Town of Oakville
Stormwater Management Master Plan

Project # TP115045 l Town of Oakville

Prepared for:

Town of Oakville

1225 Trafalgar Road, Oakville, Ontario L6H 0H3

November 13, 2019

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Final Report
Project # TP115045 l Town of Oakville

Prepared for:

Town of Oakville
1225 Trafalgar Road, Oakville, Ontario L6H 0H3

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1.0 Introduction

Town of Oakville is located in Halton Region in Southern Ontario, northwest of Lake Ontario. It is a part of the Greater Toronto Area and has a population of over 180,000 as of the 2011 census.

The focus area for the Stormwater Management Master Plan is located in the areas of the town, south of the Queen Elizabeth Way (QEW) Highway, between Winston Churchill Blvd. on east, Burloak Drive on west, and Lake Ontario to the south. This study area was selected by town staff primarily due to the age of the infrastructure in the area (greater than 50 years old), and based upon the knowledge that limited stormwater management practices were historically employed within this area. The focus area is presented in Figure 1.1.1.

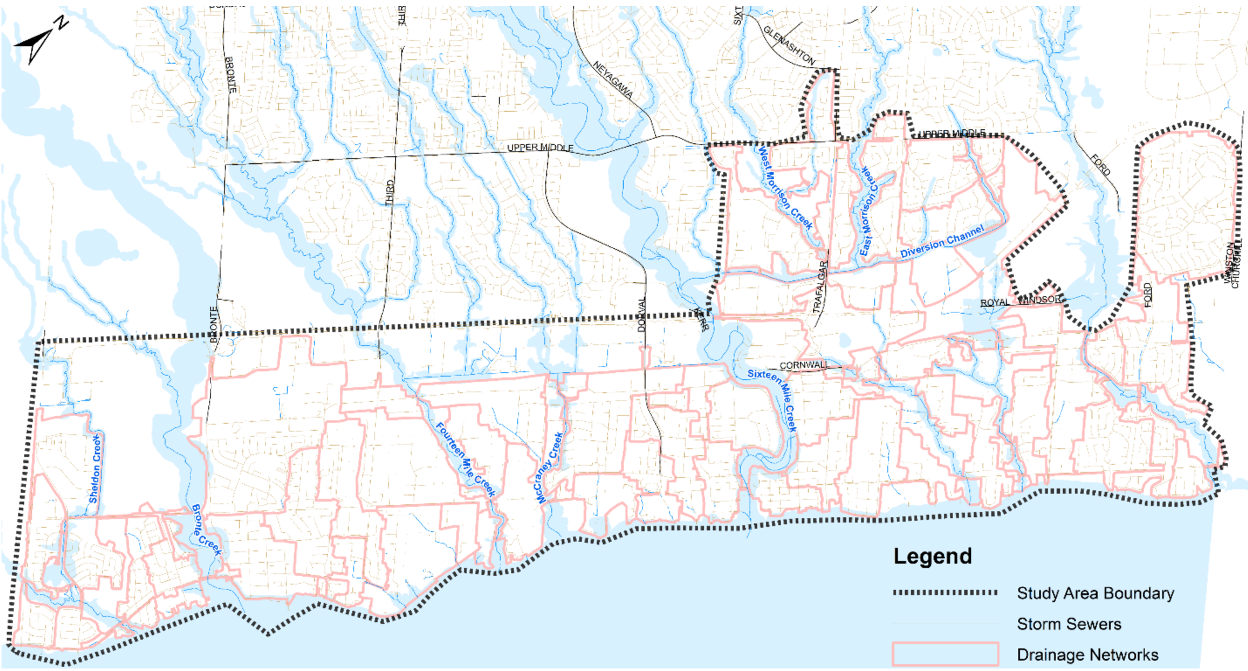

Figure 1.1.1: Focus Area Location Plan

In recent years, many southern Ontario urban centres have been impacted by extreme storm events (north Toronto 2005, Hamilton 2009, West Toronto 2013, Burlington 2014, and many more), leading to considerable flood and erosion damage. These events (speculated by many to be a result of climate change), along with a need to better manage municipal resources, have led to the Town of Oakville initiating the preparation of this Phase 2 and 3 Stormwater Management Master Plan (SWM Master Plan) as a follow-up to the Phase 1 Storm Sewer Master Plan (SSMP), (ref. Storm Sewer Master Plan Phase 1 Final Report, AMEC, February 2015).

Town Council and Senior Management have recognized the importance of developing and implementing capital programs to address the Town's infrastructure needs in a coordinated and effective manner. In the absence of an integrated and balanced SWM Master Plan, Town staff would struggle to meet the drainage needs of residents and businesses.

This next phase of the SWM Master Plan has been prepared using Approach #2 of the Municipal Engineers Association (MEA) Class Environmental Assessment (Class EA) procedures as outlined in the 2000 MEA Documentation (including the 2007, 2011, and 2015 Updates), which addresses Phases 1 and 2 of the Class EA process.

1.1 Study Objectives

As noted, this Study constitutes the second phase of the Town's Stormwater Management Master Plan. The focus of the Stormwater Management Master Plan is on the areas of the Town located south of the Queen Elizabeth Way Highway, between Winston Churchill Blvd. on east and Burloak Drive on west.

The Town's Stormwater Management Master Plan has been completed over multiple phases, "generally" laid out as:

- Phase 1: Data collection and structural needs assessment
- Phase 2: Detailed modelling and assessment, development of service level criteria/indicators allowing for evidence based project development and prioritization
- Phase 3: Development and assessment of funding strategies to support the delivery of recommended stormwater service improvement projects

In 2015, the Town completed the initial Study (Phase 1) of the Stormwater Management Master Plan focused on data collection, data gap filling, and establishing a preliminary "high level" interpretation of storm sewer needs, which has allowed Town staff to focus on the next study phases of the Master Plan in terms of budgets and priorities.

The objectives of this stage (Phase 2 and 3) of the Stormwater Management Master Plan are to formalize the understanding of the condition and capacity constraints associated with the Town's storm drainage infrastructure, and to systematically and consultatively develop a Master Plan, building from the Phase 1 Storm Sewer Master Plan data, to address the Town's flood risks and water quality problems. The findings of the Stormwater Management Plan have formed the basis for providing action-oriented recommendations, to be seamlessly and effectively programmed into the Town's capital program.

The key outcomes of the Stormwater Management Master Plan are:

- Priority-based Stormwater Management Program for flood risk mitigation
- Stormwater Management Policy recommendations
- Stormwater Quality Management Plan

The conclusions and recommendations advanced in this Stormwater Management Master Plan have also built upon guidance and direction from higher level planning documents, specifically the Town of Oakville Official Plan – Livable Oakville (2009, Updated April 2017), the Province of Ontario's Growth Plan for the Greater Golden Horseshoe (2006), Growth Plan for the Greater Golden Horseshoe (2017), and Town of Oakville Zoning Bylaw 2014-014. These planning documents provide guidance and direction regarding the location, form, and extents of future development within the Town of Oakville, with particular emphasis on redevelopment within existing built-up areas, including redevelopment on existing private residential lots, which is prevalent in the subject focus area.

1.1.1 Planning Context

As noted, the Stormwater Management Master Plan is a key municipal document which will guide Oakville's investment in the coming decades in stormwater management infrastructure, including renewal / replacement, and associated priorities. The Stormwater Management Master Plan is directly and indirectly linked to numerous Provincial and local Planning documents and their policy guidance, including:

- **Town of Oakville OP Livable Oakville (2009, 2017)** – some relevant excerpts include:

10.6 Green Buildings

10.6.1 The Town will encourage innovative programs and construction methods which support the *sustainable development* and redevelopment of buildings. Sustainable features sought by the Town may include, but are not limited to:
d) permeable paving and other innovative stormwater management methods;

10.10 Stormwater Management

10.10.1 Stormwater management techniques shall be used in the design of new developments to control both the quantity and quality of stormwater runoff. In areas where soil types permit, on-site infiltration shall be encouraged to the maximum extent feasible.

10.10.4 Potential recharge and infiltration areas shall require further studies to be conducted at the *development* application stage. The purpose of these studies is to determine whether site specific recharge and/or infiltration is feasible on the subject property and to ensure protection of their function.

10.10.7 Existing groundwater recharge rates shall be maintained in all developments, where possible.

10.108 The use of permeable surfaces and soft landscaping shall be encouraged where possible.

10.10.9 All *development* shall follow the current Provincial and Federal guidelines for stormwater management (best management practices).

10.10.12 The Town may pursue opportunities to implement quantity and quality controls for stormwater management within the Town's developed areas where current controls do not exist or are not adequate.

- **Growth Plan for Greater Golden Horseshoe (2017)** – some relevant excerpts include:

3 Infrastructure to Support Growth

3.1 Context

A clean and sustainable supply of water is essential to the long-term health and prosperity of the region. There is a need to co-ordinate investment in water, wastewater, and stormwater *infrastructure* to service future growth in ways that are fiscally sustainable and linked to decisions about how these systems are paid for and administered. Water *infrastructure* planning will be informed by *watershed planning* to ensure that the *quality and quantity of water* is maintained.

Climate change poses a serious challenge for maintaining existing *infrastructure* and planning for new *infrastructure*, however, vulnerability assessments can help to identify risks and options for enhancing resilience. Similarly, comprehensive stormwater management planning, including the use of appropriate *low impact development* and *green infrastructure*, can increase the resiliency of our communities.

3.2.7 Stormwater Management

1. Municipalities will develop *stormwater master plans* or equivalent for serviced *settlement areas* that: are informed by *watershed planning* or equivalent;

   b) protect the *quality and quantity of water* by assessing existing stormwater facilities and systems; characterize existing environmental conditions;

   d) examine the cumulative environmental impacts of stormwater from existing and planned development, including an assessment of how extreme weather events will exacerbate these impacts and the identification of appropriate adaptation strategies;

e) incorporate appropriate *low impact development* and *green infrastructure*;

f) identify the need for stormwater retrofits, where appropriate;

g) identify the full life cycle costs of the stormwater *infrastructure*, including maintenance costs, and develop options to pay for these costs over the long-term; and include an implementation and maintenance plan.

2. Proposals for large-scale *development* proceeding by way of a secondary plan, plan of subdivision, vacant land plan of condominium or site plan will be supported by a *stormwater management plan* or equivalent, that: is informed by a *subwatershed plan* or equivalent;

b) incorporates an integrated treatment approach to minimize stormwater flows and reliance on stormwater ponds, which includes appropriate *low impact development* and *green infrastructure*;

c) establishes planning, design, and construction practices to minimize vegetation removal, grading and soil compaction, sediment erosion, and impervious surfaces; and

d) aligns with the *stormwater master plan* or equivalent for the *settlement area*, where applicable.

4.2.10 Climate Change

1. Upper- and single-tier municipalities will develop policies in their official plans to identify actions that will reduce greenhouse gas emissions and address climate change adaptation goals, aligned with other provincial plans and policies for environmental protection, that will include:

   - undertaking stormwater management planning in a manner that assesses the impacts of extreme weather events and incorporates appropriate *green infrastructure* and *low impact development*;

- **Town of Oakville Zoning By-Law (2014-14)** – some relevant excerpts include:

Part 5 – Parking, Loading, & Stacking Lane Provisions

5.1 General Provisions

5.1.8 Hardscape Surface Treatment

All *parking areas*, *loading spaces*, and *stacking spaces* in any *Zone* other than an Environmental *Zone* or Other *Zone* shall be surface treated with asphalt, concrete, interlocking brick, similar hardscaped surface, or other material sufficient to provide stability, prevent erosion, be usable in all seasons, and allow infiltration of surface water.

- **Provincial Policy Statement 2014 (approved)**– some relevant excerpts include:

Part V: Policies

1.6 Infrastructure and Public Service Facilities

1.6.6 Sewage, Water and Stormwater

1.6.6.1 Planning for *sewage and water services* shall:

a) direct and accommodate expected growth or development in a manner that promotes the efficient use and optimization of existing:

   i) municipal sewage services and municipal water services; and

   ii) private communal sewage services and private communal water services, where municipal sewage services and municipal water services are not available;

b) ensure that these systems are provided in a manner that:

   i) can be sustained by the water resources upon which such services rely;

   ii) is feasible, financially viable and complies with all regulatory requirements; and

   iii) protects human health and the natural environment;

c) promote water conservation and water use efficiency;
d) integrate servicing and land use considerations at all stages of the planning process; and
e) be in accordance with the servicing hierarchy outlined through policies 1.6.6.2, 1.6.6.3, 1.6.6.4 and 1.6.6.5.

1.6.6.7 Planning for stormwater management shall:

a) minimize, or, where possible, prevent increases in contaminant loads;
b) minimize changes in water balance and erosion;
c) not increase risks to human health and safety and property damage;
d) maximize the extent and function of vegetative and pervious surfaces; and
e) promote stormwater management best practices, including stormwater attenuation and re-use, and low impact development.

2.0 Wise Use and Management of Resources

2.2 Water

2.2.1 Planning authorities shall protect, improve or restore the *quality and quantity of water* by:

h) ensuring stormwater management practices minimize stormwater volumes and contaminant loads, and maintain or increase the extent of vegetative and pervious surfaces.

1.2 Master Plan Process

The Ontario Environmental Assessment Act provides for *"…the betterment of the people of the whole or any part of Ontario by providing for the protection, conservation and wise management in Ontario of the environment."* An approved Class Environmental Assessment (Class EA) document describes the process that a proponent must follow for a class or group of undertakings in order to satisfy the requirements of the Environmental Assessment Act, and represents a method of obtaining an approval under the Environmental Assessment Act and provides alternatives to carrying out individual environmental assessments for each separate undertaking or project within the class.

Master Plans are one form of Class EA document which represent long range plans which integrate infrastructure requirements for existing and future land use with environmental assessment planning principles. The following characteristics distinguish the Master Planning Process from other processes:

a. The scope of Master Plans is broad and usually includes an analysis of the system in order to outline a framework for future works and developments. Master Plans are not typically undertaken to address a site-specific problem.

b. Master Plans typically recommend a set of works which are distributed geographically throughout the study area and which are to be implemented over an extended period of time. Master Plans provide the context for the implementation of the specific projects which make up the plan and satisfy, as a minimum, Phases 1 and 2 of the Class EA process (ref. Figure 1.2.1). Notwithstanding that these works may be implemented as separate projects, collectively these works are part of a larger management system. Master Plan studies in essence conclude with a set of preferred alternatives and, therefore, by their nature, Master Plans will limit the scope of alternatives which can be considered at the implementation stage.

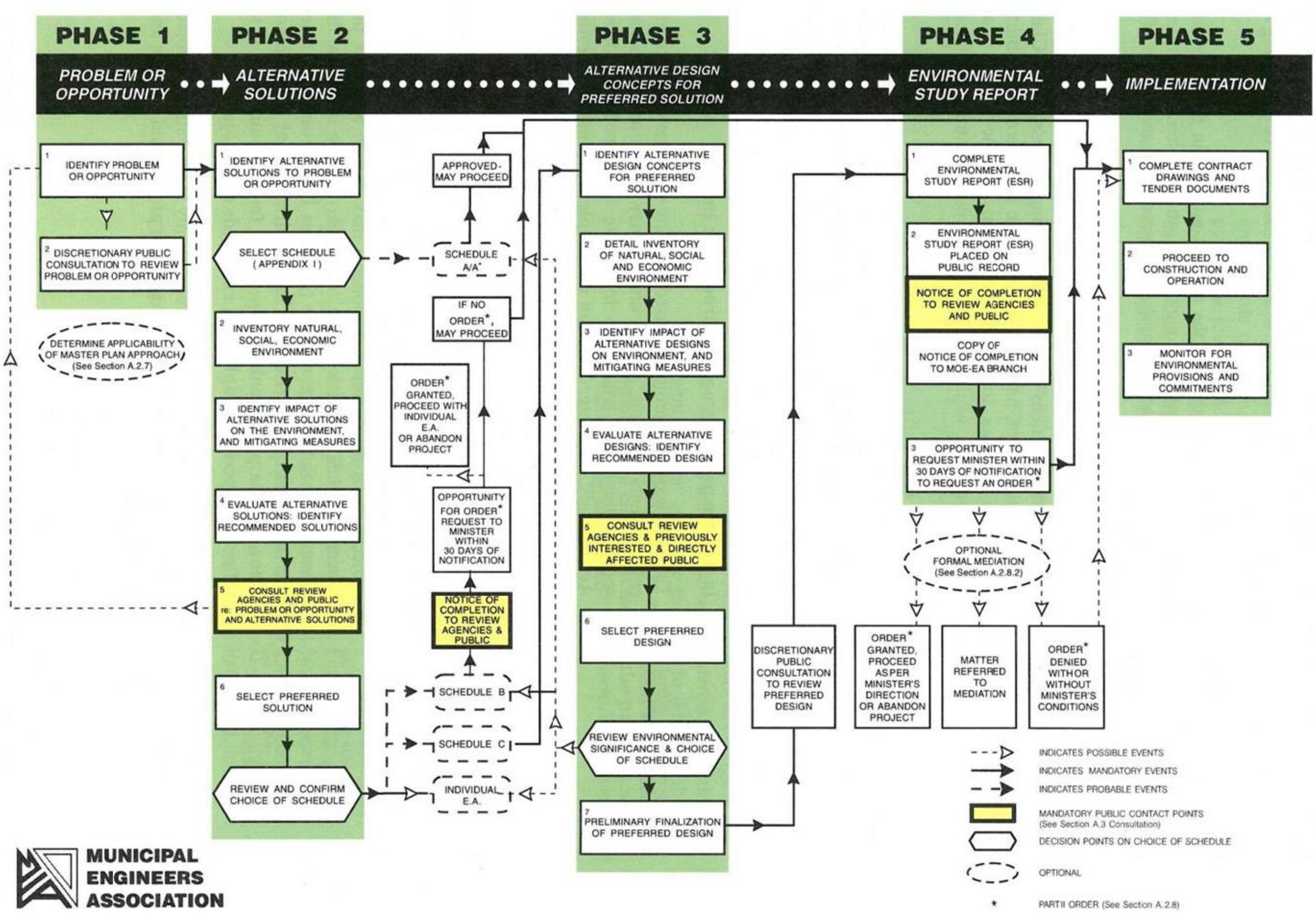

Figure 1.2.1: Municipal Class EA Process

The following are some examples of drainage projects classified according to the Municipal Class EA process:

Schedule A/A+ (Pre-approved)

- Installation of inlet control devices (ICDs) within existing catch basins.
- Maintenance or repair of roadside ditches, culverts and such incidental stormwater works constructed solely for the purpose of servicing municipal road works.
- Storm sewer replacement.
- Implementation of online storage.
- Stormwater management retrofits for water quality management (where additional property is not required)
- Regrading or reconstruction of municipal road right-of-way with no change to capacity, use, horizontal alignment, and limits of road and right-of-way

Schedule B (Potential for some adverse environmental effects)

- Establish new stormwater retention/detention ponds for water quality management including outfalls to receiving water bodies where additional property is required.
- Regrading or reconstruction of municipal right-of-way which may alter the capacity, use, horizontal alignment, and/or limits of road and/or right-of-way.
- Grading to divert runoff within municipal drainage systems.

The Town of Oakville Stormwater Management Master Plan has been conducted as a Master Plan in compliance with Section A.2.7 Master Plans (ref. Municipal Engineers Association "Municipal Class Environmental Assessment," (October 2000, as amended 2007, 2011, and 2015) which addresses Phases 1 and 2 of the Class EA Process. Subsequent Schedule B projects which are implemented in accordance with the recommendations provided in this Master Plan, may proceed directly to the *Notice of Completion* and then the detailed design and implementation stages.

1.3 Public/Agency Consultation

Technical Steering Committee

This Master Plan has been completed under the oversight of a Technical Steering Committee which included representatives from various town departments. Members of the Technical Steering Committee met at key milestones throughout the project to provide input and information for use in the study, review findings, and provide guidance and direction.

Public Information Centres and Online Survey

Public Information Centres (PIC) have been held at strategic points in the Master Plan process. The first PIC for the Town of Oakville Stormwater Management Master Plan was held on June 23, 2016 at the Town of Oakville Town Hall. Notifications of the PIC were sent to stakeholders, local residents, agencies and municipal staff by mail and email, as well as notices within the local newspaper.

The PICs were attended by representatives from the Town of Oakville along with the consulting team from Wood (formerly Amec Foster Wheeler). The PICs took an Information Session format including display boards and maps detailing the project objectives, progress, and next steps within the context of the Class Environmental Assessment requirements. Copies of the display material presented at the PICs are provided in Appendix A.

Comment Forms were available to members of the public to promote the opportunity of providing input/comments by submitting their comments on site, or via mail, fax or email. The second PIC was held at the Town of Oakville Town Hall on June 25, 2019, to present the preliminary preferred solutions to the public. The format of the event was similar to the first PIC. Comment forms were made available to members of the public to provide input/comments pertaining to the study. In addition, an online survey was initiated by the Town of Oakville during the course of the study. The survey was conducted to gather information regarding general thoughts and concerns from the public regarding storm drainage.

1.4 Project Organization

The following lists the key individuals and roles related to completing the Stormwater Management Master Plan:

Town Staff:	Kristina Parker, Project Manager Philip Kelly, Senior Advisor Darnell Lambert, Project Advisor Rita Juliao, Project Advisor

	Diana Friesen, Project Advisor Cindy Toth, Project Advisor Trish Henderson, Project Advisor Erik Zutis, Project Advisor Glenn Anger, Project Advisor Steve Pozzobon, Project Advisor
Consulting Team:	Ron Scheckenberger, Project Manager Aaron Farrell, Project Engineer Patrick MacDonald, Project Analyst Allison Zhang, Project Analyst

1.5 Study Scope – Phase 2

The following are the primary study tasks conducted for this study:

Task 1 Study Area Characterization

Task 2 Analysis and Assessment of Stormwater Management System

Task 3 Evaluation of Alternatives

Task 4 Preferred Stormwater Management Strategy

Task 5 Implementation Plan

Task 6 Flow Monitoring and Inlet Inventory

Task 7 Water Quality Assessment

Task 8 Stormwater Management Master Plan Report

2.0 Background Information

Considerable background information has been compiled for this study which has included monitoring data, Geographic Information Systems (GIS) mapping, reports and drawings and modelling data. A summary description of the information used for this study has been provided in the following. A data tracking chart, with detailed information regarding each data element, has been provided in Appendix B.

2.1 Monitoring Data

Monitoring data which include measured rainfall data, as provided by the Town of Oakville, and local flow monitoring conducted by Wood within the Town's storm sewer network, are provided in Appendix B. Flow data have been recorded in 5 minute intervals at six (6) locations; three (3) monitoring locations within the Town's storm sewer network recorded from October 2012 to December 2012 and three (3) monitoring locations within the open channel system in the study area, recorded from September 2011 to December 2011 (ref. Appendix B).

2.2 GIS Data and Mapping

Town of Oakville GIS data include shapefiles for topography and storm water management infrastructure, such as storm sewers, maintenance holes, catch basins, laterals, outfalls, as well as aerial imagery for the study area. Additional data provided include various creek cross section locations, ELC data, road network, structure outline, abandoned structures, land use mapping, building footprints, North Oakville proposed roads, channels, driveway culverts, fittings, inlet-outlet structures, pipe protection, pond footprints, pumps, pumping stations, stormwater management ponds, topographic contours, topographic spots, topographic points, utility corridors, Oakville property parcels, virtual lines, and virtual points.

In addition to the mapping information, Town of Oakville staff conducted a scoped field reconnaissance to confirm the presence and approximate extent of direct downspout connections on residential properties within the study area. Information collected by Town staff in this regard is provided in Appendix B.

2.3 Reports and Drawings

Numerous reports and drawings (over 30,000 +/-) have been reviewed as part of this study, which include approved contract drawings for the construction and rehabilitation of roads, storm drainage systems, subdivision plans, MTO-highway contract drawings and Region of Halton contract drawings.

2.3.1 Storm Sewer Master Plan - Phase 1 Report

In 2015, the Town completed Phase 1 of the Storm Sewer Master Plan, which focused on data collection and gap filling for the overall Stormwater Management Master Plan. Of key importance, the Phase 1 report documents findings associated with detailed storm sewer inspections within the study area to assess the physical condition of the storm drainage infrastructure, high-level capacity analyses, and preliminary recommendations for prioritizing the future maintenance and replacement of the storm sewer infrastructure within the focus area. The information, conclusions, and recommendations of the Phase 1 report, thus represent a key input to the overall Stormwater Management Master Plan for the Town of Oakville.

2.4 Modelling Data

The following modelling data have been provided by the Town of Oakville and Conservation Halton for use in this study:

- HEC-2 and HEC-RAS hydraulic models for Bronte Creek, McCraney Creek, Sixteen Mile Creek, Joshua Creek, Lower Morrison Creek, Lower Wedgewood Creek and Sheldon Creek and their tributaries (Conservation Halton).
- PCSWMM model developed as part of the Fourteen Mile Creek/McCraney Creek Flood Management Alternative Assessment, Town of Oakville, 2013

3.0 Baseline Characterization

The background information listed in Section 2 and Appendix B has been reviewed in order to develop a baseline characterization of the physiographic conditions and drainage systems within the focus area. The general findings of this baseline characterization are as follows.

3.1 Soils

A review of the classification of soils within the focus area has been conducted using the latest version (version 3) of the detailed soil surveys for Ontario from the National Soils Database by Agriculture Canada, 2013 (ref. Drawing 3.1). The results of this review indicate that soils for a large portion of the focus area have not been classified, particularly for the urban areas south of the QEW, however for the sewersheds located at the east of the study area, the dominant soil classes are Clay Loam for lands located north of the QEW and Sandy Loam for lands located south of the QEW.

3.2 Land Use Conditions

Land use information has been abstracted from the Town of Oakville Official Plan (ref. The Livable Oakville Plan, 2009, Updated April 2017), as well as through a review of 2015 aerial imagery of the existing land use conditions across the focus area. The current (2018) land use conditions of the study area, as presented in the Town of Oakville Official Plan and the aerial imagery are primarily employment for the lands located towards the north limit of the focus area, south of the QEW and residential areas with some interspersed commercial parkland and open space areas for the remainder of the lands. Future redevelopment through formal infill and intensification zones (I/I) has been planned for some of the lands within the focus area (ref. The Livable Oakville Plan, 2009, Updated February 2015, Schedule F and Schedule G).

The Livable Oakville Plan defines the designated locations of growth through intensification and redevelopment within the focus area; these locations are depicted on Schedule A1 of the Town's Official Plan (ref. Appendix C), and include:

- Palermo Village
- Uptown Core
- Midtown Oakville
- Downtown Oakville
- Kerr Village
- Bronte Village

In addition to the foregoing designated locations for I/I, much of the residential lands in the older portions of the focus area are under pressure to intensify through teardowns and larger footprint newer homes, with extensive hardscaping and related amenity areas. This phenomenon is widespread in the focus area, significantly increasing impervious coverage over time.

3.3 Drainage Systems

The distribution and characterization of drainage systems within the focus area is presented on Drawing 3.2. The drainage systems within the focus area include "urban" (curb and gutter with storm sewers and catch basins), "semi-urban" (curb, gutter outlets mixed sewer and ditch servicing), and "rural" (ditches and driveway culverts) drainage. The existing storm sewer network for the focus area includes over 4800 storm sewer pipes (roughly 263 km), over 4300 maintenance holes, 168 km of ditches and over 200 outfalls, providing service for the majority of the lands located within the study area (37.2 km^2). The foundation drains for certain properties and neighbourhoods are directly connected to storm sewers posing a higher risk to area homes from sewer system surcharging. The foundation drain connections are typically associated with the vintage of the development and the prevailing design standards at the time of design and implementation, however it is recognized that the foundation drains may have been disconnected at the discretion of the individual property owner and sump pumps installed to discharge foundation drains to surface rather than directly to the storm sewers. The drainage system within the focus area also relies on overland conveyance along roadways with both urban and rural drainage systems (i.e. ditches, swales, and driveway culverts) within areas of existing residential development, albeit due to the age, most areas have not been designed with a dual drainage network (major / minor) with continuously positive overland drainage.

In addition to the foregoing drainage systems within the Municipal right-of-way, portions of the drainage system include "remnant channels" within private properties. These drainage features have been retained and/or realigned as part of the historic residential developments, and are generally in the form of defined surface drainage features (i.e. ditches and swales). Of particular importance, these features are primarily in private ownership, hence are not routinely maintained or managed by the Town of Oakville, and they are also not regulated by Conservation Halton.

3.4 Historic Maintenance Practices and Sewer Cross-Connections

The Town of Oakville has maintained an inventory of areas requiring frequent or regular maintenance to better ensure the operation and performance of the storm drainage infrastructure, primarily during formative storm events. The locations of these areas (referred to as "hot spots") are depicted on Drawing 3.3.

Maintenance practices are currently more reactive in terms of maintaining or addressing the physical conditions of the storm sewer pipes. Downspouts are mostly disconnected within the focus area. Based on consultation with the Town of Oakville and Halton Region staff during the Phase 1 component of the Stormwater Management Master Plan, it is suspected that some cross connections exist between the sanitary and storm sewer networks; however, no specific information is available regarding the extent or location of possible cross connections. The Region is currently (2018/2019) conducting further study as part of a separate initiative to establish a better understanding of the extent of cross-connections.

3.5 Physical Conditions Assessment

3.5.1 Structural Condition and Operation and Maintenance

The physical condition of the storm sewers was characterized as part of the Phase 1 Storm Sewer Master Plan based upon a ZOOM™ Camera inspection conducted in 2012 and 2013 for the storm sewer pipe network. The structural conditions and maintenance requirements were evaluated using the Pipeline Assessment and Certification Program Version 3.0.2 (PACP) Code Matrix, developed by National Association of Sewer Service Companies (NASSCO), which summarizes the estimated time before which any observed defects can cause complete line failure, and assigns a numerical score of 1 to 5 to each storm sewer pipe, with 1 representing "Excellent" condition and 5 representing a condition requiring "Immediate Attention". The description of each grade is presented below:

Grade	Description
Excellent	Minor Defects
Good	Defects that have not begun to deteriorate
Fair	Moderate defects that will continue to deteriorate
Poor	Severe defects that will become Grade 5 defects within foreseeable future
Immediate Attention	Defects requiring immediate attention

The specific description and details regarding the structural and maintenance condition for each storm sewer pipe encompass a wide range of characteristics, which include fractures, pipe failure, collapse, deformation, chemical and mechanical surface damage, lining failure, and weld failure, for structural condition and deposit attachment, deposit settlement, deposit ingression, root infiltration, and obstacles for operational and maintenance condition. Recognizing that the deterioration process for each pipe is highly variable and dependent on local conditions, the estimated time before which the defect can cause complete line failure, as per the NASSCO, is provided in general terms as follows:

Grade 1- Failure unlikely in the foreseeable future
Grade 2- Pipe unlikely to fail for at least 20 years
Grade 3- Pipe may fail in 10 to 20 years
Grade 4- Pipe will probably fail in 5 to 10 years
Grade 5- Pipe has failed or will likely fail within the next five years.

The structural condition of the storm sewers is summarized on Drawing 3.4 and the maintenance condition of the sewers is summarized on Drawing 3.5. A summary of the results of the video inspection (ZOOM Camera) of the storm sewer pipes conducted in 2013 by Aquadata for the study area is presented in Table 3.5.1 for both structural and operations and maintenance ratings.

Table 3.5.1 Total Percentage (%) of Storm Sewer Pipes for Structural and O&M Rating (1 to 5)

Grade Class	1	2	3	4	5	Not Rated
Structural	68	16	9	2	1	4
Operation and Maintenance	21	58	12	3	2	4

As the information indicates, the majority of the storm sewers (~84%) in the study area are considered to be in a *good* to *excellent* structural condition and a very small percentage (~3%) are anticipated to have failed or would be expected to fail within the next 5 to 10 years. Similarly, a high majority (~79%) of the pipes have a *good* to *excellent* condition related to operation and maintenance, and only a small percentage (~5%) require maintenance immediately or within the next 5 to 10 years.

The storm sewers within the focus area in the Town of Oakville are generally in good condition with respect to physical condition. The infrastructure needs related to the structural condition of the minor system and the maintenance requirements are attributable to each individual pipe rather than segments or networks of storm sewers.

3.5.2 Rurally-Serviced Areas

Drainage issues have been identified by Town staff in various rurally-serviced areas of the focus area (i.e. West Street, Belvedere, Coronation Park, Maplehurst). The specific drainage issues vary by location, according to the specific conditions of the area. Some of the identified drainage issues within the rurally-serviced areas include the following:

- reduced conveyance capacity and/or standing water within ditches as a result of unapproved alterations to the ditches by members of the public or by utilities companies
- deficient inlet capacity where ditches discharge to storm sewer systems
- collapsed driveway culverts
- frequent or prolonged sump pump discharge to ditches, sometimes resulting from groundwater interception by utilities connection
- alterations to private lot grading
- undersized ditches (i.e. inadequate conveyance capacity)
- ditches on private property, not owned by Town, which are altered but not subject to approval
- backwater created by fluctuating water levels at Lake Ontario where ditches outlet to the lake

3.5.3 Other

The Phase 1 Storm Sewer Master Plan also provided an assessment and review of the storm sewer network specific to:

- Areas with decreasing pipe diameter
- Areas with adverse slopes
- Locations with submerged outfalls

These data have been explicitly incorporated into the detailed analytical modelling conducted through this Phase 2 and 3 investigation.

4.0 Problem Statement

4.1 Development Trending and Climate Change

As noted earlier, the subject area of the Town of Oakville constituting this study's Focus Area, represents a region of historic development. The vintage of development within the subject area ranges between 5 and 70 years (+/-) old, with varying sizes of residential lots and corresponding coverage of residential units (i.e. houses) on the lots, consistent with the changes in the form of residential land use over that time. Over time, the landscape within the focus area has changed, as homeowners have further increased the hard surface coverage on their lots by adding amenities to their homes (i.e. decks, patios, gazebos), or by expanding their homes and/or driveways. These increases in hard surfaces (which represent increases to impervious coverage on residential lots) have reduced the amount of runoff infiltrating into the soil, and correspondingly increased the rate and volume of runoff discharging to the Town's storm drainage and stormwater management systems. If unmitigated or unmanaged, further increases would be anticipated to reduce the level of service (LOS) within the municipal drainage systems, potentially resulting in more frequent and increased extents of flooding within the area.

In addition, it is recognized and generally accepted, that trends in climate patterns have changed over the past two decades plus. These changes, considered by many to be a result of climate change, have been manifested by increased frequency and intensity of storm events, particularly during summer conditions. These shifts in climate patterns, combined with the trending of development to increase the hard surfaces on private properties, are anticipated to further reduce the level of service provided by the Town's drainage infrastructure.

4.2 Stormwater Management Master Plan Objectives and Outcomes

The objectives of the overall Master Plan are to provide the town with clear direction regarding:

i. The existing issues with respect to the structural condition, flow capacity and maintenance requirements of the Municipal storm system,
ii. The location and extent of these issues,
iii. Opportunities and recommendations to address and mitigate identified problems,
iv. Timeline and priorities for implementation of the recommendations,
v. Costs for the implementation and long term maintenance of the system, and
vi. Preferred financial and funding mechanisms.

This phase of the Stormwater Management Master Plan has been initiated to conduct detailed analyses of the existing storm infrastructure within the historic areas of the Town of Oakville, and to develop an action-oriented plan to address existing and future requirements to manage the quantity and quality of storm runoff from the area, with particular emphasis on reducing and/or mitigating existing flood risks to private properties.

As such, the Problem Statement for this phase of the overall Stormwater Management Master Plan can be summarized as providing the town with clear direction regarding:

i. What issues or deficiencies currently exist within the town's storm system with respect to the conveyance capacity of the networks,
ii. What additional issues are imposed by potential future development and climate change,
iii. Where these deficiencies and issues exist within the town,
iv. How the town should proceed to address these deficiencies, and
v. When these works should to be completed.

5.0 Gap Filling

Over the course of the study, numerous information gaps have been identified in the storm system information specifically pertaining to the maintenance hole rim elevations and the sewer pipe invert elevations. The identified gaps within the sewershed database are summarized in detail in the Town of Oakville Storm Sewer Master Plan Phase 1 Report (AMEC, September 2015). In order to fill these data gaps, additional geodetic survey has been completed as part of Phase 2 of the Stormwater Management Master Plan. This exercise involved field survey of approximately 5,190 manholes, and collecting approximately 10,060 inverts for input into the minor system model. Nevertheless, a 100 % complete dataset could not be developed due to some accessibility issues encountered during the data collection (i.e. elements were inaccessible by the survey crew due to the presence of gates, fences, or dense vegetation), as well as inconsistencies between the Town's sewer database and conditions observed in the field (i.e. elements listed within the database were not identified in the field). As such, where these conditions were encountered, the following methods were applied to address these residual data gaps and to complete the dataset for developing the database for the major and minor system hydrologic and hydraulic modelling.

5.1 Proposed and As-Built Drawings

It is noteworthy that the data contained within as-built drawings pertaining to inverts and elevations were often found to vary significantly from the surveyed values. This was particularly prevalent for sewer systems that were built during the 1980's or earlier. However, other information that could be abstracted from the design drawings, such as slopes, pipe geometry, and sewer locations, did prove useful in the gap filling exercise. Notwithstanding, circumstances arose where pipe geometry was unavailable, such as diameter, where an adjacent pipe diameter was applied to the unknown pipe. If a dimension change occurred on the adjacent pipes, then the most "reasonable" pipe diameter was applied with consideration given to the catchment area and the number of catch basins connected in the vicinity of the unknown pipe. Further, while pipe lengths were typically provided, some pipe lengths needed to be measured based on the distance between maintenance holes using aerial imagery and GIS techniques.

5.2 Interpolation

Unknown maintenance hole inlet and outlet inverts have been interpolated based on known upstream and downstream inverts and the lengths of the storm sewer pipes. The interpolated inverts have been assumed to be the same for the inlet and outlet sewer pipes discharging to, and from, a maintenance hole. The same method has been applied to maintenance holes with unknown rim elevations; the upstream and downstream rim elevations were used to interpolate the unknown rim elevation. This elevation was then compared to the contour data and the topographic spot elevations provided by the Town of Oakville, to confirm the accuracy of the interpolated rim elevation. In areas where interpolation of the rim elevation was not possible, a rim elevation has been estimated based on contour data or the topographic spot elevations. Approximately 350 pipes required interpolation within the focus area with an approximately equal number of rim elevations. These have been specifically identified in the database and can be more accurately established through future field survey.

