyance systems in the form of storm sewers (minor system), and surface flow routes (major system). These systems discharge to receiving watercourses.

Community development planned and constructed after the late 1980s included stormwater detention facilities for major and minor flows to slow the release of urban runoff to reduce potential flooding and erosion downstream. However, the range of storm events addressed with these early stormwater management systems were relatively small, and included only extreme events, beyond the 1:2-year return event. Approximately 90% of the annual runoff remained uncontrolled, and urban streams experienced significant deterioration in water quality and erosion

The Eastern Subwatersheds will need to undergo significant transformation over the long-term in order to address stormwater impacts to receiving watercourses and the local reach of the Ottawa River.

Three initial SWM retrofit scenarios, made up of different combinations and levels of implementation of retrofit measures, were considered for evaluation and comparison to the existing condition:

(1) Opportunistic Implementation:
A lower level of lot level (10%) and conveyance measures combined with 5 end-of-pipe facilities

(2) Moderate Implementation:
A moderate level of lot level (30%) and conveyance (30%) measures combined with 10 end-of-pipe facilities

(3) Significant Implementation:
A significant level of lot level (50%) and conveyance (50%) measures combined with feasible 19 end-of-pipe facilities.

The results of this initial evaluation are provided in Appendix E. Further review was subsequently undertaken and the retrofit scenarios were adjusted to preclude end-of pipe facilities. The following retrofit scenarios were carried forward:

(1) Lot level Implementation:
A 30% uptake of lot level measures

(2) Conveyance Implementation:
A 50% implementation of conveyance measures

(3) Lot Level and Conveyance Implementation:
A 30% uptake of lot level measures and a 50% implementation of conveyance measures.

The watershed hydrology model developed for the existing condition was modified to reflect these three scenarios. The results of this analysis provide a means to evaluate the effectiveness of the scenarios in relation to runoff volume reductions, pollutant removal, and erosive velocities.

The water quality model, developed for the existing conditions was modified to represent future land use conditions. The future condition was then used for the basis of simulated conditions under the retrofit scenarios, defined as 30% lot level control only, 50% conveyance control only, and combined 30% lot level and 50% conveyance control.

4.7.1 Stream Erosion Analysis

4.7.1.1 Overview of Existing Conditions

As detailed in the Existing Conditions report, main channels within each subwatershed were delineated into reaches based upon form, function, gradient, geology, sinuosity, and valley setting. In total, 27 reaches were delineated for detailed study. Reach characteristics were identified through a synoptic level field investigation which documented channel morphology, prominent channel processes, and channel stability.

Evaluated erosion sites are as follows:

- Taylor Creek: Eighteen (18) erosion sites;
- Voyageur Creek: Forty-two (42) erosion sites;
- Cyrville Creek: Eleven (11) erosion sites;
- Mather Award Drain: Nineteen (19) erosion sites; and
- McEwan Creek: Eleven (11) erosion sites.

Tractive Force Analysis, carried out as part of the Existing Conditions report revealed that flow competence (m/s) to entrain the median particle size in the stream bed for the five creek systems is as follows:

- Taylor Creek: (0.5 – 0.69m/s);
- Voyageur Creek: (0.2 – 1.3m/s);
- Cyrville Creek: (0.51 – 0.85m/s);
- Mather Award Drain: 0.62m/s; and
- McEwan Creek: (0.2 – 1.08m/s).

Appendix D presents detailed information concerning tractive forces and erosion hazards within the five (5) creek systems, with description of erosion hazards, risk, and priority for restoration.

4.7.1.2 Modelling Approach – Stream Erosion

The erosion analysis to examine the effect of SWM retrofit scenarios was based on developing Flow Duration Curves (FDC) as commonly practiced for assessing stormwater management impacts on receiving watercourses. Flow Duration Curves (FDC) is a valuable tool to compare the impact of environmental and anthropogenic changes on a study area. These changes may include urban development, flow regulation (i.e. dams or water withdrawal), and SWM retrofit scenarios.

A typical rainfall-runoff year (2010) was used for FDC analysis since it was assumed that the flow regime was representative of the historic hydrology of the study area. Figures and tables were developed presenting the percentage of time flows were equaled or exceeded under the three (3) SWM retrofit scenarios, in addition to existing conditions.

Of particular concern to erosion analysis are less frequent extreme flows that are generally driving stream erosion and deposition processes. Specifically, flows ranging from 1 to 10 percent equaled or exceeded were analyzed under all scenarios. These flows have been cited in literature as responsible for highest erosion rate per stream mile (Sekely et al., 2002).

4.7.1.3 Reducing the Risk of Stream Erosion

The results from the flow duration analysis show that the implementation of all three SWM retrofit scenarios decrease the probability of exceedance of extreme peak flows, thereby reducing the 'erosion potential'. Scenario 3 achieves the most improved results.

Table 4-2: Probability of Exceedance of Extreme Flows for 2010 Rainfall

Subwatershed	Percent Equalled or Exceeded	Peak Flows (m^3/s)			
		Existing	Scenario 1 Lot Level 30%	Scenario 2 Conveyance 50%	Scenario 3 Lot Level 30% & Conveyance 50%
Bilberry	1	3.1	2.5	1.6	0.9
	2	2.4	2.0	1.2	0.7
	4	1.6	1.3	0.8	0.5
	8	0.9	0.7	0.5	0.3
	10	0.7	0.6	0.4	0.3
Green's	1	10.0	8.9	6.9	5.9
	2	7.2	6.5	5.1	4.3
	4	4.6	4.2	3.3	2.7
	8	2.5	2.2	1.7	1.4
	10	2.0	1.8	1.3	1.1
Taylor	1	1.9	1.6	1.1	1.2
	2	1.5	1.3	0.8	0.5
	4	1.1	0.9	0.6	0.3
	8	0.7	0.6	0.4	0.2
	10	0.7	0.6	0.3	0.2
Voyageur	1	3.0	2.4	1.5	0.8
	2	2.2	1.8	1.1	0.6
	4	1.6	1.3	0.8	0.4
	8	0.9	0.8	0.5	0.3
	10	0.8	0.6	0.4	0.2

4.8 Modeling Results – Water Quality, Quantity, Runoff Volume

The following sections summarize the modelling methodology applied to the retrofit scenarios as well as the results of the modeled scenarios.

4.8.1 Water Quality Assessment

Water quality modelling is applied to estimate and analyze water quality characteristics within a watershed in response to implementation of stormwater management and changes in land use. Water quality characteristics include particular pollutant concentrations and loading.

In this study, PCSWMM models were used to quantify the impact of implementing lot level and conveyance controls within the five (5) largest Eastern Subwatersheds tributaries that flow to the Ottawa River, namely Bilberry Creek, Green's Creek (Urban Subwatersheds: Cyrville, Mather Award, and McEwan), Queenswood catchments, Taylor Creek, and Voyageur Creek.

The following sections summarize the water quality assessment of the SWM retrofit scenarios.

4.8.2 Existing Conditions

The Existing Conditions section presented the baseline conditions for water quality. The model, representing existing conditions, simulated the concentrations of key pollutants in the streams as well as the loadings to the Ottawa River from stormwater runoff. The water quality models were calibrated using field measurements.

Based on the results from the existing conditions analysis portion of this study, the flow in Green's, Bilberry, Voyageur and Taylor Creeks do not meet current CCME guidelines for TSS under wet-weather conditions. None of the Eastern Subwatersheds streams meet the Provincial Water Quality Objectives (PWQO) of 0.03 mg/L of Total Phosphorus. Heavy Metals are also above the PWQO standards, and none of the Eastern Subwatersheds streams meet the Health Canada recreational water quality criterion of 100 E.Coli/100 mL.

The Green's Creek subwatershed is the highest contributor of all pollutants with the exception of E.Coli, where the Queenswood subwatershed contributes the highest concentration levels. This may be linked to the measured high E.Coli concentration at the outfall of Taylor Creek (almost eight (8) times the concentration at the Green's Creek outfall). Modelled results were found to be reasonably close to observed results obtained from the City of Ottawa corresponding to the period between 2009 and 2011.

4.8.3 Water Quality Modeling Approach

The PCSWMM model has been widely applied in practice to simulate the build-up, wash-off, transport, and treatment of many water quality constituents. The water quality model, developed and calibrated as described in Section 3.7, was applied to represent baseline conditions (Do Nothing) in comparison to the simulated conditions under SWM retrofit scenarios.

Three pollutants were evaluated in the models representing the three SWM scenarios: Total Suspended Solids (TSS), TP and E.Coli. These three pollutants were selected due to their significance to the study objectives and to the evaluation of effects in the Ottawa River.

The effect of LIDs was modelled in PCSWMM through adjusting the “Decay Coefficient” under “Pollutants” editor and “Washoff BMP Efficiency” under “Land Uses” editor. Decay coefficient was set to 0.4, 0.2 and 0.5 for Scenario 1, Scenario 2 and Scenario 3, respectively, for the Green’s Creek; 0.7, 0.5 and 0.9 for Scenario 1, Scenario 2 and Scenario 3, respectively, for the other watersheds from Voyageur to Taylor. Washoff BMP efficiency (in percent) was set to 16-18, 7-8 and 23-25 for Scenario 1, Scenario 2 and Scenario 3, respectively, for the Green’s Creek; 16-18, 7-8 and 23-25 for Scenario 1, Scenario 2 and Scenario 3, respectively, for the other watersheds from Voyageur to Taylor. Washoff BMP efficiency was applied only to institutional, commercial, industrial and residential land uses.

4.8.4 Pollutant Reduction

The concentrations of three pollutants (E.Coli, TP and TSS) were modelled to evaluate the potential for the reduction in pollutant loadings as a comparison between baseline conditions and the retrofit scenarios. The results of runoff volumes for the lot level control only, conveyance control only, and combination of lot level and conveyance control retrofit scenarios are presented in Table 4-3. Runoff volume reduction ranges from 18 to 25% for the combined scenario on the individual subwatershed basis.

The reduction in E.Coli, TP and TSS loadings and concentrations is mainly attributed to the reduction in surface runoff volume because of increased infiltration and evapotranspiration volumes. This results in reducing the pollutant loading of untreated stormwater.

4.8.5 E.Coli Reduction

Table 4-4 presents the pollutant loadings to the Ottawa River. The combined lot level and conveyance scenario shows the greatest E.Coli removal at the outfalls. Percentage removal ranges from 23.9% for Queenswood subwatershed to 29.8% for Green’s Creek and Bilberry subwatershed in #/100 mL. The concentrations resulting from the combined scenario (lot level control plus conveyance control) are still greater than the 200 Counts/100mL target, however, there is a significant decrease in concentrations and loadings.

4.8.6 TSS Reduction

According to Table 4-4, the combined scenario shows the greatest TSS removal at the outfalls. Percentage removal ranges from 19.7% for Green’s Creek subwatershed to 25.4% for the Taylor East subwatershed. The concentrations resulting from the combined scenario are still greater than 25 mg/L (CCME), however, there is a decrease in loading. Further details are provided in Appendix H.

Table 4-3: Annual Runoff Volumes to the Ottawa River (for 2010 Rainfall)

Subwatershed	Existing Land Use (2010), No Controls (ML)	Lot Level Control 30% (ML)	Conveyance Control 50% (ML)	Lot Level plus Conveyance Control (ML)
Bilberry	3,279	2,682	3,053	2,485
	% Reduction	*18.2*	*6.9*	*24.2*
Green's	17,095	14,639	16,530	14,019
	% Reduction	*14.4*	*3.3*	*18.0*
Queenswood	589	482	544	440
	% Reduction	*18.2*	*7.7*	*25.3*
Taylor	1,345	1,103	1,251	1,019
	% Reduction	*18.1*	*7.0*	*24.2*
Voyageur	1,824	1,489	1,694	1,373
	% Reduction	*18.3*	*7.1*	*24.7*
Total	**24,132**	**20,395**	**23,072**	**19,335**
	% Reduction	***15.5***	***4.4***	***19.9***

Table 4-4: Pollutants to the Ottawa River (for 2010 Rainfall)

Subwatershed	Existing			Lot Level Control 30%			Conveyance Control 50%			Lot Level plus Conveyance Control		
	E.Coli (#/100mL)	TP (mg/L)	TSS (mg/L)	E.Coli (#/100mL)	TP (mg/L)	TSS (mg/L)	E.Coli (#/100mL)	TP (mg/L)	TSS (mg/L)	E.Coli (#/100mL)	TP (mg/L)	TSS (mg/L)
Bilberry	5653	0.40	225	4432	0.35	187	4958	0.38	208	3969	0.32	173
			% Removal	*21.6*	*14.0*	*16.8*	*12.3*	*6.2*	*7.6*	*29.8*	*20.2*	*23.4*
Green's	4766	0.40	239	3763	0.35	204	4526	0.38	225	3344	0.33	192
			% Removal	*21.0*	*13.0*	*14.7*	*5.0*	*5.3*	*6.1*	*29.8*	*17.9*	*19.7*
Queenswood	6515	0.42	235	5465	0.36	194	5993	0.39	217	4959	0.33	178
			% Removal	*16.1*	*14.9*	*17.4*	*8.0*	*6.5*	*7.7*	*23.9*	*21.3*	*24.2*
Taylor (East)	6258	0.4	221	5050	0.34	180	5582	0.37	201	4549	0.31	165
			% Removal	*17.4*	*16.3*	*18.8*	*10.8*	*7.9*	*9.2*	*25.4*	*22.5*	*25.4*
Voyageur	6137	0.41	230	5070	0.35	190	5584	0.38	212	4575	0.32	174
			% Removal	*17.4*	*14.8*	*17.4*	*9.0*	*6.5*	*7.7*	*25.4*	*21.2*	*24.1*

4.8.7 Ottawa River Model Results

The water quality modeling results for the existing condition confirm Baird & Associates (2011) conclusion that Bilberry, Green's and Voyageur Creeks are significant contributors of bacterial contamination to Petrie Island. This is reinforced by the results of the *Ottawa River Water Quality Model Simulations 2018* completed by Baird & Associates which is included in Appendix H.