5.3 Extrapolation

Occasions where a single pipe invert was missing, such as the downstream end of a sewer pipe at an inaccessible outfall, gap filling using interpolation was not possible. In these cases, the slope of the pipe, as available within the GIS database provided by the Town of Oakville or obtained from the available design drawings, has been used to determine the missing invert. Approximately 330 pipe inverts were determined using the slope of the pipe in this manner. As above, these have been specifically identified in the database and can be more accurately established through future field survey.

5.4 Inlet Condition Assessment

As part of this phase of the Study, field reconnaissance has been completed to visually inspect the condition of storm sewer inlets, which would be anticipated to be subject to blocking/obstruction from debris and/or would be in a condition which may warrant maintenance or replacement. The locations for conducting the field reconnaissance have been determined based upon a review of the rural and urban drainage systems, and coincide with locations where predominantly rural drainage systems and remnant channels drain to urban systems. The sites of the field reconnaissance for the subject inlets are provided on Drawing 5.1.

A photographic inventory of the field reconnaissance and Key findings from the field reconnaissance are provided are provided in Appendix D.

6.0 Integrated Hydrologic / Hydraulic Model Development

As part of the Phase 1 Storm Sewer Master Plan study, numerous locations within the storm sewer network were identified as having conveyance constraints using a simplified analytical approach developed for that study phase as a screening technique. Specifically, the local system return period design flow was determined and, a comparison was conducted of the design flow with the required hydraulic conveyance capacity of each sewer pipe, as per the current design standards required by the Town of Oakville. The simplified approach applied for Phase 1 was based upon the Rational Method, which is based on a simple hydrologic estimation of peak flows without considering the mechanics of overland conveyance hydraulics, system capture and influence of runoff routing within the drainage system. In addition, the influence of the major (i.e. overland conveyance) system was also not considered as part of the Phase 1 study of the Town of Oakville Storm Sewer Master Plan. As such, further detailed assessment has been undertaken as part of this phase of the Stormwater Management Master Plan to analyze the locations and extent of the anticipated capacity constraints within the Town's major / minor system, based upon analytical techniques which account for the influence of tailwater conditions within the receiving watercourses and/or the stormwater management facilities within the Town. In addition, the analyses conducted as part of this assessment have evaluated the conveyance capacity of the major system, and thereby have assessed the performance of the major system under the 100 year return period storm, as related to flooding impacts within the Municipal right-of-way and towards private property.

The integrated hydrologic and hydraulic analyses completed for the current study have applied the PCSWMM methodology. PCSWMM combines hydrologic modelling (i.e. simulated storm runoff response from land areas), with hydraulic modelling (i.e. calculated water surface elevations and velocities within storm sewers, road surfaces, open watercourses, culverts). The integration of hydrologic and hydraulic analyses facilitates the concurrent evaluation of system hydraulics and performance, including: detention in ponding areas, backflow in pipes, surcharging of manholes, tailwater conditions (which may affect upstream storage and flow capacity within pipes), capacity at inlets to the sewer network (which would reduce the amount of runoff entering the sewer network and increase the amount of runoff conveyed overland during storm events), and depth of flooding of overland conveyance systems; these capabilities of the PCSWMM software make it particularly well-suited for analyzing urban drainage systems such as those within the Town of Oakville.

PCSWMM is capable of applying both Event Methodology for single storm events and continuous simulation of a long-term period of record for multiple storm events. For this assessment the Event Methodology, using synthetic design storms, has been used. PCSWMM is capable of accounting for various conditions at outlets (i.e. open/unobstructed/free-flowing, partially/completely submerged to a constant depth, time-varying depth conditions, gated conditions). The hydraulic routing component within PCSWMM can be completed for unsteady state (i.e. time-varying flow) conditions using Kinematic Wave or Dynamic Wave routing techniques of the core St. Venant equations (which combine continuity and momentum equations to solve for 1-dimensional flow). The dynamic wave routing technique is the full solution of this set of equations, and is thus capable of accounting for complex hydraulic situations such as pressure and reverse flow. The kinematic wave routing technique is a simplified solution which is more appropriate for simplified flow conditions. Given the expected surcharging and complex hydraulics within the focus area, dynamic wave routing has been applied in this study. The numerical stability of the PCSWMM platform allows for complex networks and systems to be readily modelled in the unsteady state condition, with little to no requirement for network simplification. The PCSWMM model is capable of simulating either one-dimensional (i.e. linear) or two-dimensional (i.e. spatial/spreading) flow conditions. The one-dimensional approach is consistent with the traditional application of the PCSWMM/EPASWMM methodology, and affords more efficient computation time and data management than the two-dimensional simulation approach. The one-dimensional modelling has been applied for this study, and is considered appropriate for simulating and analyzing conveyance of the subject conduits (i.e. storm sewers and major system contained to the right-of-way); furthermore, this approach is considered suitable for the modelling of a flooded minor system and assessing the potential for flow conveyance beyond the right-of-way. The two-dimensional modelling is typically applied to simulate the overland flow more for larger, less frequent storm events, if large scale flooding occurs beyond the right-of-way. It is primarily used for defining the location, extent, and direction of flow beyond the right-of-way if it is unknown. Furthermore, the two-dimensional flow condition requires more discrete topographic data, and is thus typically applied for analysis of specific locations and smaller study areas, as opposed to a systems-wide assessment of a larger study area as completed for this study.

PCSWMM employs the United States EPA-SWMM computational engine as its base, thus modelling files created in PCSWMM can be opened and executed within the EPA-SWMM program as well as PCSWMM. This also provides an additional degree of reliability and quality assurance to the modelling program.

6.1 PCSWMM Model Discretization and Initial Parameterization

For this study, a dual drainage assessment has been conducted using the PCSWMM methodology in order to evaluate the performance of the major system (overland, roads) and the minor system (sewers, ditches) within the focus area under different storms and various land use and climate conditions. The PCSWMM models developed for this study include hydraulic elements and junctions representing the minor system, such as maintenance holes and storm sewer pipes, as well as components of the major system and the road right-of-way including curb and gutter in urban areas and road side ditches in rural sections. The modelling has largely applied the network delineations developed for Phase 1 (ref. Drawing 6.1), and has refined the drainage areas within each network based upon the additional detailed information provided for use in this study. The following summarizes the approach and information applied to discretize the focus area and to parameterize the key hydrologic and hydraulic elements represented within the PCSWMM model.

6.1.1 Subcatchments

The subcatchments within all sewersheds in the focus area have been initially established based on the preliminary drainage area boundaries advanced as part of the Phase 1 Storm Sewer Master Plan. The subcatchment boundaries have been further refined and revised as part of the Phase 2 and 3 investigation based on topographic data (contours/spot elevations) provided by the Town, in order to reflect the drainage system geometry based upon the catch basin and lateral locations provided within the Town's GIS database. The Town provided as-built drawings which have been used to validate topographic data and subcatchment boundaries where possible; this procedure was not always feasible though due to the vintage of selected sewersheds within the focus area and lack of relevant drawings. As such, there is a recognized limitation to the accuracy of the subcatchment delineation which should be validated with field reconnaissance in the future as part of detailed studies including updated DEMs, to confirm the delineation assumptions of this study. The delineated subcatchments for all sewersheds within the focus area are provided in Appendix E.

Based on the subcatchment delineation, subcatchment parametrization has been established based upon the mapping and GIS data provided for this study, and using available tools and techniques within the PCSWMM modelling software and ESRI ArcGIS™ package. The following provides further details regarding the parameterization of the subcatchments within the PCSWMM hydrologic model.

Imperviousness

Imperviousness represents the amount of hard surfaces (buildings, roads, driveways, sidewalks) within a given subcatchment. The impervious coverage applied for hydrologic analyses is recognized to represent a central and sensitive parameter for modelling, whereby small changes in the parameter value may result in relatively high changes in simulated peak flow and runoff volume, compared to adjustments to other model parameters (i.e. soil parameters, shape parameters, etc.). Consequently, it has been recognized that the approach used to establish impervious coverage for the model subcatchments would need to satisfy the following criteria:

- Impervious coverages are to consider variation in land uses across the focus area.
- Impervious coverages are to consider differences in zoning within residential areas.
- Impervious coverages within residential areas are to distinguish between coverage on the lot versus coverage within the road right-of-way in order to accommodate assessing increased imperviousness on private residential properties for future conditions.
- Impervious coverages are to be consistent with manual measurements.
- Impervious coverages are to account for hard surfaces attributable to residential rooftops, as well as urban amenities (i.e. patios, gazebos, driveway expansions, hardscaping) which would be anticipated to be implemented by residents over time.

Various alternatives for establishing impervious coverage have been explored over the course of the study in consultation with Town staff, to represent the extent of hard surfaces within the focus area. The conventional practice of applying a standard impervious coverage based upon land use (i.e. "low density residential", "medium density residential", high density residential") was screened from consideration, as this approach would not account for variations in coverage by zoning, and would not distinguish between coverage from roads and coverage from lots, nor would it account for changes to coverage over time resulting from implementing amenity surfaces.

An alternative approach was investigated, whereby the impervious coverages for existing land use conditions would be established through aerial image processing of aerial photography and GIS screening using ArcGIS, to identify the hard surfaces representing total impervious coverage (TIMP) within the area. Although this approach was noted to account for the variation in coverage by residential zone, as well as the influence of amenity surfaces, the coverages generated using the image processing technique for test areas were noted to differ from hard measured values by as much as 10 %, with no consistency in the variation between the image processed and measured values. The variation and magnitude of the discrepancy was noted to be attributable to the influence of shading in the aerial imagery, which varies according to the density of canopy cover, height of structures, as well as the time of day and season during which the aerial image was taken. Consequently, the approach of applying the image processing technique was not considered a viable and reliable technique for establishing existing impervious coverage for the Stormwater Management Master Plan.

Following further consultation with Town staff, an alternative approach was advanced and assessed for establishing the existing impervious coverage within the focus area for the Oakville Stormwater Master Plan, whereby a "standard" impervious coverage was established by land use or zone classification, using the aerial imagery, property ownership, and land classification shapefile provided for use in this study. This method permitted for a more distributed sampling area, particularly for the residential zones, based on the Town's Official Plan zoning classification (i.e. RL-1, RL-2, RL-3, etc.), rather than applying a single (i.e. uniform) impervious coverage based upon density (i.e. "low density", "medium density", etc.). Furthermore, the information generated under this approach maintains consistency with the Town's GIS and zoning data.

The Town's GIS land use zoning database was screened to identify the different zoning designations within the focus area, for which impervious coverages are required. The 2015 aerial imagery was visually inspected to identify the variability in impervious coverage across the focus area for each land use zone designation/classification (zone). Individual properties corresponding to each zone have been selected to develop a stratified sampling, which would capture the variability in impervious coverage noted from the visual inspection of the aerial imagery, and the impervious coverage for each individual property has been determined based upon manual measurement of the hard surfaces on the properties (i.e. building roofs, driveways, decks, pools, gazebos, sheds, parking lots). The areally-weighted impervious coverage has been calculated for each zone classification, in order to establish the corresponding imperviousness for use in hydrologic modelling of existing land use conditions. For residential areas, separate impervious coverages have been established for the residential lots and the municipal right-of-way using the above approach.

The locations of the properties used to establish the impervious coverages for each zone classification are provided in Appendix E, and the resulting impervious coverages for each zone classification are presented in Tables 6.1.1 and 6.1.2. Detailed calculations are provided in Appendix E.

Table 6.1.1 Impervious Coverages for Residential Zones and Municipal Rights-of-Way (%)

Zone Classification	Type	Imperviousness
Residential Low (RL1)	ROW	60.1
	Lot	44.5
Residential Low (RL1-0)	ROW	64.0
	Lot	34.0
Residential Low (RL2)	ROW	NA[1]
	Lot	55.0
Residential Low (RL2-0)	ROW	64.1
	Lot	39.1
Residential Low (RL3)	ROW	70.8
	Lot	47.4
Residential Low (RL3-0)	ROW	58.8
	Lot	43.2
Residential Low (RL4)	ROW	NA[2]
	Lot	NA[2]
Residential Low (RL4-0)	ROW	58.4
	Lot	40.4
Residential Low (RL5)	ROW	70.8
	Lot	58.3
Residential Low (RL5-0)	ROW	70.5
	Lot	49.1
Residential Low (RL6)	ROW	63.6
	Lot	62.9
Residential Low (RL7)	ROW	65.1
	Lot	62.5
Residential Low (RL7-0)	ROW	59.0
	Lot	58.3
Residential Low (RL8)	ROW	76.1
	Lot	58.9
Residential Low (RL8-0)	ROW	73.4
	Lot	49.4
Residential Low (RL9)	ROW	76.4

Table 6.1.1 Impervious Coverages for Residential Zones and Municipal Rights-of-Way (%)

Zone Classification	Type	Imperviousness
	Lot	61.5
Residential Low (RL10)	ROW	NA[1]
	Lot	46.7
Residential Low (RL10-0)	ROW	NA[1]
	Lot	47.0
Residential Low (RL11)	ROW	79.0
	Lot	51.4
Residential Medium (RM1)	ROW	80.5
	Lot	61.5
Residential Medium (RM2)	ROW	NA[2]
	Lot	NA[2]
Residential Medium (RM3)	ROW	NA[2]
	Lot	NA[2]
Residential Medium (RM4)	ROW	63.9
	Lot	80.4
Residential High	ROW	60.4
	Lot	68.3
Residential Uptown Core	ROW	NA[2]
	Lot	NA[2]

Notes: [1] No road right-of-ways are associated with the residential zones based on the zoning information and property parcel data provided by the Town
[2] The residential zone or right-of way is not found within the focus area based on the zoning information and property parcel data provided by the Town

Table 6.1.2 Impervious Coverages for Non-Residential Zones (%)

Class	Imperviousness
Neighbourhood Commercial	82.9
Community Commercial	85.2
Core Commercial	89.3
Central Business District	100.0
Cemetery	8.7
Community Use	30.1
Office Employment	84.0
Business Employment	93.4
Industrial	77.8
Institutional	75.1
Business Commercial	87.9
Existing Development	62.7
Greenbelt	5.0
Midtown Transitional Commercial	92.2
Midtown Transitional Employment	82.8
Main Street 1	100.0
Main Street 2	95.0
Urban Centre	90.0
Urban Core	95.0
Natural Area	5.0
Park	10.0

Table 6.1.2 Impervious Coverages for Non-Residential Zones (%)	
Class	**Imperviousness**
Private Open Space	5.0
Parkway Belt Public Use	25.0
Parkway Belt Complementary Use	10.0
Utility	26.6

Based upon the foregoing assessment of impervious coverages for each of the Town's land use zoning classifications, the impervious coverages developed using the above approach have been applied to determine the imperviousness at the subcatchment scale.

Flow Length and Slope

The maximum overland flow length, as defined in the EPA SWMM 5 manual, represents the length of the flow path from the inlet to the furthest drainage point of the subcatchment. The subcatchment slope represents the average gradient across the subcatchment surface. For the Oakville Stormwater Management Master Plan, flow length has been explicitly measured for each subcatchment, as the average length for sheet flow, before becoming channelized. Slope for each subcatchment has been determined using the topographic contour data.

Manning Roughness Coefficients

Manning's roughness coefficients represent the type of surface for the subcatchment, and the associated friction applied to the flow across the subcatchment surface. Manning's roughness coefficients have been determined for the pervious and impervious portions of each subcatchment. Consistent with previous studies and literature recommended values, a value of 0.014 has been assigned to the impervious segment of each subcatchment and a value of 0.25 has been assigned to the pervious segment of each subcatchment.

Depression Storage

Depression storage represents the depth of rainfall which would be captured and detained in surface depressions within the subcatchment. Depression Storage values have been assigned to the impervious and pervious segments of each subcatchment. 1 mm of depression storage has been assigned to impervious segments of subcatchments, while 5 mm of depression storage has been assigned to pervious segments of subcatchments based on standard conventions applied across North America.

Soil Parameters

The Green and Ampt approach for parameterization of soil moisture and recovery has been selected to model the infiltration properties of subcatchment soils. The soil parameters for the Green and Ampt approach include saturated hydraulic conductivity, suction head and initial moisture deficit. Based on a review of the available soil classification within the focus area, as previously discussed under Section 3.1, no soils classification is available for the western portion of the focus area. As such, the infiltration parameters for the subcatchments in that area have been established to be consistent with soil parameters as per the PCSWMM model developed as part of the Fourteen Mile Creek/McCraney Creek Flood Management Alternative Assessment, 2013, Town of Oakville. For the balance of the subcatchments located in areas with defined soil classification, soil infiltration parameters have been selected as per recommended values in the literature (ref. Table 6.1.3).

Soil Type	Conductivity mm/hr	Suction Head mm	Initial Moisture Deficit
Sand	120.4	49.02	0.024
Loamy Sand	29.97	60.96	0.047
Sandy Loam	10.92	109.98	0.085
Loam	3.3	88.9	0.116
Silt Loam	6.6	169.93	0.135
Sandy Clay Loam	1.52	219.96	0.136
Clay Loam	1.02	210.06	0.187
Silty Clay Loam	1.02	270	0.21
Sandy Clay	0.51	240.03	0.221
Silty Clay	0.51	290.07	0.251
Clay	0.25	320.04	0.265

Table 6.1.3 Soil Parameters for Green and Ampt Infiltration Methodology

6.1.2 Minor System

The minor system has been parameterized based on the information extracted from the Town's GIS database for the storm sewer network, which includes shapefiles for the sewer pipes and maintenance holes, as well as the information collected as part of the detailed survey of the storm sewer network and associated gap filling, as described earlier. Storm sewer pipes have been represented as conduits in the PCSWMM model, while maintenance holes have been represented using junctions.

The PCSWMM model has been developed such that the runoff generated from each subcatchment is initially conveyed to the major system components and then routed to the minor system through orifices representing catch basins, catch basin leads and maintenance hole leads, which have all been modelled explicitly in order to allow for the analysis of inlet control devices as part of the remediation alternatives. The sizes of the openings of orifices within the PCSWMM model have been determined to be equivalent to the sum of the open area of the inlet elements. The number of catch basins within each model subcatchment have been counted, and an equivalent size opening has been determined based upon assuming a uniform size for each catch basin. In addition, a value of 0.013 has been selected for Manning's coefficient for all the sewer pipes within the focus area.

6.1.3 Major System

The major system components in the model have been established based on the various road right-of-way (ROW) sections within the Town. The ROW cross sections are generally comprised of either, urban cross sections with curb and gutters, or rural cross sections with road side ditches. Routing elements representing the urban cross sections have been developed based on standard Town ROW cross sections with an additional 2 % cross-fall for the portion of the cross-section beyond the ROW, extending to the front of adjacent buildings or structures. Various cross sections have been developed to represent the various road classifications and corresponding variation in the number of lanes within the ROW, as determined using the Town's GIS layers for roads and aerial imagery.

The major systems and minor systems generally have coincident locations and have largely been modelled as such. However, several networks have been identified with major-minor splits where a major system is conveyed in a direction that is not coincident with the minor system and has been modelled accordingly where appropriate.

In addition to the ROW cross sections, local open water features have been incorporated into the PCSWMM model to represent the remnant channels, or in areas where the major system ROW discharges to a primary swale for conveyance to a larger natural watercourse. In these cases, cross sections have been developed for the PCSWMM model to represent overland flow in swales running between houses on adjacent lots.

Weir elements have also been incorporated into the model to simulate low points in the ROW where the water would be conveyed to a natural water course. These have only been used where swales were not present and where a conveyance barrier existed. The weir height was dependent on the barrier which often corresponds to the curb height or the height at the front of a house as defined in the ROW cross sections.

6.1.4 Other Refinements

The observations from the field reconnaissance for rurally serviced areas have, as expected, noted the presence of driveway culverts crossing the roadside ditches. In order to account for the hydraulic impact of driveway culverts and embankments of varying size and condition, a sensitivity analysis of the hydraulic performance of this form of drainage system has been conducted to establish surrogate techniques to represent the combined hydraulic influence of the driveway culverts in the model, without explicitly incorporating each individual driveway culvert in the PCSWMM model. For these analyses, a typical road profile including the drainage ditches on both sides has been modelled in HEC-RAS with driveway culverts in-place. The model has been executed for a range of flows, from low flows contained within the drainage ditches, to high flows overtopping the road crown. Subsequently, as part of the sensitivity analysis, the driveway culverts have been removed from the road profile geometry and the profile of the drainage ditches has been modified such that the computed water surface elevation under each flow profile would match the computed water surface elevation under corresponding flow profile for the original scenario, with driveway culverts in-place. Through this assessment, an equivalent cross-section for the drainage ditch has been developed which has a reduced conveyance capacity, comparable to the original drainage ditch cross-section. This equivalent cross-section has thus been used to simulate the impacts of driveway culverts versus incorporating the culverts individually in the PCSWMM model. The original Drainage Ditch sections along with the equivalent cross-sections are presented in Appendix E.

6.2 Model Validation

As noted previously, the soils across the focus area are generally homogeneous, hence the soil parameterization established for the validation is considered representative of the soils conditions throughout the focus area. The following provides a summary of the approach and results of the model validation for the Natural Capital Study (ref. Municipal Natural Assets Initiative, Town of Oakville Pilot Study, January 2018).

The PCSWMM model has been validated using data collected for the Natural Capital pilot study, including water level data obtained at two (2) locations in the study's remnant channel. A HOBO™ level logger was installed at each location and water level data were collected from October 20, 2016 to December 6, 2016 and from March 29, 2017 to July 10, 2017. A summary of the water level data collected at each location is provided in Figures 6.2.1, 6.2.2, 6.2.3, and 6.2.4.

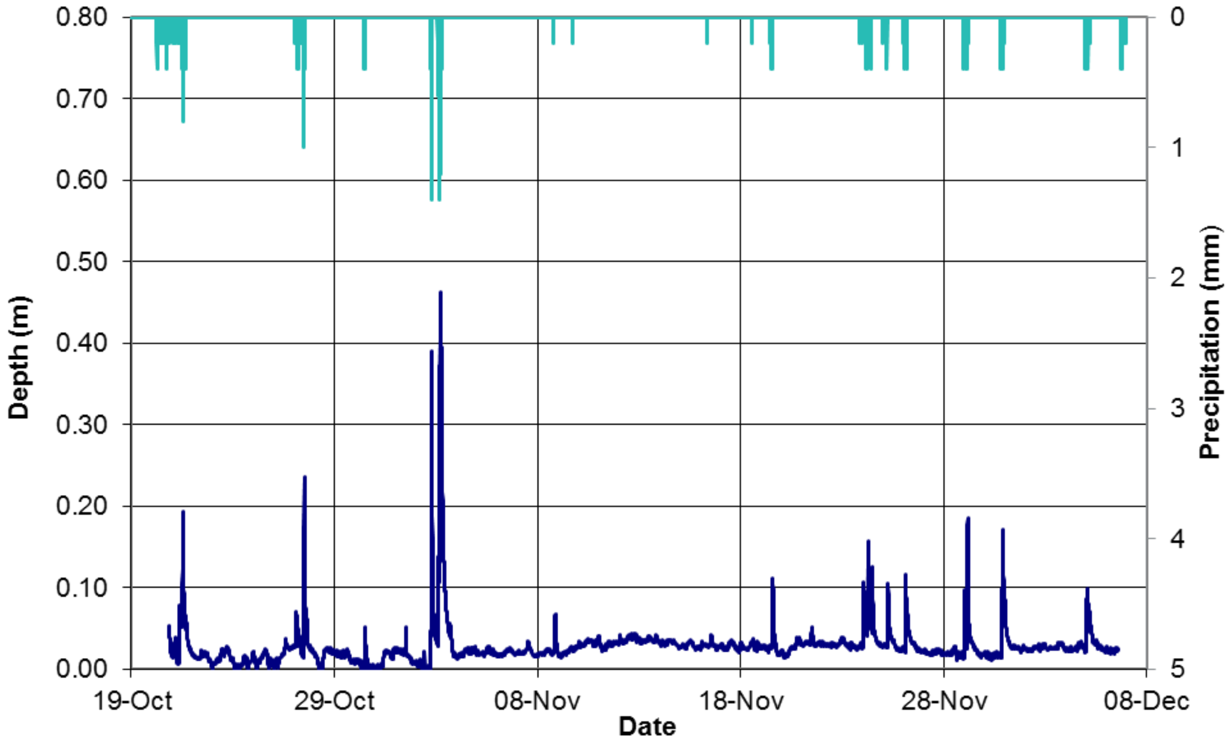

Figure 6.2.1: Maplehurst Avenue Recorded Water Level for 2016

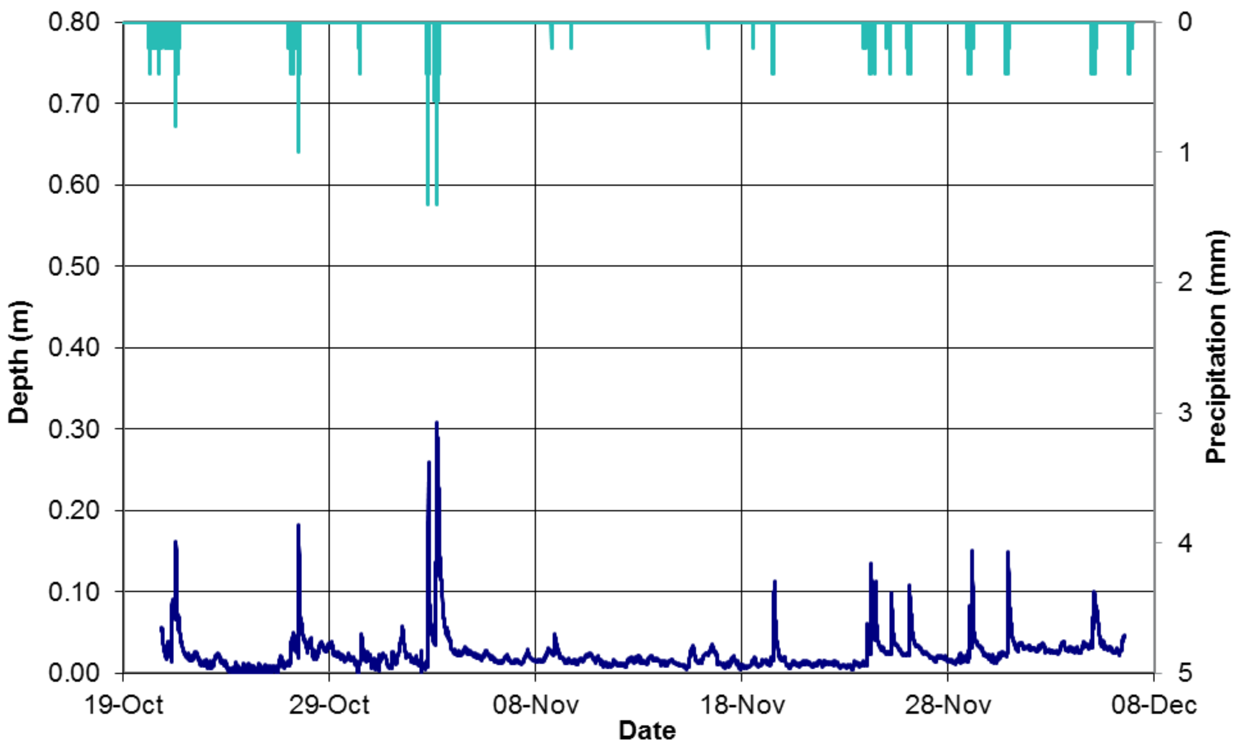

Figure 6.2.2: Fourth Line Recorded Water Level for 2016

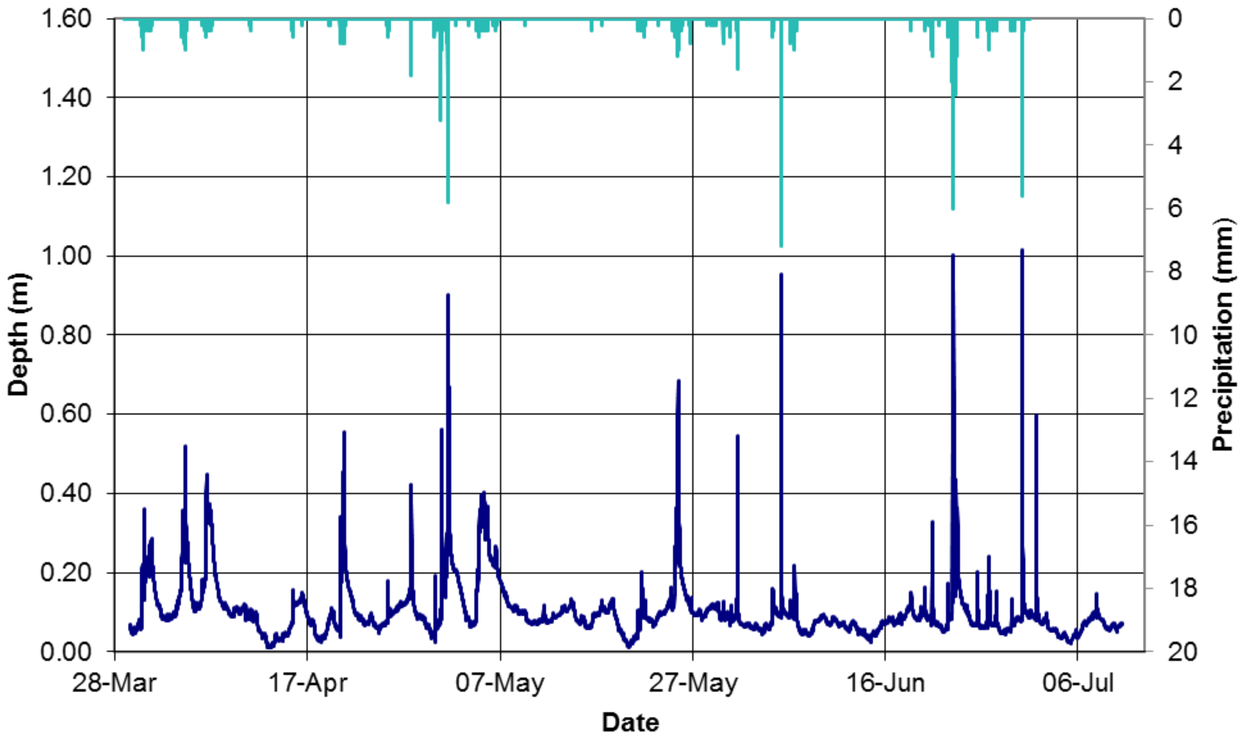

Figure 6.2.3: Maplehurst Avenue Recorded Water Level for 2017

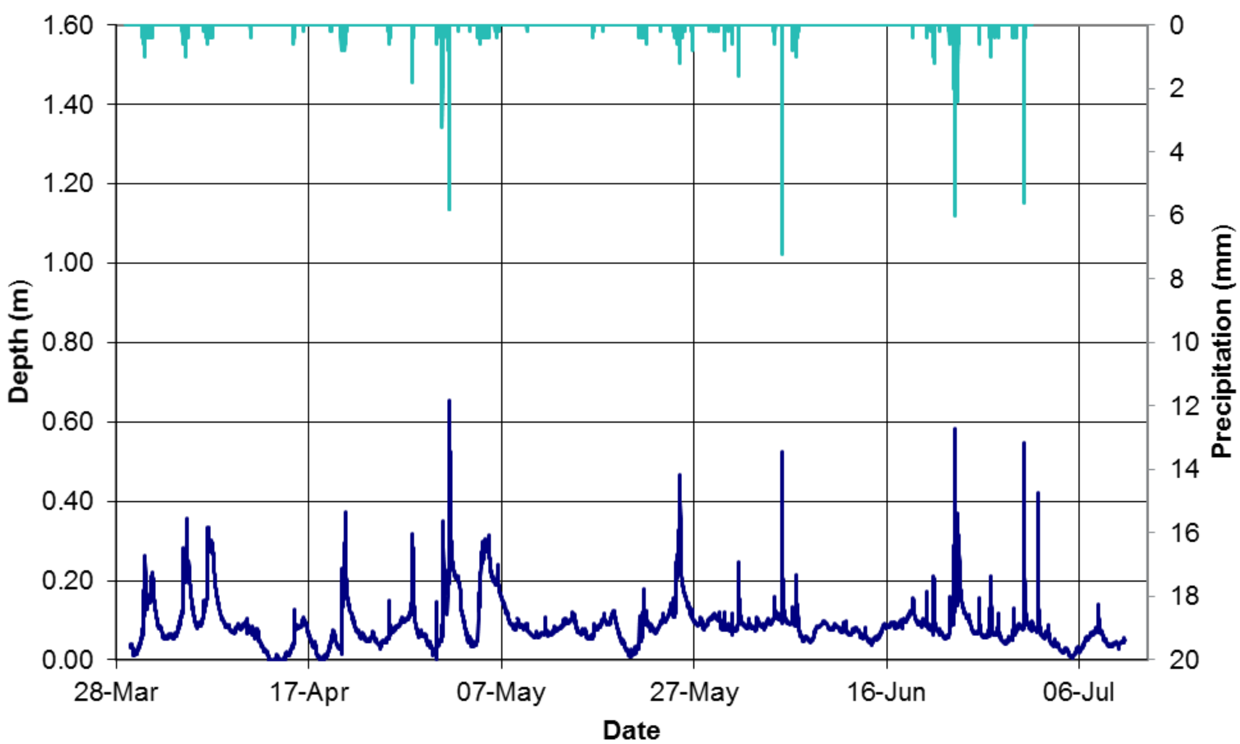

Figure 6.2.4: Fourth Line Recorded Water Level for 2017

The precipitation data provided by the Town were collected in 5 min intervals at the Central Ops rain gauge station, located at 1140 South Service Road, which is 1 km (+/-) northwest from the Maplehurst Avenue monitoring station. Due to the frequent rainfall events that occurred in the spring and early summer of 2017, several "good" events were recorded with rainfall volumes greater than, or equal to, 12 mm. The same frequency of "good" events was not observed during the fall of 2016 and the events that did have sufficient volume were not selected due to their low intensity and longer duration. A summary of the initially selected events for the hydrologic validation process are provided in Table 6.2.1.

Table 6.2.1. Selected Rainfall Events for Model Calibration

Date	Volume (mm)	Duration (min)	Duration (hr)	Peak Intensity (mm/hr)
6-Apr-17	26	1500	25.0	4.8
20-Apr-17	31.6	825	13.7	6.4
30-Apr-17	50	2060	34.3	12
25-May-17	43.8	740	12.3	9.2
5-Jun-17	12	20	0.3	12
22-Jun-17	39.2	1500	25.0	16.2
30-Jun-17	15.2	180	3.0	14.6

The rating curves for the streamflow data collection sites were developed for both monitoring locations based on the observed depth and velocity measurements obtained at the surveyed cross sections. A HEC-RAS model of the channel was also created to simulate the flow in the channel (theoretical) and 'fit' the observed water level data to a rating curve. Similarly, the Manning's and Orifice equations were generated locally to calculate the flow-depth relationship through the 900 mm (+/-) culvert and the 1800 mm culvert for verification of the channel HEC-RAS model. The results, shown in Figure 6.2.5 and Figure 6.2.6, indicate a close fit of the observed data for the Maplehurst Avenue monitoring station rating curve and a reasonable fit of the observed data for the Fourth Line monitoring station rating curve. The rating curves were used to calculate the channel flows based on the recorded water level data for the calibration of the PCSWMM model.

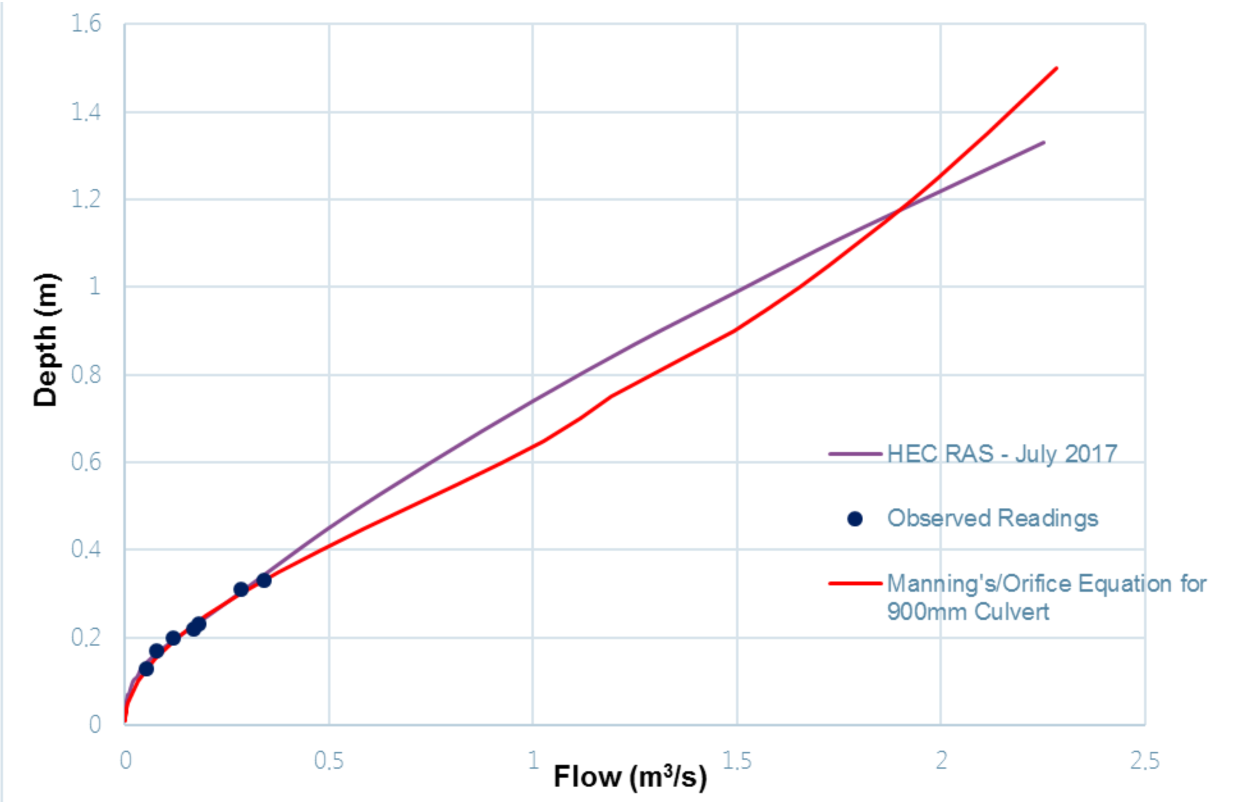

Figure 6.2.5: Maplehurst Avenue Rating Curve 2016 - 2017

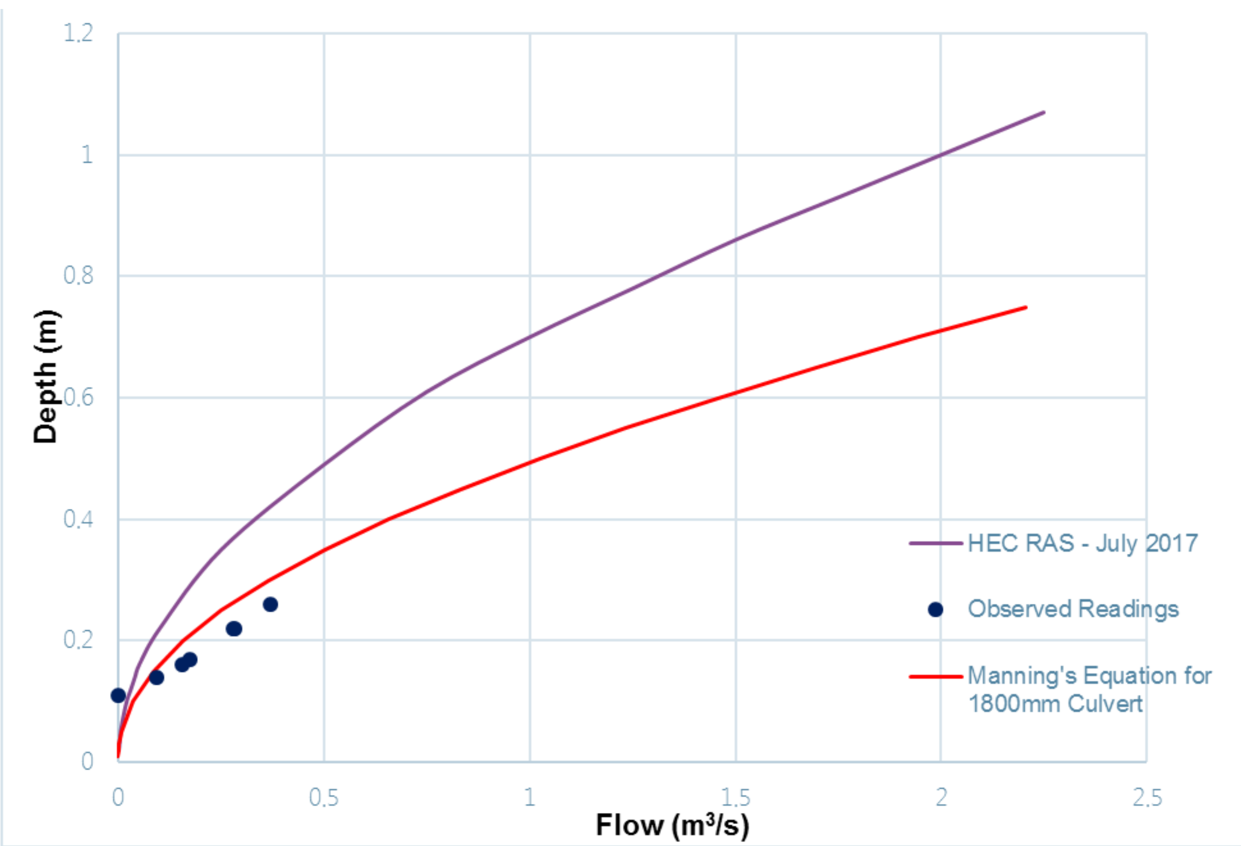

Figure 6.2.6: Fourth Line Rating Curve 2016 - 2017

The validation of the PCSWMM model for the subject drainage network was completed on the basis of best fitting three (3) traits of the selected simulated hydrographs in comparison to the observed data; the volume, peak flows, and the timing. For this assessment, the base flow was subtracted from the observed data to assist in producing comparable simulated runoff volumes. Seven (7) storms were initially selected for the validation process, listed in Table 6.2.1, however (3) of those storms were screened due to data anomalies specific to simulated volumes. The hydrographs of the remaining four (4) storm events are shown in Figures 6.2.7, 6.2.8, 6.2.9, and 6.2.10. The Fourth Line data were not used in the calibration process, as the simulated results were observed to be inconsistent with the observed data, which suggests the rating curve for this location was potentially not as accurate as the rating curve for the Maplehurst Avenue location.

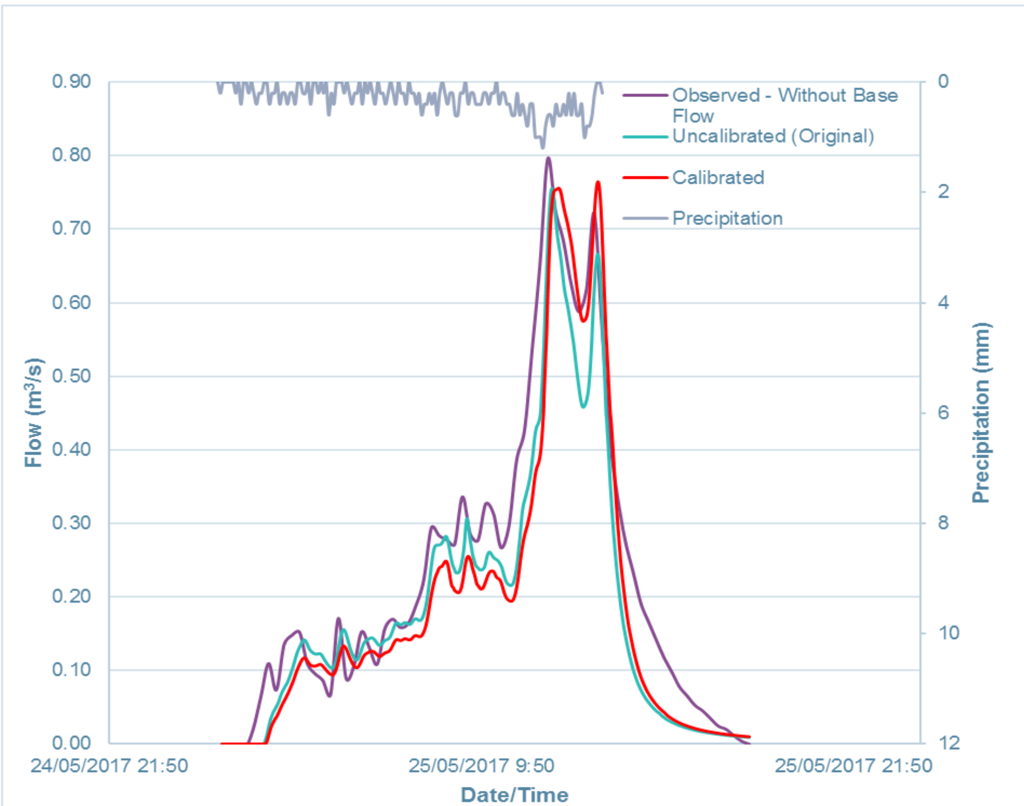

Figure 6.2.7: Maplehurst Avenue, May 25, 2017

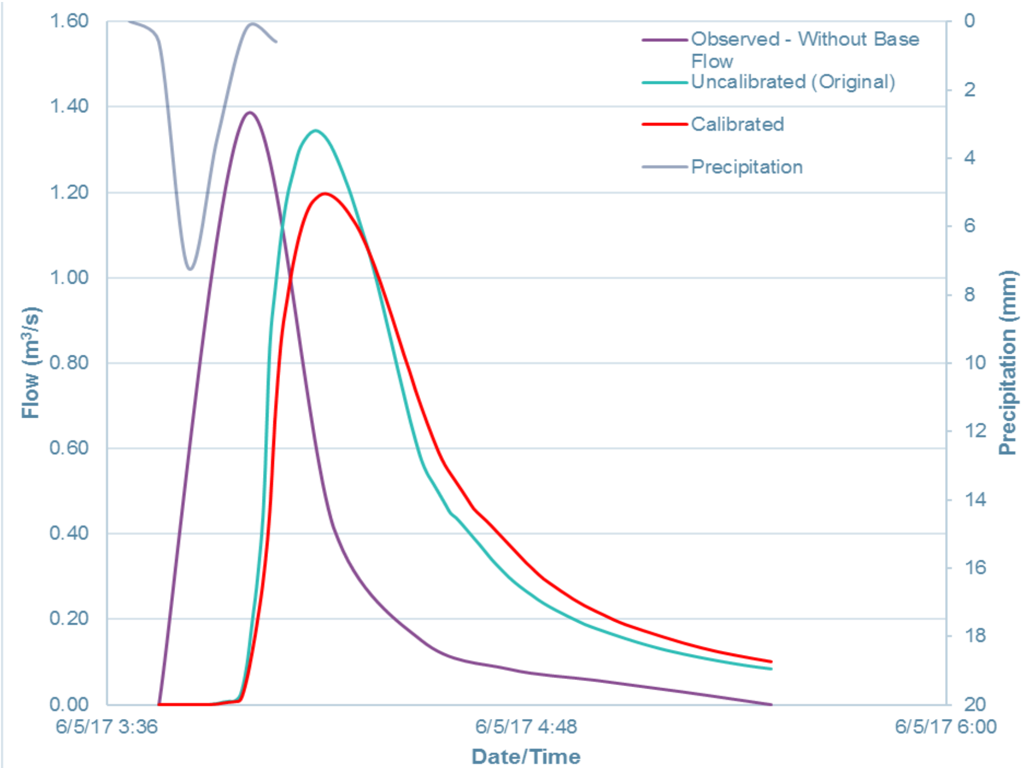

Figure 6.2.8: Maplehurst Avenue, June 5, 2017

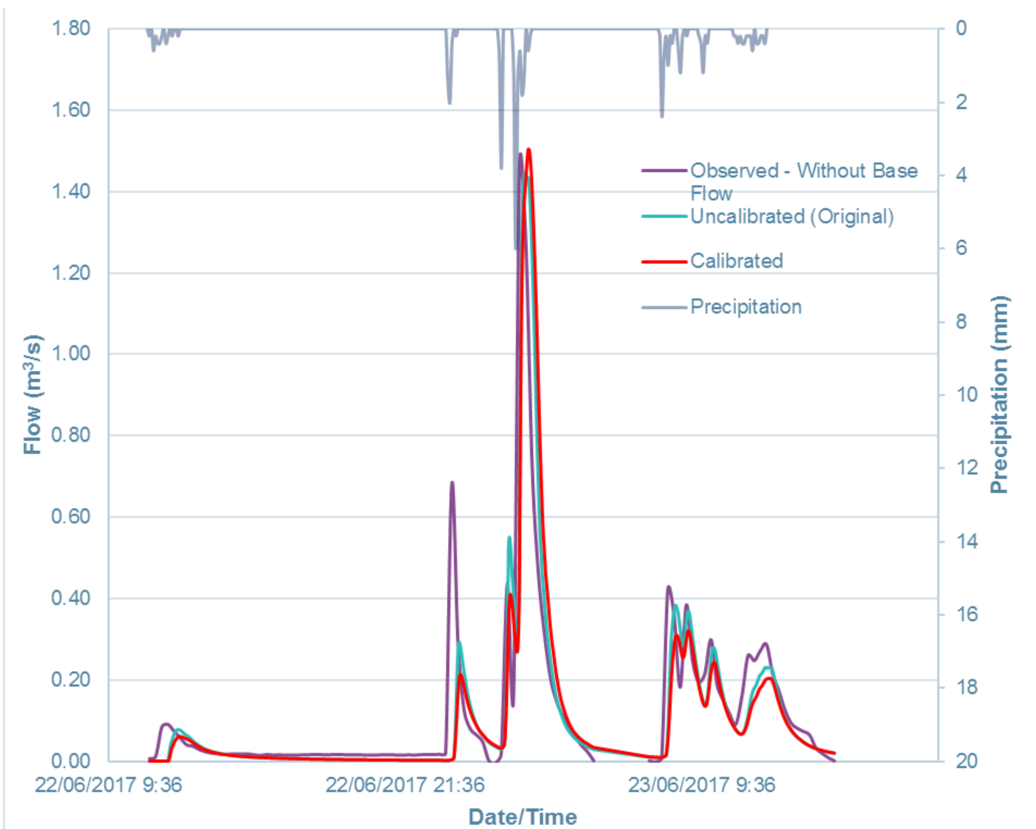

Figure 6.2.9: Maplehurst Avenue, June 22, 2017

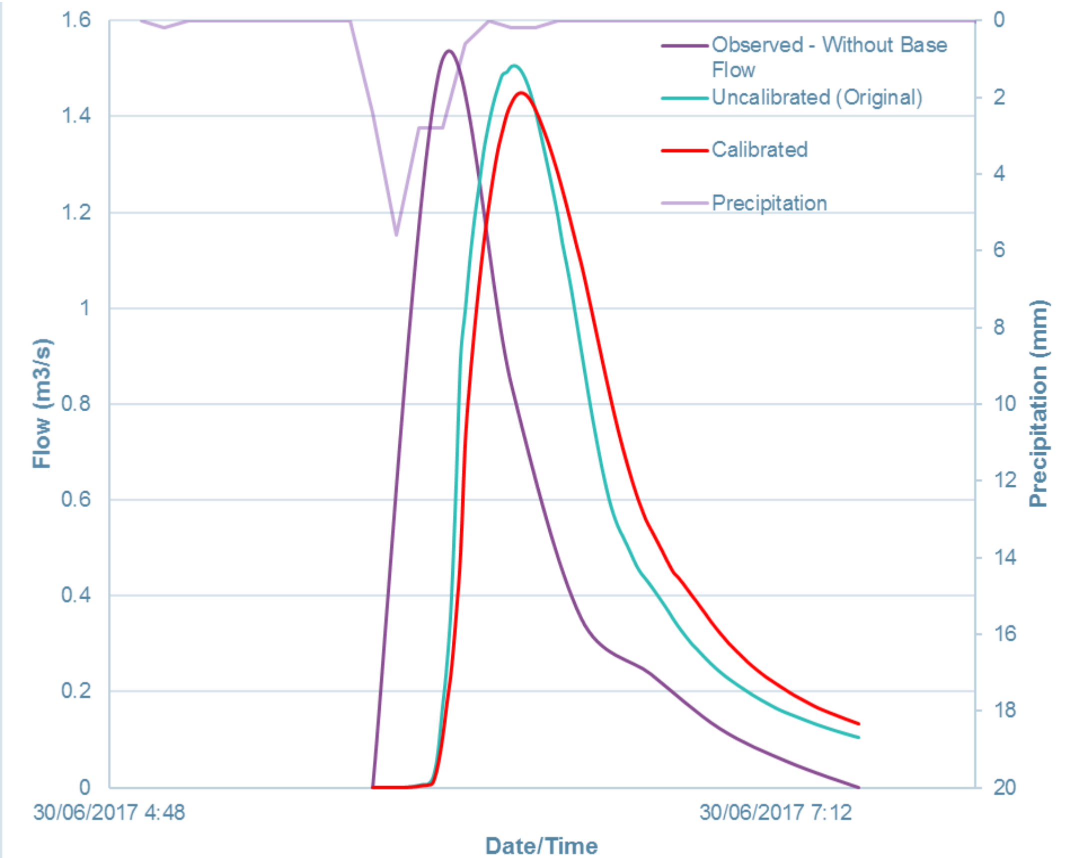

Figure 6.2.10: Maplehurst Avenue, June 30, 2017

The initial model Green and Ampt soil parameters for the PCSWMM model were obtained from literature. The impervious values for the subcatchments were calculated from GIS mapping. For the Natural Capital Pilot Study, the impervious measurements were taken from aerial imagery to confirm the impervious values previously assigned to the subcatchments. The initial imperviousness for the residential areas was observed to be high and was reduced for the residential areas. Furthermore, the soil parameters were adjusted to account for the reduction in imperviousness with the initial and validated parameters shown in Table 6.2.2. Given the close fit of the simulated volume and peak flow results for the selected rain events demonstrated in Figures 6.2.11 and 6.2.12, the PCSWMM model is considered adequately validated.

Table 6.2.2 PCSWMM Soil Parameters		
PCSWMM Parameters	**Original**	**Validated**
Depression Storage Impervious(mm)	1	1
Depression Storage Pervious (mm)	5	5
Zero Imperviousness (%)	25	25
Subarea Routing	Pervious	Pervious
Percent Routed (%)	40	40
Suction Head (mm)	200	50
Conductivity (mm/hr)	7.5	3.5
Initial Deficit (ratio)	0.25	0.25

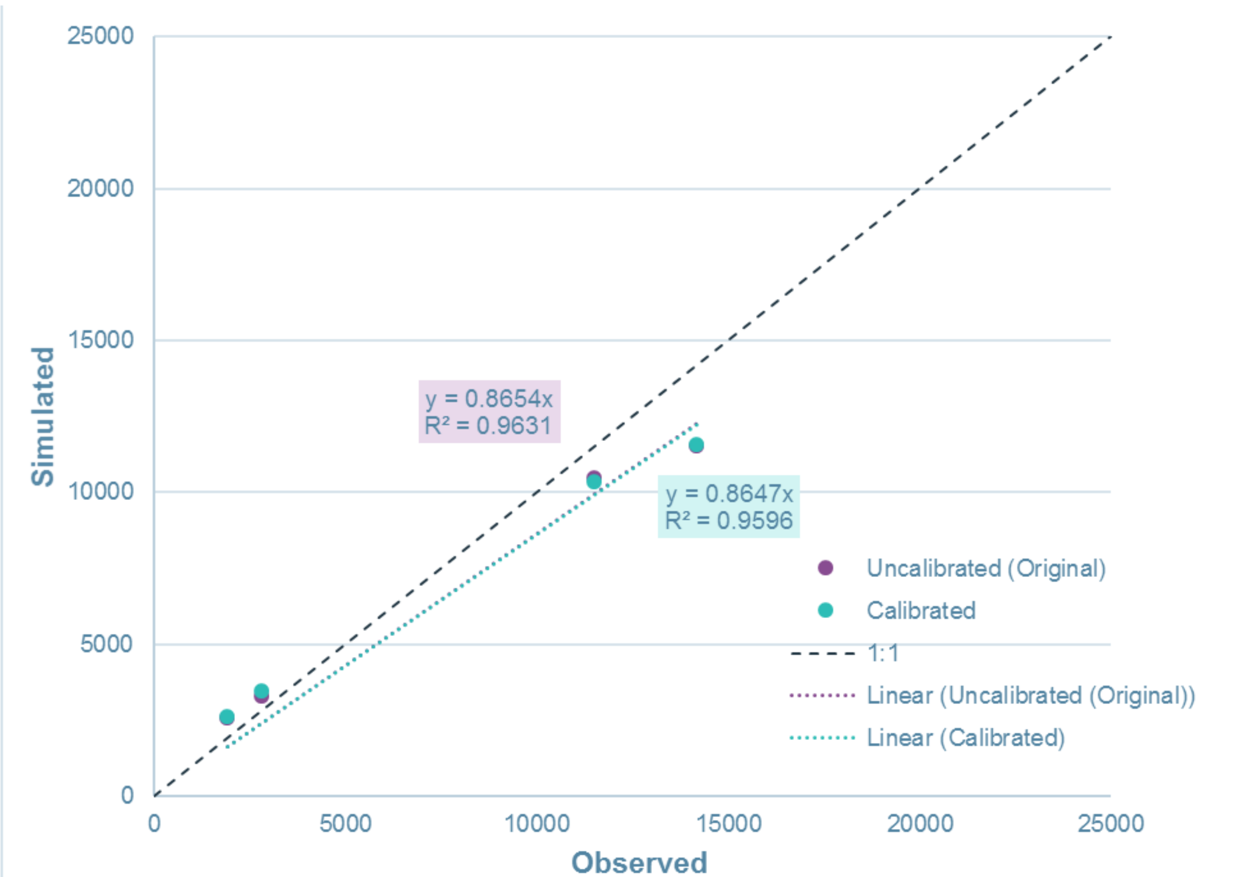

Figure 6.2.11: Comparison of Observed and Simulated Runoff Volumes for Validation Events (m^3)

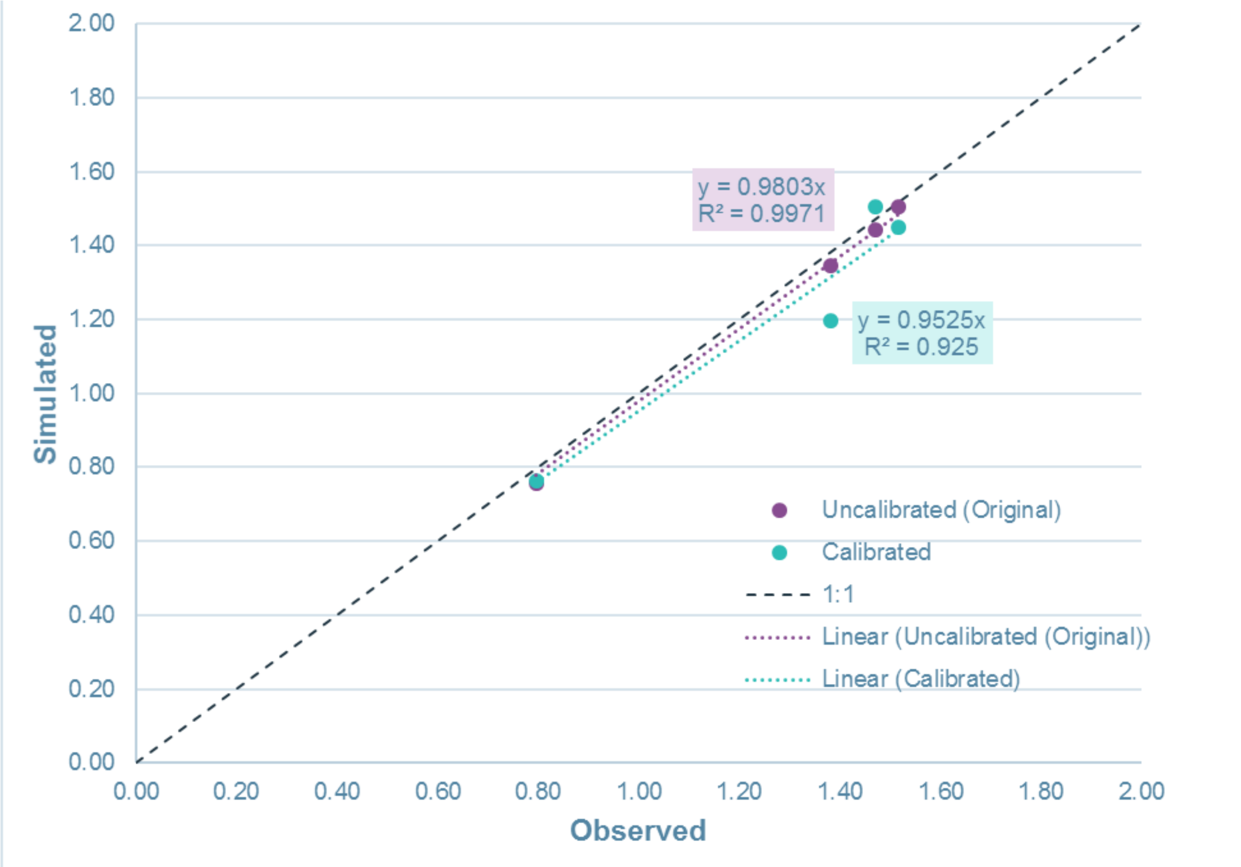

Figure 6.2.12: Comparison of Observed and Simulated Peak Flows for Validation Events (m^3/s)

The performance of the PCSWMM model has been further validated using the rainfall and flow data collected as part of the Phase 1 Storm Sewer Master Plan. Rainfall data from rain gauges operated by the Town of Oakville, as well as flow data measured at three (3) monitoring gauges installed in the Town of Oakville's storm sewer network, have been used for this assessment.

In addition to the flow data collected at the three (3) monitoring locations within the Town's storm sewer network, flow data have been collected at three (3) other locations within the open channel systems in the focus area as part of the monitoring work conducted for the Phase 1 Storm Sewer Master Plan (ref. Drawing 6.2). These flow data for the open watercourse systems have been screened for this validation assessment, as the measured flow values include the hydraulic influence of runoff routing within open channel and creek systems, while the estimated flows from the PCSWMM model for the current assessment have been focused upon validating the model performance and runoff routing within the tributary storm sewer network and the major system outside of the open watercourse systems (i.e. pluvial network).

A further review of the monitoring data has indicated that the flows measured at two (2) of the monitoring locations within the Town of Oakville's Storm Sewer network, (Sarah Lane and Arbour Drive) had poor flow response; hence on this basis, the validation process has focused on using the flow data collected from the storm sewer manhole adjacent to 565 Patricia Drive, from October 2012 to December 2012 which demonstrated a very good flow response to rainfall events during the monitoring period.

The rainfall data used for the model validation have been provided by the Town. Rainfall data from the rain gauges in closest proximity to the respective monitored areas have been used for the current assessment.

The flow data and rainfall data have been reviewed to identify candidate events for supplemental model validation, based upon coincident rainfall and runoff response, corresponding shape of hyetograph and hydrographs, and magnitude of storm event. The candidate events for model validation at each monitoring station are presented in Table 6.3.1.

Table 6.3.1 Summary of Storm Events for Model Validation

Monitoring Location	Date	Volume (mm)	Duration (min)	Duration (hr)	Peak Intensity (mm/hr)
Yolanda Drive Remnant Channel	23-Sep-11	25.6	470	7.8	6.8
	29-Sep-11	14.2	1190	19.8	8.2
Patricia Drive Storm Sewer	14-Oct-12	33.2	1090	18.2	5.6
	23-Oct-12	17.8	865	14.4	4.8
	27-Oct-12	19.4	575	9.6	4
South Service Road Outfall	12-Oct-11	20.8	755	12.6	6.2
	19-Oct-11	53.8	1880	31.3	6.4
	29-Nov-11	55.2	1580	26.3	7.4
Ford Drive Outfall	23-Sep-11	26	505	8.4	8.2
	29-Sep-11	12.6	135	2.3	10.8

The simulated hydrographs generated by the PCSWMM hydrologic model for the validation events have been visually compared with the observed hydrographs. The results are presented in Figures 6.3.1 to 6.3.10.

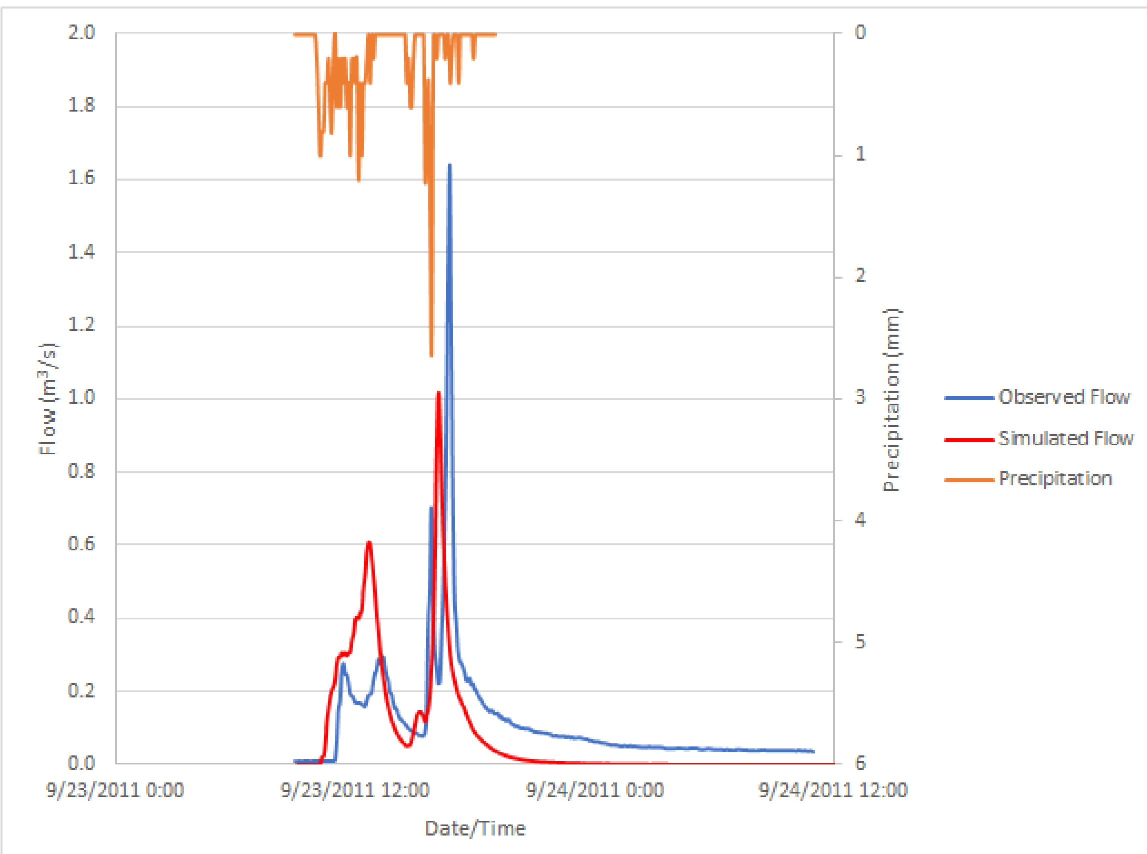

Figure 6.3.1: Comparison of Observed and Simulated Hydrographs at Yolanda Drive for September 23, 2011 Validation Event

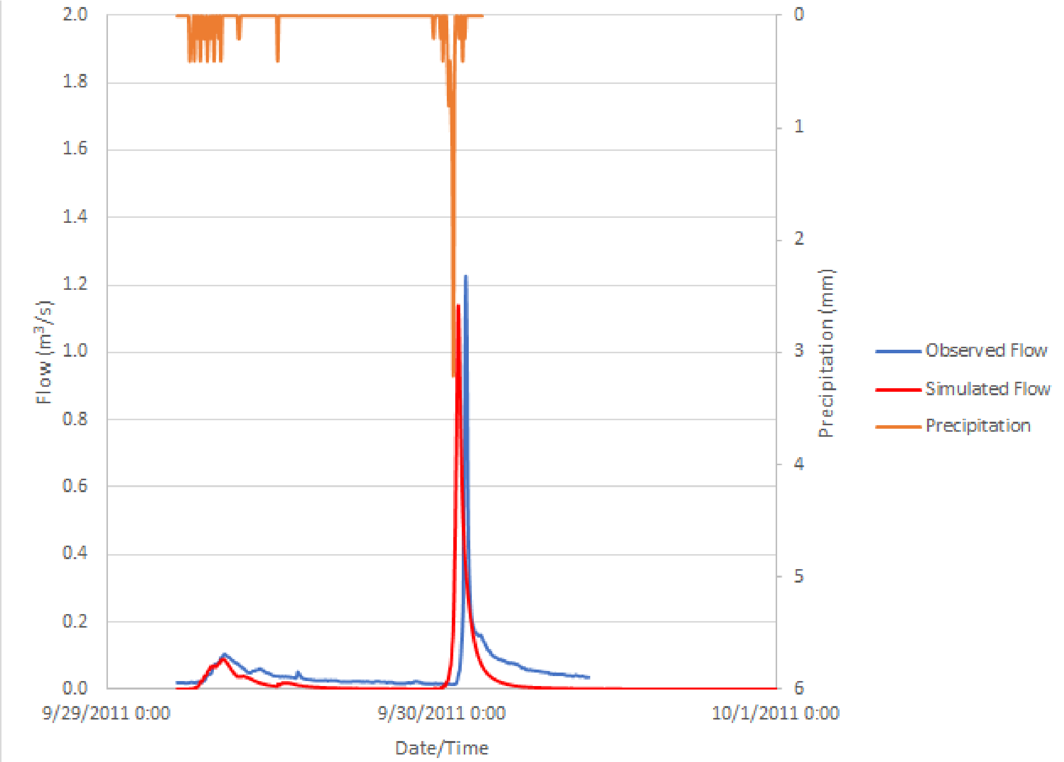

Figure 6.3.2: Comparison of Observed and Simulated Hydrographs at Yolanda Drive for September 29, 2011 Validation Event

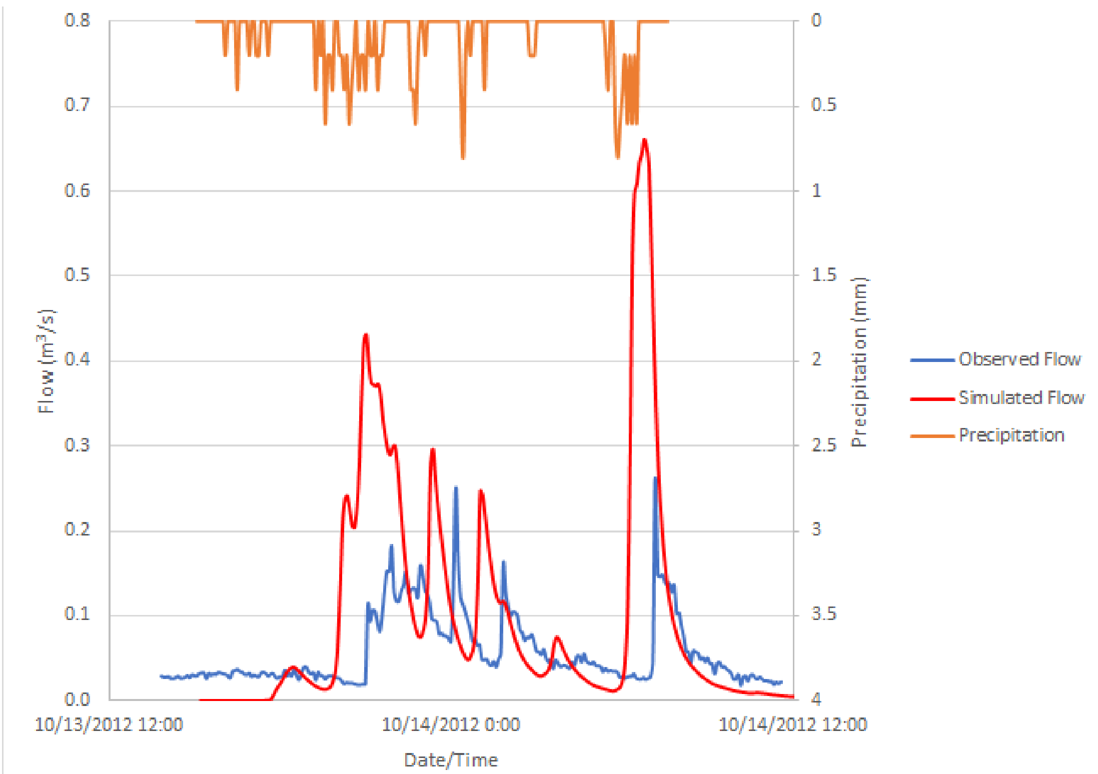

Figure 6.3.3: Comparison of Observed and Simulated Hydrographs at Patricia Drive for October 14, 2012 Validation Event

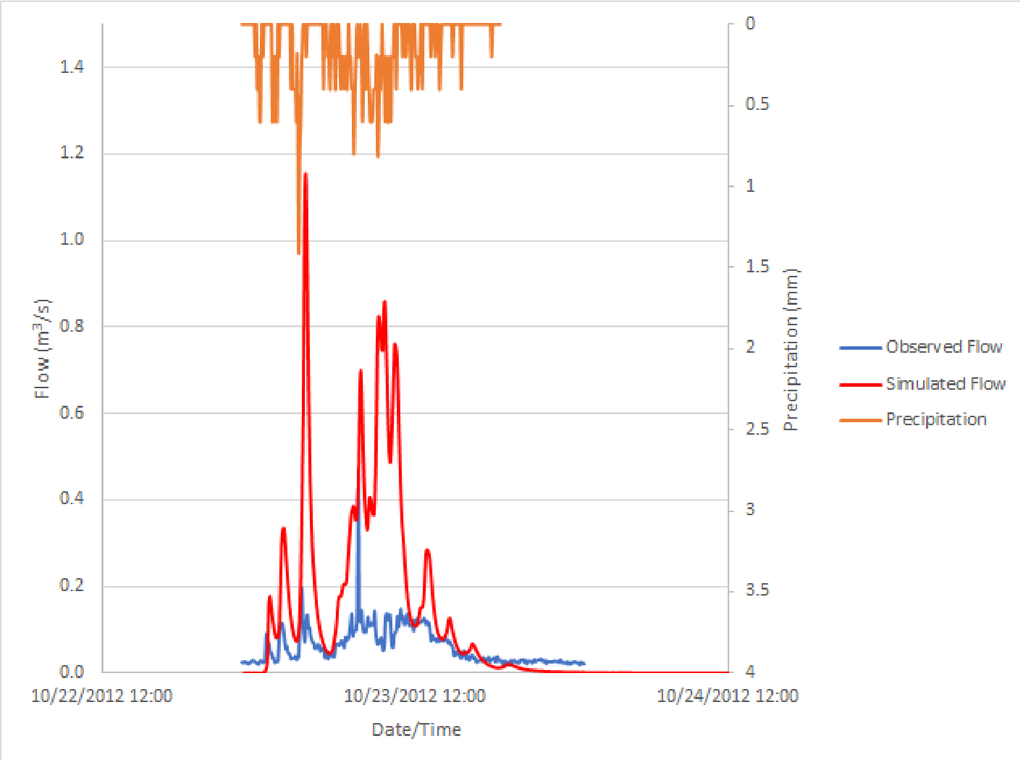

Figure 6.3.4: Comparison of Observed and Simulated Hydrographs at Patricia Drive for October 23, 2012 Validation Event