4.8.8 Water Quantity Assessment

4.8.8.1 Hydrologic Analysis

The hydrology for the Eastern Subwatersheds study area with the SWM retrofit scenarios was modelled using PCSWMM (Version 7.0.2340 and Engine SWMM 5.1.010). The model was structured such that Individual models were created for each of the three SWM retrofit scenarios (lot level control only, conveyance control only, combined source plus conveyance) for each subwatershed.

The following methodology was applied as part of the SWM retrofit hydrologic analysis:

(1) Review of existing conditions models;
(2) Development and analysis of SWM retrofit models; and
(3) Evaluation of model results.

4.8.8.2 Modelling Approach

The PCSWMM hydrologic models prepared for the existing condition was applied as the basis for the SWM retrofit hydrology models. After the existing land use was updated with the City of Ottawa Vacant Land Use layers to account for future development, the existing condition model was established as the base condition. SWM control measures were added to evaluate the relative effectiveness of the retrofit strategies to reduce runoff volume, peak flows discharging to watercourses, and the effect on reducing pollutant loading to the Ottawa River.

Runoff generated from each subcatchment is typically directed to an "outlet". To simulate lot level and conveyance control measures in the models, a portion of the subcatchment runoff (the uptake rate 30% for lot level control and 50% for conveyance control) is diverted to the "pervious" areas of the subcatchment.

As previously noted, end-of-pipe facilities were not included in the Stormwater Management retrofit scenarios.

In order to evaluate the impact of SWM retrofit measures when implemented separately, the hydrologic model was set up for three different scenarios:

Scenario 1:	30% uptake rate for lot level only
Scenario 2	50% uptake rate for Conveyance Control only
Scenario 3	Combination of 30% lot level and 50% conveyance control measures.

All models made use of the MTO type SCS design storms for 2-Year, 25-Year, and 100-Year storms; and continuous rainfall data for the year 2010. The continuous rainfall data was compiled as part of the existing conditions analysis, using data obtained from regional rain gauge stations. Copies of the SWM retrofit models are provided in Appendix J.

The 30% lot level control uptake rate is represented by routing the runoff from 30% of impervious lot area to the pervious area (e.g. runoff from roof and driveways are directed to lawn or garden areas through downspout redirection, rain gardens, and pervious pavers). Figure 4.3 illustrates the implementation of lot level control measures. The uptake rate of 30% for lot level control measures was applied on industrial, commercial, institutional (ICI) and residential property areas. This is achieved using the PCSWMM Subarea Routing function in the Subcatchment Layer. For example, the total of residential and ICI areas for the subcatchment BIC01 is 25.9 ha which accounts 53.8% of the total subcatchment area (48.16 ha). The *Subarea Routing* percentage was calculated as 0.30x53.8%=**16.1%** of the catchment's total impervious area and directed to *pervious* area.

The uptake rate of 50% for conveyance control measures was applied *only* on ROW areas within the subcatchments. This is achieved using the PCSWMM *Subarea Routing* function in the Subcatchment Layer. For example, the ROW area for the subcatchment BIC01 is 14.5 ha which accounts for 30.2% of the total subcatchment area (48.16 ha). The imperviousness of the ROW areas was estimated to be 55% after reviewing the imperviousness for the different types of roads. Then, the *Subarea Routing* percentage was calculated as 0.50x0.55x30.2%=**8.3%** of the catchment's total area.

The combination of Lot Level and Conveyance Control Measures: the uptake rate of 30% for the lot level control measures and the uptake rate 50% for the conveyance control measures were applied together.

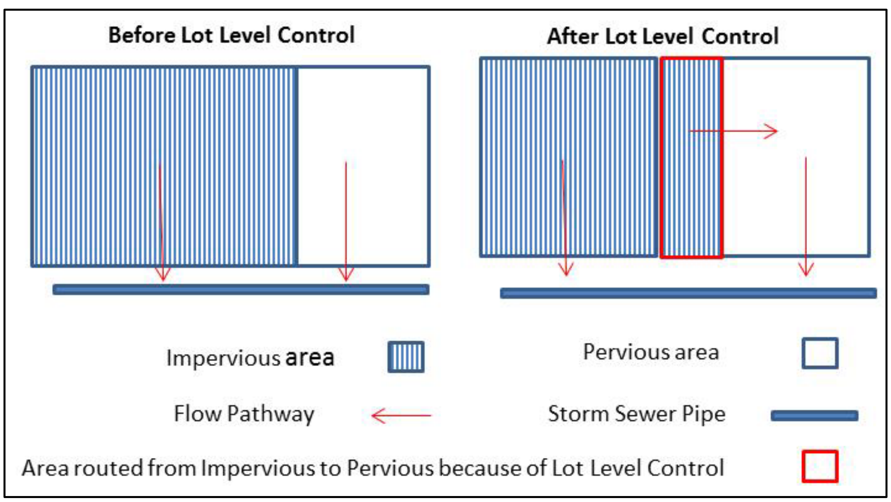


Figure 4.3: Lot Level Control Simulation – Routing from Impervious to Pervious

4.8.8.3 Results – Surface Runoff Volume Reduction

Table 4-5 shows the results of the hydrologic model in terms of the hydrologic cycle volumes (mm). Surface runoff volumes decrease while infiltration and evaporation increase with the implementation of more SWM retrofits. The decrease in surface runoff volumes and the increase in infiltration and evaporation can be explained by the following key hydrologic processes that are promoted by SWM retrofit opportunities:

- The routing of runoff from impervious to pervious areas through lot level control measures
- Attenuation of peak flows through lot level and conveyance control measures
- Reduction of runoff volume through infiltration.

Table 4-5: Hydrologic Cycle Results under Existing Conditions and SWM Retrofit Scenarios

Subwatershed	Existing Land Use (2010)		Lot level control 30%		Conveyance Control 50%		Lot Level plus Conveyance Control	
	Surface Runoff	Infiltration + ET	Surface Runoff	Infiltration + ET	Surface Runoff	Infiltration + ET	Surface Runoff	Infiltration + ET
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
Bilberry	295	615	244	666	277	633	226	684
Green’s	144	766	123	787	139	771	118	792
Queenswood	297	613	243	667	275	635	222	688
Taylor	290	620	242	668	272	638	224	686
Voyageur	229	681	188	722	214	696	174	736

The hydrologic cycle results indicate that applying lot level control measures provides a relatively greater benefit than conveyance control measures only. This occurs despite the uptake rate of the lot level control being less than the conveyance control measures. The reason for this is that developed lots provide a much larger contribution to runoff than the rights of way for City streets, so the relative contribution of LID on lots provides a greater impact than conveyance control. There is also an inherent assumption in the model where runoff from lots, which may be intercepted by conveyance control measures, is not taken into account. Therefore, the benefit of conveyance control on runoff volume reduction is likely understated by the analysis. Table 4-6 to Table 4-11 summarize the peak flows from subwatersheds for 2-Year, 25-Year, and 100-Year storms for the existing condition and SWM retrofit scenarios.

Table 4-6: Peak Flows to the Ottawa River for the 2-Year Design Storm

Peak Flows (m^3/s)					
Subwatershed	Node	Existing Land Use (2010), No Controls	Lot Level Control 30%	Conveyance Control 50%	Lot Level plus Conveyance Control
Bilberry	BIC-Out-01	15.7	13.2	14.8	12.1
Green's	GRC-Out-01	23.5	19.8	22.5	18.8
Queenswood	QUC-Out-03	7.9	6.5	7.3	6.0
Taylor	TAC-Out-01	9.4	7.8	8.8	7.2
	TAC-Out-02	5.0	4.3	4.7	4.0
	TAC-Out-03	4.4	3.7	4.1	3.4
Voyageur	VOC-Out-01	20.2	16.7	18.9	15.5

Table 4-7: Peak Flows to the Ottawa River for the 25-Year Design Storm

Peak Flows (m^3/s)					
Subwatershed	Node	Existing Land Use (2010), No Controls	Lot Level Control 30%	Conveyance Control 50%	Lot Level plus Conveyance Control
Bilberry	BIC-Out-01	45.3	40.4	43.4	38.9
Green's	GRC-Out-01	65.9	61.5	64.7	60.4
Queenswood	QUC-Out-03	14.2	13.9	14.1	14.0
Taylor	TAC-Out-01	19.9	17.5	18.9	16.7
	TAC-Out-02	11.4	10.4	11.1	10.1
	TAC-Out-03	11.25	10.1	10.7	9.5
Voyageur	VOC-Out-01	45.17	40.3	43.3	38.7

Table 4-8: Peak Flows to the Ottawa River for the 100-Year Design Storm

Peak Flows (m^3/s)					
Subwatershed	Node	Existing Land Use (2010), No Controls	Lot Level Control 30%	Conveyance Control 50%	Lot Level plus Conveyance Control
Bilberry	BIC-Out-01	66.1	60.4	63.9	58.6
Green's	GRC-Out-01	94.2	88.9	93.0	87.8
Queenswood	QUC-Out-03	15.6	15.4	15.5	15.2
Taylor	TAC-Out-01	25.3	22.7	24.4	21.7
	TAC-Out-02	14.8	13.7	14.5	13.4
	TAC-Out-03	15.1	13.6	14.4	13.0
Voyageur	VOC-Out-01	56.4	50.9	54.5	49.1

Table 4-9: Future Uncontrolled Peak Flows to the Ottawa River for the 2-Year Design Storm

Peak Flows (m^3/s)					
Subwatershed	Node	Future Land Use, No Controls	Lot Level Control 30%	Conveyance Control 50%	Lot Level plus Conveyance Control
Bilberry	BIC-Out-01	16.3	13.9	15.5	13.0
Green's	GRC-Out-01	27.3	22.8	26.1	21.7
Queenswood	QUC-Out-03	7.9	6.6	7.3	6.0
Taylor	TAC-Out-01	10.7	8.7	9.9	8.0
	TAC-Out-02	5.9	5.0	5.6	4.6
	TAC-Out-03	4.6	3.9	4.2	3.5
Voyageur	VOC-Out-01	20.2	16.7	18.9	15.5

Table 4-10: Future Uncontrolled Peak Flows to the Ottawa River for the 25-Year Design Storm

Peak Flows (m^3/s)					
Subwatershed	Node	Future Land Use, No Controls	Lot Level Control 30%	Conveyance Control 50%	Lot Level plus Conveyance Control
Bilberry	BIC-Out-01	48.1	42.5	45.7	41.1
Green's	GRC-Out-01	69.6	64.9	68.3	63.9
Queenswood	QUC-Out-03	14.2	14.1	14.3	14.0
Taylor	TAC-Out-01	22.6	19.8	21.5	18.8
	TAC-Out-02	13.3	12.0	12.9	11.5
	TAC-Out-03	11.6	10.3	10.9	9.7
Voyageur	VOC-Out-01	45.2	40.3	43.3	38.8

Table 4-11: Future Uncontrolled Peak Flows to the Ottawa River for the 100-Year Design Storm

Peak Flows (m^3/s)					
Subwatershed	Node	Future Land Use, No Controls	Lot Level Control 30%	Conveyance Control 50%	Lot Level plus Conveyance Control
Bilberry	BIC-Out-01	68.6	62.9	66.5	61.2
Green's	GRC-Out-01	98.5	93.3	97.2	92.0
Queenswood	QUC-Out-03	15.9	15.6	15.7	15.4
Taylor	TAC-Out-01	28.5	25.3	27.4	24.1
	TAC-Out-02	17.3	15.7	16.8	15.2
	TAC-Out-03	15.5	13.9	14.7	13.2
Voyageur	VOC-Out-01	56.7	51.0	54.6	49.2

4.9 Evaluation of Scenarios

A set of criteria was developed to rank and select the preferred alternative from the three alternative retrofit scenarios. The evaluation addresses eleven (11) main considerations:

(1) Reduction of erosion impacts,
(2) Response matching the natural hydrologic cycle,
(3) Improvement to water quality,
(4) Reduction of the impact of runoff on water quality at the beach,
(5) Reduction in flood risk,
(6) Implementation time,
(7) Degree of control,
(8) Community/User health and safety,
(9) Public Acceptance,
(10) Impact on open space areas and City parks, and
(11) Total annual (lifecycle) costs.

The individual criteria, indicators, indicator rationale, and explanation of the scoring used for each indicator are presented in Table 4-12.

Table 4-12: Criteria and Scoring used for Scenario Evaluation

No.	Criteria	Indicator	Rationale	Scoring
1	Reduce Erosion Impacts	In-stream Erosion Potential	Instream erosion potential needs to be moved closer to natural (historic) levels to:	4 – 40% reduction in time of threshold flow exceedance 3 – 30% reduction in time of threshold flow exceedance 2 – 20% reduction in time of threshold flow exceedance 1 – 10% reduction in time of threshold flow exceedance 0 – no net reduction in time of threshold flow exceedance
2	Natural Hydrologic Cycle	Runoff Threshold event	Detaining flows for frequent (5 to 10mm) rainfall events promotes a more natural hydrologic process by increasing evapotranspiration , groundwater infiltration and re-use of rainfall and runoff	4 – 40% increase in evapotranspiration + infiltration 3 – 30% increase in evapotranspiration + infiltration 2 – 20% increase in evapotranspiration + infiltration 1 – 10% increase in evapotranspiration + infiltration 0 – no net increase in evapotranspiration or infiltration
		Watershed Peakiness	Watershed peakiness needs to be reduced in order to reduce the risk of flooding, reduce erosion, protect riparian terrestrial and aquatic habitats and replenish groundwater aquifers	4 – $Q_{Bankfull/Qbaseflow}$ equal to or less than 16 3 – $Q_{Bankfull/Qbaseflow}$ equal to or less than 18 2 – $Q_{Bankfull/Qbaseflow}$ equal to or less than 20 1 – $Q_{Bankfull/Qbaseflow}$ equal to or less than 22 0 – $Q_{Bankfull/Qbaseflow}$ equal to or less than 24
3	Improve Water Quality	Total Suspended Solids (TSS)	Improving water quality conditions results in improved aesthetics, higher quality fish communities and non-eutrophic conditions. Total Suspended Solids (TSS) is often used to provide a general indication of water quality conditions.	4 – TSS & TP targets achieved 40% of time 3 – TSS & TP targets achieved 30% of time 2 – TSS & TP targets achieved 20% of time 1 – TSS & TP targets achieved 10% of time 0 – TSS & TP targets achieved 0% of time

Continued - Table 4-12: Criteria and Scoring used for Scenario Evaluation

No.	Criteria	Indicator	Rationale	Scoring
4	Reduce Impact of runoff on the beach	Instream *E.Coli* at outfall to Ottawa River	Reduction in *E. Coli* levels from each of the watercourses will reduce the risk of contracting disease from incidental exposures to recreational waters (e.g., boating, wading) and may contribute to reduced postings at Petrie Island Beach	4 – 40% reduction in E. Coli loadings at the mouth of the watercourse 3 – 30% reduction in E. Coli loadings at the mouth of the watercourse 2 – 20% reduction in E. Coli loadings at the mouth of the watercourse 1 – 10% reduction in E. Coli loadings at the mouth of the watercourse 0 – no net reduction in E. Coli loadings at the mouth of the watercourse
5	Reduce Flooding	Frequency of overtopping of watercourse crossings	Overtopping of watercourse crossings during extreme rainfall events impacts vehicular (and pedestrian safety) and may result in structural problems.	4 – 40% reduction in the 100 year storm flow 3 – 30% reduction in the 100 year storm flow 2 – 20% reduction in the 100 year storm flow 1 – 10% reduction in the 100 year storm flow 0 – no net reduction in the 100 year storm flow
6	Timing to Implement	Estimated implementation time for strategy to be operational	Length of time to implement the strategy including: • degree to which new legislation/by laws are needed • time for approvals	4 – 0 to 13 years 3 – 5 to 26 years 2 – 10 to 39 years 1 – 20 to 50 years 0 – > 50 years
7	Degree of Control	Degree of implementation which City has control over	Degree that strategy can be controlled to continually be effective, includes: • public compliance • land ownership • technical/scientific uncertainty	4 – City has complete control 3 – City has considerable control 2 – City has moderate control 1 – City has little control 0 – City has no control

Continued - Table 4-12: Criteria and Scoring used for Scenario Evaluation

No.	Criteria	Indicator	Rationale	Scoring
8	Community/User Health and Safety	Risk to community health and safety	Potential risk/liability or benefit to community health and safety during or after construction	4 – Strategy has considerable benefit on health and safety 3 – Strategy has a small benefit on health and safety 2 – Strategy has no impact on health and safety 1 – Strategy has a considerable impact on health and safety 0 – Strategy has potential to significantly impact health and safety
9	Public/User Acceptance	Public acceptance	Public acceptance of overall strategy including: • possible lifestyle changes • possible property value impacts • construction impacts	4 – Strategy strongly accepted by public 3 – Strategy well accepted by public 2 – strategy moderately accepted by public 1 – strategy somewhat accepted by public 0 – Strategy not accepted by public
10	Open Space Areas/Parks	Impact on open spaces/parks	Potential to impact existing uses in conservation lands, open spaces including parks, vacant lots	4 – Strategy improves existing value in open spaces 3 – Strategy 2 – Strategy has no impact on open spaces 1 – Strategy 0 – Strategy adversely impacts existing uses
11	Total Annual (Lifecycle) Costs	Relative total cost	Total annual capital and operation and maintenance costs, including construction costs, staffing, energy and land	4 – lowest overall cost 3 – within 10% of lowest cost 2 – within 20% of lowest cost 1 – within 30% of lowest cost 0 – within 40% of lowest cost

Section 4.14 provides the relative scoring of each of the stormwater management retrofit scenarios. The combined 30% lot level control scenario with the 50 % conveyance control provides the highest score in comparison to Lot level control only and 50% conveyance control scenario.

4.10 Costing of Retrofit Scenarios

Cost estimates were developed to allow for a relative comparison between the scenarios for ranking and planning purposes only. Table 4-13 provides a summary of the total cost contribution required for each scenario being evaluated.

Table 4-13: Summary of Total Cost for SWM Retrofit Scenario

Scenario	Lot Level Control (30%)	Conveyance 50% Control	Stream Restoration and Erosion Sites	Total Cost
	($M)	($M)	($M)	($M)
1 - Lot level 30%	12.8	-	14.1	**26.9**
2 - Conveyance 50%	-	194.4	14.1	**208.5**
3 - Lot level (30%) and Conveyance (50%)	12.8	194.4	14.1	**221.3**

The capital and operational cost estimates for each SWM retrofit scenario is further explained in the following sections. A detailed breakdown of the SWM retrofit scenario cost comparison and evaluation is provided in Appendix F.

4.11 Lot Level Control Measures

The adoption of lot level control measures in the Eastern Subwatersheds study area is not limited by technical constraints. The lots are generally sufficiently large to construct effective lot level measures. There is limited experience with the adoption of widespread lot level controls in Canada. Most municipalities who have invested in a lot-level control program have used incentive programs as part of a stormwater utility fee system. A unit cost rate for lot level SWM of $50,000 per hectare was used in this study, and is based on discussions with various municipalities as well as the incremental cost above conventional landscaping and parking lot rehabilitation. For example, this cost represents the additional investment needed to install a permeable driveway as compared to a conventional asphalt driveway, and the additional cost to install a rain garden as part of naturalizing a rear yard area. Lot level works are considered private property so no operation and maintenance costs (for the City) have been included.

30% has been assumed to be a reasonable long term uptake rate for lot level measures that people will ‘voluntarily’ implement based on social marketing studies that have been completed for other jurisdictions. In addition to the cost of a social marketing program, the City could consider funding a portion of the capital cost of lot level controls, as an incentive to achieve the 30% uptake level. The mechanism to achieve this could be similar to the way municipalities have traditionally contributed to specific lot level measures like downspout disconnection, backflow valves, and rain barrels.

4.12 Conveyance Control Measures

The lifecycle cost of conveyance control stormwater management retrofit program depends on a number of factors. These factors include the total size of the captured tributary area, and the type of LID measure, as well as the implementation strategy. LID designs for relatively small captured areas will result in higher costs per tributary area. Bioswales, rain gardens and permeable pavers have a higher unit cost than infiltration trenches. The unit costs for LID projects are much higher if the project is implemented solely as an LID retrofit project, as opposed to being integrated with road reconstruction projects.

According to a summary of LID cost information for 24 LID projects in Ontario (R.J. Muir), the average cost per hectare of impervious area is $575,000. Projects range from bioswales, to rain gardens to permeable pavements. However, if only the projects which have catchment areas of between 1.6 and 2.3 hectares (close to 40% of the projects summarized) are used, the average unit cost per hectare is $95,700.

The cost of three LID pilot projects in Ottawa (Sunnyside Avenue, Stewart Street, and Hemmingwood) range from $180,800 per hectare in the case of Stewart Street, to $609,700 per catchment hectare for Sunnyside. However, the total catchment area for Stewart Street is over 2 hectares, while Sunnyside is less than 0.4 hectares.

All of the unit cost calculations are based on stand-alone retrofit projects, and not applicable to estimating program costs where the LID measures will be implemented as part of the road rehabilitation program. There is no documentation available of the cost of conveyance control when it is implemented as part of a fully integrated capital roads program.

For the purposes of this study, a unit lifecycle cost of $178,000 per hectare is proposed for conveyance control. Over a 50-year program, this equates to an annual investment of $4.6M per year. This cost is based on the assumption that the cost of the LID works is the incremental cost above investments required for complete road rehabilitation. The unit cost is made up of $100,000 plus an additional $78,000 per hectare for operation and maintenance, based on an annual investment of 2% of the initial capital cost over 50 years.

4.13 Erosion Sites and Stream Restoration

As part of the current study, the fluvial geomorphological assessment identified and prioritized observed erosion sites for Taylor Creek, Voyageur Creek, Cyrville Drain, the Award Mather Drain, and McEwan Creek. A previous fluvial geomorphological study of Bilberry creek was completed separately.

The fluvial geomorphological investigations identified three medium to high priority erosion sites – one located on the Cyrville Drain, one on the Mather-Award Drain and one on Taylor Creek. In addition, 9 medium priority sites were identified, and 24 sites were identified as medium to low priority. There are 66 locations where the priority was assessed as low priority. Investments should be planned to address the medium to high and medium priority sites, with on-going monitoring of all of the erosion sites.

The Geomorphological Systems Master Implementation Plan for Bilberry Creek, completed in May of 2014 by GHD, identified short-term restoration requirements at 4 priority locations, with a total estimated cost of $820,000. Reach B10/B10A and B10/B10B have been already scheduled for the implementation. The study also identified restorations for a 10 to 20-year planning horizon. No cost estimates are available from the Bilberry Creek study for these longer-term restorations. A total of ten (10) bank erosion sites were identified as a medium or medium to high priority. These sites are listed in Table 4-14.

Table 4-14: Priority Erosion Sites - Eastern Subwatersheds

Watercourse	Reference Location (From Fluvial Geomorphology Report)	Description	Risk and Priority
Taylor	TC 1B/ ES4	Bank Repair: Exposed material on right bank, 50cm drop on bed, geotextile exposed on bed and banks	Highway 174 culvert. Medium
Taylor	TC3/ ES1	Repair of failed Armour Storm Wall	Private Parking Lot Medium
Taylor	TC3/ ES4	Failure of gabion baskets on bed creating 0.5m drop, exposed geotextile, undercut and broken gabion	Highway culvert located downstream. Medium
Bilberry	MB2*	Rip rap bank and buried stone treatments at the valley wall contact for long-term stability Minor channel relocation would relieve erosive forces- Energy dissipation pool downstream of the stormwater outlet to address the existing scour pool	Within 5 years. Currently acting against the valley wall and threatening private property
Bilberry	B10A*	Combination of energy dissipation pool and Filtrexx rocky riffle swale at the two B10A storm outlet	Risk of valley wall erosion and adjustment at the toe of slope.
Bilberry	B10/B10A Confluence*	Removal of woody debris jam and beaver dam upstream of the pedestrian crossing. Minor realignment of the reach downstream of the crossing is proposed to enhance the confluence. Filtrexx rocky riffle proposed within the realigned B10A to provide additional stability and grade control to the system. Live stakes to reduce flow velocities along the bank and limit erosion, while providing local stream shading and overhanging vegetation.	Pedestrian crossing
Bilberry	B10/B10B Confluence*	Localized armouring of the bed to mitigate risk to the existing sanitary crossings. Hydraulically-sized riffle material placed around sewer pipe to enhance bed stability and aquatic habitat. An additional riffle is proposed at the confluence to enhance channel stability at the confluence and create a backwater zone at the sewer crossings. Live stakes to reduce flow velocities along the bank and limit erosion, while providing local stream shading and overhanging vegetation.	Existing sanitary crossings
Voyageur	VC1/ ES4	pipe with constant flow of water exiting pipe, water flow down the bank slope as well	Private Parking Lot Medium
Voyageur	VC2/ ES1	Concrete ramp is undercut and broken causing drop into pool, knickpoints present ~5-6m downstream from ramp	Adjacent parking lots Medium

Continued - Table 4-14: Priority Erosion Sites - Eastern Subwatersheds

Voyageur	VC2/ ES6	Erosion scar extends to toe of bank, riprap and concrete have been dumped on slope, exposed storm sewer outlet, broken gabion baskets upstream, riprap and small knickpoints on bed	Adjacent Parking Lot Medium
Voyageur	VC5/ ES5	Steep valley slope, properties less than 5m from top of slope; large woody debris in channel causing right bank to be undercut	Private property less than 5m from top of slope. Medium
Voyageur	VC9/ ES3	Gabion baskets have detached from banks, riprap and gabion in channel, geotextile material exposed	Culvert Medium
McEwan	MEC-1/ ES2	Bank erosion identified near construction of new road bridge, channel bend is bare, roots exposed, and is slightly undercut	Bridge Medium
Cyrville Drain	CD1/ES2	Concrete portion along bed drops into plunge pool to native bed, is undercut, riprap exposed underneath	Medium
Cyrville Drain	CD3/ES4	~1200 storm sewer outlet, baffles, ~2m drop to channel bed, exposed stone all the way down, creation of plunge pool	Medium to High
Mather Award Drain	MD2/ES3	Meander bend at location of newly constructed road bridge, erosion scars and exposed roots present	Medium to High
*As documented in the Geomorphic Systems Master Implementation Plan for Bilberry Creek, GHD, 2014.			

As the erosion sites identified are related to existing infrastructure, the works are considered Schedule A or pre-approved per the MEA Class EA.