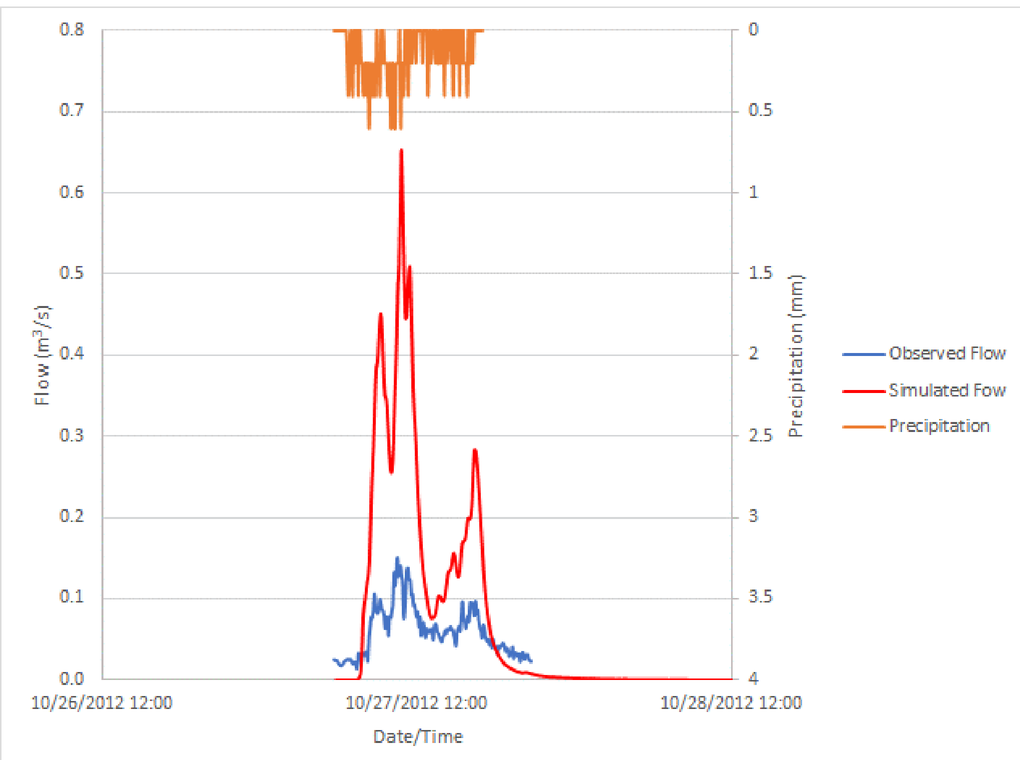

Figure 6.3.5: Comparison of Observed and Simulated Hydrographs at Patricia Drive for October 27, 2012 Validation Event

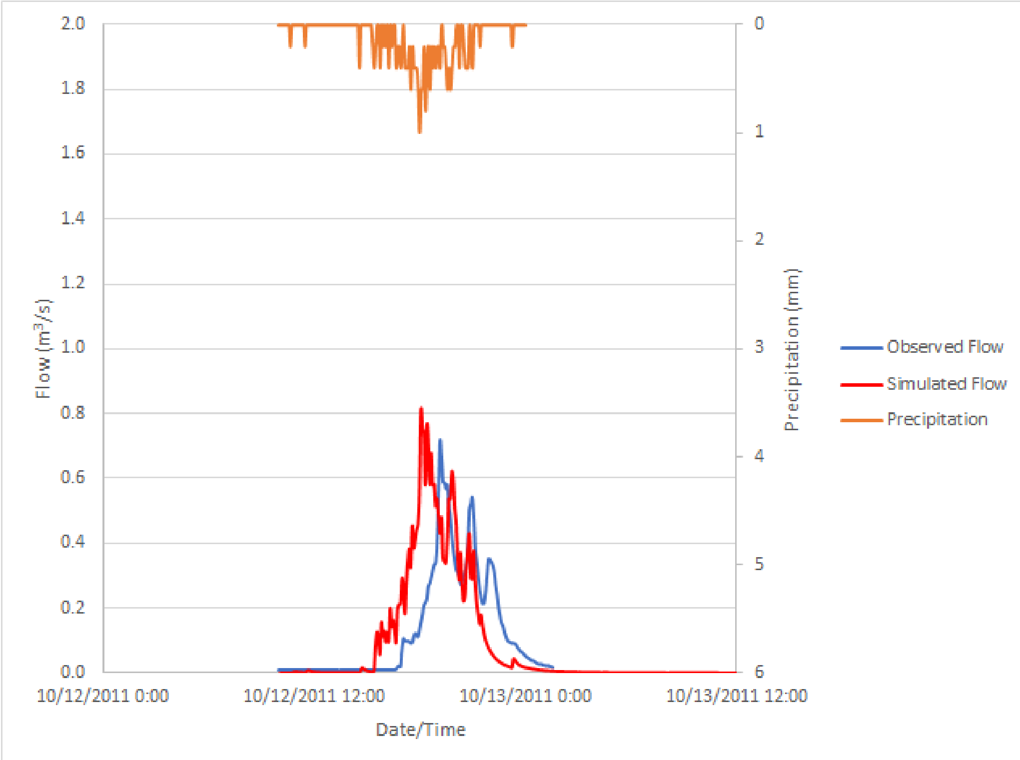

Figure 6.3.6: Comparison of Observed and Simulated Hydrographs at South Service Road for October 12, 2011 Validation Event

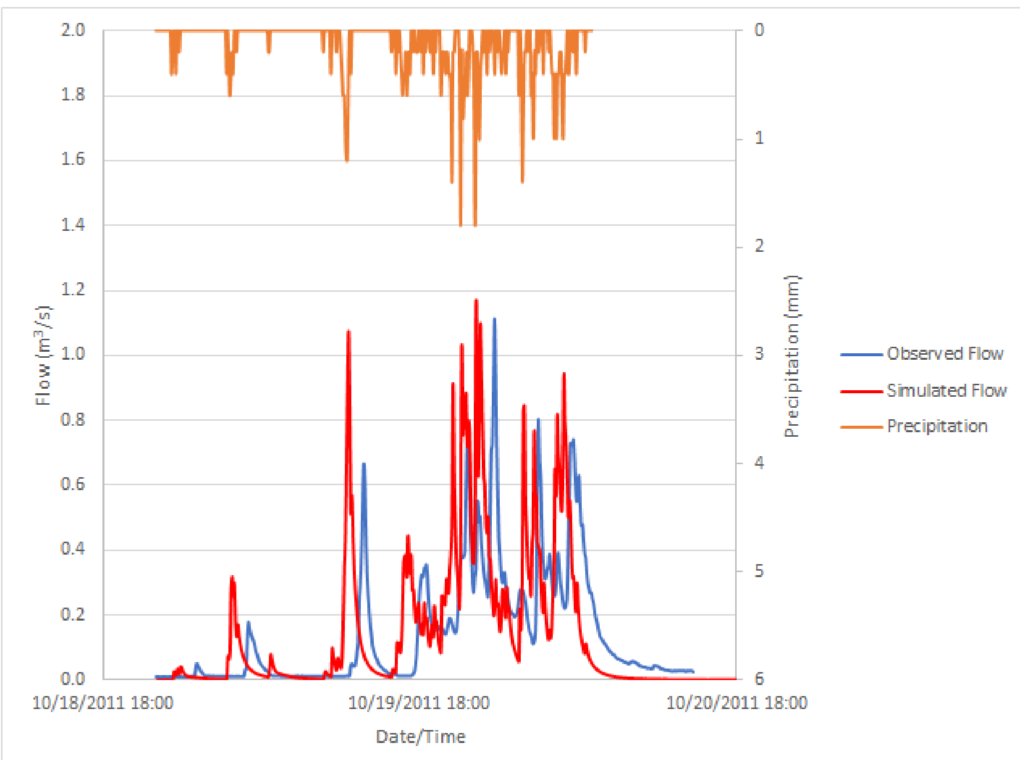

Figure 6.3.7: Comparison of Observed and Simulated Hydrographs at South Service Road for October 19, 2011 Validation Event

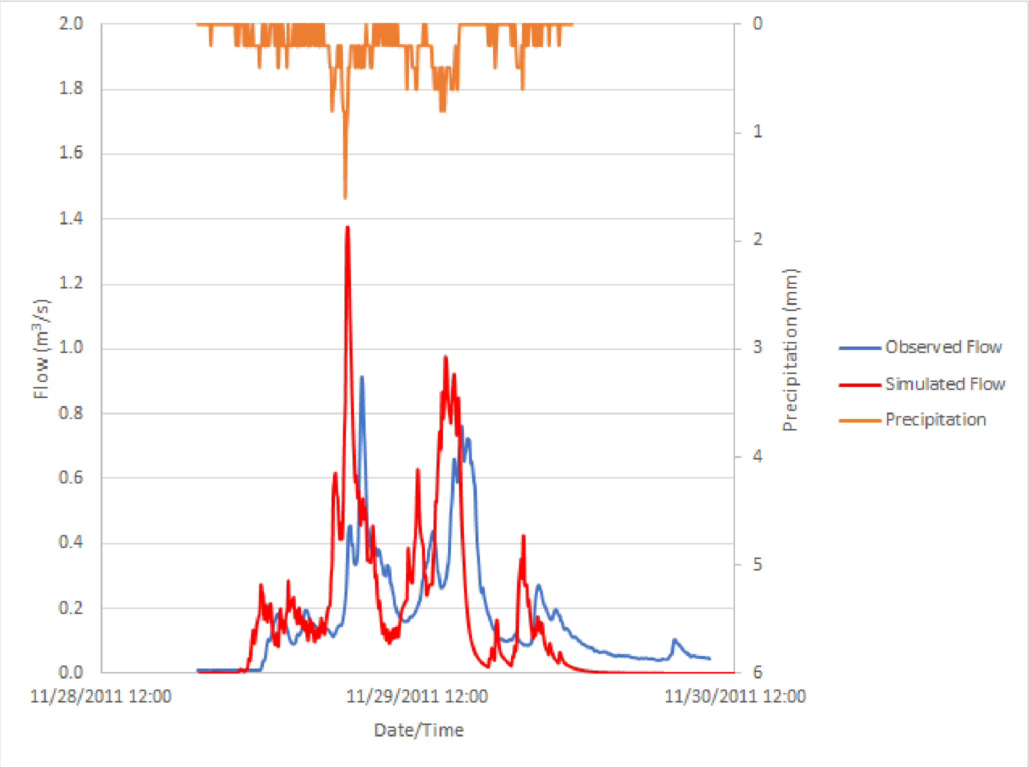

Figure 6.3.8: Comparison of Observed and Simulated Hydrographs at South Service Road for November 29, 2011 Validation Event

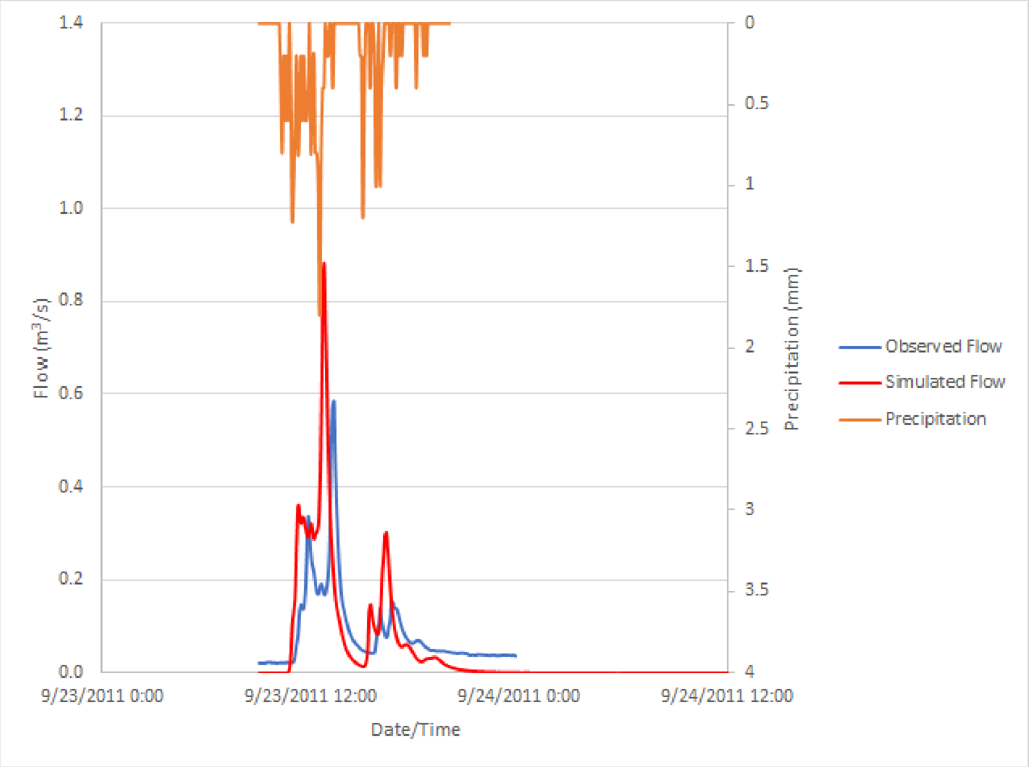

Figure 6.3.9: Comparison of Observed and Simulated Hydrographs at Ford Drive for September 23, 2011 Validation Event

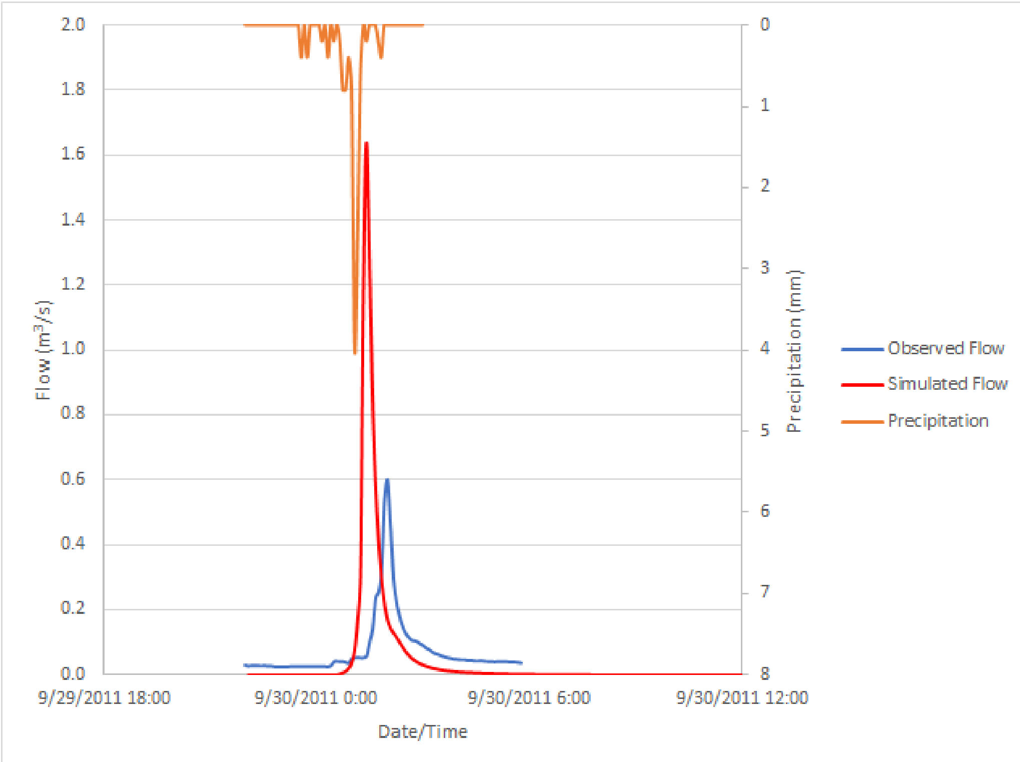

Figure 6.3.10: Comparison of Observed and Simulated Hydrographs at Ford Drive for September 29, 2011 Validation Event

The results indicate that the calibrated PCSWMM hydrologic model largely generates simulated hydrographs comparable to observed hydrographs for the validation events at the Yolanda monitoring station and the South Service Road monitoring station. The results also indicate that the simulated hydrographs at the Patricia Drive and Ford Drive monitoring stations tend to over-estimate the runoff response compared to observed conditions (i.e. peak flow and runoff volume), however the PCSWMM observed runoff responses at these locations are noted to be atypically low given the urban land use conditions contributing to these areas.

Recognizing the strong correlation between the observed and simulated runoff response for the validation events, and the strong correlation between the observed and simulated runoff response for the validation events at two of the monitoring stations, the PCSWMM model is considered to be representative of the hydrologic conditions within the focus area, and suitable for use in the current study.

6.3 Meteorological Input/Climate Change

Baseline

The Town of Oakville defines its rainfall standard in the *Development Engineering Procedures and Guidelines Manual1*. As noted in this Manual:

> *"Since there are no satisfactory meteorological data for Oakville, the data available from the Toronto Bloor Street station, which has continuous rainfall data for the last 50 years, shall be used in Oakville. Table 3.1 gives the rainfall intensity-duration-frequency (IDF) values that shall be used for all frequencies from 1:2 years to 1:100 years."*

The Toronto Bloor Street station is currently referred to as the Toronto City station (Gauge ID 6158355). The data record for this station spans 1940 to 2018.

Climate Change

It is generally recognized that historic meteorologic trends and patterns are not necessarily representative of future rainfall probabilities. The general consensus among professionals recognizes that meteorologic trends are shifting, whereby the frequency of intense storm events is increasing compared to historic observations, as a result of climate change.

As part of the Stormwater Management Master Plan, an investigation into options for representing future climate change scenarios has been conducted. The results of this investigation (ref. Appendix G) indicated that numerous approaches are available to support the estimation of future Intensity-Duration-Frequency (IDF) relationships under climate change, however all of these approaches have limitations of some kind, and no one approach has to-date been deemed to be better than the others. Most studies that incorporate climate change influenced rainfall rely on model-generated projections. These projections are most often computed with the use of global climate models (GCMs), which are dynamic system-based models that represent complex interactions between physical processes in the atmosphere, ocean, cryosphere and land surface. These are currently the most advanced tools to estimate how the climate system may respond to the natural and human driven stresses (e.g., increasing in greenhouse gas emissions, population, and other behaviours).

There are various climate organizations that conduct climate change modelling research and share their projections to the Coupled Model Inter-comparison Project Phase 5 (CMIP5). CMIP5 is the official body of science used by the Intergovernmental Panel on Climate Change (IPCC), which is a United Nations body founded with the purpose of evaluating climate change science. There are currently twenty (20) different climate modelling organizations that lead the evolution of climate models, resulting in a large repository of models available for various applications.

It is important to note that because each GCM provides a slightly different conceptualization of the earth-atmosphere system, the IPCC recommends using an ensemble approach. An ensemble is a grouping of climate projections. Together, the models in an ensemble provide a better characterization of the future and its uncertainty, than a single model used in isolation.

In addition to the Stormwater Management Master Plan, various climate change rainfall scenarios have been reviewed to determine an appropriate rainfall distribution to reflect the potential meteorologic impacts resulting from climate change; full results are provided in Appendix G (ref. Nimmrichter/Scheckenberger-Parker, December 18, 2018) while the consensus of a selection is discussed further in Section 7.5.3.

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1 Available via URL https://www.oakville.ca/assets/general%20-%20business/DevelopmentEngProceduresManual.pdf

7.0 Drainage System Performance Assessment

The validated PCSWMM model (ref. Section 6.2) has been executed using the Town of Oakville synthetic design storms without climate change adjustments to identify system performance and associated capacity constraints along the major and minor systems within the focus area. Performance of the minor system has been evaluated using the 5 year design storm and the performance of the major system has been evaluated under the 100 year design storm, in accordance with current design standards in the Town of Oakville. The synthetic design storms have been generated using the Chicago distribution with a 24 hour duration, consistent with the Town of Oakville's Development Engineering Procedures and Guideline Manual. The time series for the design storms with the 5 year and 100 year return periods have been generated using the Intensity-Duration-Frequency relationships provided in Town of Oakville's Development Engineering Procedures and Guideline Manuals (2011), which the Town's standards note apply the dataset from the City of Toronto Bloor Street Gauge (ref. Section 6.3). The precipitation depth totals for the town's current 5 year and 100 year 24 hour design storm events are presented in Table 7.1.0. The following sections discuss the results of the analyses.

Table 7.1.0 Town of Oakville 24 Hour Design Storm Event Precipitation Depths

Design Storm Event Return Period	Total Precipitation Depth (mm)
5 Year	60.0
100 Year	98.4

7.1 Capacity Constraints

7.1.1 Piped Urban and Hybrid Minor Systems

The validated PCSWMM hydrologic model has been used to assess the performance of the minor system, comprised of existing storm sewers within the urban and hybrid (i.e. combination of urban and rural systems) rights-of-way in the focus area. The resulting hydraulic gradeline has been used to determine the total length of pipe in each modelled network for which the hydraulic gradeline would fall into the following performance categories (depicted on Drawing 7.1):

- Hydraulic gradeline at or below pipe obvert.
- Hydraulic gradeline above pipe obvert, but below 50% of the height between the obvert and the top of the manhole.
- Hydraulic gradeline above 50% of the height between the obvert and the top of the manhole, but below the top of the manhole.
- Hydraulic gradeline above the top of the manhole.

As noted in Section 3.3, the storm sewers within the focus area include areas with connected foundation drains, and areas with disconnected foundation drains which discharge to surface via sump pumps. Areas of potential minor system surcharge to the basement elevation due to connection of foundation drains to gravity storm sewers within the focus area have been identified using the GIS dataset provided by the town which identifies those areas of foundation drain connections to the minor system. These locations have been cross-referenced with the vintage of infrastructure and development within the area, as well as the incidental observations from the field reconnaissance undertaken as part of Phase 1 for this study, in order to determine whether foundation drain connections plausibly exist within the respective segments of the focus area. The sites of potential foundation drain connections to the storm sewer are presented in Drawing 7.2.

Distinct storm sewer performance criteria have been adopted for the laterally connected areas and the disconnected areas respectively; the laterally connected areas have been assessed using the 100 year design storm event, while the disconnected areas have been assessed using the 5 year design storm event. While it is understood that basement elevations can vary within and between neighbourhoods, for this study it town has been assumed that the elevations of the laterally connected basements are approximately at 50% of the height between the obvert and the top of the manhole. This approximation has been considered appropriate in the context of developing a Master Plan. Future studies and planning/design of area infrastructure will need to consider a higher resolution of information. The total length of pipe within each network, which falls into the respective performance criteria, has been summarized in Table 7.1.1, and the percentage of total pipe length within each network within each category has been presented in Table 7.1.2. The results are depicted graphically in Drawings 7.3 and 7.4 for the 5 year design storm event and 100 year design storm event respectfully, and more detailed graphics are provided in Appendix F. Based on the preceding assessments, the level of risk by network for the laterally connected properties potentially impacted by minor system surcharging to the assumed basement elevation, during a 100 year storm event, is presented in Drawing 7.5.

Table 7.1.1 Summary of Minor System Performance for the Existing Land Use Conditions - Total Length By Network (m)										
Network ID	Laterally Connected Minor System (100 Year HGL)					Road Only Minor System (5 Year HGL)				
	Unsurcharged	Below 1/2 Surcharging Depth and Above Obvert	Above 1/2 Surcharging Depth and Below Rim Elevation	Surcharged Above Rim Elevation	Total Minor System Length	Unsurcharged	Below 1/2 Surcharging Depth and Above Obvert	Above 1/2 Surcharging Depth and Below Rim Elevation	Surcharged Above Rim Elevation	Total Minor System Length
1	0	0	1998	800	**2798**	75	74	416	137	**701**
2	1009	1184	0	0	**2193**	567	0	0	0	**567**
3	2487	861	89	0	**3437**	766	160	220	522	**1669**
4	1148	3995	113	0	**5255**	1413	523	0	0	**1937**
5	0	0	0	0	**0**	2646	794	779	558	**4778**
6	0	0	150	56	**206**	103	248	96	0	**448**
7	0	170	678	110	**957**	0	114	91	0	**205**
8	0	247	2244	1318	**3809**	0	521	253	0	**774**
9	0	80	1020	1194	**2294**	440	516	551	69	**1575**
10	0	0	0	0	**0**	0	130	0	11	**140**
11	0	232	273	101	**606**	408	419	0	0	**827**
12	0	0	0	0	**0**	88	64	308	185	**645**
13	0	300	1775	1479	**3553**	1514	1210	1240	166	**4130**
14	56	543	5192	3832	**9622**	1718	1677	2465	361	**6221**
15	0	141	1125	4017	**5282**	180	652	1064	855	**2751**
16	0	27	152	37	**215**	0	81	0	0	**81**
17	0	405	222	103	**731**	243	233	184	298	**959**
18	0	386	429	1421	**2236**	462	440	651	766	**2319**
19	124	0	0	112	**236**	103	0	323	461	**887**
20	0	0	1196	943	**2139**	1374	552	1084	1396	**4407**
21	50	0	0	62	**112**	537	793	200	0	**1530**
22	0	0	0	0	**0**	316	140	55	0	**511**
23	0	34	261	237	**532**	0	453	354	602	**1409**
24	0	80	1081	358	**1519**	51	633	877	121	**1682**
25	0	369	1043	447	**1859**	800	535	270	212	**1818**
26	53	59	129	80	**322**	140	420	432	150	**1143**
27	25	258	1125	1441	**2848**	582	1382	2614	1882	**6460**
28	60	92	264	254	**670**	317	207	185	109	**817**
29	100	353	141	189	**782**	549	272	662	128	**1611**
30	0	76	828	1002	**1905**	730	855	1945	880	**4410**
31	0	0	462	338	**800**	169	12	54	123	**358**
32	0	0	179	141	**319**	885	396	327	274	**1882**
33	127	112	457	87	**783**	1341	854	1259	112	**3566**
34	0	62	914	604	**1579**	90	933	1796	967	**3786**
35	379	594	917	276	**2165**	1432	442	236	192	**2301**
36	0	0	698	420	**1117**	1263	781	1174	579	**3797**
37	220	593	1018	391	**2222**	1699	1227	331	218	**3475**
38	0	82	647	397	**1127**	0	0	528	311	**839**
39	250	120	293	243	**906**	1156	791	771	671	**3388**

Table 7.1.1 Summary of Minor System Performance for the Existing Land Use Conditions - Total Length By Network (m)										
Network ID	Laterally Connected Minor System (100 Year HGL)					Road Only Minor System (5 Year HGL)				
	Unsurcharged	Below 1/2 Surcharging Depth and Above Obvert	Above 1/2 Surcharging Depth and Below Rim Elevation	Surcharged Above Rim Elevation	Total Minor System Length	Unsurcharged	Below 1/2 Surcharging Depth and Above Obvert	Above 1/2 Surcharging Depth and Below Rim Elevation	Surcharged Above Rim Elevation	Total Minor System Length
40	0	0	497	215	**712**	59	281	97	179	**615**
41	0	58	292	54	**404**	537	17	354	339	**1248**
42	64	0	510	204	**778**	261	607	314	371	**1554**
43	0	0	614	340	**954**	344	905	0	58	**1307**
44	28	93	776	651	**1548**	802	201	767	60	**1830**
45	147	421	986	897	**2452**	0	86	594	458	**1138**
46	112	123	1176	605	**2016**	4238	1048	911	498	**6695**
47	237	647	2740	1857	**5482**	0	0	1079	741	**1820**
48	658	1459	626	61	**2804**	207	73	0	0	**280**
49	601	1145	2381	929	**5055**	2428	136	330	144	**3038**
50	0	415	2763	1449	**4627**	0	207	397	84	**688**
51	93	581	738	0	**1412**	283	247	135	16	**681**
52	6175	4571	5107	1890	**17743**	2452	517	374	0	**3343**
53	563	1101	3340	293	**5297**	1251	1009	340	92	**2691**
54	1196	1734	2596	557	**6083**	4634	1769	2085	2207	**10695**
55	388	471	1729	487	**3075**	614	444	863	952	**2872**
56	421	1394	4094	2582	**8490**	1736	1093	1645	433	**4908**
Total	**16771**	**25668**	**58075**	**35559**	**136072**	**44005**	**28174**	**34081**	**19948**	**126207**

Network ID	Laterally Connected Minor System (100 Year HGL)					Road Only Minor System (5 Year HGL)				
	Unsurcharged	Below 1/2 Surcharging Depth and Above Obvert	Above 1/2 Surcharging Depth and Below Rim Elevation	Surcharged Above Rim Elevation	Total Minor System Length	Unsurcharged	Below 1/2 Surcharging Depth and Above Obvert	Above 1/2 Surcharging Depth and Below Rim Elevation	Surcharged Above Rim Elevation	Total Minor System Length
1	0	0	71	29	**80**	11	11	59	19	**20**
2	46	54	0	0	**79**	100	0	0	0	**21**
3	72	25	3	0	**67**	46	10	13	31	**33**
4	22	76	2	0	**73**	73	27	0	0	**27**
5	0	0	0	0	**0**	55	17	16	12	**100**
6	0	0	73	27	**31**	23	55	21	0	**69**
7	0	18	71	11	**82**	0	56	44	0	**18**
8	0	6	59	35	**83**	0	67	33	0	**17**
9	0	3	44	52	**59**	28	33	35	4	**41**
10	0	0	0	0	**0**	0	92	0	8	**100**
11	0	38	45	17	**42**	49	51	0	0	**58**
12	0	0	0	0	**0**	14	10	48	29	**100**
13	0	8	50	42	**46**	37	29	30	4	**54**
14	1	6	54	40	**61**	28	27	40	6	**39**
15	0	3	21	76	**66**	7	24	39	31	**34**
16	0	13	70	17	**73**	0	100	0	0	**27**
17	0	55	30	14	**43**	25	24	19	31	**57**
18	0	17	19	64	**49**	20	19	28	33	**51**
19	52	0	0	48	**21**	12	0	36	52	**79**
20	0	0	56	44	**33**	31	13	25	32	**67**
21	44	0	0	56	**7**	35	52	13	0	**93**
22	0	0	0	0	**0**	62	27	11	0	**100**
23	0	6	49	45	**27**	0	32	25	43	**73**
24	0	5	71	24	**47**	3	38	52	7	**53**
25	0	20	56	24	**51**	44	29	15	12	**49**
26	17	18	40	25	**22**	12	37	38	13	**78**
27	1	9	39	51	**31**	9	21	40	29	**69**
28	9	14	39	38	**45**	39	25	23	13	**55**
29	13	45	18	24	**33**	34	17	41	8	**67**
30	0	4	43	53	**30**	17	19	44	20	**70**
31	0	0	58	42	**69**	47	3	15	34	**31**
32	0	0	56	44	**15**	47	21	17	15	**85**
33	16	14	58	11	**18**	38	24	35	3	**82**
34	0	4	58	38	**29**	2	25	47	26	**71**
35	18	27	42	13	**48**	62	19	10	8	**52**
36	0	0	62	38	**23**	33	21	31	15	**77**
37	10	27	46	18	**39**	49	35	10	6	**61**
38	0	7	57	35	**57**	0	0	63	37	**43**
39	28	13	32	27	**21**	34	23	23	20	**79**

Table 7.1.2 Summary of Minor System Performance for the Existing Land Use Conditions - Percentage of Total Minor System Length By Network(%)

Table 7.1.2 Summary of Minor System Performance for the Existing Land Use Conditions - Percentage of Total Minor System Length By Network(%)										
	Laterally Connected Minor System (100 Year HGL)					Road Only Minor System (5 Year HGL)				
Network ID	Unsurcharged	Below 1/2 Surcharging Depth and Above Obvert	Above 1/2 Surcharging Depth and Below Rim Elevation	Surcharged Above Rim Elevation	Total Minor System Length	Unsurcharged	Below 1/2 Surcharging Depth and Above Obvert	Above 1/2 Surcharging Depth and Below Rim Elevation	Surcharged Above Rim Elevation	Total Minor System Length
40	0	0	70	30	**54**	10	46	16	29	**46**
41	0	14	72	13	**24**	43	1	28	27	**76**
42	8	0	65	26	**33**	17	39	20	24	**67**
43	0	0	64	36	**42**	26	69	0	4	**58**
44	2	6	50	42	**46**	44	11	42	3	**54**
45	6	17	40	37	**68**	0	8	52	40	**32**
46	6	6	58	30	**23**	63	16	14	7	**77**
47	4	12	50	34	**75**	0	0	59	41	**25**
48	23	52	22	2	**91**	74	26	0	0	**9**
49	12	23	47	18	**62**	80	4	11	5	**38**
50	0	9	60	31	**87**	0	30	58	12	**13**
51	7	41	52	0	**67**	42	36	20	2	**33**
52	35	26	29	11	**84**	73	15	11	0	**16**
53	11	21	63	6	**66**	46	37	13	3	**34**
54	20	29	43	9	**36**	43	17	19	21	**64**
55	13	15	56	16	**52**	21	15	30	33	**48**
56	5	16	48	30	**63**	35	22	34	9	**37**
Total	**12**	**19**	**43**	**26**	**52**	**35**	**22**	**27**	**16**	**48**

The results summarized in 7.1.1 and 7.1.2 indicate that approximately 56% of the storm sewers within the focus area would have sufficient capacity, or be subjected to relatively minor surcharge conditions, during the 5 year storm event, hence are generally compliant with the Town's current standards for storm sewer design without considering climate change or land use change). The results indicate that approximately 44 % of the storm sewers within the focus area have deficient conveyance capacity, being susceptible to high levels of surcharge and/or resulting in surcharging above the rim elevation during the 5 year storm event.

7.1.2 Major Systems

The validated PCSWMM hydrologic model has been used to assess the performance of the existing major system (without climate change or land use change), which encompasses urban, ditched, and hybrid drainage systems within the focus area. The hydraulic gradeline generated for the 100 year synthetic design storm has been used to determine the total length of road right-of-way in each network for which the hydraulic gradeline would fall into the following performance categories and depicted in Drawing 7.6:

- 100 Year flow contained within the top of curb/top of ditch.
- 100 Year flow above top of curb/top of ditch but contained within right-of-way.
- 100 Year flow above edge of right-of-way but less than 50% of the distance between the right-of-way and the adjacent structure.
- 100 Year flow above 50% of the distance between the right-of-way and the adjacent structure.

The total length of right-of-way within each network, which falls into each of the above performance categories, is summarized in Table 7.1.3, and the percentage of total major system within each network within each category is presented in Table 7.1.4. The grand total in each table represents the total length of the storm sewers for each network and the percentage of the storm sewers in the focus area respectfully. The curbed and ditched performance results are depicted graphically in Drawing 7.7, and more detailed graphics are provided in Appendix F. The graphical performance results of only the ditched areas are presented in Drawing 7.8 for the 5 year storm event and Drawing 7.9 for the 100 year storm event.