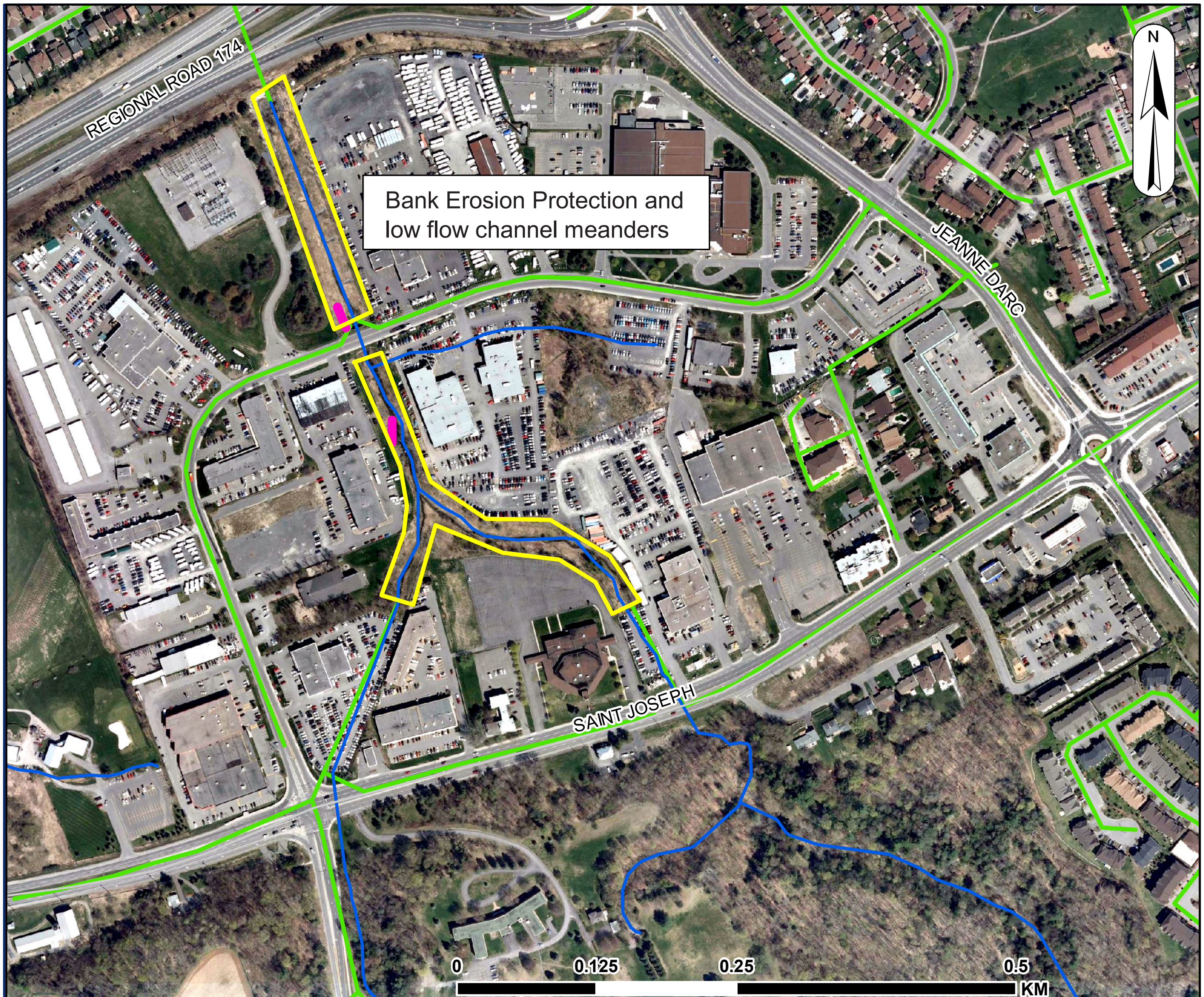
The estimated cost of the repair of identified bank erosion sites listed in Table 4-14 (rated Medium or Medium to High), excluding Bilberry Creek sites, is $1,500,000. This is based on a cost of $125,000 per site including engineering and contingency.

There are no opportunities for implementing stream daylighting within the study area. Most potential daylighting is constrained by property limitations caused by historical development. Stream daylighting and restoration for areas where streams have been enclosed by storm sewers would be very expensive and logistically difficult to execute.

Stream restoration and enhancement opportunities are identified for Voyageur Creek, Cyrville Drain, and the Mather Award Drain. Figure 4.4 to Figure 4.7 provide descriptions of these potential opportunities. While further investigation and consultation would be required to confirm feasibility and refine costing, these opportunities have been included or consideration in the long-term implementation plan.

Overall, stream and watercourse restoration costs are based on an estimated construction cost of $3,000 per meter plus engineering and contingency, for a total of $4,500 per meter. Based on a total length of 2.7 kilometers of stream restoration, the total investment in stream restoration and repair of erosion sites effort for the Eastern Subwatersheds would be $13.7M.

In addition to above, it was also noted by RVCA potential unstable slopes downstream of St. Joseph Boulevard culvert and recommended for shoreline/slope rehabilitation as priority for this site.



DESCRIPTION
Reconstruct low flow channel with meanders to reduce gradient and potential bank erosion
Create drop structures to reduce channel erosion
Prevent encroachment from adjacent private property
Potential channel daylighting on east and west branches
Reach Length = 750m
City owned land.

Legend
- Bank Erosion Protection
- Erosion Sites
- Watercourse
- Storm sewer

Eastern Subwatersheds Stormwater Management Retrofit Study

Voyageur Creek Stream Restoration

Morrison Hershfield | Aquafor Beech Limited

Figure 4.4

August, 2018 | Project No. 2124041

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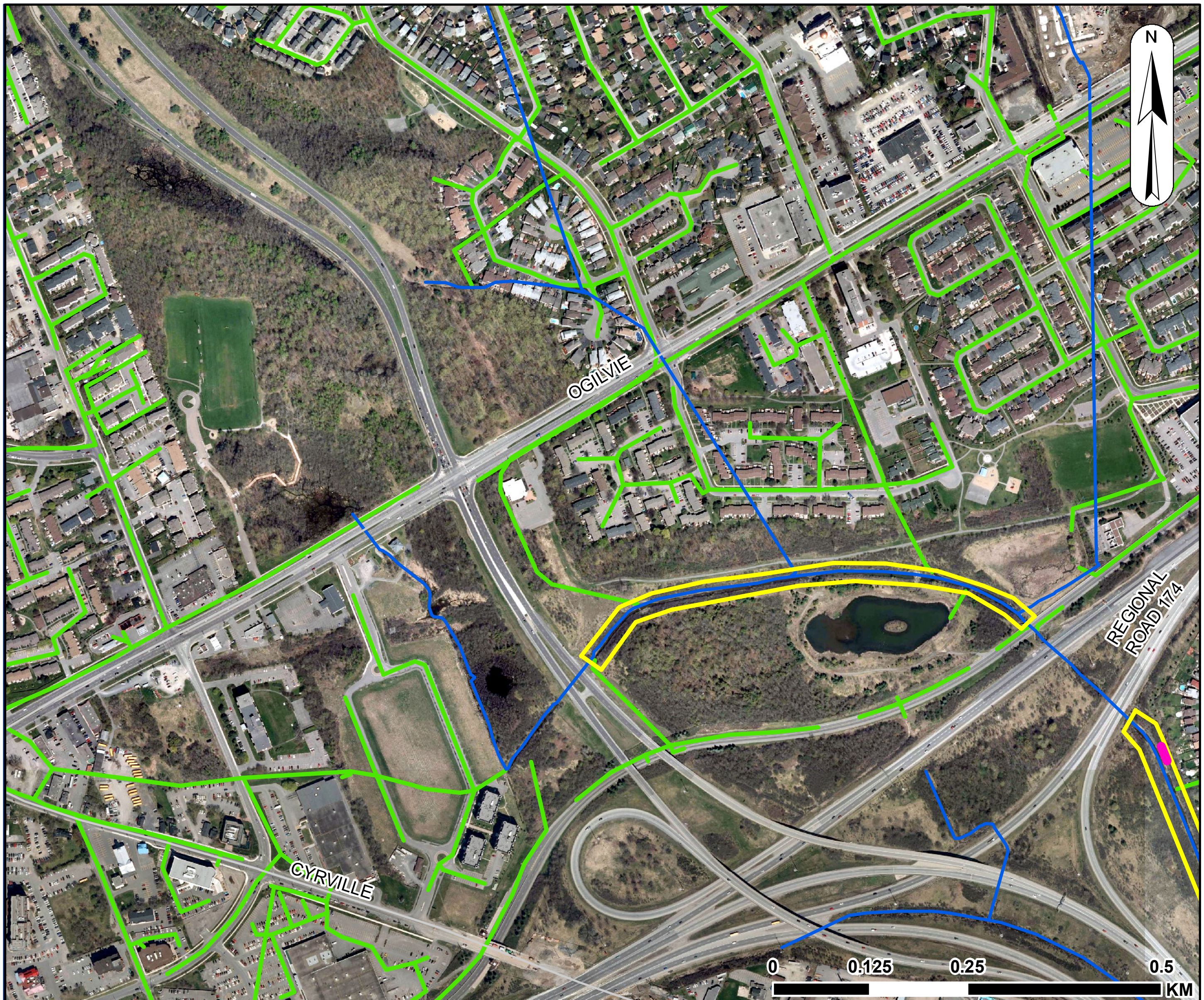

DESCRIPTION
Reconstruct low flow channel with meanders to reduce gradient, optimize sediment transport and create complexity
Reach Length = 1000m
NCC owned land.

Ottawa

Legend
- Erosion Site
- Watercourse
- Storm sewer
- Reconstructed Channel

Eastern Subwatersheds Stormwater Management Retrofit Study

North Branch Cyrville Drain Stream Restoration Opportunity 1

MORRISON HERSHFIELD | Aquafor Beech Limited

Figure 4.5

August, 2018	Project No. 2124041

DESCRIPTION
Wide, publically owned corridor
The reach is a direct tributary to Greens Creek
The channel can be moved west and away from close proximity to the residential properties Highway 174 to Cirville Road. Reconstruct low flow channel to create meandering within the corridor between Highway 417 and the residential property
Reach Length = 700m
Provincially owned land.

Ottawa

Legend

RealignedChannel
Watercourse
Storm sewer

Eastern Subwatersheds Stormwater Management Retrofit Study

North Branch Cyrville Drain Creek Restoration Opportunity 2

MORRISON HERSHFIELD
Aquafor Beech Limited

Figure 4.6

August, 2018 | **Project No. 2124041**

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DESCRIPTION
Create stilling/settling basin at outlet with protected channel
Stabilize banks to prevent loss of trees and vegetation, and stabilize channel to prevent sedimentation downstream
Drop structures if necessary
Reach Length = 200m
NCC owned land.

Ottawa

Legend

- Watercourse
- Storm sewer
- BackErosionProtection

Eastern Subwatersheds Stormwater Management Retrofit Study

South Branch Cyrville Drain Creek Restoration Opportunity

Morrison Hershfield | Aquafor Beech Limited

Figure 4.7

August, 2018	Project No. 2124041

4.14 Scoring and Ranking of Scenarios

For each of the eleven (11) comparative criteria presented in **Section 4.7**, a score ranging from 0 to 4 was assigned to each of the 3 scenarios, where 0 represents the worst condition and 4 indicates the best. The criteria were divided into three categories, and each category was assigned a weighting factor to be multiplied by the total score. The weighting factor indicates the relative importance or impact of each category. The categories with their respective weighting factors are listed in Table 4-15. The actual scoring of the scenarios is given in Table 4-16.

Table 4-15: Criteria Categories and Weighting Factors

Criteria	Weighting Factor
Category A: Technical Considerations	
1. Reduce Erosion Impacts 2. Natural Hydrological Cycle 3. Improve Water Quality 4. Reduce Impact of Runoff at Beaches 5. Reduce Flooding	Weighting Factor: 4
Category B: Implementation Considerations	
6. Implementation Time 7. Degree of Control 8. Community/ User Health and Safety 9. Public/ User Acceptance 10. Open Space/ Parks	Weighting Factor: 3
Category C: Cost Considerations	
11. Total Annual (Lifecycle) Costs	Weighting Factor: 3

A total score was obtained in each category for the 3 scenarios, multiplying the category sum by its weighting factor. The overall score for each scenario was obtained by adding the total weighted scores of categories A, B and C. Subsequently a ranking was assigned for each alternative solution with the highest overall total assigned 1 and the others sequentially 2, 3, etc. based on the scoring.

In the evaluation methodology proposed, the best ranking corresponds to No. 1 and is the preferred alternative. The worst ranking is the least desirable alternative. The evaluation of the alternative solutions is presented in Table 4-16 with additional information on the scoring of the alternatives for each criterion summarized in the following sections.

Table 4-16: Scoring of Scenarios

ID	Criteria	Indicator	30% Lot Level	50% Conveyance	30% Lot Level and 50% Conveyance
1	Reduce Erosion Impacts	In-stream erosion potential	2	1	3
2	Natural Hydrologic Cycle	Runoff threshold event	2	1	3
		Watershed peakiness	2	1	3
3	Improve Water Quality	Total Suspended Solids (TSS)	2	1	3
4	Reduce impact of runoff on the beach	Instream E.Coli at outfall to Ottawa River	2	1	3
5	Reduce Flooding	Frequency of overtopping of watercourse crossings	2	1	3
		Category A Total (Score x Weighting Factor of 4)	***48***	***24***	***72***
6	Timing to implement	Estimated implementation time for strategy to be operational	2	1	2
7	Degree of Control	Degree of implementation which City has control over	1	3	2
8	Community/User Health and Safety	Risk to community health and safety	3	2	2
9	Public /User Acceptance	Public acceptance	2	3	2
10	Open Space Areas/Parks	Impact on open spaces/parks	4	4	4
		Category B Total (Score x Weighting Factor of 3)	***36***	***39***	***36***
11	Total Annual (Lifecycle) Costs	Relative total cost	4	3	2
		Category C Total (Score x Weighting Factor of 3)	***12***	***9***	***6***
		OVERALL SCORE (Sum of Category Totals)	**96**	**72**	**114**

4.15 Technical Considerations

Hydrologic, hydraulic, and water quality modelling was carried out to assess stream erosion, natural hydrologic cycle, water quality, and flooding under the three alternative retrofit scenarios and for existing conditions. Below is a brief explanation of how the scoring scheme was implemented.

4.15.1 Reduce Erosion Impacts

The analysis of erosion was based on the exceedance probability of peak flows that would cause streambank and stream bed erosion. A long-term continuous model was developed to evaluate the overall flow regime (at the outlet) under the three scenarios and existing conditions.

While all of the three scenarios reduce the risk of erosion, Scenario 3 achieves the highest reduction and thus was assigned a score of 3. This high score is primarily attributed to the significant implementation of lot level control (30%) and conveyance control measures (50% uptake). This helps attenuate events by routing surface runoff from impervious to pervious areas in addition to conveying surface runoff through conveyance control measures which promote infiltration and runoff rate reduction.

Scenario 1 was assigned a score of 2 since it achieves moderate reduction in erosion. Scenario 2 was assigned the minimal degree of erosion reduction with a score of 1.

4.15.2 Natural Hydrologic Cycle

The natural hydrologic cycle was assessed through the evaluation of the water balance within the study area:

$$\textit{Precipitation (mm)} = \textit{Surface Runoff (mm)} + \textit{Infiltration (mm)} + \textit{Evaporation (mm)}$$

The scoring of alternatives was based on assigning higher score to the scenario which achieves higher increase in infiltration and evaporation, therefore mimicking the natural hydrologic cycle.

Scenario 3 was given the highest score (3) for significantly improving natural hydrological processes by increasing infiltration (above 20% increase in infiltration). This increase is primarily attributed to the hydrologic routing within lot level and conveyance control measures proposed within the study area. Scenarios 1 and 2 had moderate to low increase, respectively.

Watershed peakiness, which refers to the flashiness of the watershed hydrograph, was lowest under Scenario 3; therefore assigned a score of 3. $Q_{bankfull}$ estimates were based on the 2-year storm events, and the $Q_{baseflow}$ estimates were based on dry weather flow data. Scenario 2 shows moderate results in regard to reducing watershed peakiness, and Scenario 1 has nominal impact on reducing watershed peakiness.

4.15.3 Improve Water Quality (TSS)

The results of the water quality assessment show that Scenario 3 provides the best results compared to Scenarios 1 and 2. Specifically, the reduction in Total Suspended Solids (TSS) concentrations under Scenario 3 ranged between 20 and 25%, therefore a score of 3 was assigned. This significant decrease in TSS is primarily attributed to the significant reduction in surface runoff volume in addition to the removal efficiencies of lot level control and conveyance control measures within the study area. Scenarios 1 showed a reduction between 15 and 20%, and scenario 2 showed less than 10% reduction; therefore, they were assigned the scores of 2 and 1, respectively.

4.15.4 Reduce Impact of Runoff on the Beach (E.Coli)

The reduction of E.Coli concentrations was highest under Scenario 3 (24% to 30% reduction), with lower reductions under Scenarios 1 and 2. Therefore, a score of 3 was assigned to Scenario 3. This significant decrease in E.Coli is primarily attributed to the significant reduction in surface runoff volume in addition to the removal efficiencies of source control and conveyance control measures within the study area.

4.15.5 Reduce Flooding

An assessment of the overall reduction in surface runoff rate resulting from the 100-year storm event was carried out for the five subwatersheds. The evaluation was primarily based on the overall reduction of the flow rate at the outlet.

The results show that the study area significantly benefits from implementing Scenario 3 (approximately 10% reduction in the peak flow for the 100-year storm event). The reduction in the 100-year surface runoff rate is a result of decreasing surface runoff volume by infiltrating to the ground in addition to attenuating the flows throughout the right of ways using conveyance control measures. Scenario 1 has moderate impact of approximately 6%. Therefore, a score of 3 was assigned to Scenario 1. Scenario 2 had the lowest impact in regard to reducing the 100-year peak flow (less than 3%), therefore a score of 1 was assigned.

4.16 Implementation Considerations

4.16.1 Timing to Implement

This criterion defines the length of time it will take until the strategy is implemented and operational and includes time for approvals, requirement for legislation, policies or by-laws.

Scenario 1 scored 2 as it contains a lot level program which could be implemented with the least requirement for change in homeowner and business behavioral patterns.

Scenario 2 was assigned a score of 1 as this scenario will require longer time to implement conveyance control measures, while Scenario 3 was assigned a score of 2 as this scenario will be a combination of Scenario 1 and 2.

4.16.3 Degree of Control

The degree of control assesses the level of control that the City has over such items as land ownership, public compliance and technical/scientific uncertainty.

Scenario 2 was assigned a score of 3 as the City would have considerable control over the implementation of conveyance measures. Some effort would have to be put into enacting a program to improve homeowner and business owner uptake rates on private property for the lot level measures. Scenarios 1 and 3 were assigned scores of 1 and 2 respectively as the degree of control for the items as noted above are further reduced as levels of lot level and conveyance control increase on non-City owned lands increases.

4.16.4 Community/User Health and Safety

This criterion looks at factors such as the benefit to the community as a result of implementing a group of measures (lot level and conveyance level control). In general, the measures as proposed have a beneficial impact on the community with respect to health and safety. Scenario 1 was scored the highest 3 followed by Scenario 2 and Scenario 3 to be 2.

4.16.5 Public/User Acceptance

Public/User Acceptance includes considerations such as possible lifestyle changes, impact on property values and construction impacts.

Scenario 1 was assigned a score of 2 as this strategy would involve the least change with respect to shift in existing lifestyle patterns and involves the least impact associated with construction. Scenario 2 was assigned a score of 3 as works would take place in the right-of-ways which will impact least and improve the aesthetic view. Scenario 3 was assigned a score of 2 as combination of lot level and conveyance control measures.

4.16.6 Open Space Areas/Parks

This criterion considers factors such as the potential to impact existing uses in conservation lands, open spaces including parks and vacant lots.

The scoring for this strategy is primarily based on the end-of-pipe components and takes into consideration that the potential impacts on existing uses may be adversely impacted by converting park or open space lands to stormwater facilities. Since there is no end-of-pipe facility all Scenarios were assigned the highest score 4.

4.17 Cost Considerations

This criterion defines the total relative cost for each scenario based on total annual capital and operation and maintenance costs including construction land and operation and maintenance costs.

Scenario 1 was assigned a score of 4 as this is the least cost scenario while Scenario 2 was assigned a score of 3 and Scenario 3 a score of 2.

4.18 Summary of Results

An analysis of the implementation of three stormwater management retrofit opportunities within the Eastern Subwatersheds study area was completed. The analysis consisted of the identification, selection, and evaluation of a number of possible implementation scenarios. The following three (3) SWM retrofit scenarios, consisting of a combination of lot level and conveyance control measures, were considered:

(1) *Scenario 1 – Lot level 30% uptake*
(2) *Scenario 2 – Conveyance 50% uptake*
(3) *Scenario 3 – Lot level 30% uptake and conveyance 50% uptake.*

Each scenario was evaluated on criteria relating to technical, implementation, and cost considerations. Based on the scoring and ranking of the three scenarios, Scenario 3 was determined to be the preferred alternative, having a score of 114 points. Scenarios 1 and 2 had scores of 96 points and 72 points, respectively. Therefore, Scenario 2 was the least desirable alternative. Therefore Scenario 3 was selected as the preferred scenario.

5 RECOMMENDED SWM RETROFIT PLAN

The majority of the streets within the Eastern Subwatersheds contain underground infrastructure that is in relatively good condition. Some of the oldest infrastructure in the study area was constructed in the early 1960s. Therefore, widespread road re-construction is not expected to be required in the study area until beyond 2060. Resurfacing projects will come on line earlier than 2060, however, retrofits in these instances have higher incremental costs. For this reason, initial efforts will focus on moving forward with lot level controls.

Table 5-1: Summary of Total Cost for SWM Retrofit Scenario

Scenario	Lot Level 30% Control	Conveyance 50% Control	Stream Restoration and Erosion Sites	Total Cost
	($M)	($M)	($M)	($M)
Retrofit Scenario	12.8	194.4	13.7	**221.3**

6 PUBLIC CONSULTATION

A public consultation plan was developed to meet the following objectives:

- Meet the requirements of the Municipal Class EA approach #1 for Master Plans
- Meet the requirements of the City's Public Participation Policy
- Meet the applicable requirements under the Accessibility for Ontarians with Disabilities Act (2005)
- Inform and gain feedback from the public and other potentially affected parties

A virtual Open House was initiated and presented in 2013 through the City of Ottawa website. This was an introductory session and included narrated slideshows of open house materials (may include photos or video sections of areas within study area) and a comment area for receiving public feedback and questions. A copy of the Public Information Center presentation is in Appendix G.

A second open house was conducted in June of 2014 as part of the Environmental Round Table session. The results of the existing condition report and the evaluation of three preliminary retrofit strategies.

A third open house was held in 2018 to present the recommendations from the Retrofit Study. No comments were received form the public or from any Community Associations located within the study area.

7 IMPLEMENTATION PLAN

7.1 Lot Level Controls

The following sections describe how a Lot level stormwater control program can be implemented for the Eastern Subwatersheds. Both publicly and privately-owned lands are included in the program.

7.1.1 Community Engagement Plan

Securing lot level control of stormwater and pollution prevention within the Eastern Subwatersheds requires the participation of private property owners in the residential sector. To support landowners implementing stormwater mitigation measures a Community Engagement Plan tailored specifically to the opportunities and constraints of the community is required.

A successful Community Engagement Plan considers two primary strategies to drive uptake of lot level measures by private property owners, specifically:

1. The creation of drivers for lot level actions by private landowners;
2. The strategic engagement of the marketplace to drive uptake of lot level actions by property owners and builders/developers.

This section of the report outlines the objectives of a Community Engagement Plan for residential areas of the Eastern Subwatersheds, as well as the stages, activities and costs.

7.1.2 Marketing Lot Level Stormwater Control Measures to the Community

Whether public outreach is education or incentive-based, low participation is a common challenge. Securing significant uptake of lot level measures requires an understanding of the community and an effective message. Municipalities across Ontario have found that despite promising initial uptake and steady funding, the number of residents implementing lot level measures plateaus after the first few years of municipal implementation programs. This is largely due to the way municipal professionals (engineers, planners, etc.) are marketing these stormwater controls to the public. Municipalities often use technical information to encourage residential uptake of measures like disconnecting downspouts, installing rain barrels and other LID (Low Impact development) practices. Market research shows that people respond better to material that inspires desires or wants rather than presenting an informed argument. Market research provides an understanding of desires, perceptions, and drivers (Credit Valley Conservation (CVC), 2015). This research is used to create a Community Engagement Plan and deliver an effective outreach program that will drive maximum residential uptake.

Municipalities that have implemented Community Engagement Plans founded on community-based market research for securing the uptake of lot level measures have generally been more successful. Examples of these programs in Ontario include the Fusion Landscaping® programs implemented in the Region of Peel and Region of Durham.

7.1.3 Initial Program (Years 1–5)

Years 1 through 5 of a Community Engagement Plan for lot level stormwater control measures are crucial to setting the tone within the community and ensuring long-term project targets will be reached. To reach the recommended level (30%) of residential uptake within the Eastern Subwatersheds study area, several key steps will need to be taken. These steps are:

- Building the project team
- Determining which Lot Level measures are appropriate
- Identifying targets and program benchmarks
- Completing market research
- Identifying strategic partnerships
- Creating a marketing plan
- Project costs

7.1.4 Building the Project Team

When building a project team, it is important to consider the interdisciplinary nature of a residential stormwater program and the roles project management and municipal staff may need to fill. The Community Engagement Plan may involve engineering, planning, marketing, communications (internal and external with residents), landscaping, operations and maintenance, and other tasks. Ensure that municipal departments capable of filling these roles are included on the project team.

A Community Liaison Committee (CLC) is recommended to provide regular input and feedback from a community perspective to the project team. At the first CLC meeting, members should review program goals and objectives. It is recommended that the CLC be comprised of community advocates, landscape related businesses, local environmental groups, the local conservation authority and key influencers within the community. The CLC should have good community representation to build support for neighbourhood-based initiatives.

7.1.5 Determining Which Lot Level Measures are Appropriate

Lot level measures previously identified include:

- Disconnection/redirection of Roof Leader
- Rain Gardens (and Enhanced Yard Vegetation)
- Bioretention Areas
- Reduced Lot Grading
- Permeable Driveways
- Soakaway Pits / Infiltration Trenches
- Oil Grit Separators
- Green Roof Technology

While all the above measures will provide stormwater benefits, there are different approaches associated with fostering implementation within the community. The residential marketing strategy should focus on those measures that provide green or garden-like landscape features or can be designed to provide an enhanced landscape aesthetic. Rain gardens, bioretention areas and the disconnection of roof leaders (to surface features) are easily implementable on most residential properties and can be marketed as aesthetic improvements that residents can be proud of.