Table 7.1.3 Summary of Major System Performance for the 100 Year Design Storm Event for Existing Land Use Conditions - Total Length By Network (m)

Network ID	Within Ditch	Within Curb	Above Ditch Within ROW	Above Curb Within ROW	Flow Beyond ROW (Less Than 50% to Building) - Ditches	Flow Beyond ROW (Less Than 50% to Building) - Curbed	Flow Beyond ROW (Greater Than 50% to Building) - Ditches	Flow Beyond ROW (Greater Than 50% to Building) - Curbed	Grand Total
1	0	2020	0	1242	0	0	0	51	3313
2	0	1814	0	494	0	83	0	479	2869
3	220	3158	37	1452	0	188	0	125	5180
4	0	4770	0	2151	0	290	0	132	7343
5	552	655	360	1601	319	43	78	179	3788
6	0	567	0	0	0	0	0	0	567
7	54	564	92	42	0	49	143	136	1080
8	52	3623	10	196	83	41	0	804	4809
9	65	2442	213	906	431	36	99	296	4489
10	4	82	178	0	531	0	84	0	879
11	0	1226	0	23	0	0	333	0	1582
12	0	676	0	286	0	0	0	0	963
13	161	6397	259	1302	686	271	562	629	10265
14	271	7053	501	4370	0	779	894	2739	16607
15	455	3539	761	1681	1047	959	1282	2272	11995
16	130	253	0	0	0	0	0	0	383
17	361	951	452	6	505	0	980	0	3254
18	407	442	1179	499	2963	0	3377	712	9580
19	174	102	302	41	0	0	826	18	1464
20	253	1144	1248	1160	5146	414	1883	1141	12389
21	0	839	223	0	202	0	310	323	1897
22	8	136	0	0	0	14	342	52	553
23	63	80	244	107	629	43	862	61	2089
24	582	564	574	1619	2148	0	195	279	5960
25	823	2024	1157	1008	1875	150	1983	191	9210
26	0	738	17	488	429	0	366	171	2209
27	368	3372	2023	1169	3263	197	1832	1080	13303
28	413	1050	392	0	859	91	1232	0	4035
29	122	1435	654	1552	295	5	31	213	4307
30	74	2789	360	1663	365	934	772	660	7616
31	0	651	0	463	0	0	0	86	1200
32	0	1233	49	702	0	0	113	92	2188
33	0	3193	0	901	154	163	216	488	5117
34	56	1624	642	1261	1605	407	708	203	6505
35	174	4306	262	130	55	0	222	46	5195
36	0	2776	526	504	158	39	439	689	5132
37	0	5021	285	1381	0	90	371	204	7350
38	0	1234	0	96	9	107	335	183	1965
39	396	782	608	461	1263	117	2525	119	6271
40	0	783	717	150	460	0	757	0	2867
41	0	834	114	610	1559	192	212	66	3587
42	135	826	485	333	866	33	984	48	3709
43	328	202	189	439	295	0	710	45	2208
44	0	1198	569	482	1117	0	888	70	4323
45	197	1676	314	453	515	91	1197	218	4662
46	102	2917	1756	940	1493	290	969	660	9126
47	44	4969	0	1401	0	50	608	838	7910

Table 7.1.3 Summary of Major System Performance for the 100 Year Design Storm Event for Existing Land Use Conditions - Total Length By Network (m)									
Network ID	Within Ditch	Within Curb	Above Ditch Within ROW	Above Curb Within ROW	Flow Beyond ROW (Less Than 50% to Building) - Ditches	Flow Beyond ROW (Less Than 50% to Building) - Curbed	Flow Beyond ROW (Greater Than 50% to Building) - Ditches	Flow Beyond ROW (Greater Than 50% to Building) - Curbed	Grand Total
48	0	2347	0	492	0	40	0	86	2965
49	404	3290	81	2988	0	189	471	919	8342
50	74	3855	0	1106	0	255	0	248	5538
51	0	1358	197	265	100	26	8	77	2031
52	553	12576	152	5742	0	1684	0	1464	22171
53	603	5160	255	1552	332	35	396	376	8709
54	1750	11308	745	2572	1510	105	1030	1196	20216
55	178	3580	346	590	825	155	383	0	6056
56	0	8220	0	3463	0	262	91	951	12986
LMC	335	0	985	0	1148	0	413	0	2881
LWC	368	102	1715	30	1692	0	732	0	4640
Total	**10605**	**140423**	**19527**	**54533**	**34088**	**8915**	**32099**	**22117**	**322307**

Table 7.1.4 Summary of Major System Performance for the 100 Year Design Storm Event for Existing Land Use Conditions - Percentage of Total Major System Length By Network(%)

Network ID	Within Ditch	Within Curb	Above Ditch Within ROW	Above Curb Within ROW	Flow Beyond ROW (Less Than 50% to Building) - Ditches	Flow Beyond ROW (Less Than 50% to Building) - Curbed	Flow Beyond ROW (Greater Than 50% to Building) - Ditches	Flow Beyond ROW (Greater Than 50% to Building) - Curbed	Grand Total
1	0%	61%	0%	37%	0%	0%	0%	2%	1%
2	0%	63%	0%	17%	0%	3%	0%	17%	1%
3	4%	61%	1%	28%	0%	4%	0%	2%	2%
4	0%	65%	0%	29%	0%	4%	0%	2%	2%
5	15%	17%	10%	42%	8%	1%	2%	5%	1%
6	0%	100%	0%	0%	0%	0%	0%	0%	0%
7	5%	52%	8%	4%	0%	5%	13%	13%	0%
8	1%	75%	0%	4%	2%	1%	0%	17%	1%
9	1%	54%	5%	20%	10%	1%	2%	7%	1%
10	0%	9%	20%	0%	60%	0%	10%	0%	0%
11	0%	78%	0%	1%	0%	0%	21%	0%	0%
12	0%	70%	0%	30%	0%	0%	0%	0%	0%
13	2%	62%	3%	13%	7%	3%	5%	6%	3%
14	2%	42%	3%	26%	0%	5%	5%	16%	5%
15	4%	30%	6%	14%	9%	8%	11%	19%	4%
16	34%	66%	0%	0%	0%	0%	0%	0%	0%
17	11%	29%	14%	0%	16%	0%	30%	0%	1%
18	4%	5%	12%	5%	31%	0%	35%	7%	3%
19	12%	7%	21%	3%	0%	0%	56%	1%	0%
20	2%	9%	10%	9%	42%	3%	15%	9%	4%
21	0%	44%	12%	0%	11%	0%	16%	17%	1%
22	2%	25%	0%	0%	0%	2%	62%	9%	0%
23	3%	4%	12%	5%	30%	2%	41%	3%	1%
24	10%	9%	10%	27%	36%	0%	3%	5%	2%
25	9%	22%	13%	11%	20%	2%	22%	2%	3%
26	0%	33%	1%	22%	19%	0%	17%	8%	1%
27	3%	25%	15%	9%	25%	1%	14%	8%	4%
28	10%	26%	10%	0%	21%	2%	31%	0%	1%
29	3%	33%	15%	36%	7%	0%	1%	5%	1%
30	1%	37%	5%	22%	5%	12%	10%	9%	2%
31	0%	54%	0%	39%	0%	0%	0%	7%	0%
32	0%	56%	2%	32%	0%	0%	5%	4%	1%
33	0%	62%	0%	18%	3%	3%	4%	10%	2%
34	1%	25%	10%	19%	25%	6%	11%	3%	2%
35	3%	83%	5%	3%	1%	0%	4%	1%	2%
36	0%	54%	10%	10%	3%	1%	9%	13%	2%
37	0%	68%	4%	19%	0%	1%	5%	3%	2%
38	0%	63%	0%	5%	0%	5%	17%	9%	1%
39	6%	12%	10%	7%	20%	2%	40%	2%	2%
40	0%	27%	25%	5%	16%	0%	26%	0%	1%
41	0%	23%	3%	17%	43%	5%	6%	2%	1%
42	4%	22%	13%	9%	23%	1%	27%	1%	1%
43	15%	9%	9%	20%	13%	0%	32%	2%	1%
44	0%	28%	13%	11%	26%	0%	21%	2%	1%
45	4%	36%	7%	10%	11%	2%	26%	5%	1%
46	1%	32%	19%	10%	16%	3%	11%	7%	3%

Table 7.1.4 Summary of Major System Performance for the 100 Year Design Storm Event for Existing Land Use Conditions - Percentage of Total Major System Length By Network(%)									
Network ID	**Within Ditch**	**Within Curb**	**Above Ditch Within ROW**	**Above Curb Within ROW**	**Flow Beyond ROW (Less Than 50% to Building) - Ditches**	**Flow Beyond ROW (Less Than 50% to Building) - Curbed**	**Flow Beyond ROW (Greater Than 50% to Building) - Ditches**	**Flow Beyond ROW (Greater Than 50% to Building) - Curbed**	**Grand Total**
47	1%	63%	0%	18%	0%	1%	8%	11%	2%
48	0%	79%	0%	17%	0%	1%	0%	3%	1%
49	5%	39%	1%	36%	0%	2%	6%	11%	3%
50	1%	70%	0%	20%	0%	5%	0%	4%	2%
51	0%	67%	10%	13%	5%	1%	0%	4%	1%
52	2%	57%	1%	26%	0%	8%	0%	7%	7%
53	7%	59%	3%	18%	4%	0%	5%	4%	3%
54	9%	56%	4%	13%	7%	1%	5%	6%	6%
55	3%	59%	6%	10%	14%	3%	6%	0%	2%
56	0%	63%	0%	27%	0%	2%	1%	7%	4%
LMC	12%	0%	34%	0%	40%	0%	14%	0%	1%
LWC	8%	2%	37%	1%	36%	0%	16%	0%	1%
Total	**3%**	**44%**	**6%**	**17%**	**11%**	**3%**	**10%**	**7%**	**100%**

The results in Tables 7.1.3 and 7.1.4 indicate that approximately 70 % of the major system within the focus area would satisfy current Town LOS standards for major system conveyance (i.e. conveyance of 100 year flow remains within the right-of-way). The results further indicate that approximately 14 % of the major system within the focus area would exhibit relatively minor deficiencies with respect to Town standards for major system conveyance, and approximately 17 % would fail to comply with current Town performance standards for major system conveyance.

7.1.3 Remnant Channels

The validated PCSWMM model has been used to identify potential capacity constraints along the remnant channels within the focus area. The results of the PCSWMM model have been reviewed in order to determine whether a potential exists for the 100 year flow along the remnant channel to adversely encroach onto private property, based on the performance criteria depicted in Drawing 7.10 and described as follows:

- 100 Year flow is contained within the remnant channel or does not impact the adjacent property.
- 100 Year flow is beyond the remnant channel banks but does not significantly encroach on private property.
- 100 Year flow is on private property but not to the main property structure.
- 100 Year flow is encroaching on the main property structure.

The results of the assessment are presented on Drawing 7.11.

7.2 Level of Service Categories

In order to further convey the understanding of existing system performance, the results of the PCSWMM modelling for the 5 year and 100 year piped minor system and the 100 year major system, have been reviewed in order to establish criteria and categories for corresponding level of service for the drainage systems within the focus area. The performance criteria which have been applied to determine whether the individual sewer and road segments satisfy the requirements for conveyance are summarized in Table 7.2.1.

Table 7.2.1 Performance Criteria for Minor and Major System Capacity Assessment

Storm Event	Areas with Disconnected Foundation Drains	Areas with Connected Foundation Drains
5 Year	HGL below top of the manhole for sewer network	HGL below 50% of the height between the obvert and the top of the manhole for sewer network
100 Year	Overland Flow limits less than 50% of the distance to the adjacent structure on private property from the ROW	HGL below 50% of the height between the obvert and the top of the manhole for sewer network
		Overland Flow limits less than 50% of the distance to the adjacent structure on private property from the ROW.

As noted earlier, for the purpose of the Master Plan assessments, it has been assumed that the elevations of the laterally connected basements are not below 50% of the height between the adjacent obvert and the top of the manhole. The foregoing criteria have been used to establish levels of service for the storm sewers, as well as for the major systems within the focus area. The criteria and corresponding qualitative level of service category for each network area (as a composite of all individual pipe systems in that network) are summarized in Tables 7.2.2 and 7.2.3 for the minor and major systems respectively.

Table 7.2.2 Level of Service Criteria for Piped Minor System

Level of Service	Criteria
A	Most of the storm sewer pipes within the network meet the Town's performance criteria.
B	Many of the storm sewer pipes within the network meet the Town's performance criteria.
C	Some of the storm sewer pipes within the network meet the Town's performance criteria.
D	Few of the storm sewer pipes within the network meet the Town's performance criteria.

Table 7.2.3 Level of Service Criteria for Major Systems

Level of Service	Criteria
A	Most of the rights-of-way within the network meet the Town's performance criteria.
B	Many of the rights-of-way within the network meet the Town's performance criteria.
C	Some of the rights-of-way within the network meet the Town's performance criteria.
D	Few of the rights-of-way within the network meet the Town's performance criteria.

The foregoing qualitative criteria have been applied to determine the level of service for the piped minor systems and major systems for each network within the focus area to establish the corresponding level of service category for each network. The results of this assessment are summarized in Table 7.2.5, and are presented graphically in Drawings 7.12 and 7.13.

The existing conditions level of service for the connected and disconnected minor system, as well as the major system, have been numerically weighted, based upon significance/importance of the condition to be mitigated. The weighting factors (ref. Table 7.2.4) have been developed to assist in prioritizing mitigation of impacts within those networks with basement connections to storm sewers, where there is potential for the minor system to surcharge to the basement elevation. Storm sewers that do not have basement connections, and typically only convey surface runoff, have been assigned a lower weighting due to their reduced relative risk potential for adverse impacts. Major systems that have the potential to convey surface flow greater than 50 % beyond the ROW have been assigned a moderate weighting for prioritization.

Table 7.2.4 Weighting Scores for Net Level of Service

System	Basement Connections	Weighting Factor
Minor System	Yes	3
	No	1
Major System	N/A	2

The weighting factors have been multiplied by the percentage of each networks assets that do not meet the performance criteria, outlined in Table 7.2.1, for each of the three (3) systems. The total weighted net score has been summed; a lower score indicates a low priority network, while a higher score indicates a high priority network that requires more immediate mitigation efforts. The networks have been assigned a weighted net level of service grade based on the summed scores (ref. Table 7.2.5) which has been graphically presented in Drawing 7.14.

Table 7.2.5 Existing Conditions Level of Service Assessment for Piped Minor System and Major Systems for Network Areas																		
Network ID	Minor System								Major System				Weighted Net Score					
	Connected				Disconnected								Score					
	Length Pass (m)	Length Total (m)	% Pass	LOS	Length Pass (m)	Length Total (m)	% Pass	LOS	Length Pass (m)	Length Total (m)	% Pass	LOS	1	2	3	Total Score	Net LOS
1	0	2798	0	D	564	701	81	A	3262	3313	98	A	2.40	0.04	0.04	2.48	D
2	2193	2193	100	A	567	567	100	A	2391	2869	83	A	0.00	0.00	0.34	0.34	A
3	3348	3437	97	A	1146	1669	69	B	5055	5180	98	A	0.05	0.10	0.04	0.19	A
4	5143	5255	98	A	1937	1937	100	A	7211	7343	98	A	0.05	0.00	0.04	0.09	A
5		0			4220	4778	88	A	3530	3788	93	A	0.00	0.12	0.14	0.26	A
6	0	206	0	D	448	448	100	A	567	567	100	A	0.94	0.00	0.00	0.94	B
7	170	957	18	D	205	205	100	A	801	1080	74	B	2.03	0.00	0.52	2.55	D
8	247	3809	6	D	774	774	100	A	4005	4809	83	A	2.33	0.00	0.34	2.67	D
9	80	2294	3	D	1506	1575	96	A	4093	4489	91	A	1.72	0.02	0.18	1.91	C
10		0			130	140	92	A	795	879	89	A	0.00	0.08	0.20	0.28	A
11	232	606	38	D	827	827	100	A	1249	1582	79	B	0.78	0.00	0.42	1.20	B
12		0			460	645	71	B	962	963	100	A	0.00	0.29	0.00	0.29	A
13	300	3553	8	D	3964	4130	96	A	9076	10265	90	A	1.27	0.02	0.22	1.51	C
14	598	9622	6	D	5860	6221	94	A	12974	16607	78	B	1.71	0.02	0.42	2.15	D
15	141	5282	3	D	1896	2751	69	B	8442	11995	71	B	1.92	0.11	0.60	2.63	D
16	27	215	13	D	81	81	100	A	383	383	100	A	1.91	0.00	0.00	1.91	C
17	405	731	55	C	660	959	69	B	2275	3254	70	B	0.58	0.18	0.60	1.35	B
18	386	2236	17	D	1553	2319	67	B	5490	9580	57	C	1.22	0.17	0.84	2.23	D
19	124	236	52	C	426	887	48	C	619	1464	43	C	0.30	0.41	1.14	1.85	C
20	0	2139	0	D	3011	4407	68	B	9365	12389	75	B	0.98	0.21	0.48	1.67	C

Table 7.2.5 Existing Conditions Level of Service Assessment for Piped Minor System and Major Systems for Network Areas

Network ID	Minor System								Major System				Weighted Net Score				
	Connected				Disconnected								Score				
	Length Pass (m)	Length Total (m)	% Pass	LOS	Length Pass (m)	Length Total (m)	% Pass	LOS	Length Pass (m)	Length Total (m)	% Pass	LOS	1	2	3	Total Score	Net LOS
21	50	112	44	C	1530	1530	100	A	1264	1897	67	B	0.11	0.00	0.66	0.77	B
22		0			511	511	100	A	158	553	29	D	0.00	0.00	1.42	1.42	B
23	34	532	6	D	807	1409	57	C	1166	2089	56	C	0.77	0.31	0.88	1.96	C
24	80	1519	5	D	1562	1682	93	A	5487	5960	92	A	1.35	0.04	0.16	1.55	C
25	369	1859	20	D	1606	1818	88	A	7037	9210	77	B	1.22	0.06	0.48	1.75	C
26	113	322	35	D	993	1143	87	A	1672	2209	75	B	0.43	0.10	0.50	1.03	B
27	283	2848	10	D	4577	6460	71	B	10392	13303	78	B	0.83	0.20	0.44	1.47	B
28	152	670	23	D	708	817	87	A	2805	4035	69	B	1.04	0.07	0.62	1.74	C
29	453	782	58	C	1482	1611	92	A	4063	4307	94	A	0.41	0.05	0.12	0.59	B
30	76	1905	4	D	3530	4410	80	A	6185	7616	82	A	0.87	0.14	0.38	1.39	B
31	0	800	0	D	235	358	66	B	1114	1200	93	A	2.07	0.11	0.14	2.32	D
32	0	319	0	D	1608	1882	85	A	1984	2188	90	A	0.44	0.12	0.18	0.74	B
33	239	783	31	D	3454	3566	97	A	4411	5117	86	A	0.38	0.03	0.28	0.68	B
34	62	1579	4	D	2819	3786	74	B	5595	6505	86	A	0.85	0.18	0.28	1.31	B
35	973	2165	45	C	2109	2301	92	A	4927	5195	95	A	0.80	0.04	0.10	0.94	B
36	0	1117	0	D	3218	3797	85	A	4003	5132	78	B	0.68	0.12	0.44	1.24	B
37	813	2222	37	D	3257	3475	94	A	6777	7350	92	A	0.74	0.04	0.16	0.94	B
38	82	1127	7	D	528	839	63	B	1446	1965	73	B	1.59	0.16	0.52	2.27	D
39	370	906	41	C	2717	3388	80	A	3627	6271	57	C	0.37	0.16	0.84	1.37	B
40	0	712	0	D	436	615	71	B	2110	2867	73	B	1.61	0.13	0.52	2.26	D

Table 7.2.5 Existing Conditions Level of Service Assessment for Piped Minor System and Major Systems for Network Areas

Network ID	Minor System								Major System				Weighted Net Score				
	Connected				Disconnected				Length Pass (m)	Length Total (m)	% Pass	LOS	Score				
	Length Pass (m)	Length Total (m)	% Pass	LOS	Length Pass (m)	Length Total (m)	% Pass	LOS					1	2	3	Total Score	Net LOS
41	58	404	14	D	908	1248	73	B	3309	3587	91	A	0.63	0.21	0.16	0.99	B
42	64	778	8	D	1182	1554	76	B	2678	3709	72	B	0.92	0.16	0.56	1.64	C
43	0	954	0	D	1250	1307	96	A	1453	2208	66	B	1.27	0.03	0.68	1.97	C
44	121	1548	8	D	1770	1830	97	A	3366	4323	78	B	1.27	0.02	0.46	1.74	C
45	569	2452	23	D	680	1138	60	C	3246	4662	70	B	1.57	0.13	0.62	2.32	D
46	235	2016	12	D	6197	6695	93	A	7498	9126	81	A	0.61	0.06	0.36	1.03	B
47	885	5482	16	D	1079	1820	59	C	6464	7910	83	A	1.89	0.10	0.38	2.37	D
48	2118	2804	76	B	280	280	100	A	2879	2965	97	A	0.67	0.00	0.06	0.73	B
49	1746	5055	35	D	2894	3038	95	A	6952	8342	83	A	1.23	0.02	0.34	1.58	C
50	415	4627	9	D	604	688	88	A	5290	5538	96	A	2.38	0.02	0.08	2.47	D
51	674	1412	48	C	665	681	98	A	1946	2031	96	A	1.06	0.01	0.08	1.15	B
52	10746	17743	61	B	3343	3343	100	A	20707	22171	94	A	1.00	0.00	0.14	1.14	B
53	1664	5297	31	D	2600	2691	97	A	7937	8709	91	A	1.36	0.01	0.18	1.56	C
54	2930	6083	48	C	8488	10695	79	B	17990	20216	90	A	0.56	0.13	0.22	0.92	B
55	859	3075	28	D	1920	2872	67	B	5674	6056	95	A	1.12	0.16	0.12	1.40	B
56	1814	8490	21	D	4475	4908	91	A	11945	12986	92	A	1.49	0.03	0.16	1.69	C

Focus Area-wide summary results of Table 7.2.5 are provided in Table 7.2.6 which sum the number of networks by their level of service grade for minor system (connected and disconnected), major system, and the weighted net level of service. The results demonstrate that 39 networks with minor system connections have a D level of service while zero (0) with the minor system disconnected have a D level of service, and one (1) network has a major system with a D level of service. The application of the weighting shown in Table 7.2.4 ultimately results in 12 networks with a D weighted net level of service. The majority of the minor system disconnected networks and the major system networks are within the acceptable level of service criteria; however these results also demonstrate that the weighting has placed an emphasis on prioritizing the minor system connected networks that are at higher risk of exposure, as there are only eight (8) networks with an A weighted net level of service grade.

Table 7.2.6 Existing Conditions Network Level of Service Summary Results (# of Networks)

LOS Grade	Minor System		Major System	Weighted Net
	Connected	Disconnected		
A	3	37	35	8
B	2	15	18	23
C	8	4	4	15
D	39	0	1	12

7.3 Other Investigations

7.3.1 Catch basin Capture

Hydrologic analyses have been conducted using the PCSWMM hydrologic model to define the potential influence of catch basin inlet obstructions on major overland system performance. For this assessment, the existing catch basins inlet area (orifice) in the PCSWMM model has been decreased by 50 % to represent a corresponding blockage to the catch basin inlet. Following discussion with Town staff, the analyses have used the 25 year return period synthetic design storm, as this event was considered to represent the most frequent storm event during which major system conveyance would occur and hence would be the most susceptible and sensitive to reductions in catch basin inlet capacity. The summary results, presented in Table 7.3.1, indicate that reductions to catch basin inlet capacity would be anticipated to increase the depth of flow along the major system, however would not be anticipated to appreciably increase the extent of surface flow beyond the right-of-way or on private properties; more detailed results are provided in Appendix F. As such, it has been concluded that the extent of flooding beyond the municipal right-of-way and on private properties is relatively insensitive to reductions in catch basin capture.

Table 7.3.1 Catch Basin Capture Assessment Summary Results - Total Major System Length (%)

Scenario	Within Ditch	Within Curb	Above Ditch Within ROW	Above Curb Within ROW	Flow Beyond ROW (Less Than 50% to Building) (Ditches)	Flow Beyond ROW (Less Than 50% to Building) (Curbed)	Flow Beyond ROW (Greater Than 50% to Building) (Ditches)	Flow Beyond ROW (Greater Than 50% to Building) (Curbed)	Total
Existing Conditions	4.7	52.4	8.2	11.8	9.7	1.6	7.3	4.2	100.0
Half Blocked	4.3	51.1	8.4	12.6	9.8	1.8	7.5	4.6	100.0

Additional review of the results, has indicated that the areas with the greatest difference in depth of flooding, under the reduced catch basin capture scenario, coincides with low points (i.e. sags) along the municipal roads. Consequently, additional review has been conducted to identify the locations of low points along the municipal roads, which are considered to represent areas with the highest potential impact during conditions where the catch basin inlet becomes obstructed (ref. Section 7.3.2).

7.3.2 Major System Low Point Mapping

The DEM provided for use in this study (ref. 2012) has been used to identify low points (i.e. sags) along the municipal major systems, where storm runoff would potentially pond during significant storm events. As noted in the preceding section, major system low points were noted to be the areas potentially most impacted by blockages in the catch basin inlets, which would reduce the amount of storm runoff conveyed by the storm sewers and correspondingly increase the amount of runoff conveyed overland.

For this assessment, a tool has been used in GIS to fill in the depressions in the DEM data. A depression has been identified if elevation points surrounded/encircled another elevation point with at least a 0.2 m decrease in elevation from the outer points. Low point mapping has been over laid with the GIS existing conditions major system performance data for flow beyond the ROW less than 50 % to buildings (moderate risk) and greater than 50 % to buildings (high risk). The Halton Region sanitary sewer data has also been added to denote areas of potential impact during major system flow conditions, particularly where catch basin inlets become obstructed. The results of this assessment are provided on Drawing 7.15.

The results of this assessment indicate that the low points within the focus area, representing potential ponding areas within the Town of Oakville, are dispersed throughout the focus area and encompass both private properties, as well as public properties and rights-of-way. In general, the low points are located within sewersheds comprised of developments and infrastructure of older vintages; this is considered indicative of the prevailing design standards of the times, which did not require major system design for conveyance. Furthermore, several low points within the rights-of-way are noted to coincide with street intersections; this is considered attributable to the grading requirements at intersections, which consequently in some cases result in low points at the limits, and generally require implementing double catch basins for storm runoff capture under more contemporary design standards.

7.4 Local Historic Storms Assessment

Analyses have been completed to assess the performance of the major system within the focus area using recent historical storms in southern Ontario. The precipitation data have been obtained from radar generated data, calibrated to local rainfall stations, and the analyses have (due to the small size of the urban networks under analysis) applied the formative (i.e. most intense) cell from the dataset uniformly across the focus area. The events selected and their respective precipitation volumes and intensities are provided in Table 7.4.1.

Table 7.4.1 Summary of Historic Extreme Storm Events

Storm Event	Precipitation Volume (mm)	Peak Intensity (mm/hr)	Duration (hr)
100 Yr 24 Hr Chicago	98.1	227.3	24.0
Oakville, May 2000	83.7	107.3	6.0
Hamilton, July 2009	134.9	78.64	3.7
Burlington, August 2014	196.1	126.75	6.5

The rainfall data for the extreme storm events have been used as a stress test to assess the major system performance under existing land use conditions. Full details are provided in Appendix F, and results are summarized in Table 7.4.2.

Table 7.4.2 Major System Performance for Existing Land Use Conditions Under 100 Year Return Period Design Storm and Historic Storm Events - Percentage of Total Major System Length by Scenario (%)

Scenario	Within Ditch	Within Curb	Above Ditch but Within ROW	Curb but Within ROW	Beyond ROW (Ditches)	Beyond ROW (Curbed)
100 Yr 24 Hr Chicago	4.4	45.2	5.1	14.5	20.8	10.0
Oakville, May 2000	9.1	59.7	7.0	6.3	14.1	3.7
Hamilton, July 2009	3.5	39.4	4.0	17.8	22.8	12.5
Burlington, August 2014	6.2	55.7	6.5	7.5	17.6	6.5

The results indicate that the Oakville, May 2000 storm event and the Burlington, August 2014 storm event results in less surface flow beyond the Municipal right-of-way than the town's current 100 year design storm event. The results also demonstrate that the Hamilton, July 2009, storm event results in a slightly higher incidence of surface flow beyond the Municipal right-of-way, compared to the 100 year design storm event, hence exceeds the 100 year design standard

7.5 Future Conditions Impact Assessment

7.5.1 Future Land Use Conditions

Hydrologic and hydraulic analyses have been conducted to assess the performance of the minor and major system under future land use conditions within the focus area. The impervious coverages for the future land use conditions scenario have been established assuming full development of the designated intensification areas, as per the current Official Plan (i.e. Livable Oakville), and assuming full development of the remaining residential lands to the extent permitted under the Town's By-Laws.

The maximum impervious coverages permitted on private residential lots per the Town's current By-Law's have been established in consultation with the Town. The As-of-Right impervious values assume the residential zones (RL1 – RL5-0) would have an increase of the imperviousness on the residential lots due to building footprint increases and the addition of impervious amenity areas, as shown in Table 7.5.1.

Table 7.5.1 As-of-Right Impervious Values by Residential Zone

Residential Zone	Average Lot % Impervious As-of-Right
RL1	47.9
RL1-0	47.9
RL2	55.0
RL2-0	48.3
RL3	55.7
RL3-0	55.7
RL4	50.6
RL4-0	50.6
RL5	62.5
RL5-0	62.5

The future redevelopment/intensification areas located within the focus area, per Livable Oakville, include Bronte Village, Downtown Oakville, and Kerr Village. The imperviousness for the Downtown Oakville area has been retained at the current value of 100 % for existing conditions. The Bronte Village and Kerr Village areas contain a variety of land use designations, including low, medium, and high residential zones. The associated impervious values used for the Livable Oakville future conditions for Bronte Village and Kerr Village are provided in Table 7.5.2. The remainder of the zone designations imperviousness values were not adjusted, as they were already considered high (75-100 %) and were not as likely to be further increased, based on direction from town staff.

Table 7.5.2 Livable Oakville Future Conditions Imperviousness

Residential Zone Classification	Livable Oakville Imperviousness (%)
Low Density	65
Medium Density	70
High Density	75
Non-Residential Zones Located in Livable Oakville Areas	
Central Business District	100
Main Street 1	100
Main Street 2	95
Urban Core	95
Urban Centre	90
Institutional	75.1
Parks and Open Space	10
Natural Area	5

The PCSWMM hydrologic model has been updated to incorporate the impervious coverages for the redevelopment and intensification areas, as well as to reflect the as-of-right condition, as per the values provided in the foregoing. The impervious coverages have been areally-weighted based upon the proportion of each lot and land use within the respective catchments. The net impervious coverages within the sewer networks under existing and future land use conditions are summarized in Table 7.5.3.

Table 7.5.3 Impervious Coverages for Sewer Networks Under Existing and Future Land Use Conditions (%)

Sewershed	Area (ha)	Existing Conditions	Future Conditions	Difference
1	25.10	57.23	60.83	3.61
2	21.27	57.46	60.35	2.89
3	45.80	69.85	69.85	0.00
4	47.46	53.92	53.92	0.00
5	82.52	86.99	86.99	0.00
6	4.96	40.12	42.61	2.49
7	8.21	47.47	54.52	7.05
8	38.44	50.46	52.24	1.78
9	32.17	51.24	57.36	6.11
10	14.06	47.50	56.36	8.86
11	8.89	49.63	54.63	5.00
12	3.16	75.25	76.11	0.86
13	84.77	59.50	64.32	4.81
14	251.69	63.25	66.44	3.19
15	85.99	44.85	51.76	6.91
16	2.35	65.81	65.81	0.00
17	23.36	46.30	50.58	4.28
18	81.36	44.29	51.86	7.56
19	34.99	42.26	49.32	7.06
20	120.68	51.47	58.01	6.54
21	29.37	81.19	81.53	0.34
22	20.23	44.03	50.30	6.27
23	47.93	45.44	52.83	7.38
24	84.16	64.56	68.54	3.97
25	76.91	44.52	51.22	6.70
26	27.69	64.43	68.80	4.37
27	115.20	60.91	66.28	5.37
28	40.74	42.47	50.68	8.21
29	48.28	41.58	46.50	4.92
30	67.32	55.54	60.97	5.43
31	9.37	51.08	59.61	8.54
32	27.99	81.29	83.51	2.22
33	41.03	68.25	70.49	2.24

Table 7.5.3 Impervious Coverages for Sewer Networks Under Existing and Future Land Use Conditions (%)

Sewershed	Area (ha)	Existing Conditions	Future Conditions	Difference
34	62.81	48.96	56.06	7.10
35	32.35	69.78	72.22	2.44
36	51.74	55.26	61.48	6.21
37	54.11	50.97	57.76	6.79
38	19.94	59.85	66.03	6.18
39	79.95	38.89	49.30	10.41
40	26.39	40.59	50.66	10.07
41	30.72	40.04	49.57	9.53
42	32.48	52.87	58.73	5.86
43	24.31	76.85	79.72	2.87
44	49.01	39.60	50.13	10.53
45	58.77	42.21	50.17	7.96
46	107.47	55.73	62.03	6.30
47	69.49	43.38	51.37	7.99
48	22.17	46.84	56.04	9.20
49	100.42	59.12	63.30	4.17
50	41.12	45.07	52.90	7.83
51	23.83	40.72	45.40	4.67
52	190.63	59.01	61.07	2.07
53	77.23	53.81	55.34	1.54
54	211.74	52.02	54.59	2.56
55	62.02	55.69	56.36	0.67
56	133.03	61.63	65.22	3.59
CP	66.03	31.71	36.31	4.59
LMC	160.27	52.95	55.92	2.97
LWC	264.89	60.99	63.08	2.09

7.5.2 Impact Assessment From Change In Land Use

The PCSWMM hydrologic model for future land use conditions has been used to assess the performance of the minor and major system for the 5 year and 100 year return periods under future land use conditions. The results are presented in Tables 7.5.4 to 7.5.9.

Table 7.5.4 Summary of Minor System Performance Under the 5 Year Design Storm Event for the Future Land Use Conditions - Total Length By Network (m)

Network	Unsurcharged	Below 1/2 Surcharging Depth and Above Obvert	Above 1/2 Surcharging Depth and Below Rim Elevation	Surcharged Above Rim Elevation	Grand Total
1	233	658	2364	244	3499
2	1360	1328	72	0	2760
3	3629	734	220	522	5105
4	4416	2711	65	0	7192
5	2646	794	779	558	4778
6	103	320	231	0	654
7	0	524	638	0	1162
8	94	1175	2868	445	4583
9	754	1188	1707	270	3919
10	0	130	0	11	140
11	533	764	136	0	1433
12	88	64	308	185	645
13	1828	1948	3232	675	7683
14	2018	3872	7801	2151	15843
15	228	653	3834	3318	8033
16	65	195	37	0	297
17	735	300	232	422	1689
18	497	919	1545	1594	4555
19	227	0	235	661	1123
20	1278	1103	2402	1762	6545
21	527	915	200	0	1642
22	316	87	108	0	511
23	16	576	588	761	1941
24	51	646	2192	313	3202
25	893	1665	624	495	3677
26	253	549	432	230	1465
27	643	1921	3987	2756	9308
28	517	388	527	56	1487
29	964	530	771	128	2393
30	710	649	3311	1646	6315
31	169	0	710	279	1158

Table 7.5.4 Summary of Minor System Performance Under the 5 Year Design Storm Event for the Future Land Use Conditions - Total Length By Network (m)

Network	Unsurcharged	Below 1/2 Surcharging Depth and Above Obvert	Above 1/2 Surcharging Depth and Below Rim Elevation	Surcharged Above Rim Elevation	Grand Total
32	885	463	485	369	2201
33	1548	1315	1374	112	4349
34	0	847	3442	1077	5366
35	2647	949	590	279	4466
36	1469	1138	1619	689	4915
37	2213	2440	727	318	5698
38	0	136	1311	519	1966
39	1410	870	1266	748	4294
40	259	596	245	228	1327
41	591	236	431	393	1652
42	414	949	542	427	2332
43	526	1422	213	100	2261
44	716	912	1371	380	3379
45	786	380	1596	828	3589
46	4091	1909	2098	613	8711
47	1505	1100	3366	1330	7302
48	393	1131	1500	61	3085
49	1470	2138	3730	755	8094
50	293	1351	3264	406	5315
51	786	858	434	16	2093
52	6649	5670	6923	1844	21086
53	3525	3343	1028	92	7988
54	7746	3159	3666	2207	16778
55	1723	1287	1826	1112	5948
56	4185	3776	3819	1618	13398
Total	**71623**	**65680**	**89027**	**36000**	**262330**

Table 7.5.5	Summary of Minor System Performance Under the 5 Year Design Storm Event for the Future Land Use Conditions - Percentage of Total Minor System Length By Network (%)				
Network	**Unsurcharged**	**Below 1/2 Surcharging Depth and Above Obvert**	**Above 1/2 Surcharging Depth and Below Rim Elevation**	**Surcharged Above Rim Elevation**	**% Total of Focus area**
1	6.6	18.8	67.6	7.0	1.3
2	49.3	48.1	2.6	0.0	1.1
3	71.1	14.4	4.3	10.2	1.9
4	61.4	37.7	0.9	0.0	2.7
5	55.4	16.6	16.3	11.7	1.8
6	15.8	48.9	35.3	0.0	0.2
7	0.0	45.1	54.9	0.0	0.4
8	2.1	25.6	62.6	9.7	1.7
9	19.2	30.3	43.6	6.9	1.5
10	0.0	92.3	0.0	7.7	0.1
11	37.2	53.3	9.5	0.0	0.5
12	13.6	9.9	47.8	28.6	0.2
13	23.8	25.4	42.1	8.8	2.9
14	12.7	24.4	49.2	13.6	6.0
15	2.8	8.1	47.7	41.3	3.1
16	21.9	65.7	12.3	0.0	0.1
17	43.5	17.8	13.7	25.0	0.6
18	10.9	20.2	33.9	35.0	1.7
19	20.2	0.0	20.9	58.9	0.4
20	19.5	16.9	36.7	26.9	2.5
21	32.1	55.7	12.2	0.0	0.6
22	61.8	17.1	21.1	0.0	0.2
23	0.8	29.7	30.3	39.2	0.7
24	1.6	20.2	68.5	9.8	1.2
25	24.3	45.3	17.0	13.5	1.4
26	17.3	37.5	29.5	15.7	0.6
27	6.9	20.6	42.8	29.6	3.5
28	34.7	26.1	35.4	3.8	0.6
29	40.3	22.1	32.2	5.4	0.9
30	11.2	10.3	52.4	26.1	2.4
31	14.6	0.0	61.3	24.1	0.4
32	40.2	21.0	22.0	16.7	0.8
33	35.6	30.2	31.6	2.6	1.7
34	0.0	15.8	64.1	20.1	2.0
35	59.3	21.3	13.2	6.3	1.7

Table 7.5.5	Summary of Minor System Performance Under the 5 Year Design Storm Event for the Future Land Use Conditions - Percentage of Total Minor System Length By Network (%)				
Network	**Unsurcharged**	**Below 1/2 Surcharging Depth and Above Obvert**	**Above 1/2 Surcharging Depth and Below Rim Elevation**	**Surcharged Above Rim Elevation**	**% Total of Focus area**
36	29.9	23.2	32.9	14.0	1.9
37	38.8	42.8	12.8	5.6	2.2
38	0.0	6.9	66.7	26.4	0.7
39	32.8	20.3	29.5	17.4	1.6
40	19.5	44.9	18.4	17.2	0.5
41	35.8	14.3	26.1	23.8	0.6
42	17.8	40.7	23.3	18.3	0.9
43	23.3	62.9	9.4	4.4	0.9
44	21.2	27.0	40.6	11.2	1.3
45	21.9	10.6	44.5	23.1	1.4
46	47.0	21.9	24.1	7.0	3.3
47	20.6	15.1	46.1	18.2	2.8
48	12.8	36.7	48.6	2.0	1.2
49	18.2	26.4	46.1	9.3	3.1
50	5.5	25.4	61.4	7.6	2.0
51	37.5	41.0	20.7	0.7	0.8
52	31.5	26.9	32.8	8.7	8.0
53	44.1	41.8	12.9	1.1	3.0
54	46.2	18.8	21.8	13.2	6.4
55	29.0	21.6	30.7	18.7	2.3
56	31.2	28.2	28.5	12.1	5.1
Total	**27.3**	**25.0**	**33.9**	**13.7**	**100.0**

Table 7.5.6 Summary of Minor System Performance Under the 100 Year Design Storm Event for the Future Land Use Conditions - Total Length By Network (m)