Permeable driveways (and permeable parking lots), soakaway pits and infiltration trenches, oil grit separators, and green roof technology do not have the benefit of being as widely implementable by residents nor do they provide as much of an aesthetic improvement. Targeting specific property types such as commercial, institutional and multi-residential is a better option for these measures. Field reconnaissance should be conducted to determine property specific opportunities for these measures within the study area.

At this stage, a review of existing municipal by-laws is important. Some lot level stormwater control options do not conform to conventional design standards. By-laws that set standards for drainage, grading and landscaping may impact implementation of measures that relay on the detention and infiltration of stormwater. Amendments, special policies, or pilot project designations may be required to overcome these constraints.

7.1.6 Identifying Targets and Program Benchmarks

The target for the Community Engagement Plan is a 30% long-term uptake rate within the study area. Additional benchmarks should be developed for this target in consultation with the CLC. Benchmarks may include:

- Specific neighbourhood uptake targets in priority areas;
- Retrofit of widely used public facilities (e.g. community centres, schools, recreation centres, places of worship, etc.) to be used a demonstration sites within a specific time from project initiation; and
- Annual targets or target trends for uptake.

Monitoring of project success through the achievement of benchmarks will require a tracking system. Ideally this will be integrated with the City's GIS network to provide both temporal and spatial analysis of uptake as well as tracking of community interest throughput the duration of the program.

7.1.7 Market Research

To develop a successful Community Engagement Plan, market research is essential. There are two kinds of market research. These are:

1. Secondary Research
2. Primary Research

Secondary research draws on the experience of other municipalities. Where possible, Community Engagement Plans from external project areas with similar demographics can be used to guide research within the Eastern Subwatersheds study area. Examples from Ontario that may be relevant include the following community engagement projects for lot level stormwater control measures:

- The **Region of Peel** has implemented a **Fusion Landscaping®** program for lower tier municipalities to promote water efficient gardening practices.
- **Credit Valley Conservation** and the **Town of Caledon** are promoting LID practices in the neighbourhood of Alton Village via unique community-based marketing strategies.
- **REEP Green Solutions** has partnered with the **City of Kitchener** to run a home visit program called **RAIN** for homeowners interested in residential retrofits.

- **RainScaping** has provided expertise and experience to Lake Simcoe Region Conservation Authority's LID program.

Primary research with residents and community service providers offers the best and most accurate data about the community and is the methodology recommended within the Eastern Subwatersheds study area. Primary research should be done with focused research sessions on representative community sample groups. Information on selective representative sample groups can be found in CVC's Low Impact Development Residential Retrofits: Engaging Residents to Adopt Low Impact Development on their Properties. Primary market research should be conducted through a marketing consultant with expertise in these studies. The results of the research session should help to:

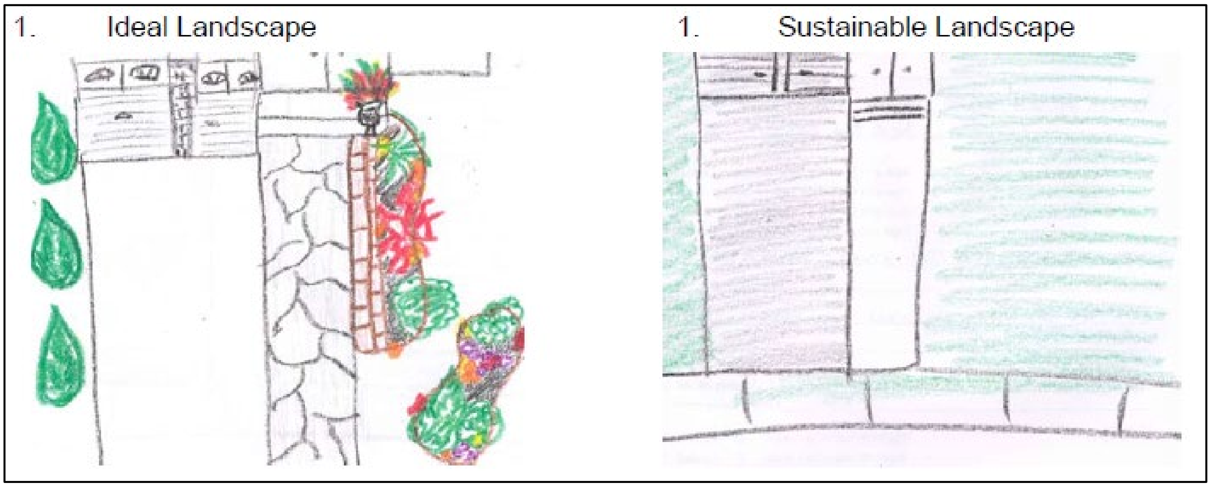
- Uncover homeowners' fundamental motivations regarding their property;
- Understand residents' perceptions of lot-level stormwater control measures;
- Identify images and messages pertaining to lot level stormwater that resonate with homeowners;
- Identify key stakeholders that directly influence the practices and attitudes of homeowners;
- Identify potential barriers towards the application of lot level stormwater control measures on a homeowner's property; and
- Determine the preferred lot-level stormwater control measures for residential properties based on resident perceptions.

A marketing consultant may provide dozens of questions to get a feel for the community. A few examples of questions that can generate valuable responses include, but are not limited to:

Q1) What is the most important aspect of your home's landscape?
Q2) Who designed your home's landscape?
Q3) Where do you purchase flowers, trees and shrubs?
Q4) What is a rain garden?
Q5) Name a plant that is native to Ontario
Q6) Where does water collected in the storm sewer go?

A marketing consultant may also ask the sample group to draw landscape concepts to help understand property improvement motivations and constraints. Figure 7.1 shows pictures drawn for a Residential Market Research Study that was undertaken as part of the City of Mississauga's Water Quality Strategy (Freeman and Associates, 2008). A total of 68 respondents participated in this study. Of these respondents 46% had less colour and fewer landscape features in their "Ideal" landscapes when compared to their "Sustainable" landscapes, 41% showed no change, and 13% had more natural features in their "Ideal" landscapes.

Figure 7.1: "Ideal" and "Sustainable" Landscape from a City of Mississauga Resident.



A marketing consultant may also ask the sample group to rate or rank photos of landscape features. Figure 7.2 shows photos that were presented as part of the City of Mississauga's Residential Market Research Study and their associated mean score, out of ten (Freeman and Associates, 2008).

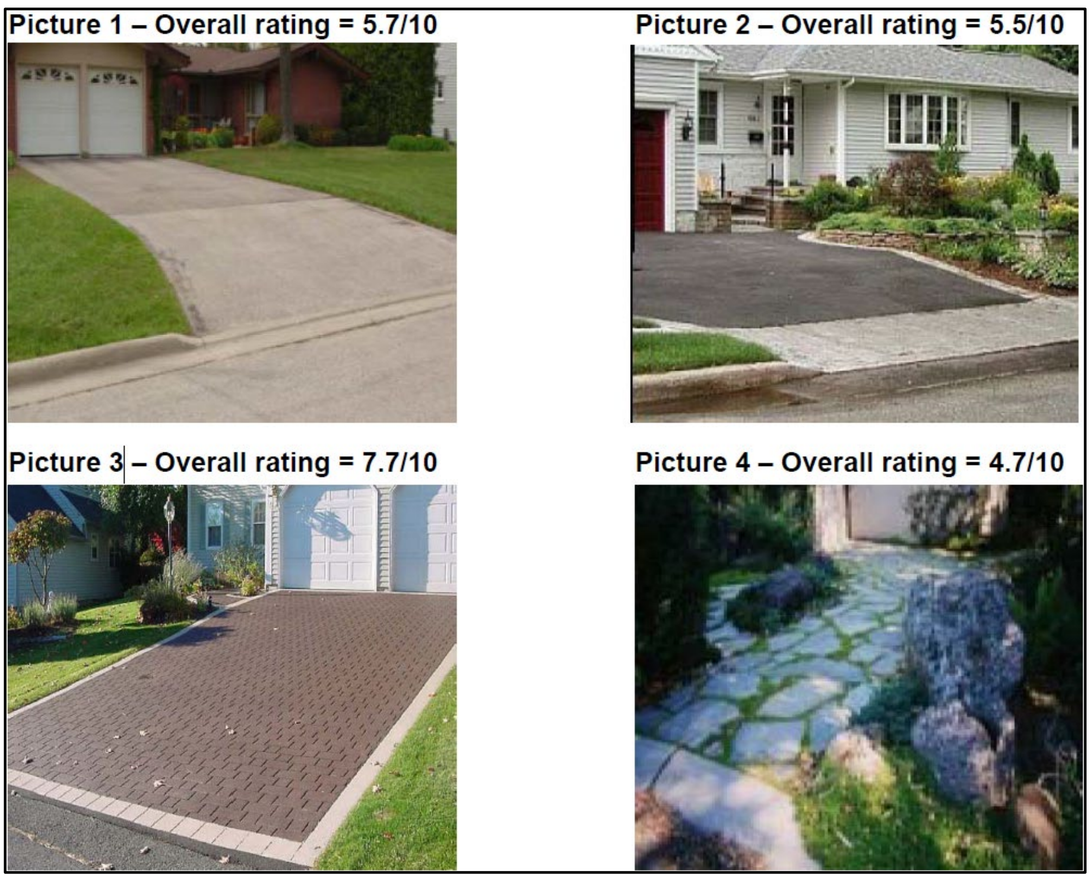


Figure 7.2: Driveway preferences from Residential Market Research Study in the City of Mississauga

7.1.8 Identifying Strategic Partnerships

Partnerships with community retailers and service providers such as landscape contractors is important for maximizing community engagement. These project partners can provide valuable insight about the community. Bringing established community retailers and service providers onboard will help promote the use of lot level stormwater control measures because of the trust and relationships they have already built in the targeted community. It is essential to consider incentives for these partners when attempting to bring these potential partners onboard.

7.1.9 Creating a Marketing Plan

Marketing plans typically include multiple components to reach as many people across the community as possible. Marketing plans should build upon the information gathered via primary and secondary market research. There are many ways to promote landscape improvements that result in stormwater benefits. These marketing options include print advertising, digital advertising, demonstration sites, displays at retail stores, and establishing partnerships with local garden centres and nurseries for staff to speak confidently about lot level stormwater control measures such as rain gardens and enhanced yard vegetation. Options that should be considered within the Eastern Subwatersheds Study Area include:

A. Hosting Special Community Events

Open house events can be useful in launching the program and creating initial community interest. An approach that has worked in the Village of Alton is an "Ask a Designer Night". These events bring together interested homeowners, municipal program managers and landscape designers. Each home owner in attendance has the opportunity to show the designer photos of their property and receive advice tailored to their home landscape. During the City of Mississauga's Residential Market Research Study, 93% of respondent homeowners expressed interest in using a landscape advisory service if it was made available to them at no-charge (Freeman and Associates, 2008). Other community events that can provide interaction between the project team, expert advisors and the public include community BBQs and festivals.

B. A Tour of Demonstration Sites

Once demonstration sites have been established on public properties or on properties of early adopters, a tour is a good way to show off the aesthetic benefits of lot level stormwater control measures. Depending on the geographic spread of these sites and the neighbourhood demographics, a tour could be conducted by bus, bike or on foot.

C. Signage Within the Community

Community signage is easy to overlook if not designed and sited properly. Signs should avoid technical jargon and focus on simple visual concepts that resonate with homeowners. Figure 7.3 shows a sign used for the Region of Peel's Fusion Landscaping® program. Simple interpretive signage can also be incorporated into demonstration sites in heavily used public areas. The City of Ottawa has already incorporated interpretive signage along Pinecrest Creek and the Ottawa River to educate the public in stormwater management issues.

Photo 33: A Homeowner Receiving Advice from A Landscape Designer at the Ask A Designer Night in Alton Village (CVC, 2015)

Figure 7.3: Signage used by the Region of Peel to market their Fusion Landscaping® program (Region of Peel).

D. Resource Materials

Resource materials can answer questions homeowners have about the program but can also be used as reference material for design purposes. These resources typically work best after the community interest has been established through other marketing tools. It is important to continue to use the highly aesthetic imagery in these resources and not make them too technical for the average homeowner to understand. Useful examples of resource materials include the **Region of Durham's Fusion Landscape® Guide for Homeowners** and the **TRCA's Greening Your Grounds: A Homeowners Guide to Stormwater Landscaping Projects**.

Figure 7.4: Region of Durham's Fusion Landscape® Guide for Homeowners

Figure 7.5: TRCA's Greening Your Grounds: A Homeowners Guide to Stormwater Landscaping Projects

7.1.10 Project Costs

The cost of individual marketing components will vary dramatically depending on the scope and duration of the Community Engagement Plan. A Community Engagement Plan may require up to $1,000,000 for a study area of this size. This budget would allow for a robust Community Engagement Plan using several marketing tools. Cost ranges for individual Community Engagement Plan components are provided in Table 7-1.

Table 7-1: Marketing Component Costs

Activity	Marketing Components	Cost Considerations	Estimated Cost for 2-year Program
Development of a marketing plan	Qualitative research	• in-person research session: $10,000 per session • $100 per participant recruitment costs • Report >$10,000	$24,000 - $60,000
	Marketing plan		$15,000 - $50,000
Potential Marketing plan components	Social media campaign	• $2,500 - $50,000 per month	$60,000 - $1,200,000
	Outdoor signage	• Bus exterior - $150-$8,500 • Shelter- $150-$2,500 • Bench - $75-$500 • Bus interior - $20-$125 Billboard - $700- • $2,500 • (4-week period)	$6,000 - $95,000
	Print advertising	• Local paper: • $250-$1,000/quarter page • $500-$2,500/full-page	$6,000 - $36,000
	Web site		$10,000 - $150,000
	Creative	• Total cost depends upon municipality's internal communication resources	$0 - $250,000
	Special events	• $250 - $25,000 per event	$1,000 - $50,000
	Demonstration sites	• $5,000 to $30,000 per site	$5,000 - $375,000
	Incentives and rebates		$25,000 - $1,000,000
Program Benchmarking And tracking	Quantitative survey (telephone, email, on-line). For tracking purposes only and dependent on size of survey.		$10,000 - $100,000

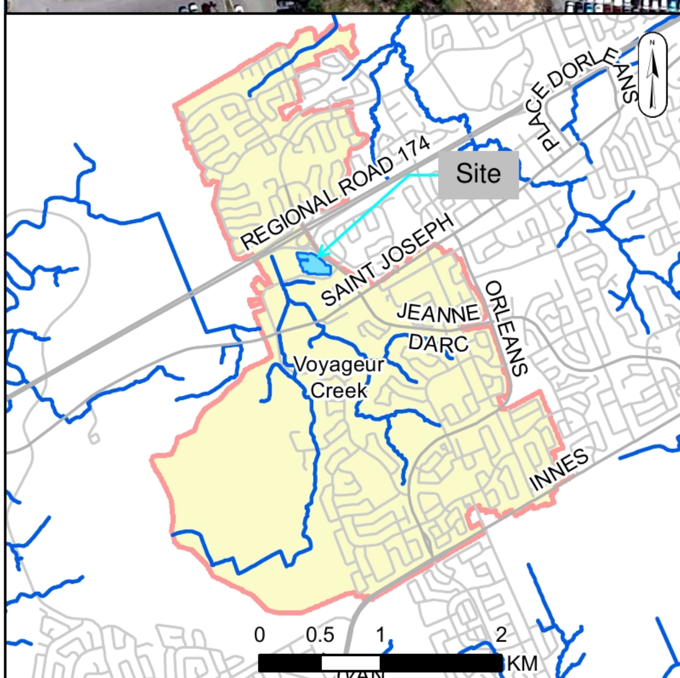
Source: Freeman and Associates, 2008 – Updated for CVC, 2015

7.1.11 Long-Term Program (Years 6+)

To maintain residential uptake for the long-term, it is essential to create market transformation within the community during the initial years of the project. This involves imbedding the use of lot level stormwater control measures as standard practices for landscape projects. To do this the project team must build on community partnerships with product suppliers and landscape professionals. A market-based approach uses the marketplace as delivery agent for landscape-based stormwater initiatives with the ultimate goal of generating transformative, sustained change. Market transformation is a strategic process of market intervention that focuses on removing constraints and leveraging opportunities to internalize cost effective lot level stormwater control measures to the degree they become standard procedure in the marketplace. A market-based approach requires more effort and larger investments upfront versus broad-based programs. Over the longer-term, market forces take over and costs inputs decline. Drivers of a market-based approach include grants, financing and subsidy programs, promotional initiatives, and homeowner recognition and award programs.

7.1.12 Public (City Owned) Lands

The City of Ottawa compiled an inventory of all City-owned properties within the Eastern Subwatersheds. The City of Ottawa has a five-year rehabilitation plan, updated annually. Specific lot level controls will be planned and implemented as part of the facilities rehabilitation works.



Entrance of Bob Macquarrie Recreation Complex
(Source: Google Map)

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Legend

- Roads
- Watercourse
- Storm sewer
- Greenspace
- Catchment Area
- Site

Eastern Subwatersheds Stormwater Management Retrofit Study

Bob Macquarrie Recreation Complex 1490 Youville Drive

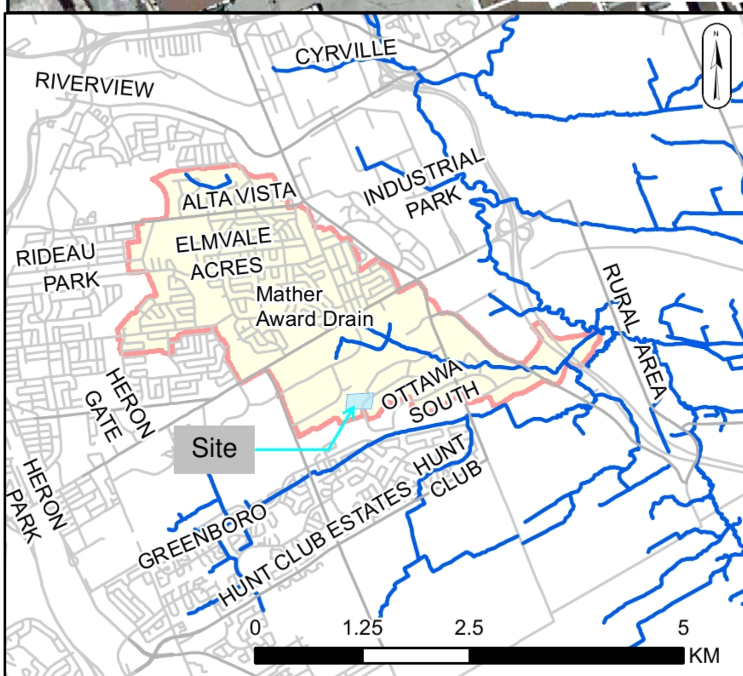
Morrison Hershfield

Aquafor Beech Limited

Figure 7.6

Scale Varies

August, 2018 | **Project No. 2124041**



Entrance of 2799 Swansea Crescent,
(Source: Google Map)

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Ottawa

Legend

- Roads
- Watercourse
- Storm sewer
- Greenspace
- Catchment Area
- Site

Eastern Subwatersheds Stormwater Management Retrofit Study

Charles Sim Municipal Workshop
2799 Swansea Crescent

Morrison Hershfield
Aquafor Beech Limited

Figure 7.7

Scale Varies

August, 2018 | **Project No. 2124041**

7.2 Conveyance Controls

The following section describes the implementation for conveyance control measures. This refers to projects planned in municipal right-of-way designed to treat stormwater as it travels overland or through storm sewers to the downstream outlet.

Conveyance control measures include the types of projects described in the following sections:

7.2.1 Bioretention / Bioswales:

Along municipal roads, bioretention areas can be placed at the edge of paved areas, either between the curb and sidewalk, or extending into the road in the approximate area of one parking spot. These 'low-tech' water quality treatment systems use plants and soil to trap and treat petroleum products, metals, nutrients, sediments and other pollutants that typically accumulate on asphalt surfaces.

Photo 34: Bioretention Unit During Construction

Photo 35: Completed Bioretention Unit in the Road Boulevard

Photo 36: Bioretention Unit Along the Road

Photo 37: Bioretention Unit in a Cul-de-Sac

7.2.2 Exfiltration Trench / Perforated Pipe System:

An exfiltration trench / perforated pipe system can be constructed adjacent to a road in the grassed area between the curb and the sidewalk. These systems promote infiltration of road drainage as it is conveyed along road right-of-ways. Road drainage is first directed to the grassed surface where pollutants such as sediment, oil, grease, or grit, are filtered prior to entering the trench. After water has percolated through the gravels and pollutants have been removed, the water can then either infiltrate into the native soils or if the volume and rate of incoming water exceeds the infiltrative capacity it is conveyed to a local stormwater drain system.

Photo 38: Exfiltration Trench / Perforated Pipe System During Construction

Photo 39: Exfiltration Trench / Perforated Pipe System After Construction

7.2.3 Grass Swales

Linear channels lined with grass and designed to promote shallow flow conditions. Grassed swales improve water quality through the trapping of sediment. Improvement in water quality is directly correlated to sediment trapping since contaminants typically adhere to or form part of the sediment. Dissolved contaminants, such as salt, are not treated by grassed swales.

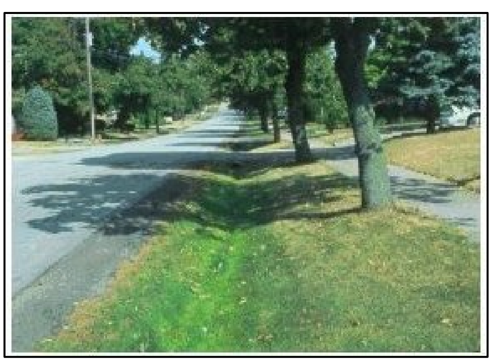


Photo 40: Grassed Swales Infiltrate Stormwater and Improve Water Quality

7.2.4 Pervious Catch Basins:

This technique involves a standard catch basin with a large sump which is physically connected to exfiltration storage media to make the walls or bottom of the catch basin pervious.

7.2.5 Permeable Pavement:

Permeable pavement allows rain to pass through, collecting in the void space of the base course and ultimately draining away by natural infiltration. The City of Ottawa has deemed permeable pavers as an inappropriate measure for public rights of way, although it may be applied in individual lots in parking areas.

Photo 41: Permeable Pavement Use within the Municipal Right Of Way

7.2.6 Implementation of Conveyance Control

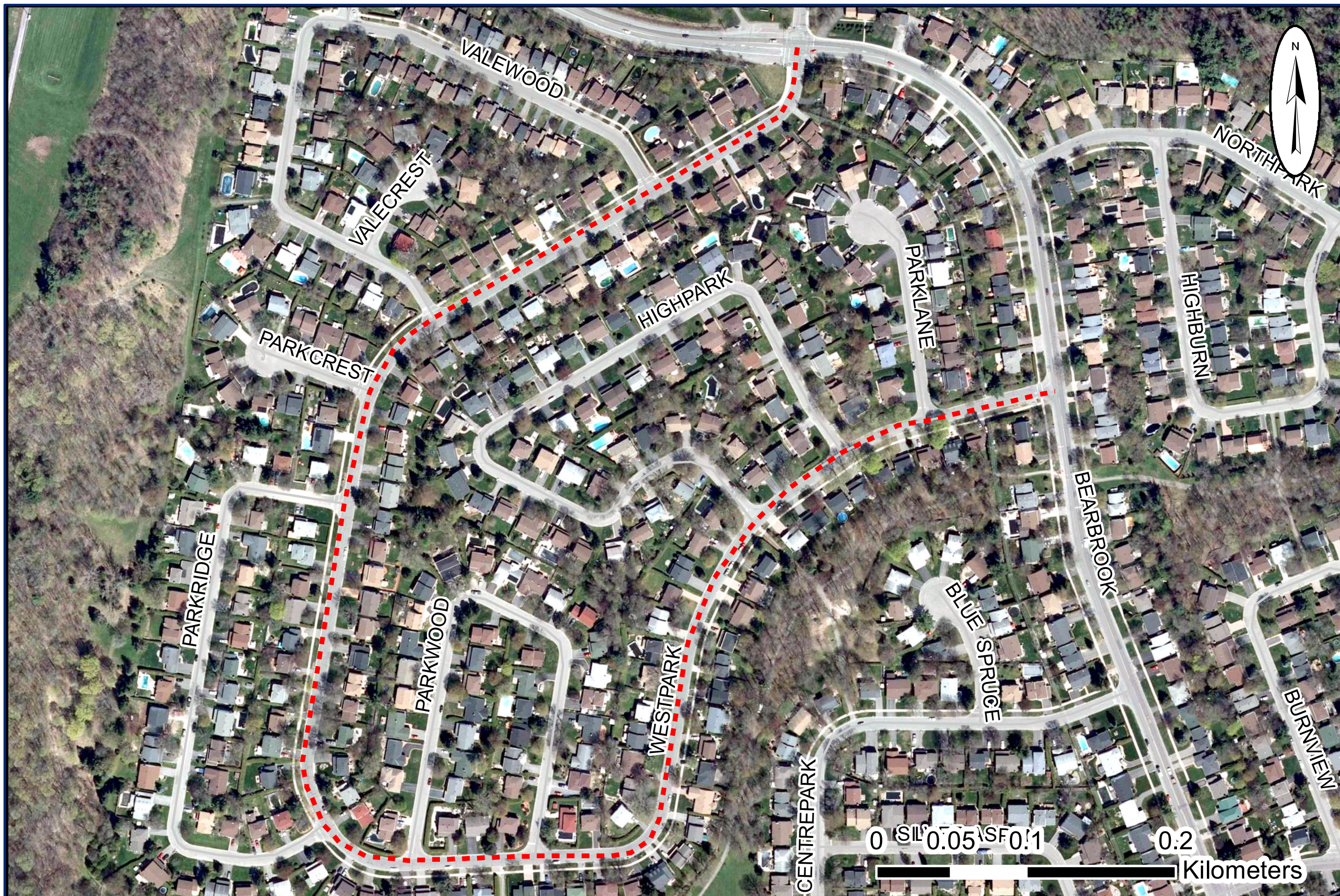
The City of Ottawa is in the process of completing three different pilot projects that include conveyance controls in municipal right-of-ways. The selection of particular streets for application of conveyance control depends on criteria, such as soil conditions, hydrology, utility locations, planned future works such as traffic calming, cycle tracks, and street greening, as well as parking restrictions. The City is in the process of developing a project screening tool to assist in the selection of potential applications of conveyance control.