Network	Unsurcharged	Below 1/2 Surcharging Depth and Above Obvert	Above 1/2 Surcharging Depth and Below Rim Elevation	Surcharged Above Rim Elevation	Grand Total
1	75	50	2261	1112	3499
2	1243	1517	0	0	2760
3	2739	997	529	841	5105
4	2484	4508	201	0	7192
5	1025	1774	844	1135	4778
6	0	101	371	182	654
7	0	170	854	139	1162
8	0	291	2697	1594	4583
9	0	365	1389	2115	3869
10	0	130	0	11	140
11	120	375	641	297	1433
12	88	64	275	217	645
13	429	1081	3995	2179	7683
14	1147	1794	7468	5434	15843
15	134	323	2317	5259	8033
16	0	27	233	37	297
17	48	601	449	592	1689
18	67	533	928	3027	4555
19	227	0	41	855	1123
20	841	162	2111	3431	6545
21	92	782	538	231	1642
22	214	137	53	107	511
23	0	359	529	1053	1941
24	0	495	1745	962	3202
25	528	735	1372	1042	3677
26	194	252	684	335	1465
27	114	844	4139	4212	9308
28	371	197	465	455	1487
29	127	717	648	902	2393
30	52	439	3014	2811	6315
31	72	97	490	499	1158
32	690	321	617	574	2201
33	736	1108	1886	619	4349
34	0	304	2416	2646	5366
35	926	1466	1526	547	4466

Table 7.5.6 Summary of Minor System Performance Under the 100 Year Design Storm Event for the Future Land Use Conditions - Total Length By Network (m)

Network	Unsurcharged	Below 1/2 Surcharging Depth and Above Obvert	Above 1/2 Surcharging Depth and Below Rim Elevation	Surcharged Above Rim Elevation	Grand Total
36	0	267	3056	1592	4915
37	450	1755	2135	1357	5698
38	0	82	840	1044	1966
39	784	1194	1113	1204	4294
40	0	72	746	509	1327
41	332	250	518	550	1652
42	104	339	796	1093	2332
43	0	698	935	628	2261
44	63	535	1542	1238	3379
45	147	471	1434	1537	3589
46	2448	1241	3112	1910	8711
47	237	647	3402	3016	7302
48	720	1653	651	61	3085
49	1789	1991	2637	1676	8094
50	0	415	3103	1797	5315
51	376	726	840	151	2093
52	7948	5211	5758	2169	21086
53	801	2022	4432	734	7988
54	4102	3463	5305	3908	16778
55	672	679	2600	1997	5948
56	1094	1884	6502	3918	13398
Total	**36848**	**48713**	**99179**	**77540**	**262279**

Table 7.5.7	Summary of Minor System Performance Under the 100 Year Design Storm Event for the Future Land Use Conditions - Percentage of Total Minor System Length By Network (%)				
Network	**Unsurcharged**	**Below 1/2 Surcharging Depth and Above Obvert**	**Above 1/2 Surcharging Depth and Below Rim Elevation**	**Surcharged Above Rim Elevation**	**% Total of Focus area**
1	2.1	1.4	64.6	31.8	1.3
2	45.0	55.0	0.0	0.0	1.1
3	53.6	19.5	10.4	16.5	1.9
4	34.5	62.7	2.8	0.0	2.7
5	21.5	37.1	17.7	23.7	1.8
6	0.0	15.5	56.7	27.8	0.2
7	0.0	14.6	73.4	12.0	0.4
8	0.0	6.3	58.9	34.8	1.7
9	0.0	9.4	35.9	54.7	1.5
10	0.0	92.3	0.0	7.7	0.1
11	8.4	26.2	44.7	20.7	0.5
12	13.6	9.9	42.7	33.7	0.2
13	5.6	14.1	52.0	28.4	2.9
14	7.2	11.3	47.1	34.3	6.0
15	1.7	4.0	28.8	65.5	3.1
16	0.0	9.1	78.6	12.3	0.1
17	2.8	35.6	26.6	35.0	0.6
18	1.5	11.7	20.4	66.5	1.7
19	20.2	0.0	3.6	76.2	0.4
20	12.9	2.5	32.3	52.4	2.5
21	5.6	47.6	32.7	14.0	0.6
22	41.8	26.9	10.3	21.0	0.2
23	0.0	18.5	27.3	54.3	0.7
24	0.0	15.4	54.5	30.1	1.2
25	14.4	20.0	37.3	28.3	1.4
26	13.2	17.2	46.7	22.9	0.6
27	1.2	9.1	44.5	45.2	3.5
28	24.9	13.2	31.2	30.6	0.6
29	5.3	30.0	27.1	37.7	0.9
30	0.8	7.0	47.7	44.5	2.4
31	6.2	8.4	42.3	43.1	0.4
32	31.3	14.6	28.0	26.1	0.8
33	16.9	25.5	43.4	14.2	1.7
34	0.0	5.7	45.0	49.3	2.0
35	20.7	32.8	34.2	12.2	1.7

Table 7.5.7	Summary of Minor System Performance Under the 100 Year Design Storm Event for the Future Land Use Conditions - Percentage of Total Minor System Length By Network (%)				
Network	**Unsurcharged**	**Below 1/2 Surcharging Depth and Above Obvert**	**Above 1/2 Surcharging Depth and Below Rim Elevation**	**Surcharged Above Rim Elevation**	**% Total of Focus area**
36	0.0	5.4	62.2	32.4	1.9
37	7.9	30.8	37.5	23.8	2.2
38	0.0	4.2	42.7	53.1	0.7
39	18.2	27.8	25.9	28.0	1.6
40	0.0	5.4	56.2	38.4	0.5
41	20.1	15.2	31.4	33.3	0.6
42	4.5	14.5	34.1	46.9	0.9
43	0.0	30.9	41.3	27.8	0.9
44	1.9	15.8	45.6	36.6	1.3
45	4.1	13.1	40.0	42.8	1.4
46	28.1	14.2	35.7	21.9	3.3
47	3.2	8.9	46.6	41.3	2.8
48	23.3	53.6	21.1	2.0	1.2
49	22.1	24.6	32.6	20.7	3.1
50	0.0	7.8	58.4	33.8	2.0
51	18.0	34.7	40.1	7.2	0.8
52	37.7	24.7	27.3	10.3	8.0
53	10.0	25.3	55.5	9.2	3.0
54	24.4	20.6	31.6	23.3	6.4
55	11.3	11.4	43.7	33.6	2.3
56	8.2	14.1	48.5	29.2	5.1
Total	**14.0**	**18.6**	**37.8**	**29.6**	**100.0**

Table 7.5.8 Summary of Major System Performance Under the 100 Year Design Storm Event for the Future Land Use Conditions - Total Length By Network (m)

Network	Within Ditch	Within Curb	Above Ditch Within ROW	Above Curb Within ROW	Flow Beyond ROW (Less Than 50% to Building) (Ditches)	Flow Beyond ROW (Less Than 50% to Building) (Curbed)	Flow Beyond ROW (Greater Than 50% to Building) (Ditches)	Flow Beyond ROW (Greater Than 50% to Building) (Curbed)	Grand Total (m)
1	0	1948	0	1314	0	0	0	51	3313
2	0	2208	0	246	0	24	0	390	2869
3	257	4262	0	563	0	98	0	0	5180
4	0	6137	0	1094	0	47	0	65	7343
5	552	655	360	1601	319	43	78	179	3788
6	0	536	0	31	0	0	0	0	567
7	54	564	92	0	0	91	143	136	1080
8	52	3623	10	196	83	41	0	804	4809
9	65	2169	213	1179	310	36	220	347	4540
10	4	82	178	0	531	0	84	0	879
11	0	1226	0	23	0	0	333	0	1582
12	0	676	0	286	0	0	0	0	963
13	161	6286	259	1413	661	271	587	629	10265
14	271	7911	501	3816	0	771	894	2443	16607
15	455	3539	761	1514	922	1078	1389	2337	11995
16	130	253	0	0	0	0	0	0	383
17	320	951	369	6	516	0	1093	0	3254
18	376	442	1049	427	2877	0	3624	784	9580
19	164	102	302	41	0	0	837	18	1464
20	253	1356	848	1160	5057	7	2160	1548	12389
21	0	839	223	0	202	0	310	323	1897
22	8	136	0	0	0	14	342	52	553
23	63	80	183	107	505	43	1047	61	2089
24	582	513	404	1571	2318	99	195	279	5960
25	752	2000	1207	1032	1875	29	2003	312	9210
26	0	738	17	488	429	0	366	171	2209
27	368	2987	2023	1275	3256	197	1838	1359	13303
28	295	963	478	0	1046	91	1162	0	4035
29	122	2244	451	563	478	5	31	213	4106
30	74	2610	272	1795	311	659	914	982	7616
31	0	651	0	463	0	0	0	86	1200
32	0	1233	49	702	0	0	113	92	2188

Table 7.5.8 Summary of Major System Performance Under the 100 Year Design Storm Event for the Future Land Use Conditions - Total Length By Network (m)									
Network	**Within Ditch**	**Within Curb**	**Above Ditch Within ROW**	**Above Curb Within ROW**	**Flow Beyond ROW (Less Than 50% to Building) (Ditches)**	**Flow Beyond ROW (Less Than 50% to Building) (Curbed)**	**Flow Beyond ROW (Greater Than 50% to Building) (Ditches)**	**Flow Beyond ROW (Greater Than 50% to Building) (Curbed)**	**Grand Total (m)**
33	0	3193	0	901	154	163	216	488	5117
34	56	1624	482	1261	1765	407	708	203	6505
35	174	4306	262	130	55	0	222	46	5195
36	0	2708	452	564	158	39	514	697	5132
37	0	4930	285	1376	0	185	371	204	7350
38	0	1197	0	115	0	45	344	264	1965
39	327	551	654	511	1065	198	2746	219	6271
40	0	783	856	150	201	0	806	0	2796
41	0	772	114	672	1471	192	300	66	3587
42	135	826	485	333	821	33	1028	48	3709
43	328	160	74	481	410	0	710	45	2208
44	0	1027	511	619	1174	0	888	104	4323
45	197	1531	220	599	609	91	1197	218	4662
46	78	2850	1633	898	1570	351	1029	717	9126
47	44	4936	0	1485	0	0	608	838	7910
48	0	2347	0	492	0	40	0	86	2965
49	404	3477	81	2902	0	328	471	679	8342
50	74	3855	0	1042	0	319	0	248	5538
51	0	1358	197	265	100	26	8	77	2031
52	553	13694	99	4975	0	1666	53	1131	22171
53	603	5160	255	1552	332	35	396	376	8709
54	1750	11391	745	2489	1510	105	1030	1196	20216
55	237	3256	631	681	791	155	306	0	6056
56	0	8337	0	3229	0	406	91	924	12986
Total	**10337**	**144186**	**18284**	**50626**	**33882**	**8429**	**33806**	**22535**	**322085**

Network	Within Ditch	Within Curb	Above Ditch Within ROW	Above Curb Within ROW	Flow Beyond ROW (Less Than 50% to Building) (Ditches)	Flow Beyond ROW (Less Than 50% to Building) (Curbed)	Flow Beyond ROW (Greater Than 50% to Building) (Ditches)	Flow Beyond ROW (Greater Than 50% to Building) (Curbed)	% Total of Focus area
Table 7.5.9	**Summary of Major System Performance Under the 100 Year Design Storm Event for the Future Land Use Conditions - Percentage of Total Major System Length By Network (%)**								
1	0.0	58.8	0.0	39.7	0.0	0.0	0.0	1.5	1.0
2	0.0	77.0	0.0	8.6	0.0	0.8	0.0	13.6	0.9
3	5.0	82.3	0.0	10.9	0.0	1.9	0.0	0.0	1.6
4	0.0	83.6	0.0	14.9	0.0	0.6	0.0	0.9	2.3
5	14.6	17.3	9.5	42.3	8.4	1.1	2.1	4.7	1.2
6	0.0	94.5	0.0	5.5	0.0	0.0	0.0	0.0	0.2
7	5.0	52.3	8.5	0.0	0.0	8.4	13.2	12.6	0.3
8	1.1	75.3	0.2	4.1	1.7	0.8	0.0	16.7	1.5
9	1.4	47.8	4.7	26.0	6.8	0.8	4.8	7.6	1.4
10	0.5	9.4	20.2	0.0	60.4	0.0	9.6	0.0	0.3
11	0.0	77.5	0.0	1.4	0.0	0.0	21.0	0.0	0.5
12	0.0	70.3	0.0	29.7	0.0	0.0	0.0	0.0	0.3
13	1.6	61.2	2.5	13.8	6.4	2.6	5.7	6.1	3.2
14	1.6	47.6	3.0	23.0	0.0	4.6	5.4	14.7	5.2
15	3.8	29.5	6.3	12.6	7.7	9.0	11.6	19.5	3.7
16	34.0	66.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
17	9.8	29.2	11.3	0.2	15.8	0.0	33.6	0.0	1.0
18	3.9	4.6	10.9	4.5	30.0	0.0	37.8	8.2	3.0
19	11.2	7.0	20.6	2.8	0.0	0.0	57.1	1.2	0.5
20	2.0	10.9	6.8	9.4	40.8	0.1	17.4	12.5	3.8
21	0.0	44.2	11.8	0.0	10.7	0.0	16.3	17.0	0.6
22	1.5	24.7	0.0	0.0	0.0	2.5	61.9	9.4	0.2
23	3.0	3.8	8.8	5.1	24.2	2.0	50.1	2.9	0.6
24	9.8	8.6	6.8	26.4	38.9	1.7	3.3	4.7	1.9
25	8.2	21.7	13.1	11.2	20.4	0.3	21.8	3.4	2.9
26	0.0	33.4	0.8	22.1	19.4	0.0	16.6	7.7	0.7
27	2.8	22.5	15.2	9.6	24.5	1.5	13.8	10.2	4.1
28	7.3	23.9	11.9	0.0	25.9	2.2	28.8	0.0	1.3
29	3.0	54.6	11.0	13.7	11.6	0.1	0.8	5.2	1.3
30	1.0	34.3	3.6	23.6	4.1	8.6	12.0	12.9	2.4
31	0.0	54.2	0.0	38.6	0.0	0.0	0.0	7.2	0.4
32	0.0	56.3	2.2	32.1	0.0	0.0	5.2	4.2	0.7

Table 7.5.9 Summary of Major System Performance Under the 100 Year Design Storm Event for the Future Land Use Conditions - Percentage of Total Major System Length By Network (%)

Network	Within Ditch	Within Curb	Above Ditch Within ROW	Above Curb Within ROW	Flow Beyond ROW (Less Than 50% to Building) (Ditches)	Flow Beyond ROW (Less Than 50% to Building) (Curbed)	Flow Beyond ROW (Greater Than 50% to Building) (Ditches)	Flow Beyond ROW (Greater Than 50% to Building) (Curbed)	% Total of Focus area
33	0.0	62.4	0.0	17.6	3.0	3.2	4.2	9.5	1.6
34	0.9	25.0	7.4	19.4	27.1	6.3	10.9	3.1	2.0
35	3.3	82.9	5.0	2.5	1.1	0.0	4.3	0.9	1.6
36	0.0	52.8	8.8	11.0	3.1	0.8	10.0	13.6	1.6
37	0.0	67.1	3.9	18.7	0.0	2.5	5.0	2.8	2.3
38	0.0	60.9	0.0	5.9	0.0	2.3	17.5	13.5	0.6
39	5.2	8.8	10.4	8.1	17.0	3.2	43.8	3.5	1.9
40	0.0	28.0	30.6	5.4	7.2	0.0	28.8	0.0	0.9
41	0.0	21.5	3.2	18.7	41.0	5.4	8.4	1.8	1.1
42	3.6	22.3	13.1	9.0	22.1	0.9	27.7	1.3	1.2
43	14.8	7.3	3.3	21.8	18.6	0.0	32.1	2.0	0.7
44	0.0	23.7	11.8	14.3	27.2	0.0	20.5	2.4	1.3
45	4.2	32.8	4.7	12.8	13.1	2.0	25.7	4.7	1.4
46	0.9	31.2	17.9	9.8	17.2	3.8	11.3	7.9	2.8
47	0.6	62.4	0.0	18.8	0.0	0.0	7.7	10.6	2.5
48	0.0	79.2	0.0	16.6	0.0	1.4	0.0	2.9	0.9
49	4.8	41.7	1.0	34.8	0.0	3.9	5.6	8.1	2.6
50	1.3	69.6	0.0	18.8	0.0	5.8	0.0	4.5	1.7
51	0.0	66.9	9.7	13.0	4.9	1.3	0.4	3.8	0.6
52	2.5	61.8	0.4	22.4	0.0	7.5	0.2	5.1	6.9
53	6.9	59.3	2.9	17.8	3.8	0.4	4.6	4.3	2.7
54	8.7	56.3	3.7	12.3	7.5	0.5	5.1	5.9	6.3
55	3.9	53.8	10.4	11.2	13.1	2.6	5.1	0.0	1.9
56	0.0	64.2	0.0	24.9	0.0	3.1	0.7	7.1	4.0
Total	**3.2**	**44.8**	**5.7**	**15.7**	**10.5**	**2.6**	**10.5**	**7.0**	**100.0**

Compared with the results presented previously for existing land use conditions, the results in Tables 7.5.4. to 7.5.9 indicate the following:

- The future development within the focus area would marginally increase the categories of LOS related to surcharge and flooding within the minor system during the 5 year return period storm.
- The future development within the focus area would marginally increase categories of LOS related to surcharge and flooding within the minor system during the 100 year return period storm.
- The future development within the focus area would marginally increase the categories of LOS related to flooding beyond the Municipal right-of-way during the 100 year return period storm.

While the future development scenario demonstrates comparatively small decreases in the category specific performance of the major and minor storm conveyance systems (based on LOS bands), there is a greater impact to the peak flow rates in the system contributing to the receiving water courses, due to the increase in imperviousness associated with future development in comparison to the existing conditions. The increase in peak flow rates though are not necessarily reflected in the performance results due to the established performance bands; an increase in peak flow rate in a minor or major system may not be sufficient to change the performance band of the system. As such, there is also an anticipated increase of erosion potential to the receiving water courses. When combined with climate change, there could be as much as a 30 % increase in the peak flow rates, which tend to range between 15 and 30%.

7.5.3 Impact Assessment From Change In Land Use and Climate Change

Additional hydrologic analyses have been conducted to assess the performance of the Town's minor and major systems under both a future land use conditions and projected climate change influenced rainfall. As noted previously, there are currently twenty (20) different climate modelling organizations that lead the evolution of climate models, resulting in a large repository of models available for various applications.

As a parallel process to the Stormwater Management Master Plan, options for representation of rainfall scenarios to reflect climate change impacts were investigated to determine an appropriate method and corresponding rainfall distribution to reflect the potential meteorologic impacts resulting from climate change; full results are provided in Appendix G (ref. Nimmrichter/Scheckenberger-Parker, December 18, 2018). This review evaluated the rainfall projections from the following sources under a climate change scenario:

- Environment and Climate Change Canada
- University of Western Ontario IDF CC Tool
- Ontario Climate Change Data Portal
- Ministry of Transportation Ontario Trending Tool

Each of the tools used in this assessment embodies its own methods of analysis, display and output of data. It has been noted that the direct comparison of the IDF scenarios generated by the various tools is not feasible as the input parameters upon which the scenarios have been generated do not overlap exactly. Therefore, the comparison of the scenarios ensemble developed from the various data sources (both historical based IDF, as well as those that incorporate outputs from climate modelling) has been approached using simplified analytics.

In total, eighty-nine (89) rainfall estimates (15 – current/historic, 37 – 2050s, 37 – 2080s) have been developed, reviewed and compared. Table 7.5.10 highlights the range of the rainfall estimates developed from all of the available scenarios.

Table 7.5.10 All Scenarios Statistical Analysis – Summary

Return Period	Minimum	25th Percentile	Median	Average	75th Percentile	90th Percentile	Maximum
	Present Day						
5 Year (Oakville Design Event 60.0 mm)	57.6	59.3	60.0	65.6	67.7	84.5	91.2
100 Year (Oakville Design Event 98.4 mm)	84.0	94.5	96.6	107.3	112.1	146.4	165.6
2050s							
5 Year	62.4	69.0	80.6	82.6	95.3	100.8	110.4
100 Year	96.6	128.0	159.3	163.2	191.0	221.8	277.5
2080s							
5 Year	65.8	73.1	86.6	87.5	96.0	109.4	127.2
100 Year	100.8	145.5	174.5	179.0	214.0	246.2	276.3

Based upon the results of the assessment, and following consultation with Town staff, it has been determined that the City of Toronto Bloor Street Station should be maintained as the basis for the Town's IDF relationships, and that the University of Western Ontario IDF climate tool be applied with a RCP value of 4.5 to generate projected rainfall distributions for the 2050 and 2080 scenarios. The resulting IDF relationships are presented in Appendix G while the precipitation depth comparison is presented in Table 7.5.9. Forecasting the impacts due to climate change is an emerging area of study and as such it is recommended that the town should conduct a future study to determine appropriate IDF parameters which reflect the impacts of climate change for use in the design of the town's storm sewer infrastructure.

Table 7.5.11 Comparison of Design Storm Volumes Under Existing Conditions and Climate Change Scenarios (mm)

Return Period (Years)	Existing Climate Conditions	2050	Increase (%)	2080	Increase (%)
5	60.0	64.0	6.7	67.2	12.0
100	98.4	103.6	5.3	110.0	11.8

The IDF relationship for the 5 year 2080 climate change scenario (given that any infrastructure planned under the Master Plan would be expected to have an engineered life of 50 to 100 years) has been used in the future land use conditions modelling to illustrate the impact to the minor system under a future land use condition with climate change. A summary of the results is presented in Table 7.5.10, along with the results for the existing land use scenario.

Table 7.5.12 Summary of Minor System Performance Under the 5 Year Design Storm Event for the Existing Land Use Conditions and Rainfall versus Future Land Use Conditions with Climate Change- Percentage of Total Minor System Length By Network (%)

Scenario	Unsurcharged	Below 1/2 Surcharging Depth and Above Obvert	Above 1/2 Surcharging Depth and Below Rim Elevation	Surcharged Above Rim Elevation	Grand Total
Existing Land Use and Climate	37%	24%	28%	12%	100%
Future Land Use and Climate Change	21%	25%	36%	18%	100%

The results in Table 7.5.10 indicate that under future land use conditions and climate change, the incidence of unacceptable surcharge and road flooding within the focus area would be anticipated to increase compared to existing conditions. As such, it is anticipated that the change in land use, combined with the change in rainfall patterns under a climate change scenario, would reduce the level of service along the Town's drainage infrastructure compared to existing conditions.

8.0 Drainage System Alternative Assessment

Detailed analyses have been completed to evaluate alternative solutions to mitigate the deficiencies identified in the town's storm drainage system within the subject focus area under existing and future land use, and climate change. It should be noted that the mitigation associated with the projected impacts of land use change and climate change, has been addressed separately (ref. Section 8.8).

The analyses have been completed to specifically evaluate the preferred alternatives for the storm sewers, major systems, ditched systems, and remnant channels. The following sections summarize the results of these analyses.

8.1 Storm Sewers (Minor System)

8.1.1 Long List of Alternatives

The following long list of alternatives has been advanced for consideration to mitigate the identified deficiencies to the conveyance capacity of the storm sewers within the focus area:

i. Do Nothing

ii. Increase size of affected storm sewers, or supplement capacity

iii. Implement super pipes to provide on-line stormwater quantity control

iv. Implement on-site stormwater management for individual private properties

v. Implement off-line storage areas within available public spaces

vi. Retrofit existing stormwater management facilities to provide additional quantity control

vii. Diversions (local, not inter-watershed)

viii. Roof leader disconnection

ix. Low Impact Development (LID) Best Management Practices (BMP) (other than Alternative viii)

x. Implement inlet control devices (ICDs) within the network catch basins to reduce inflow to the storm sewer and improve upon storm sewer capacity

xi. Disconnect the private property basement foundation drain connections to the municipal storm sewer system.

xii. Combinations

8.1.2 Short List of Alternatives

The long list of alternatives has been reviewed to screen those alternatives which have been deemed unacceptable or infeasible, and thereby advance a short list of alternatives for further consideration and detailed analysis. The following summarizes the alternatives which have been screened from further consideration, and the associated basis for screening:

i. **Do Nothing**: Under this alternative, the existing capacity constraints and associated flood risk to adjacent properties would continue, hence would not achieve the objectives of this study. Consequently, this alternative has been screened from further consideration.

iv. **Implement on-site stormwater management for individual private properties**: Under this alternative, the existing drainage systems on private properties would be retrofitted to incorporate quantity controls to reduce runoff volumes and peak flows to existing infrastructure. Due to the prominently residential land use within the focus area, this alternative would require extensive consultation with individual property owners, and would require acceptance from each property owner in order to achieve effective reductions in runoff volumes and peak flows to the receiving systems. Due to the number of private properties and owners required to be consulted to achieve effective results, as well as the anticipated issues and costs associated with monitoring the long-term operation and maintenance by the private landowners, this alternative has been screened from further consideration for full-scale application. Nevertheless, it is recognized that a voluntary program may be implemented which would assist in reducing the impacts to the existing drainage systems, although there would be no reliance on these retrofits as part of the recommendations for this Master Plan.

viii. **Roof leader disconnection**: Similar to Alternative iv, this alternative would require extensive consultation with and acceptance from each individual property owner to be effectively implemented. While these disconnects may be implemented on a voluntary basis by the individual property owners, there would be no reliance on these disconnects as part of the recommended public works for this Master Plan.

ix. **Low Impact Development (LID) Best Management Practices (BMP):** Similar to Alternative iv, existing drainage systems on private properties would be retrofitted to incorporate LID BMPs to reduce runoff volumes to minor systems. This alternative would likewise require extensive consultation with and acceptance from each individual property owner in order to achieve effective results. As such, this alternative has been screened from further consideration to address storm sewer system deficiencies, notwithstanding Section 8.8 describes the use of LID BMPs for managing the impacts due to land use change and climate change. While these disconnects may be implemented on a voluntary basis by the individual property owners, there would be no reliance on these disconnects as part of the recommendations for this Master Plan.

The following short list of alternatives has been advanced for further consideration:

ii Increase size of affected storm sewers, or supplemental capacity

iii, v, vi Provide detention storage online within super pipes, offline within available public spaces, or through retrofits to existing stormwater management facilities

vii Diversions (local, not inter-watershed)

x Implement inlet control devices (ICDs) within the network catch basins to reduce inflow to the storm sewer and improve upon storm sewer capacity

xi Disconnect the private property basement foundation drain connections to the municipal storm sewer system.

xii Combinations

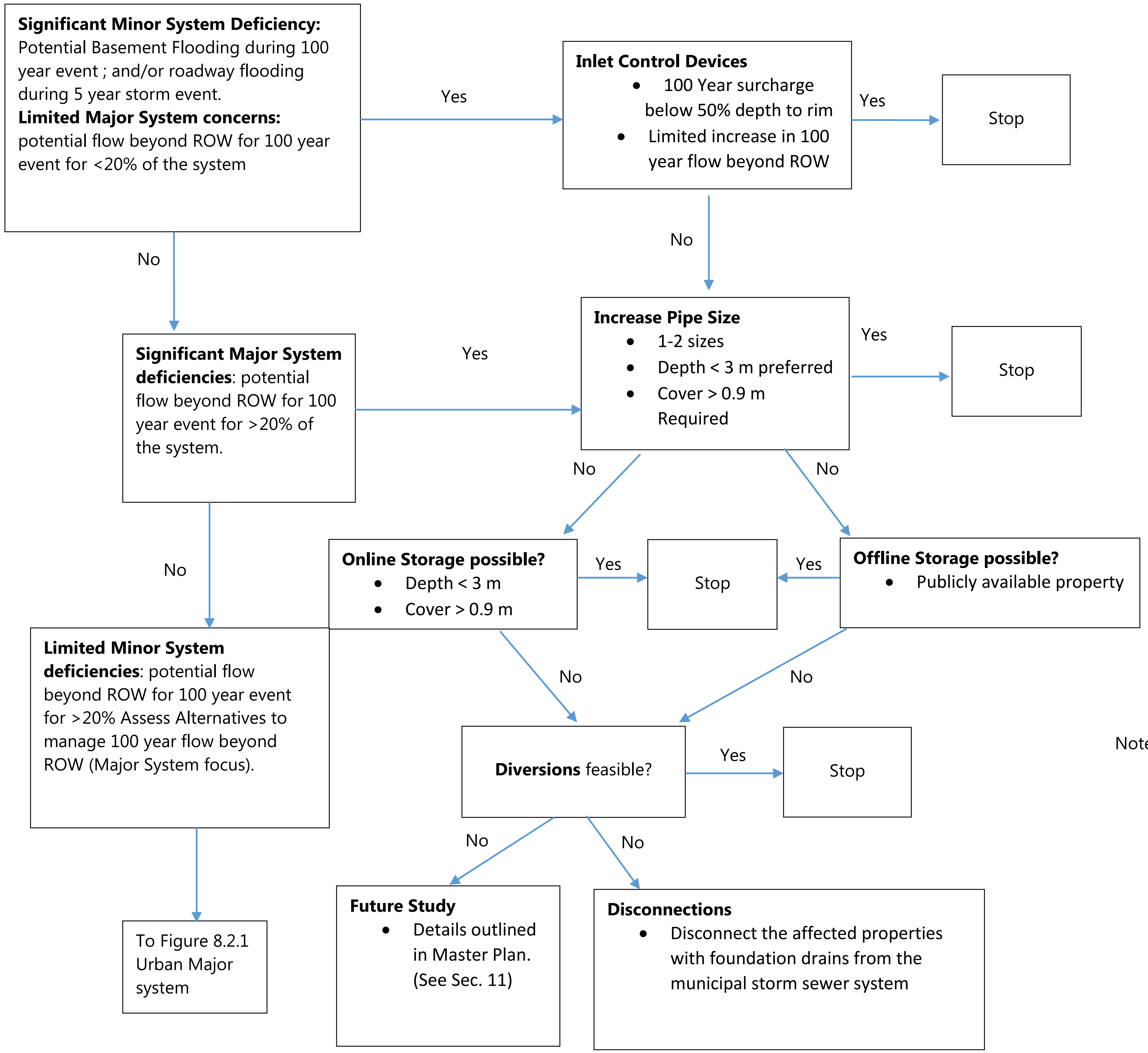
8.1.3 Assessment Methodology and Criteria

Detailed analyses have been conducted using the PCSWMM hydrologic model for existing land use conditions to evaluate the requirements and effectiveness of the short listed alternatives. The PCSWMM model has been modified as follows, to evaluate the specific alternatives:

- Inlet Control Devices – Size of catch basin geometry for each subcatchment in PCSWMM model has been adjusted to represent and assess various applications of inlet control devices (i.e. 100 mm opening) within the network catch basins (i.e. inlet control devices applied to 50%, 75%, and 100% of the catch basins within the network)
- Size of storm pipes simulated in the PCSWMM model has been increased based upon commercially available pipe sizes to assess effectiveness of increasing the size of storm sewers within the network.
- The inverts of increased storm sewer pipes have been lowered where necessary to achieve acceptable cover depth and to provide sufficient slope.
- Large size pipes and storage-discharge relationships have been incorporated into the PCSWMM model to represent online and offline storage areas at candidate locations.
- Connectivity of subcatchments to the major and minor system within the PCSWMM model has been adjusted to account for the localized diversion of runoff to optimize system performance.

The hierarchy of alternatives and corresponding criteria for evaluating feasibility for implementation are presented in Figure 8.1.1. A recommendation to disconnect the basement foundation drain connections from the minor system has been made where the identified alternatives have been unable to fully meet the town's LOS criteria.

Figure 8.1.1: Evaluation Criteria and Hierarchy for Urban and Hybrid System Conveyance Capacity Improvements (Minor Systems) [1.]



Note: [1.] LID BMPs, while supportable, from a water quality / water balance perspective, generally have limited effectiveness for significant Level-of-Service (LOS) improvements. Their utility and benefits have been incorporated into the Water Quality Master Plan as well as off-setting measures for addressing climate change and land use change in the focus area (ref. Sections 8.8 and 9.0)

8.1.4 Preferred Alternatives

The preferred alternatives for enhancing the performance of the urban and hybrid minor systems within the focus area vary by network area, based upon the needs, system performance, and physical conditions within each network area. The preferred alternative for each network is summarized in Table 8.1.1, while the major capital upgrades are presented graphically on Drawing 8.1, and further information is provided on the drawings in Appendix H.

The application of ICDs has been recommended as either 75 % implementation or >75 % implementation as shown in table 8.1.1. The >75 % implementation has been assessed as 100 % implementation in the PCSWMM model, however it is recognized that at the time of execution, the required number of ICDs should be confirmed and it is anticipated to be between 75 and 100 % implementation.

Future studies have been recommended for three (3) classifications of recommended works: Schedule A/A+ EA works Schedule B EA works, and detailed network studies. A confirmatory study should be completed as a Schedule A/A+ EA or Schedule B EA, to validate the data and verify the results with more detailed information of the site parameters. This study should be undertaken at a minimum prior to commencing future work. The capital works which require Schedule A/A+ and B studies (confirmatory studies) are outlined in Section 11.2.1 and study costs have been provided in Appendix J. The second study type is further assessment (detailed network analysis study) which should be undertaken where the information used for the Master Plan required several assumptions, the network performance results were poor or did not meet the town's LOS criteria following the alternative assessment, or the alternative assessment recommendations require substantial capital investment to mitigate the drainage system performance. These studies are typically recommended for networks with an existing conditions High Priority ranking. The detailed network studies (ref. Table 8.1.1) have been recommended either due to the large extent of the recommended works to achieve a level of service acceptable to the town's standard, data gap confirmation, or to validate the recommended alternatives.

Table 8.1.1 Summary of Preferred Alternatives by Network for Mitigating Deficiencies to Urban and Hybrid Minor Systems (i.e. Storm Sewers)

Network ID	Preferred Alternative	Comments
1	Confirm extent of existing ICDs and verify the existence of the negative sloped pipes near the outlet	75 % ICD implementation has been assumed for the existing conditions while >75% implementation has been recommended for the alternative assessment
2	No Action	The minor system performance is satisfactory
3	No Action	The minor system performance is satisfactory
4	No Action	The minor system performance is satisfactory
5	No Action	The minor system performance is satisfactory
6	Install ICDs (75% of Sewershed)	Instances of surcharge due to tailwater condition at outlet proximate to Sheldon Creek and Lake Ontario. This network should be considered for disconnecting the basement connections or foundations drains from the storm sewer system.
7	Pipe replacement	Confirm and replace pipes with negative slope to mitigate the surcharging in the minor system
8	Install ICDs (>75% of sewershed)	Significant mitigation efforts, other than ICDs, are not required

Table 8.1.1	Summary of Preferred Alternatives by Network for Mitigating Deficiencies to Urban and Hybrid Minor Systems (i.e. Storm Sewers)	
Network ID	**Preferred Alternative**	**Comments**
9	Install ICDs (75% of sewershed)	Note: Minor Pipe replacement upgrades are also recommended in addition to pipe upgrades as per the Lakeshore Road (Draft) Class EA. Instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system. Future study recommended with additional investigation to address residual data gaps and to validate alternatives.
10	Pipe Replacement	The extent of the minor system deficiencies in this network is limited.
11	No Action	Satisfactory performance of the minor systems in urbanized areas, modelled with a swale in a park which exceeds capacity. A dedicated foundation drain sewer pipe has been identified in this network; the extent, location, and performance of this drain should be confirmed as it has not been modelled.
12	Install ICDs (>75% of sewershed)	Note: Upgrade pipes per recommendations of Lakeshore Road (Draft) Class EA
13	Install ICDs (75% of sewershed)	Note: Upgrade pipes per recommendations of Lakeshore Road (Draft) Class EA. Instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system.
14	Pipe replacement, online/offline storage	Further mitigation possible through lowering inverts and increasing sizes (to be considered at next stages of planning and design). Future study recommended with additional investigation to address residual data gaps and to validate alternatives due to the extent of recommended works.
15	Pipe replacement, online/offline storage	Further mitigation possible through lowering inverts and increasing sizes (to be considered at next stages of planning and design). Future study recommended with additional investigation to address residual data gaps and to validate alternatives due to the extent of recommended works
16	Install ICDs (75% of sewershed)	Significant mitigation efforts, other than ICDs, are not required
17	Diversion, Pipe Replacement, online storage	Note: Diversion and pipe replacement per recommendations of Coronation Park Class EA and the Lakeshore Road (Draft) EA
18	Diversion, Pipe Replacement, Online/Offline Storage	Note: Diversion, pipe replacement, and online/offline storage per recommendations of Coronation Park Class EA. Future study recommended with additional investigation to address residual data gaps and to validate alternatives. Additional storage could be considered as part of a future study rather than upsizing storm sewers on private property.
19	Diversion, Pipe Replacement	Note: Diversion and pipe replacement per recommendations of Coronation Park Class EA and the Lakeshore Road (Draft) Class EA. Instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system.
20	Pipe replacement	Further mitigation possible through lowering inverts and increasing sizes (to be considered at next stages of planning and design). Future study recommended with additional

Table 8.1.1	Summary of Preferred Alternatives by Network for Mitigating Deficiencies to Urban and Hybrid Minor Systems (i.e. Storm Sewers)	
Network ID	**Preferred Alternative**	**Comments**
		investigation to address residual data gaps and to validate alternatives due to the extent of recommended works.
21	Pipe replacement	Instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system.
22	Pipe replacement and new sewers	Note: Install pipes as per the Lakeshore Road (Draft) Class EA
23	Pipe replacement	Further mitigation possible through lowering inverts and increasing sizes (to be considered at next stages of planning and design)
24	Diversion, pipe replacement	Diversion storm sewer pipe conveyed to Network 25 to provide mitigation from tailwater conditions in remnant channel
25	Pipe replacement	Note: Upgrade pipes per recommendations of Lakeshore Road (Draft) Class EA, and diversion from Network 24
26	No Action	Instances of surcharge due to tailwater condition at outlet proximate to McCraney Creek are not mitigable through capital works
27	Pipe replacement, online/offline storage	Further mitigation possible through lowering inverts and increasing sizes (to be considered at next stages of planning and design); future study recommended with additional investigation to address residual data gaps and to validate alternatives due to the extent of recommended works. This network should be considered for disconnecting the basement connections or foundations drains from the storm sewer system.
28	Pipe replacement	Note: Upgrade pipes per recommendations of Lakeshore Road (Draft) Class EA
29	Install ICDs (>75% of sewershed)	Note: Upgrade storm sewers per Lakeshore Road (Draft) Class EA
30	Pipe replacement, online/offline storage	Pipe replacement and offline/online storage to mitigate both major and minor systems; future study recommended with additional investigation to address residual data gaps and to validate alternatives due to the extent of recommended works. Incidences of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system.
31	Install ICDs (75% of sewershed)	Future study recommended with additional investigation to address residual data gaps and to validate alternatives as implementing ICDs does not fully mitigate to the town's standards. This network should be considered for disconnecting the basement connections or foundations drains from the storm sewer system.
32	Install ICDs (75% of sewershed), pipe replacement	Minor instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system or addressed as part of future long-term maintenance.
33	Install ICDs (>75% of sewershed), offline storage	Offline storage near water treatment plant as well as increasing pipe sizes through water treatment plant are recommended.
34	Pipe replacement	Pipe replacement recommended to mitigate surcharging

Table 8.1.1 Summary of Preferred Alternatives by Network for Mitigating Deficiencies to Urban and Hybrid Minor Systems (i.e. Storm Sewers)

Network ID	Preferred Alternative	Comments
35	Install ICDs (>75% of sewershed)	Significant mitigation efforts, other than ICDs, are not required
36	Pipe replacement, online storage	Instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system.
37	Install ICDs (75% of sewershed), pipe replacement	Minor instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system or addressed as part of future long-term maintenance.
38	Pipe replacement	Instances of surcharge due to tailwater condition at outlet to Lower Morrison Creek. This network should be considered for disconnecting the basement connections or foundations drains from the storm sewer system. There is an ongoing fluvial study for Lower Morrison Creek; a follow up study should be considered for this network following the recommendations of the fluvial study with a study cost to be determined.
39	Pipe replacement, diversion	Pipe replacement mitigates surcharging
40	Pipe replacement	Pipe replacement mitigates surcharging
41	Pipe replacement	Pipe replacement mitigates surcharging. Minor instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system or addressed as part of future long-term maintenance.
42	Offline storage, pipe replacement	Storage and upgrades per recommendations of Cornwall Road Class EA, have been completed. As such, these works have not been included in the cost estimate for this study. Nevertheless, there continue to be instances of surcharge within the minor system due to tailwater condition at outlet to Lower Morrison Creek. This network should be considered for disconnecting the basement connections or foundations drains from the storm sewer system. There is an ongoing fluvial study for Lower Morrison Creek; a future study should be considered for this network following the recommendations of the fluvial study with a study cost to be determined
43	Pipe replacement	Storage and upgrades per recommendations of Cornwall Road Class EA, have been completed. As such, these works have not been included in the cost estimate for this study. Additional pipe replacement has been recommended to mitigate residual surcharging.
44	Pipe replacement	Pipe replacement mitigates the minor system. Minor instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system or addressed as part of future long-term maintenance.
45	Pipe replacement	Pipe replacement mitigates minor system surcharging; limited cover on pipes at the Lower Wedgewood Creek outlet necessitates the use of box culverts for the storm sewer.
46	Pipe replacement	Minor instances of surcharge at isolated locations with basement connections or foundations drains should be

Table 8.1.1	Summary of Preferred Alternatives by Network for Mitigating Deficiencies to Urban and Hybrid Minor Systems (i.e. Storm Sewers)	
Network ID	Preferred Alternative	Comments
		considered for disconnection from the storm sewer system or addressed as part of future long-term maintenance.
47	Install ICDs (>75% of sewershed)	Significant mitigation efforts, other than ICDs, are not required
48	Pipe replacement	Pipe replacement recommended to mitigate instances of surcharging
49	Pipe replacement	Pipe replacement recommended to mitigate instances of surcharging. Surface flow conveyed to the 3000 mm x 1500 mm drop inlet structure, south of the rail corridor, causes surcharging in the minor system. Future study recommended with additional investigation to address residual data gaps and to validate alternatives.
50	Install ICDs (>75% of sewershed)	Significant mitigation efforts, other than ICDs, are not required
51	Install ICDs (75% of sewershed)	Pipe replacement recommended to mitigate minor instances of surcharging
52	Pipe replacement	Pipe replacement recommended to mitigate instances of surcharging. Sump pumps have been identified on town drawings, however, sump pump presence should be confirmed as part of future analysis.
53	Confirm extent of existing ICDs	Verify existence of negative sloped pipes and confirm the extent of the existing ICDs
54	Confirm extent of existing ICDs	Confirm the extent of the existing ICDs and implement pipe replacement to mitigate instances of surcharging
55	Install ICDs (75% of sewershed)	Pipe replacement recommended to mitigate instances of surcharging
56	Install ICDs (>75% of sewershed)	Significant mitigation efforts, other than ICDs, are not required

8.2 Major System

8.2.1 Long List of Alternatives

The following long list of alternatives has been advanced for consideration to mitigate the identified deficiencies to the conveyance capacity of the major (overland) system within the focus area associated with existing land use and existing climate:

i. Do Nothing
ii. Increase size of storm sewers to reduce depth of flooding along the major system to within acceptable limits
iii. Implement super pipes to provide on-line stormwater quantity control
iv. Implement on-site stormwater management for individual private properties
v. Implement off-line storage areas within available public spaces
vi. Retrofit existing stormwater management facilities to provide additional quantity control
vii. Modify grading on private property to mitigate flooding.
viii. Modify grading within road right of way to mitigate flooding (Roadway re-profiling).
ix. Low Impact Development (LID) Best Management Practices (BMP)
x. Combinations.

8.2.2 Short List of Alternatives

The long list of alternatives has been reviewed to screen those alternatives which have been deemed unacceptable or infeasible, and advance a short list of alternatives for further consideration and detailed analysis. The following summarizes the alternatives which have been screened from further consideration and the associated rationale:

i. **Do Nothing**: Under this alternative, the existing capacity constraints and associated flood risk to adjacent properties would continue, hence would not achieve the objectives of this study. Consequently, this alternative has been screened from further consideration.

iv. **Implement on-site stormwater management for individual private properties**: Under this alternative, the existing drainage systems on private properties would be retrofitted to incorporate quantity controls to reduce runoff volumes and peak flows to existing infrastructure. Due to the prominently residential land use within the focus area, this alternative would require extensive consultation with individual property owners, and would require acceptance from each property owner in order to achieve effective reductions in runoff volumes and peak flows to the receiving systems. Due to the number of private properties and owners required to be consulted to achieve effective results, as well as the anticipated issues and costs associated with monitoring the long-term operation and maintenance by the private landowners, this alternative has been screened from further consideration for full-scale application. Nevertheless, it is recognized that a voluntary program may be implemented which would assist in reducing the impacts to the existing drainage systems, although there would be no reliance on these retrofits as part of the recommendations for this Master Plan.

vii. **Modify grading on private property to mitigate flooding**: Existing private property would need to be regraded to reduce the major system flood risk potential from the less frequent storm events. This alternative would require extensive consultation with and acceptance from each individual property owner in order to achieve effective results. Due to the number of private properties and owners required to be consulted to achieve effective results, this alternative has been screened from further consideration for full-scale application. Nevertheless, it is recognized that a voluntary program may be implemented which would assist in reducing the impacts to the existing drainage systems, although there would be no reliance on these retrofits as part of the recommendations for this Master Plan.

viii. **Low Impact Development (LID) Best Management Practices (BMP)**: Similar to Alternative iv, existing drainage systems on private properties would be retrofitted to incorporate LID BMPs to reduce runoff volumes to minor systems. This alternative would likewise require extensive consultation with and acceptance from each individual property owner in order to achieve effective results. Furthermore, this alternative would only be effective for mitigating impacts during the more frequent storm events (i.e. 5 year storm), hence the issues associated with connected areas and major system capacity for the 100 year storm would not be effectively mitigated. As such, this alternative has been screened from further consideration.

The following short list of alternatives was advanced for further consideration:

- ii Increase size of affected storm sewers, or supplemental capacity
- iii, v, vi Provide detention storage online within super pipes, offline within available public spaces, or through retrofits to existing stormwater management facilities
- viii Modify grading within road right of way to mitigate flooding (roadway re-profiling)
- x Combinations

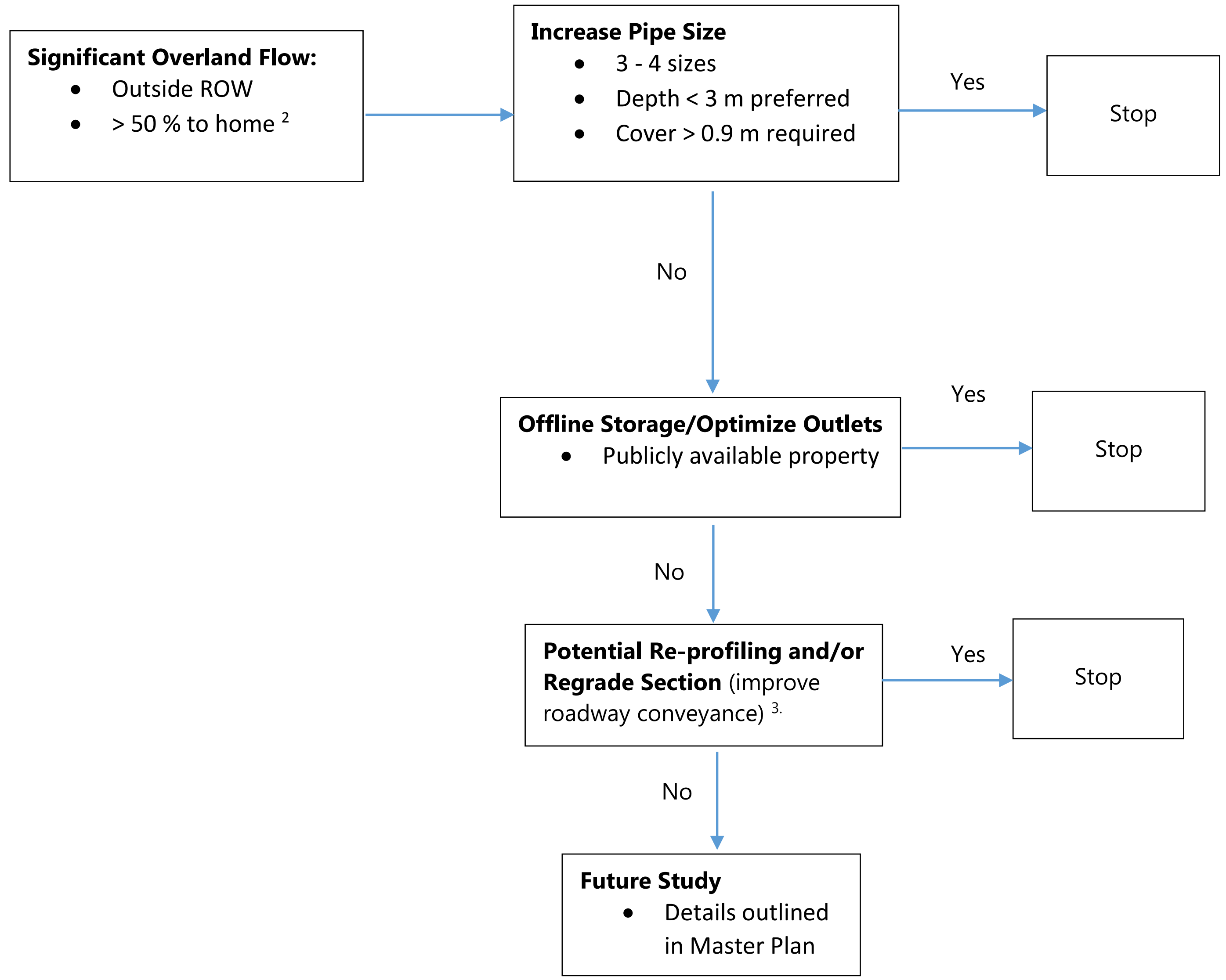
8.2.3 Assessment Methodology and Criteria

Detailed analyses have been conducted using the PCSWMM hydrologic model for existing land use and climate conditions to evaluate the requirements and effectiveness of the short listed alternatives noted above. The PCSWMM model has been modified as follows, to evaluate the specific alternatives:

- Size of storm pipes simulated in the PCSWMM model has been increased based upon commercially available pipe sizes to assess the effectiveness in reducing flood depths and extents with the major system.
- Large size pipes and storage-discharge relationships have been incorporated into the PCSWMM model to represent online and offline storage areas at candidate locations.
- Sensitivity analyses completed to determine anticipated effectiveness of grading modifications to road right-of-way to mitigate flooding in select areas.

The hierarchy of alternatives and corresponding criteria for evaluating the feasibility for implementation are presented in Figure 8.2.1. It should be noted that the analyses undertaken for the major system assessment, while detailed, are not as accurate as the detailed analyses undertaken for the minor system (ref. Section 8.1.3). This is due to the level of uncertainty related to the major system longitudinal profile which has been developed based on minor system rim elevation data and supplemented with available topographic contour data (DEM) where necessary. Furthermore, the mitigation alternative of roadway re-profiling, as noted above, has not been explicitly modelled for each area due to the number of uncertainties and need for detailed data; it does however remain as a best effort approach to mitigating flooding beyond the ROW if other alternatives do not mitigate the major system impacts to the town's LOS criteria. Further analyses are expected at the detailed design stage with locally specific and detailed data.

Figure 8.2.1: Evaluation Criteria and Hierarchy for Conveyance Capacity Improvements (Major Systems) [1.]



Note:

[1.] Remnant Channels (non-regulated open watercourses on predominantly private property) often receive drainage from the Municipal system. Where significant flood risks to private property have been identified (along remnant channels), there can be consideration for strategic application of techniques cited in Figures 8.1.1 and 8.2.1.

[2.] No action has been recommended for the major system if flow beyond the ROW is < 50 % to the buildings.

[3.] Major system re-profiling or regrading to improve roadway conveyance has not been assessed explicitly in the PCSWMM model. This is a high-level (best efforts) recommendation at the identified locations if the assessed alternatives do not mitigate the major system impacts to the town's LOS criteria. The major system re-profiling is recommended to be completed at the time of other road works.

8.2.4 Preferred Alternatives

The preferred alternatives for enhancing the performance of the major systems within the focus area varies by network area, based upon the needs, system performance, and physical conditions within each network area. The preferred alternative for each network is summarized in Table 8.2.1, while major capital upgrades are provided on Drawing 8.1, and further information is provided on the drawings in Appendix H. A preferred alternative of *No Action* is indicative of a network with a major system level of service which meets the town's criteria, as being in the lower risk category (ref. Table 8.3.1), while *No Immediate Action* is indicative of a network with some major system deficiencies that could be improved at the time of other road works, which were fully not mitigated with pipe upgrades or storage. In these particular areas, road re-profiling to the best efforts possible should be considered as a mitigation alternative, although as noted this alternative has not been explicitly verified within the PCSWMM model.

Table 8.2.1 Summary of Preferred Alternatives by Network for Mitigating Deficiencies to Major System

Network ID	Preferred Alternative	Comments
1	No action	The major system performance is satisfactory
2	No immediate action	Instances of flow beyond the ROW at sag points to be addressed at the time of other road works.
3	No action	The major system performance is satisfactory
4	No action	The major system performance is satisfactory
5	No action	The major system performance is satisfactory
6	No action	The major system performance is satisfactory
7	No Immediate action	Instances of flow beyond the ROW at sag points to be addressed at the time of other road works.
8	No Immediate action	Instances of flow beyond the ROW at sag points to be addressed at the time of other road works.
9	No action	The major system performance is satisfactory
10	Pipe replacement	Replace storm sewer at end of cemetery remnant channel
11	No action	The major system performance is satisfactory
12	Pipe replacement	The major system performance is satisfactory
13	Pipe replacement	Note: Upgrade pipes per recommendations of Lakeshore Road (Draft) Class EA
14	Pipe replacement	Instances of flow beyond the ROW at sag points to be addressed at the time of other road works.
15	Pipe replacement	Pipe placement improves major system performance, Instances of flow beyond the ROW at sag points to be addressed at the time of other road works.
16	No action	The major system performance is satisfactory
17	Diversion, pipe replacement	Note: Diversion and pipe replacement per recommendations of Coronation Park Class EA
18	Diversion, pipe replacement, online/offline storage	Note: Diversion, pipe replacement, and online/offline storage per recommendations of Coronation Park Class EA
19	Diversion, pipe replacement	Note: Diversion and pipe replacement per recommendations of Coronation Park Class EA
20	Pipe Replacement	Further mitigation possible through lowering inverts and increasing sizes (to be considered at next stages of planning and design)

Table 8.2.1 Summary of Preferred Alternatives by Network for Mitigating Deficiencies to Major System

Network ID	Preferred Alternative	Comments
21	Pipe Replacement	Pipe replacement does not mitigate flow beyond the ROW on Speers Road. Instances of flow beyond the ROW at sag points to be addressed at the time of other road works.
22	No immediate action	Instances of flow beyond the ROW at sag points to be addressed at the time of other road works in addition to evaluating other alternatives.
23	Pipe replacement	Further mitigation possible through lowering inverts and increasing sizes (to be considered at next stages of planning and design). Instances of flow beyond the ROW at sag points to be addressed at the time of other road works in addition to optimizing major system outlets.
24	No action	The major system performance is satisfactory
25	Pipe replacement	Note: Upgrade pipes per recommendations of Lakeshore Road (Draft) Class EA and implement minor system as per the Maplehurst Avenue drainage study.
26	No immediate action	Instances of flow beyond the ROW at sag points to be addressed at the time of other road works in addition to evaluating other alternatives.
27	Pipe replacement, online/offline storage	Further mitigation possible through lowering inverts and increasing sizes (to be considered at next stages of planning and design), future study recommended
28	Pipe replacement	Note: Upgrade pipes per recommendations of Lakeshore Road (Draft) Class EA
29	No action	The major system performance is satisfactory
30	Pipe replacement	Minor system pipe replacement provides benefits to the major system
31	No action	The major system performance is satisfactory
32	No action	The major system performance is satisfactory
33	No immediate action	Instances of flow beyond the ROW at sag points to be addressed at the time of other road works in addition to optimizing major system outlets.
34	Pipe replacement	Minor system pipe replacement provides benefits to the major system
35	No immediate action	Instances of flow beyond the ROW at sag points to be addressed at the time of other road works in addition to optimizing major system outlets.
36	Pipe replacement	Minor system pipe replacement provides benefits to the major system
37	No action	The major system performance is satisfactory
38	No immediate action	Instances of flow beyond the ROW at sag points to be addressed at the time of other road works.
39	Pipe replacement, diversion	Instances of flow beyond the ROW at sag points to be addressed at the time of other road works in addition to evaluating other alternatives
40	Pipe replacement	Minor system pipe replacement provides benefits to the major system
41	No immediate action	Instances of flow beyond the ROW at sag points to be addressed at the time of other road works.

Table 8.2.1 Summary of Preferred Alternatives by Network for Mitigating Deficiencies to Major System

Network ID	Preferred Alternative	Comments
42	Offline storage, pipe replacement	Note: Offline storage and upgrade pipes per recommendations of Cornwall Road Class EA; opportunities to lower inverts and provide positive grade along swale/minor system south of Cornwall to be investigated as part of future study
43	Pipe replacement	Note: Upgrade pipes per recommendations of Cornwall Road Class EA
44	Pipe replacement	Minor system pipe replacement provides benefits to the major system
45	Pipe replacement	Instances of flow beyond the ROW at sag points to be addressed at the time of other road works in addition to evaluating other alternatives
46	Pipe replacement	Minor system pipe replacement provides benefits to the major system
47	No immediate action	Instances of flow beyond the ROW at sag points to be addressed at the time of other road works.
48	No action	The major system performance is satisfactory
49	No immediate action	Instances of flow beyond the ROW at sag points to be addressed at the time of other road works.
50	No action	The major system performance is satisfactory
51	No action	The major system performance is satisfactory
52	No action	The major system performance is satisfactory
53	No action	The major system performance is satisfactory
54	No action	The major system performance is satisfactory
55	No action	The major system performance is satisfactory
56	No action	The major system performance is satisfactory
LMC	No action	The major system performance is satisfactory
LWC	No action	The major system performance is satisfactory

8.3 Recommended Works Level of Service

The PCSWMM model has been updated to reflect the recommended works for each network outlined in sections 8.1.4 for the minor system and 8.2.4 for the major system. The performance results from the PCSWMM model, with the recommended works in-place, have been used to update the network level of service, as described in Section 7.2, to the results presented in Table 8.3.1. The results in the table demonstrate the existing condition level of service for comparison to the recommended works in-place level of service which include ICD implementation, storm sewer upgrades, diversions, and online/offline quantity storage.) These results are hown graphically on Drawing 8.2 for the combined level of service with the implementation of the ICDs, and Drawing 8.3 for the combined level of service for the implementation of ICDs and major capital hydraulic upgrades.

Table 8.3.1 Comparison of the Existing Conditions Level of Service, with the Implementation of ICDs and Recommended Storm Sewer and Storage Works In-Place

Network	Existing Conditions Level of Service				ICDs with Recommended Sewer and Storage Works in-place Level of Service			
	Minor System		Major System	Weighted Net	Minor System		Major System	Weighted Net
	Connected	Disconnected			Connected	Disconnected		
1	D	A	A	D	A	B	A	A
2	A	A	A	A	A	A	A	A
3	A	B	A	A	A	B	A	A
4	A	A	A	A	A	A	A	A
5	-	A	A	A	-	A	A	A
6	D	A	A	B	D	A	A	B
7	D	A	B	D	C	A	A	B
8	D	A	A	D	A	A	A	A
9	D	A	A	C	D	A	A	C
10	-	A	A	A	-	A	A	A
11	D	A	B	B	D	A	B	B
12	-	B	A	A	-	A	A	A
13	D	A	A	C	D	A	A	B
14	D	A	B	D	A	A	B	B
15	D	B	B	D	B	A	A	B
16	D	A	A	C	A	A	A	A
17	C	B	B	B	C	A	B	B
18	D	B	C	D	C	A	B	B
19	C	C	C	C	D	A	B	B
20	D	B	B	C	C	A	B	B
21	C	A	B	B	C	A	B	B
22	-	A	D	B	-	A	D	B
23	D	C	C	C	B	A	C	B
24	D	A	A	C	A	A	A	A
25	D	A	B	C	A	A	B	B
26	D	A	B	B	B	A	B	B
27	D	B	B	B	D	A	A	B
28	D	A	B	C	B	A	B	B
29	C	A	A	B	A	A	A	A
30	D	A	A	B	D	A	A	B
31	D	B	A	D	D	A	A	D
32	D	A	A	B	C	A	A	A
33	D	A	A	B	A	A	A	A
34	D	B	A	B	A	A	A	A
35	C	A	A	B	A	A	A	A
36	D	A	B	B	D	A	A	B

Table 8.3.1 Comparison of the Existing Conditions Level of Service, with the Implementation of ICDs and Recommended Storm Sewer and Storage Works In-Place								
Network	Existing Conditions Level of Service				ICDs with Recommended Sewer and Storage Works in-place Level of Service			
	Minor System		Major System	Weighted Net	Minor System		Major System	Weighted Net
	Connected	Disconnected			Connected	Disconnected		
37	D	A	A	B	C	A	A	B
38	D	B	B	D	D	B	B	D
39	C	A	C	B	A	A	C	B
40	D	B	B	D	A	A	B	B
41	D	B	A	B	C	A	A	B
42	D	B	B	C	D	B	B	C
43	D	A	B	C	B	A	B	B
44	D	A	B	C	C	A	B	B
45	D	C	B	D	A	A	B	B
46	D	A	A	B	B	A	A	B
47	D	C	A	D	A	A	B	A
48	B	A	A	B	B	A	A	B
49	D	A	A	C	D	A	A	C
50	D	A	A	D	A	A	A	A
51	C	A	A	B	A	A	A	A
52	B	A	A	B	B	A	A	B
53	D	A	A	C	A	A	A	A
54	C	B	A	B	B	A	A	B
55	D	B	A	B	B	A	A	B
56	D	A	A	C	A	A	A	A
LMC	-	-	A	A	-	-	A	A
LWC	-	-	A	A	-	-	A	A

A comparison summary of change in level of service has been provided for the connected (foundation drains) minor systems, disconnected minor system, major systems, and the weighted net level of service (ref. Tables 8.3.2, 8.3.3, 8.3.4, and 8.3.5 respectfully). These tables demonstrate the effectiveness of the ICD implementation and the recommended storm sewer and storage major capital works.

The level of service improvement to the basement connected minor system networks (ref. Table 8.3.2) due to the ICD implementation is demonstrated through an increase of eleven (11) networks to an ‘A’ level of service and an increase of two (2) networks to a ‘B’ level of service from existing conditions. Similarly, implementing ICDs in addition to the recommended sewer and storage works results in an increase of eighteen (18) networks to an ‘A’ level of service and an increase of eight (8) networks to a ‘B’ level of service from existing conditions.

Table 8.3.2 Network Minor System Connected Level of Service Comparison Summary					
Net LOS	**Existing Conditions**	**Implement ICDs**	**Difference to Existing Conditions**	**ICDs with Recommended Sewer and Storage Works**	**Difference to Existing Conditions**
A	3	14	11	21	18
B	2	4	2	10	8
C	8	5	-3	9	1
D	39	29	-10	12	-27

The level of service improvement to the minor system networks with basements not connected for the ICD implementation and recommended sewer and storage works results in fifty-three (53) networks with an ‘A’ level of service and three (3) networks with a ‘B’ level of service (ref. Table 8.3.3). There are no networks with a ‘C’ or ‘D’ level of service following the implementation of the ICDs and recommended sewer and storage works.

Table 8.3.3 Network Minor System Disconnected Level of Service Comparison Summary					
Net LOS	**Existing Conditions**	**Implement ICDs**	**Difference to Existing Conditions**	**ICDs with Recommended Sewer and Storage Works**	**Difference to Existing Conditions**
A	37	42	5	53	16
B	15	11	-4	3	-12
C	4	3	-1	0	-4
D	0	0	0	0	0

There is minimal level of service improvement to the major system based on the results presented in Table 8.3.4. The implementation of ICDs does result in a reduction of one (1) network from an ‘A’ level of service to a ‘B’ level of service while the implementation of ICDs with the recommended sewer and storage works result in an increase of three (3) networks to an ‘A’ level of service.

Further improvements are observed in the major system performance results with the recommended works, however the performance improvements are insufficient to shift a network up a level of service grade, as per the level of service criteria. Alternative major system improvements such as reprofiling or regrading and optimizing the outlets could provide additional benefits beyond what is capable through minor systems upgrades and storage.

Table 8.3.4 Network Major System Level of Service Comparison Summary					
Net LOS	**Existing Conditions**	**Implement ICDs**	**Difference to Existing Conditions**	**ICDs with Recommended Sewer and Storage Works**	**Difference to Existing Conditions**
A	35	34	-1	38	3
B	18	19	1	17	-1
C	4	4	0	2	-2
D	1	1	0	1	0

The weighted net level of service comparison (ref. Table 8.3.5) demonstrates the overall weighted improvement of the minor system with basements connected and not connected, as well as the major system. Ultimately, there are twelve (12) networks that have increased to an 'A' level of service due to the implementation of the ICDs. The implementation of ICDs and the recommended storm sewer and storage works results in an increase of fourteen (14) networks to an 'A' level of service while there has been an increase of eight (8) networks to a 'B' level of service. Overall, there are five (5) networks that are classified as a 'C' or 'D' level of service following the implementation of ICDs and the recommended storm sewer and storage works.

Table 8.3.5 Network Weighted Net Level of Service Comparison Summary

Net LOS	Existing Conditions	Implement ICDs	Difference to Existing Conditions	ICDs with Recommended Sewer and Storage Works	Difference to Existing Conditions
A	8	20	12	22	14
B	23	19	-4	31	8
C	15	11	-4	3	-12
D	12	9	-4	2	-10

As has been demonstrated in the preceding tables, the majority of the recommended works including implementing ICDs and storm sewer upgrades, provide considerable benefit by mitigating surcharging of the minor system. This leads to a reduction in the potential risk of the minor system impacting basement connected properties and roadways. Mitigation of the major system performance deficiencies is considered more of a challenge, as demonstrated in Table 8.3.4, which may only be accomplished by regrading and re-profiling roads to remove sag points, while providing an optimized outlet for the major system.

8.4 Ditches (Rural Cross-Sections)

8.4.1 Long List of Alternatives

The following long list of alternatives has been advanced for consideration to mitigate the modelled deficiencies to the conveyance capacity of the ditch systems (rural cross-sections) within the focus area:

i. Do Nothing

ii. Implement hybrid drainage system through construction and installation of storm pipes and catch basins within ditches

iii. Replace and/or maintain driveway culverts to improve conveyance capacity within ditches

iv. Line ditches to improve conveyance capacity

v. Re-sectioning/regrading ditches

vi. Implement on-line storage within ditches

vii. Implement off-line storage areas within available public spaces

viii. Implement additional/optimized outlets for ditches

ix. Combinations.

8.4.2 Short List of Alternatives

The long list of alternatives has been reviewed to screen those alternatives which have been deemed unacceptable or infeasible, and advance a short list of alternatives for further consideration as follows:

The following summarizes the alternatives which have been screened from further consideration and the associated rationale:

i. **Do Nothing**: Under this alternative, the existing capacity constraints and associated flood risk to adjacent properties would continue, hence would not achieve the objectives of this study. Consequently, this alternative has been screened from further consideration.

iv. **Line ditches to improve conveyance capacity**: Manufactured ditch lining products such as concrete or plastic materials would likely improve the ditch conveyance capacity in areas that do not have sags or low points in the ROW. However, ditch lining would not address the capacity constraints associated with sags in the ROW where outlet improvements would be necessary to mitigate the attenuated flow in the ditch system. Furthermore, ditch lining systems would likely eliminate the informal water quality benefits that are provided by natural ditch systems. It is the recommendation of this study that the natural ditched ROWs should be maintained where possible, as they provide an informal water quality benefit that should be formalized at the time of roadway reconstruction.

vi. **Implement on-line storage within ditches**: Suitable areas have not been identified for this alternative as the storage volume required would likely be infeasible to provide meaningful benefit to the major system during the 100 year design storm event. The majority of the ditch major systems are located in residential areas, where the ROW would not accommodate on-line storage, requiring the acquisition of private property for attenuation purposes. This alternative would require extensive consultation with individual property owners and would require acceptance from each property owner in order to achieve effective reductions in runoff volumes and peak flows to the receiving ditched systems. Due to the number of private properties and owners required to be consulted to achieve effective results, as well as the anticipated issues and costs associated with monitoring the long-term operation and maintenance by the private landowners, this alternative has been screened from further consideration for full-scale application.

The following short list of alternatives was advanced for further consideration:

ii. Implement hybrid drainage system through installation of storm pipes and catch basins within ditches

iii. Replace and/or maintain driveway culverts to improve conveyance capacity within ditches

v. Re-sectioning/regrading ditches

vii. Implement off- line storage areas within available public spaces

viii. Implement additional/optimized outlets for ditches

ix. Combinations.

8.4.3 Assessment Methodology and Criteria

A desktop review of the background information provided for this study, as well as the findings of the PCSWMM modelling, have been used to determine the feasibility of each of the foregoing short-listed alternatives. The analytical process is limited by several factors including: the longitudinal profile developed from available contour and DEM data, driveway culverts not discretely represented in the modelling, rather incorporated with hydraulically equivalent cross sections and local grading/geometry of driveway embankments/ditches. While the short listed alternative strategies have not been assessed in detail with the PCSWMM model, they have been screened based on physiography, topography, proximity to a minor system, presence of the hybrid system, existing hydraulic performance of the ditches, and presence of driveway culverts. As noted, due to the limitations of the current modelling of the ditched systems, the high-level recommendations of ditch reprofiling and private driveway culvert replacement are the primary recommendations for mitigation. Ditch reprofiling and driveway culvert replacement has been recommended in locations where the 100 year design storm event demonstrated flooding beyond the ROW, (greater than 50 % to the buildings).. Other alternative strategies, such as hybrid systems, offline storage, optimizing outlets, and combinations, are recommended to be assessed at the detailed design stage (roadway reconstruction) with the emphasis on improving the capacity of the ditched systems to provide conveyance for the more frequent storm events. Each individual alternative may be insufficient at mitigating the performance of the ditched systems, hence combinations are likely required to achieve the desired performance result.

During site reconnaissance for this study, it has been observed that several driveway culverts are not in operational condition due to impediments or failure (crushed). These driveway culverts likely currently cause a hydraulic restriction in the ditch systems, preventing the ideal conveyance of stormwater runoff. The town has advised that driveway culverts are not the property of the town but rather are private property. As such, they are to be maintained and replaced by the private property owner. It is recommended that the private property owners be consulted during the detailed design phase of road works to have their driveway culverts replaced or upsized where necessary at their expense to ensure the mitigation works are effective.

One notable mitigation alternative that has been not been included as part of the long and short list of alternative strategies is converting rurally serviced/ditched ROWs to urbanized/curb and gutter ROWs. It is the recommendation of this study that the ditched ROWs should be maintained where possible, as they provide an informal water quality benefit that should be formalized at the time of roadway reconstruction. Urbanizing these systems would eliminate this informal water quality benefit to the detriment of local ecology.

8.5 Remnant Channels

8.5.1 Long List of Alternatives

The following long list of alternatives has been advanced for consideration to mitigate the modelled deficiencies to the conveyance capacity of the remnant channels within the focus area:

i. Do Nothing
ii. Replace and/or maintain and/or remove private hydraulic structures along remnant channels
iii. Line remnant channels to improve conveyance capacity
iv. Re-sectioning/regrading of channels
v. Implement on-line storage within channels
vi. Implement off- line storage areas within available public spaces
vii. Implement additional/optimized outlet for remnant channels
viii. Diversion of runoff from remnant channel contributing drainage areas

ix. Diversion of runoff from the remnant channel and capture within a storm sewer or ditches
x. Combinations.

8.5.2 Short List of Alternatives

The long list of alternatives has been reviewed to screen those options which have been deemed unacceptable or infeasible. The following summarizes the alternatives which have been screened from further consideration and the associated rationale:

i. **Do Nothing**: Under this alternative, the existing capacity constraints and associated flood risk to adjacent properties would continue, hence would not achieve the objectives of this study. Consequently, this alternative has been screened from further consideration.

The following short list of alternatives was advanced for further consideration:

ii. Replace and/or maintain and/or remove private hydraulic structures along remnant channels
iii. Line remnant channels to improve conveyance capacity
iv. Re-sectioning/regrading of channels
v. Implement on-line storage within channels
vi. Implement off- line storage areas within available public spaces
vii. Implement additional/optimized outlet for remnant channels
viii. Diversion of runoff from remnant channel contributing drainage areas
ix. Diversion of runoff from the remnant channel and capture within a storm sewer or ditches
x. Combinations.

8.5.3 Assessment Methodology and Criteria

A desktop review of the background information provided for this study, as well as the findings of the PCSWMM modelling, has been used to determine the feasibility of each of the foregoing short listed alternatives. The short list has been screened to identify a list of alternatives specific to each remnant channel, based upon the physiography, land use, topography, and performance of the ditched system within the area (ref. Appendix K). As noted previously, the remnant channels within the focus area traverse private properties, and in some instances the specific capacity constraint to the system is privately owned. As such, while certain alternatives may be functionally feasible or preferred due to the anticipated effectiveness of the solution, the presence of the remnant channel and associated "requirement" to complete the works on privately owned lands and/or infrastructure, effectively limits the feasibility of implementing the alternative. Consequently, future study is required to evaluate the alternatives in more detail, as well as to provide an opportunity to consult with the local residents along the remnant channel to further inform the screening of alternatives based upon feasibility for implementation.

The lone alternative that has been simulated in the PCSWMM model which does not require the town to traverse private property, is the diversion of runoff from the remnant channel by capturing in a local storm sewer. This has been recommended for four (4) of the sixteen (16) remnant channels that currently convey municipal stormwater. Notably, three (3) of these diversions have been recommended in previous studies and have been included in this assessment.

Drawing 8.4 has been provided to identify private properties adjacent to the remnant channels where further assessment is required should these properties be the subject of a proposed site alteration. This is to ensure proponents adjacent to the privately-owned remnant channels do not undertake works within the remnant channels which might adversely impact their neighbouring properties. More detailed drawings are provided in Appendix K.

8.6 High Capacity Inlet Improvements

As noted in Section 7, various capacity constraints have been identified at the inlets to the storm system within the focus area. The constraints coincide with various low points within the municipal right-of way (associated with limited catch basin capacity). The locations offer opportunities to reduce the potential for surface ponding through implementing additional structures and/or replacing existing inlets to increase the volume of runoff entering the minor system and thereby reduce the volume conveyed along the major system.

The candidate locations for improving inlet capacity have been identified by cross-referencing the locations of surface flow beyond the right of way from the 100 year design storm event with depression areas in the low point mapping (ref. Drawing 7.14), and with the locations of storm sewers with available capacity, in the immediate vicinity to the depression location, during the 5 year storm event. Areas where the low points were noted to coincide with, or be proximate to, the existing sewer network within the focus area, have been identified as candidate locations for improving the inlet capacity for the minor system. This process has been used to identify the locations where inlet capacity improvements are plausible, however the recommended upsized inlets have not been assessed in the PCSWMM model. The locations for inlet capacity improvements are noted on Drawing 8.5.

In total, twenty-three (23) locations have been identified where higher capacity inlets could potentially be implemented to replace the existing catch basins to mitigate the potential for ponding in the ROW; eleven (11) of these locations are in areas that do not have basement connections in the vicinity while twelve (12) of the locations do have basement connections to the storm sewer in the vicinity. These twenty-three locations would not need significant studies prior to implementing and should be considered as 'quick hit' items for the town.

8.7 Inlet Grate Improvements

An inlet inspection has been conducted by Wood staff to identify storm sewer inlets in ditches and remnant channels within the focus area that may be susceptible to clogging by debris which could lead to ponding in localized areas. The purpose of the inspection was to identify inlets that could benefit from a newer style grate to mitigate the impacts of clogging and provide recommendations for additional maintenance works. The town provided a list of 'hotspot' locations where town staff regularly unclog inlets and outlets that can result in ponding water. These 'hotspot' locations have been screened for inlet locations that primarily convey stormwater from ditches and remnant channels. Additional locations have been identified by Wood that were not identified in the town's 'hotspot' list, as they fit the established criteria. In total, twenty-eight (28) locations have been identified for inlet inspections and the results of those inspections have been summarized in Appendix D.