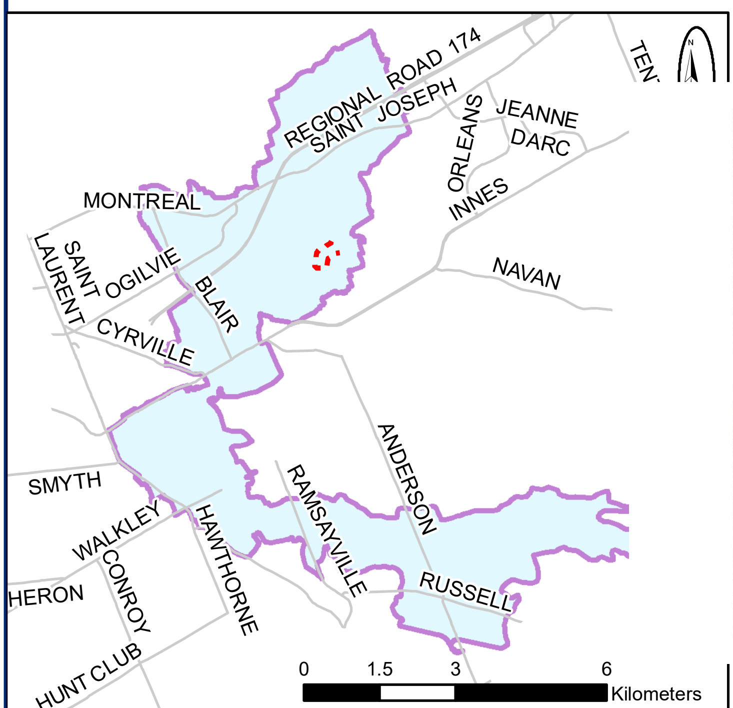
The Stewart Street pilot project is an example of the application of conveyance control. The project consisted of initially identifying the roadway contained a redundant traffic through lane. The design process involved the development of design concepts to the project team, consisting of staff responsible for the asset management, operations, planning and design functions. The project involved the combination of improvement of a cycle route as well as the narrowing of the roadway to create space for proposed bio-retention swales, or rain gardens.

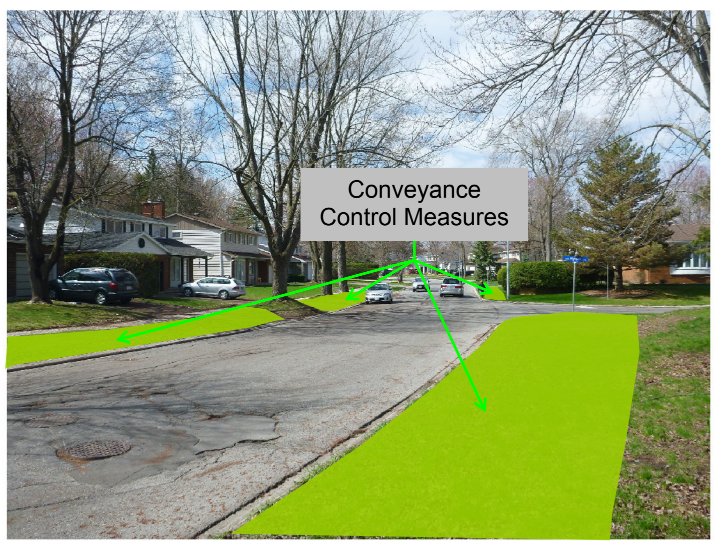
Once conceptual designs were reviewed with the development of a recommended option, the preliminary design for the preferred option progressed. This included the design of the bio media, establishing the stormwater management design criteria, examining details such as the impact of driveways, protection of trees, soil conditions and the application of sub-drains.

It is expected that this design process for conveyance control will be integrated into the normal design and construction process for road rehabilitation, traffic calming, and roadway improvement projects. The implementation of conveyance control in roadway design is consistent with the policy of the City of Ottawa to implement “Complete Street” design that accommodates all requirements.

Figure 7.8 and Figure 7.9 illustrate examples of conveyance control within different types of roadways within City rights of way.







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Ottawa

Legend

Repaving 2018-2021

Roads

Eastern Subwatersheds Stormwater Management Retrofit Study

Westpark Drive (Local) Conveyance Control Measure

Morrison Hershfield

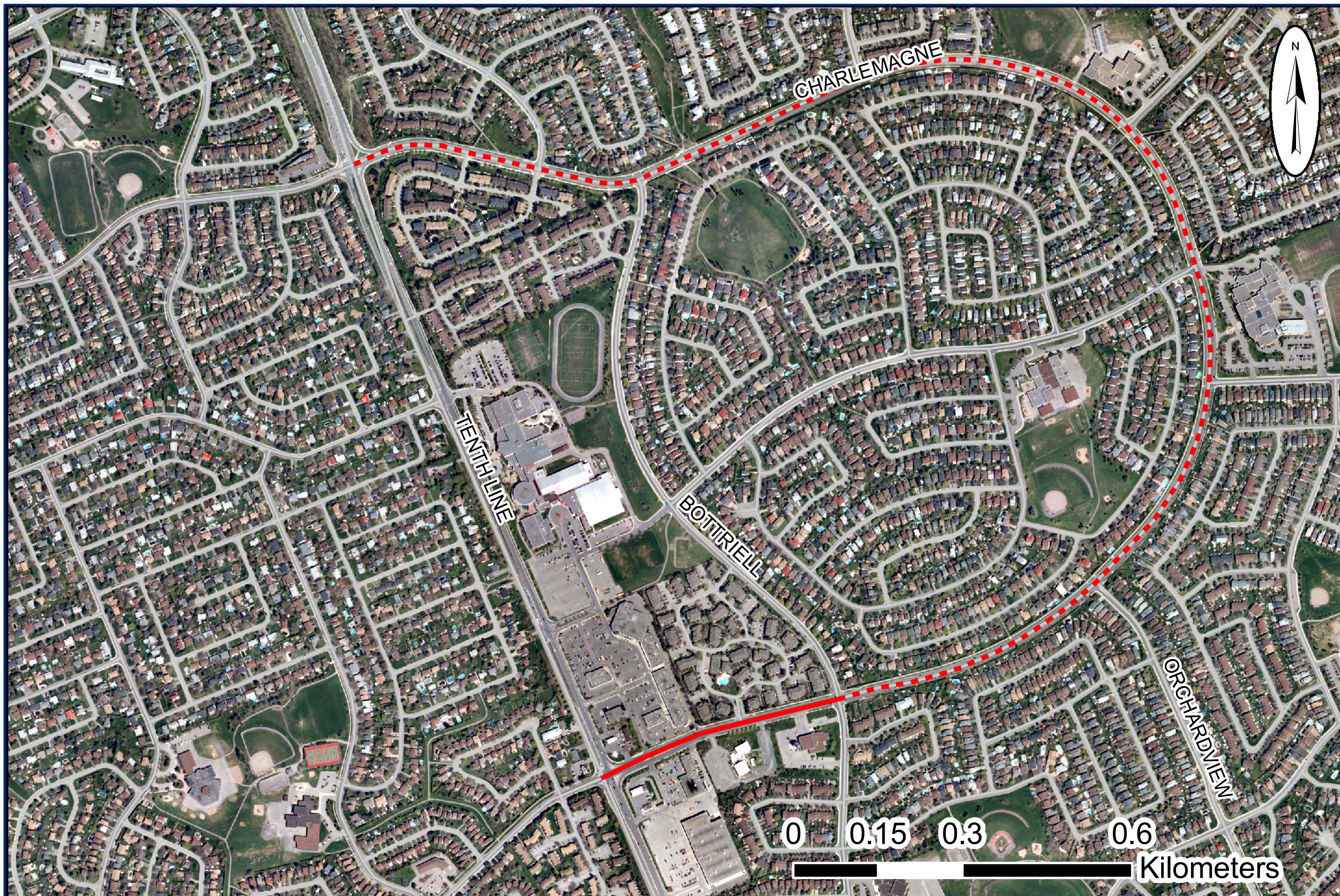
Aquafor Beech Limited

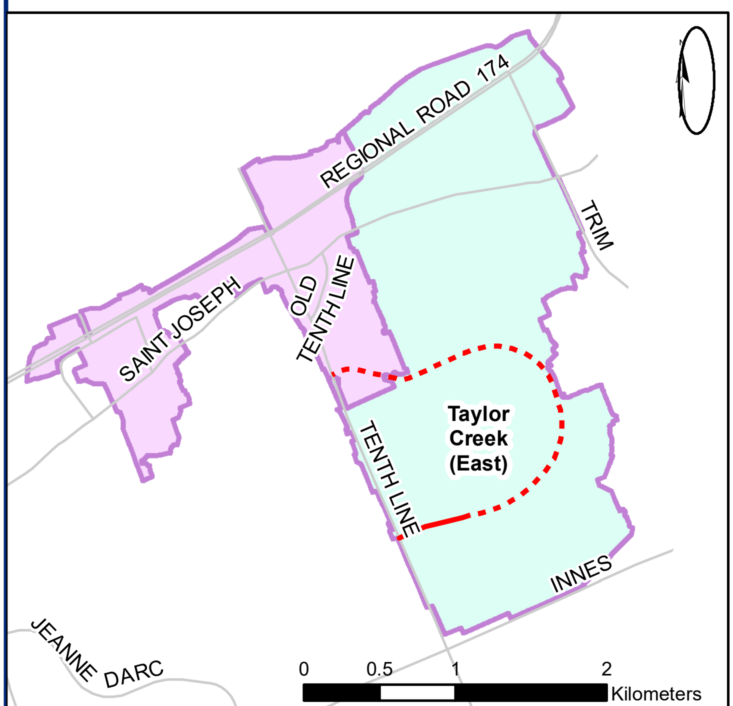
Figure 7.8

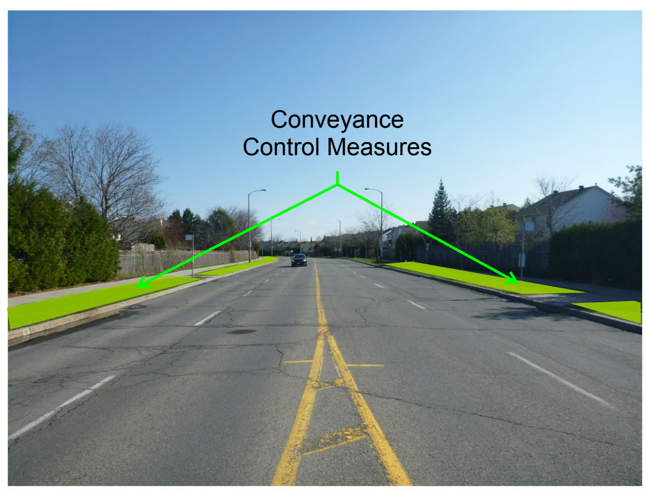
Scale varies

August, 2018

Project No. 2124041







Legend

- Repaving 2017
- Repaving 2018-2021
- Roads

Eastern Subwatersheds Stormwater Management Retrofit Study

Charlemagne Boulevard (Major Collector) Conveyance Control Measure

Morrison Hershfield

Aquafor Beech Limited

Figure 7.9

Scale varies

August, 2018

Project No. 2124041

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8 CONCLUSIONS

The City of Ottawa initiated a Stormwater Management Retrofit Study of the Eastern Subwatersheds in response to recommendations from the Ottawa River Action Plan. The objective of the study was to determine an optimum strategy for implementing stormwater management for water quality and quantity control in areas that had historically been developed without stormwater controls. The implementation of stormwater management measures in this situation is called stormwater management retrofit.

The study involved the development of PCSWMM hydrology and HEC-RAS hydraulic models of the subwatersheds and evaluating alternative strategies for lot-level controls, conveyance type controls and end-of-pipe facilities. Initially, three alternative retrofit strategies were evaluated in terms of their effectiveness in meeting water quality and quantity control targets. Further review of these alternative retrofit options was undertaken, and the retrofit scenarios were adjusted to preclude end-of pipe facilities. The carried out retrofit alternatives are summarized as follows:

(1) Lot Level Implementation: A 30% uptake of lot level measures

(2) Conveyance Implementation: A 50% implementation of conveyance measures

(3) Lot Level and Conveyance Implementation: A 30% uptake of lot level measures and 50% conveyance measures

The evaluation of the three alternative strategies revealed that option (3) is the most preferred option.

The study further evaluated the implementation of the stormwater management retrofit scenario and determined that end-of-pipe facilities could not be practically implemented due to a multitude of constraints and a lack of benefit when evaluated individually. Secondly, it was determined that conveyance controls can only be implemented economically when it is combined with integrated road reconstruction – where the underground utilities need to be rehabilitated or replaced at the same time as the road. The study area of the Eastern Subwatersheds has few opportunities where underground infrastructure requires rehabilitation or replacement in the short term. Therefore, the recommended conveyance controls can only be implemented practically and cost effectively in the longer term.

Lot-level controls, given the fact that individual properties cover the majority of the urban areas, can offer the most significant benefit. Programs to encourage lot-level controls both on private and publicly owned properties will be the focus of the retrofit program over the immediate term.

9 RECOMMENDATIONS

Stormwater Management retrofit in the Eastern Subwatersheds is recommended to improve water quality in the Ottawa River, reduce erosion and maintain and enhance aquatic habitat in the natural watercourses throughout the urban areas.

The most effective approach to stormwater management retrofit is to implement a lot-level control program to achieve a 30% adoption of LID overall in the long-term (50 years). This can be accomplished through a public marketing program and the retrofit of Low Impact Development (LID) in City owned properties. An investment level of $12.8M is recommended for this initiative. New development will be required to provide on-site control controls to achieve 80% TSS reduction and meet any other stormwater management criteria determined in consultation with the City of Ottawa.

Conveyance controls are recommended to be applied in combination with the integrated road reconstruction/rehabilitation program. The ultimate goal of the conveyance control program would be to achieve an adoption rate of 50% in the long-term (50 years). This will require an investment of $194.4M.

Stream restoration is recommended to be implemented in the natural watercourses which have experienced significant erosion. This includes reaches in Bilberry Creek, the upper reaches of Voyageur Creek and Taylor Creek. It is recommended to invest $13.7M over the long-term (50 years) in stream restoration projects.