The candidate locations for upgrading inlet grates have been recommended based on the inefficiency of the existing grates to prevent clogging while also providing stormwater conveyance. The identified locations typically have a standard road catch basin that can easily be clogged with debris, such as leaves, branches, and rubbish. In total, eight (8) inlet locations have been recommended for grate upgrading and catch basin replacement (ref. Drawing 8.6). An additional inlet has been recommended for upgrading (ref. Appendix D, Site #3), however the storm sewers in this area would also require considerable upgrades; the inlet could be upgraded at the time of the storm sewer construction works.

8.8 Managing Impacts from Land Use Intensification and Climate Change

As identified in Section 7.4, there is a system performance reduction within the focus area due to the increased runoff potential associated with land use intensification, and this is further exacerbated by increased precipitation depth/runoff associated with climate change (15 to 30% flow increase depending on location and event, and scenario). The minor system upgrade recommendations, provided in Section 8.2.4, address mitigating existing land use and climate change hydraulic deficiencies and have not been assessed for land use intensification and climate change rainfall. As such, these two hydrologic stressors have required specific assessment to assess the mitigation of impacts to the minor system specifically and major system generally.

Due to the nature of land use change (gradual and in small parcels, privately driven) and climate change shift to precipitation (longer term multi-decadal) management alternatives need to consider the pace and scale of change. Based on this perspective, the most appropriate alternative would be to implement LID BMP source controls in both the private and public realm. The remainder of the physical options outlined in Section 8.1.1 would either not address the hydrologic stressors or would be considered too costly to implement on a town-wide basis, in addition to the recommended minor system upgrades for managing current deficiencies. Notably, implementing further minor system upgrades and storage could be used as a method of building resiliency within the town's infrastructure, however this would be expected to be accomplished at a considerable financial cost to the town. In addition, given that land use changes (I/I) are being advance by the private sector, the town's philosophy is that the private sector should finance the mitigation works at no cost/impact to the town. Similarly, infrastructure renewal of roadways, through roadway reconstruction works will require the implementation of contemporary forms of stormwater management. As a result, there will be economies-of-scale to implement public sector controls on future road reconstruction projects, which further supports this form of management.

The land use intensification scenario with the 5 year 2080 climate change design storm event has been simulated in the PCSWMM model to determine the level of control needed to off-set projected impacts. The analysis has iterated the capture depth of the source control required to offset the hydrologic stressor impacts. Through the iterative process of applying source controls in 5 mm increments, the source control sizing required to offset the impacts due to climate change and land use intensification ranges between 20-25 mm of capture. This has been determined by comparing the minor system performance of the land use intensification scenario with the 5 year climate change design storm event to the minor system performance of the existing conditions scenario with the town's current 5 year design storm event (ref. Table 8.8.1). The capture sizing has been deemed sufficient as the hydrologic stressor with source control scenario performance results are similar to those of the existing conditions scenario. It should be noted that selected networks achieved the equivalent existing land use and climate conditions performance with 20 mm of source control capture, while other networks required 25 mm of capture. Due to the variation in capture required to achieve the equivalent targets, the minimum capture of 25 mm should be applied to all the networks within the focus area. The 5 year 2080 design storm event intensified land use conditions minor system performance results, provided in Table 8.8.1, demonstrate the effectiveness of the 25 mm source control capture at mitigating the minor system to the existing climate and land use conditions performance results.

Table 8.8.1	Summary of Minor System Performance for the 2080 5 Year Design Storm Event and the Intensified Land Use Conditions with 25mm Source Control - Percentage of Total Minor System Length by Network (%)				
Network	**Unsurcharged**	**Below 1/2 Surcharging Depth and Above Obvert**	**Above 1/2 Surcharging Depth and Below Rim Elevation**	**Surcharged Above Rim Elevation**	**% Total of Focus area**
1	12	38	46	4	1.3
2	74	26	0	0	1.1
3	74	11	11	3	1.9
4	75	25	0	0	2.7
5	64	8	16	12	1.8
6	48	29	23	0	0.2
7	0	58	42	0	0.4
8	2	36	55	7	1.7
9	32	37	27	4	1.5
10	0	92	0	8	0.1
11	71	29	0	0	0.5
12	14	13	63	11	0.2
13	29	29	37	4	2.9
14	15	32	44	9	6.0
15	3	10	54	32	3.1
16	57	31	12	0	0.1
17	52	14	13	22	0.6
18	16	22	32	30	1.7
19	20	0	31	49	0.4
20	31	19	28	22	2.5
21	61	27	12	0	0.6
22	62	27	11	0	0.2
23	1	30	30	39	0.7
24	2	55	39	5	1.2
25	30	44	17	8	1.4
26	21	34	35	10	0.6
27	10	21	44	25	3.5
28	35	27	34	4	0.6
29	41	32	22	4	0.9
30	15	15	49	20	2.4
31	15	10	59	16	0.4
32	52	15	19	14	0.8
33	44	33	20	3	1.7
34	4	19	59	18	2.0
35	70	14	12	5	1.7
36	34	27	26	13	1.9

Table 8.8.1	Summary of Minor System Performance for the 2080 5 Year Design Storm Event and the Intensified Land Use Conditions with 25mm Source Control - Percentage of Total Minor System Length by Network (%)				
Network	**Unsurcharged**	**Below 1/2 Surcharging Depth and Above Obvert**	**Above 1/2 Surcharging Depth and Below Rim Elevation**	**Surcharged Above Rim Elevation**	**% Total of Focus area**
37	48	35	16	1	2.2
38	4	16	57	23	0.7
39	33	21	29	17	1.6
40	34	37	12	17	0.5
41	44	6	26	24	0.6
42	23	41	20	16	0.9
43	46	49	0	4	0.9
44	28	23	42	7	1.3
45	25	9	45	21	1.4
46	53	23	18	7	3.3
47	25	16	43	16	2.8
48	23	55	19	2	1.2
49	30	50	19	2	3.1
50	7	30	55	8	2.0
51	38	41	21	1	0.8
52	42	26	25	6	8.0
53	53	41	5	1	3.0
54	48	23	18	11	6.4
55	36	23	25	16	2.3
56	40	29	21	11	5.1
Total	34	27	29	11	100.0

The 20-25 mm source control capture has been applied throughout the PCSWMM model and not only at locations with land use intensification, but rather at all developed and undeveloped areas, as should be applied within the Town of Oakville, since climate change, with increased precipitation depth and runoff, does not differentiate between undeveloped, developed, and intensified land uses. As such, the 25 mm capture should be applied to existing developments and proposed developments in the private realm in addition to buildings and roadways within the public municipal realm. It is anticipated that the residential communities in the focus area will continue to evolve over time and that all homes will, at some point in their existence, be renovated or intensified. It is during this renovation or intensification that the opportunity of implementing retroactive source controls should be undertaken. Similarly, it is anticipated that every road and town owned property will undergo reconstruction or rehabilitation at the end of their operational lifecycle. It is during the reconstruction of rehabilitation that town should consider implementing source controls as a mitigation strategy.

There are limitations to the application of the 25 mm source control capture as it inherently does not address the existing hydraulic deficiencies and should be applied in addition to the recommended storm sewer upgrades (balanced approach of “grey” and “green” infrastructure). Furthermore, the source control capture has been designed to protect the municipality against impacts to land use intensification and climate change primarily to the minor system during the 5 year design storm event. The major system performance during the 100 year design storm event with hydrologic stressors will not be fully mitigated with 25 mm source control capture. This has been confirmed with an assessment of the peak flow rates at the major system outlets which demonstrated that the land use intensification and climate change peak flow rates for the 100 year design storm event were approximately 20 % (+/-) greater than the existing conditions peak flow rates (ref. Appendix G). Source controls, and more specifically LID BMPs, are typically used for mitigating the more frequent storm events and will not address the full impacts associates with the less frequent storm events. The residual impacts due to the hydrologic stressors (land use and climate change) should be reviewed with alternative mitigation strategies such as further minor system upgrades and storage. Through future detailed network-based assessments, the town will need to review options for addressing the performance of the 100 year climate change storm events, as the impacts cannot be fully addressed with at source controls or more specifically LID BMPs.

While the source controls have not been assessed town-wide for impacts due to the 100 year climate change design storm event, in addition to the land use intensification scenario, a sample network has been selected to test the performance of the source controls for the existing climate 100 year design storm event with land use intensification. Network 44 has been selected as the test area as this network had the greatest estimated increase in imperviousness from existing land use conditions, at 39.6 % imperviousness, to intensified land use conditions, at 50.1 %, resulting in a 10.5 % relative imperviousness increase. The simulated peak flow rates have been compared at the major and minor outlets for the existing conditions, unmitigated land use intensification conditions, and the 25 mm source control mitigated land use intensification conditions (ref. Appendix G). The results demonstrate that the 25 mm source controls will mitigate the increased peak flow rates generated from land use intensification scenario at the major and minor system outlets to meet the existing conditions peak flow rates for the 100 year design storm event, not considering the impacts of climate change. This is notable as it demonstrates the efficacy of local private realm BMPs and thereby allow the town to focus on residual climate change resiliency planning of public infrastructure. The outlet peak flow rate assessment method has been used rather than comparing the performance of the major or minor systems, as those results may not demonstrate improvement within the town established performance bands, particularly for the major system performance for the 100 year design storm event, as a qualitative measurement. Whereas the peak flow rates at the outlets demonstrate a quantitative measurement.

It has been demonstrated that offsetting the impacts of land use intensification and climate change during more frequent storm event can be effectively accomplished with LID BMP source controls, which are considered “green” infrastructure. Appropriately sized source controls will maintain the existing minor system level of service for each network. However, the source controls do not address the existing performance issues with major and minor systems, which will need to be addressed with minor system upgrades such as storm sewer replacement and quantity storage facilities, also referred to as “grey” infrastructure. A balance between the implementation of “grey” and “green” should be undertaken by the town to effectively reduce the existing flood risks associated with the storm sewer infrastructure while also mitigating the anticipated impacts due to land use intensification and climate change.

It needs to be recognized, that there is a level of uncertainty associated with the impacts of climate change and how to accurately estimate the future IDF parameters, as evidenced by the investigation into options for representing climate change scenarios (ref. Appendix G). Due to this level of uncertainty, the town should consider updating its analyses and establish management requirements as part of future studies, as standards and guidance are more established within the industry. This may include sizing infrastructure to the future climate change and land use intensification levels as a form of resiliency building; however, the recommended source controls have been sized to mitigate the 5 year climate change design storm event in addition to the land use intensification.

9.0 Stormwater Quality Management Assessment

9.1 Process

A stormwater quality management plan has been developed for the Focus Area as part of the overall Stormwater Management Master Plan, to provide strategic stormwater quality control. Current Provincial standards require stormwater quality control be implemented for all new and redeveloped land uses. The future land uses and developments within the focus area, which would require stormwater quality control, consist of future infill, intensification, and redevelopment, as well as roadway reconstruction projects.

The stormwater quality management plan has been developed based upon a review of current stormwater quality practices within the focus area (formal and informal), a review of alternatives to address stormwater quality requirements for the focus area, a desktop assessment of candidate locations for implementing retrofits of, or new stormwater quality management facilities and establishing an anticipated rated capacity (i.e. impervious area treated) at each candidate location, and developing a preferred plan and prioritization for implementation.

9.2 Stormwater Quality Management Approaches

The background information has been reviewed to compile an inventory of the current stormwater management practices within the focus area. The findings of this review are presented on Drawings 9.1 and 9.2, and in Table 9.2.1.

Table 9.2.1 Town of Oakville Focus area: Existing Stormwater Management Facilities						
Stormwater Facility	**Location**	**Receiving Water Course**	**Type**	**Contributing Drainage Area (ha)**	**Impervious Area (ha)**	**Impervious (%)**
1	Cornwall Road	Lower Wedgewood Creek	Dry	6.17	5.75	93.19
2	Cornwall Road	Lower Wedgewood Creek	Dry	7.73	7.07	91.46
3	Fourth Line and South Service Road West	McCraney Creek	Dry	12.83	11.24	87.57
18	Sheridan Gardens Drive	Clearview Creek	Dry	190.63	112.48	59.00
22	Ford Drive and Kingsway Drive	Joshua Creek	Dry	21.58	5.15	23.87
25	Rebecca Street, West of Bronte Creek	Bronte Creek	Wet	1.24	0.80	64.52
28E	Creek Path Avenue	Sheldon Creek	Wet	47.46	25.29	53.29
28W	Creek Path Avenue	Sheldon Creek	Wet	23.7	15.05	63.50
39	Wyecroft Road	Sheldon Creek	Wet	10.3	9.13	88.66
40	Wyecroft Road	Sheldon Creek	Wet	34.74	28.85	83.05
41	Great Lakes Boulevard	Sheldon Creek	Wet	11.53	10.56	91.59
45	Michigan Drive	Sheldon Creek	Wet	61.27	55.28	90.22

The information on Drawings 9.1 and 9.2 and in Table 9.2.1 indicates that there are currently seven (7) end-of-pipe facilities within the focus area which provide stormwater quality control, and five (5) dry pond facilities which provide quantity control only (i.e. no stormwater quality control function). Furthermore, there are several municipal roads within the focus area which are constructed to a rural drainage condition with grassed ditches. Notably the grassed ditches provide informal stormwater quality treatment for storm runoff. Part of this plan recommends that any future improvements to the rurally serviced Municipal roads within the focus area should consider more formalized (i.e. designed) stormwater quality treatment. While there may be interest to have these roadways become urbanized systems, with curb and gutters, it is suggested that this be discouraged for reasons related to water quality and environmental water balance.

9.3 Long List of Alternatives

A detailed assessment and evaluation of stormwater quality management alternatives has been conducted in order to establish a preliminary preferred approach toward addressing the stormwater quality needs for the focus area. The following alternatives have been advanced for this assessment:

Alternative No. 1:	"Do Nothing"
Alternative No. 2:	Implement stormwater quality retrofits at existing facilities and outlets
Alternative No. 3:	Provide stormwater quality treatment on-site for designated blocks of future development/redevelopment and Roadways
Alternative No. 4:	Lot-scale stormwater management retrofits at-source
Alternative No. 5:	Combinations of the above

Each alternative is described as follows:

Alternative No. 1: "Do Nothing"

Under this alternative, no stormwater quality control would be implemented for any future infill, redevelopment, or intensification, nor would stormwater quality controls be implemented for the future improvements of the Municipal roadways. As such, this alternative would not satisfy the current Provincial requirements for the provision of stormwater quality control for all new development and redevelopment, and has thus been screened from further consideration.

Alternative No. 2: Implement stormwater quality retrofits at existing facilities and outlets

Under this alternative, stormwater quality retrofit facilities (of existing single function stormwater management facilities or outfalls where no stormwater management currently exists) would be implemented in order to provide stormwater quality treatment. These facilities could be used to provide treatment for existing (untreated) areas and to offset treatment for small scale future infill and redevelopment/intensification areas within the town, for which on-site SWM is not considered appropriate or effective. These facilities, depending on their rated capacity could also be used strategically by the town to off-set impacts from future improvements to the Municipal roads.

Alternative No. 3: Provide stormwater quality treatment on-site for designated blocks of future development/redevelopment and Roadways

Under this alternative, stormwater quality control for future redevelopment and infill development in the Focus Area (assumed for larger designated redevelopment blocks) would be provided in the form of traditional on-site stormwater management practices, such as storm ponds and oil-grit separators (OGS), complemented by LID BMPs. The implementation of this alternative would address the requirement to provide stormwater quality treatment for those eligible lands comprised of new development and redevelopment, in accordance with the current Provincial criteria. For municipal rights-of-way and associated expansions of roadways, stormwater quality treatment may be provided at source through the installation of oil-grit separators, construction of enhanced grassed swales or buffer strips, or through the implementation of LID BMPs. In areas where roads are rurally serviced (i.e. ditched), stormwater quality treatment may be achieved at source by reconstructing the ditches to an enhanced standard (bioswales/grassed swales).

Alternative No. 4: Providing lot-scale stormwater management at-source (LID BMPs) within the existing urban area for redeveloping properties

Under this strategy, individual redeveloping residential lots would be required to promote the implementation of lot-level retrofits and Low Impact Development Best Management Practices to improve upon the quality of storm runoff. The neighbourhoods where this applies are of a vintage that no stormwater quality controls are currently provided. A variety of source controls and measures are available for implementation either within the lots (private), including:

- Downspout Disconnects
- Rain Barrels
- Permeable Pavements
- Vegetated Filter Strips
- Bioretention
- Enhanced Grassed Swales
- Perforated Pipes
- Infiltration Chambers and Soakaway pits

Typically, these lot-level retrofits are implemented as best efforts to improve upon the quality of storm runoff, rather than to achieve a prescribed level of stormwater quality treatment (i.e. *Enhanced* standard of stormwater quality treatment), and are generally implemented as part of a pilot project within existing development areas as a means of generating public interest and education regarding the form and benefits of providing source controls within existing urban areas. Nevertheless, the analyses should be completed in order to determine the anticipated benefits to stormwater runoff quality which may be realized through the implementation of the source controls on the lot or local public realm.

Alternative No. 5: Combinations

Under this alternative, the stormwater quality strategy could be a strategic combination of Alternatives 2, 3, and 4, as follows:

a. Stormwater Management Retrofits

   - Implement the preferred stormwater quality retrofit facilities to provide stormwater quality control to address existing historical impacts and also off-set impacts from selected and eligible private and public development.

b. New End-of-Pipe Stormwater Management Facilities

   - Implement on-site stormwater quality management for designated future infill and redevelopment areas; these are the larger contiguous development sites, which would be of sufficient size to support a wet end-of-pipe facility or OGS, complemented with LIDs for stormwater quality control.

c. Lot-Scale BMPs (LID)

   - Implement lot level controls in existing neighbourhoods under redevelopment pressure promoting lot-level retrofits and Low Impact Development Best Management Practices on private lands to improve upon the quality of storm runoff from existing areas,

d. Regrade existing ditches within municipal rights-of-way to provide enhanced grassed swales and/or bioswales for formal stormwater quality treatment within the right-of-way.

Functionally, the combination of these alternatives would address the full complement of current Provincial requirements to provide stormwater quality control for infill and redevelopment areas, as well as municipal rights-of-way, and would better assure compliance with the design requirements of stormwater quality management facilities by providing the stormwater quality management facility within public as opposed to private ownership.

9.4 Screening of Retrofit Opportunities

9.4.1 Stormwater Management Facility Retrofits (Existing Facilities)

As noted previously, five (5) dry pond stormwater management facilities are currently within the Town of Oakville focus area, which do not include stormwater quality controls within the contributing drainage area. These dry ponds present an opportunity for implementing a stormwater quality retrofit, by way of modifying the facility to incorporate a permanent pool below the detention storage water level/volume, thereby achieving a level of stormwater quality control.

The sites have been reviewed to evaluate each candidate location (dry pond) for retrofitting and treatment potential, based upon criteria associated with the physical, natural, social, and economic environments, providing the advantages and disadvantages specific to each location. The results of this evaluation are summarized in Table 9.4.1. Plans of the facility locations are provided in Appendix I.

Table 9.4.1: Evaluation of Stormwater Management Facility Retrofits for Stormwater Quality Control					
Stormwater Facility	Evaluation Criteria				Overall Ranking
	Physical	Natural	Social	Economic	
1	• Land owned by town • Receives water from 6.17 ha (+/-) of which 4.4 ha (+/-) could be treated to Enhanced standard with a retrofit • The contributing area land use is business employment with an imperviousness of 93 % (+/-)	• Located adjacent to Lower Wedgewood Creek, a regulated channel, warmwater channel • The sensitivity of the receiving water course is low • Potential for thermal mitigation	• Site is located adjacent to business employment and residential land use • Site would not impact parkland or recreational areas	• Capital cost of $25,000/imp. ha	Medium
	Highly preferred based upon physical environment criteria however less preferable due to potential performance; overall moderate preference	Preferred based upon natural environment criteria	Less preferable due to proximity to residential area	Moderate preference due to relatively higher unitary capital cost	
2	• Land owned by town • Receives water from 7.73 ha (+/-) of which 6.7 ha (+/-) could be treated to Enhanced standard with a retrofit • The contributing area land use is business employment with an imperviousness of 91 % (+/-)	• Located adjacent to Lower Wedgewood Creek, a regulated channel, warmwater channel • The sensitivity of the receiving water course is low • Potential for thermal mitigation • Adjacent to a small 0.2 ha (+/-) wooded area to the north	• Site is located adjacent to business employment and residential land use • Site would not impact parkland or recreational areas	• Capital cost of $23,000/imp. ha	Medium
	Highly preferred based upon physical environment criteria, however less preferable due to potential performance; overall moderate preference.	Preferred based upon natural environment criteria	Less preferable due to proximity to residential area	Moderate preference due to relatively higher unitary capital cost	
3	• Land owned by town • Receives water from 12.83 ha (+/-) of which 11.3 ha (+/-) could be treated to Enhanced standard with a retrofit • Contributing drainage area right-of-way is ditched (recommended for regrading to provide enhanced grassed swales) • The contributing area land use is business employment and industrial with an imperviousness of 86 % (+/-)	• Directly connected to McCraney Creek, a regulated, warmwater channel • The sensitivity of the receiving water course is low • Potential for thermal mitigation	• Site is located adjacent to business employment, and industrial land uses as well as a rail corridor • Site would not impact parkland or recreational areas	• Capital cost of $24,000/imp. ha	Screened from further consideration
	Not preferable as the contributing area has informal water quality treatment from the ditched right-of-way	Preferable based upon natural environment criteria	Highly preferable based upon the contributing area land use	Moderate preference due to relatively higher unitary capital cost	

Table 9.4.1: Evaluation of Stormwater Management Facility Retrofits for Stormwater Quality Control					
Stormwater Facility	Evaluation Criteria				Overall Ranking
	Physical	Natural	Social	Economic	
18	• Land owned by town • Receives water from 190.63 ha (+/-) of which 102.4 ha (+/-) could be treated to Enhanced standard with a retrofit • The contributing area land uses are low and medium residential, community use, and office employment	• Outflow is conveyed to Clearview Creek, a regulated, warmwater channel, which commences approximately where the outfall for the facility is located • The sensitivity of the receiving water course is low • Potential for thermal mitigation • Site is not located near a forest, woodlands, thickets, or meadows as the area surrounding the facility is developed	• Site is located adjacent to office employment and residential land uses as well as a rail corridor • Site would not impact parkland or recreational areas	• Capital cost of $12,000/imp. ha	High
	Highly preferable based upon the potential water quality treatment performance	Preferable based upon the natural environment criteria	Preferable based upon the social criteria	Preferable based upon relatively lower capital cost.	
22	• Land owned by town • Receives water from 21.58 ha (+/-) of which 5.2 ha (+/-) could be treated to Enhanced standard with a retrofit • Contributing drainage area right-of-way is primarily ditched (recommended for regrading to provide enhanced grassed swales). • The contributing area land use are utility and park	• Outflow is conveyed to Joshua Creek, a regulated warmwater channel • Site is adjacent to a wood lot and park • Surrounding area is undeveloped	• Site is not adjacent to a residential area • Site could potentially impact the adjacent parkland and the surrounding area is zoned as parkway belt	• Capital cost of $25,000/imp. ha	Screened from further consideration
	Not preferred based upon the physical environment criteria and the anticipated performance	Preferred based upon the natural environment criteria	Not preferred based upon the social environment criteria	Moderate preference due to relatively higher unitary capital cost	

The information in Table 9.4.1 indicates that three of the five dry pond facilities (ref. Facilities 1, 2, and 18) are considered suitable for retrofitting and have been advanced as preferred candidates to provide stormwater quality control functions. The remaining two facilities (i.e. Facilities 3 and 22) are considered less preferable, and have been screened from further consideration for the purpose of this assessment. The contributing drainage area to facility 3 is rurally serviced (ditched) and currently provides informal water quality treatment; the formalization of the existing ditched systems would be considered an improvement to the water quality control and would likely be considerably less onerous to implement than retrofitting the dry SWM facility. The land use contributing drainage area to facility 22 is primarily a utility corridor and park, and the facility would not likely demonstrate an appreciable net water quality benefit/improvement if retrofitted. The next steps for advancing retrofitting existing stormwater management facilities to provide stormwater quality treatment would be to undertake additional study to confirm rated capacity of stormwater management facility retrofit for stormwater quality treatment. Retrofit of an existing SWM facility typically fall under a Schedule A Class EA, except when requiring additional land to accommodate expansion of the existing facility, in which case a Schedule B Class EA is required.

9.4.2 Stormwater Management Facility Retrofits on Public Lands (Outfalls)

A further screening exercise of outfalls and publicly owned lands in the focus area has been completed in order to establish potential candidate sites for implementing stormwater quality retrofits. The contributing drainage area to each of the long list of candidate retrofit sites has been delineated based upon the sewer data and contour mapping provided by the town. This information has been combined with the stormwater management inventory in order to determine the potential size of the contributing drainage area, as well as whether the contributing drainage area includes any untreated areas. The locations of the candidate retrofit sites for providing stormwater quality retrofits is presented on Drawing 9.3.

The long list of candidate sites has been reviewed in order to develop a preliminary short list of candidate retrofit sites for implementing stormwater quality retrofits. This review has applied various criteria related to the physical, natural, and social attributes of each site as well as the advantages and disadvantages associated with implementing a stormwater quality retrofit at each location. The results of this assessment are presented in Table 9.4.2. Conceptual footprint plans of stormwater quality retrofits at each of the short listed locations are presented in Appendix I.

Should the recommended works be undertaken, the retrofitted facilities will need to be constructed in accordance with the town's Development Engineering Procedures and Guidelines Manual, Addendum #1 for grading and outlet structure design. The next steps for advancing the retrofit location toward implementation would be to undertake a Schedule B Class EA to determine the environmental impacts to the receiving water bodies. In addition, some of the sites advanced for consideration would need to be vetted through Conservation Halton for approval, as many candidate sites lie within Regulated areas, and connections to Regulated watercourses would be subject to approval by the Authority and MECP.

Table 9.4.2 Outfall Water Quality Retrofit Assessment																				
				Physical Suitability										Natural Environment				Social Environment			
No.	Outfall Name	Location	Receiver	Drainage Area (ha)	Topographic Compatibility - Slope (%)	Topographic Compatibility Rating	Contributing Area Land Use	Contributing Area Land Use Rating	6 % of Drainage Area	Available Space (ha)	Available Space Rating	Major System Conveyance	Sensitivity of Receiving Watercourse	Sensitivity of Receiving Watercourse Rating	Compatibility with Natural Ecosystem	Erosion Mitigation Potential	Adjacent Land Use	Proximity to Residential Dwelling (m)	Publicly Available Land	Overall Retrofit Potential and Prioritization
1	O_0130_40	Lakeshore Road	Bronte Creek	39.67	6.12	Low	Single Family Residential	Low	2.4	0.43	Low	Mix	Warmwater	Medium	Low	High	Single Family Residential , ROW	13	Parkway Belt Public Use	Low
2	O_0130_43	Silverthorn Drive	Bronte Creek	7.38	1.1 (Adjacent to steep slope)	High	Single Family Residential	Low	0.4	0.30	Medium	Urban	Warmwater	Medium	Low	High	Single Family Residential	10	Parkway Belt Public Use	Medium-High
3	O_0130_48	Rebecca Street	Bronte Creek	154.46	2.3 (Adjacent to steep slope)	Low	Residential, Institutional	Medium	9.3	0.24	Low	Urban	Warmwater	Medium	Low	High	Single Family Residential	10	Park and Parkway Belt Public Use	Low
4	OF1_14	Valhalla Court and Bronte Road	Bronte Creek	97.34	52.9	Low	Residential, Industrial	High	5.8	0.00	Low	Urban	Warmwater	Medium	Low	High	Single Family Residential	11	Parkway Belt Public Use	Low
5	O_0130_49	Rebecca Street and Yolanda Drive	Remnant Channel, Bronte Creek	77.16	2.5	High	Residential	Low	4.6	0.54	Low	Urban	-	Medium	Medium	High	Park and Single Family Residential	20	Park trail	Low-Medium
6	O_0200_400175DS	Lakeshore Road and Third Line	Remnant Channel, Lake Ontario	16.03	15.6	Low	Residential	Low	1.0	0.10	Low	Mix	-	Low	Medium	Low	Park	54	Park	Low-Medium
7	O_0130_313	Lakeshore Road and Old Lakeshore Road	Remnant Channel, Lake Ontario	25.52	18.4	Low	Residential	Low	1.5	0.06	Low	Mix	-	Low	Medium	Low	Park and ROW	55	Park	Low-Medium
8	O_0130_400056	Westdale Road and Wilder Drive	Remnant Channel, Lake Ontario	10.26	2.6	High	Residential	Low	0.6	0.77	High	Urban	-	Low	High	Low	Single Family Residential	24	Park in Vicinity	Medium-High
9	O_0130_400019	Kerr Street and Burnet Street	Remnant Channel, Lake Ontario	14.80	5.06	Low	Residential, Commercial	High	0.9	0.21	Low	Mix	-	Low	High	Low	Park and WTP	20	Park in Vicinity	Medium
10	Tee16_LMC	Maple Avenue and Bohemia Crescent	Lower Morrison Creek	5.38	3.3	Medium	Residential, Commercial	High	0.3	0.23	Medium	Urban	Warmwater	Low	Low	High	Natural Area and Single Family Residential	22	Park	Medium-High

Table 9.4.2 Outfall Water Quality Retrofit Assessment

				Physical Suitability										Natural Environment				Social Environment			
No.	Outfall Name	Location	Receiver	Drainage Area (ha)	Topographic Compatibility - Slope (%)	Topographic Compatibility Rating	Contributing Area Land Use	Contributing Area Land Use Rating	6 % of Drainage Area	Available Space (ha)	Available Space Rating	Major System Conveyance	Sensitivity of Receiving Watercourse	Sensitivity of Receiving Watercourse Rating	Compatibility with Natural Ecosystem	Erosion Mitigation Potential	Adjacent Land Use	Proximity to Residential Dwelling (m)	Publicly Available Land	Overall Retrofit Potential and Prioritization
11	J817.5172	Chamberlain Lane	Lower Wedgewood Creek	12.10	3.3	Medium	Residential	Low	0.7	0.11	Low	Mix	Warmwater	Low	Low	High	Single Family Residential	9	Park	Low-Medium
12	O_0130_392	Ford Drive	Joshua Creek	39.95	2.1	High	Residential	Low	2.4	0.12	Low	Mix	Warmwater	Low	Low	High	Single Family Residential	57	Parkway Belt Public Use	Low
13	O_0130_390	Deer Run Avenue	Joshua Creek	58.20	1	High	Residential	Low	3.5	1.01	Medium	Urban	Warmwater	Low	High	High	Single Family Residential	17	Park	Medium-High
14	O_0130_389	Devon Road	Joshua Creek	9.45	14	Low	Residential	Low	0.6	0.13	Low	Urban	Warmwater	Low	Low	High	Single Family Residential	6	Parkway Belt Public Use	Low
15	O_0130_248	Kathleen Crescent	East Morrison	23.62	2.2	High	Residential	Low	1.4	0.95	Medium	Urban	Warmwater	Low	High	High	Single Family Residential	20	Park in Vicinity - Natural Area	Medium
16	J1111_55	Gainsborough Drive	Falgarwood	40.80	2.3	High	Residential	Low	2.4	0.54	Low	Mix	Warmwater	Low	High	High	Single Family Residential	22	Park	Medium
17	OF1_55	Edgeware Road	Upper Wedgewood Creek	5.58	1.9	High	Residential	Low	0.3	0.21	Medium	Urban	Warmwater	Low	High	High	Single Family Residential	8	Park in Vicinity - Natural Area	Medium

Based on the screening / review summarized in Table 9.4.2, nine (9) of the seventeen (17) potential sites have been identified as "medium" or "medium-high" candidates for retrofitting the storm outfall to provide a stormwater quality function.

9.4.3 Preferred Approach for Stormwater Quality Retrofits

The preferred approach for implementing stormwater quality retrofits combines the preferred locations for retrofitting existing dry facilities and storm outfalls. The rated capacity (i.e. impervious area treated to an *Enhanced* standard) has been determined based upon size and imperviousness of the contributing drainage area, the attainable permanent pool volume determined in the concepts for each site, and the current Provincial guidelines for sizing stormwater quality control facilities (ref. MOE, 2003). The results of this assessment are presented in Table 9.4.3.

Table 9.4.3 Stormwater Quality Retrofit Prioritization and Rated Capacity

Site	Type of Location	Attainable Permanent Pool Volume (m^3)	Impervious Area Potentially Treated (ha)	Priority
Town Pond 18	Dry Facility	18,880	102.4	High
Town Pond 2	Dry Facility	1,376	6.7	Medium
Town Pond 1	Dry Facility	421	4.4	Medium
O_0130_390	Outfall	1,167	11.5	Medium-High
O_0130_400056	Outfall	1,399	6.6	Medium-High
O_0130_43	Outfall	407	2.8	Medium-High
Tee16_LMC	Outfall	653	3.2	Medium-High
J1111_55	Outfall	451	5.5	Medium
O_0130_248	Outfall	1,619	10.1	Medium
O_0130_400019	Outfall	290	2.9	Medium
OF1_55	Outfall	310	2.1	Medium
Total			**158.2**	

The results in Table 9.4.3, and depicted on Drawing 9.4, indicate that the full implementation of the preferred stormwater quality retrofit strategy advanced in the foregoing could (subject to detailed design) achieve a rated capacity of 158.2 impervious hectares treated to an Enhanced standard. The contributing areas of the preceding retrofits are depicted in Drawing 9.5.

9.5 Short List of Alternatives

The long list of alternatives has been evaluated on the basis of the following functional, environmental, social, and economic criteria:

Functional Criteria:

e. Provincial Stormwater Quality Requirements Addressed
f. Ease of Implementation/Requirements for Additional Study

Environmental Criteria:

g. Improved Health of the Aquatic Environment
h. Improved Health of the Terrestrial Environment

Social Criteria:

i. Impacts to Private Property
j. Impacts to Recreation
k. Public Safety

Economic Criteria:

l. Capital Costs
m. Maintenance Costs

Alternatives 2, 3, 4, and 5 have been evaluated based upon the above criteria, and assessed according to whether the impact is "positive", "negative", or "neutral". The results of this assessment are summarized in Table 9.5.1.

Table 9.5.1 Evaluation of Short-List Alternatives

Criteria	Factor	Alternative 2: Stormwater Management Retrofits		Alternative 3: New End-of-pipe Stormwater Management Facilities		Alternative 4: Neighbourhood-scale BMPs		Alternative 5: Combinations	
Functional	Meets Provincial Standards	▶ Partially meets Provincial Standards for Enhanced Standard of Treatment for new development areas.	Neutral/Positive	▶ Meets Provincial Standards for Enhanced Standard of Treatment for new development areas.	Positive	▶ Does not meet Provincial Standards for Enhanced Standard of Treatment for new development areas.	Negative	▶ Meets Provincial Standards for Enhanced Standard of Treatment for new development areas.	Positive
	Ease of Implementation	▶ Requires Town to establish cash-in-lieu program. ▶ CH permitting, re-zoning	Neutral/Negative	▶ Consistent with current practice; potential	Neutral	▶ Requires development and implementation of pilot project to promote uptake within existing development areas.	Neutral/Negative	▶ Requires Town to establish cash-in-lieu program. ▶ Requires development and implementation of pilot project.	Neutral/Negative
Environmental	Aquatic Health	▶ Potentially improves conditions within aquatic systems compared to existing conditions.	Neutral/Positive	▶ Impacts to aquatic health addressed to Provincial Standards of stormwater quality control.	Neutral	▶ Partially improves impacts to aquatic health; residual impacts from new development/ redevelopment anticipated.	Neutral/Negative	▶ Improves conditions within aquatic systems compared to existing conditions.	Positive
	Terrestrial Health	▶ Potential impacts for retrofits proximate to Critical Habitat. Tree removals?	Neutral/Negative	▶ No impacts to terrestrial systems.	Neutral	▶ No impacts to terrestrial systems.	Neutral	▶ No impacts to terrestrial systems ▶ Potential impacts for retrofits proximate to Critical Habitat.	Neutral/Negative
Social	Private Property	▶ No impact due to location within public spaces.	Neutral	▶ Requires use of private property for implementation of on-site SWM.	Neutral/Negative	▶ Implementation in private properties is voluntary.	Positive	▶ Limited impacts to private property due to location of SWM facilities on fewer sites. ▶ Implementation of LID BMPs within neighbourhoods is on a voluntary basis.	Neutral/Positive
	Recreation	▶ Potential impacts to parklands and waterfront due to location of some facilities. ▶ Water quality impacts addressed to current Provincial standards.	Neutral/Negative	▶ Water quality impacts to addressed to Provincial standards.	Neutral	▶ Partially improves impacts to recreational areas; residual impacts from new development/ redevelopment anticipated.	Neutral/Negative	▶ Improves upon water quality conditions within recreational areas compared to existing conditions. ▶ Potential impacts to parklands and waterfront due to location of some facilities. ▶ Water quality impacts addressed to current Provincial standards.	Neutral/Positive
	Public Safety	▶ Potential issues due to proximity to existing residential area. Though mitigation though conventional SWM design practice? I would say neutral.	Neutral/Negative	▶ SWM practices may be designed to address public safety concerns.	Neutral	▶ Practices on private property may be selected to address safety issues.	Neutral/Positive	▶ Potential issues due to proximity of stormwater quality retrofits to existing residential areas. ▶ LID BMP's on private property may be selected to address safety issues.	Neutral

Legend	(green circle)	Positive	(half green circle)	Neutral/Positive	(empty circle)	Neutral	(half red circle)	Neutral/Negative	(red circle)	Negative

Table 9.5.1 Evaluation of Short-List Alternatives

Criteria	Factor	Alternative 2: Stormwater Management Retrofits		Alternative 3: New End-of-pipe Stormwater Management Facilities		Alternative 4: Neighbourhood-scale BMPs		Alternative 5: Combinations	
Economic	Capital Costs	▶ Relatively lower capital costs compared to conventional on-site controls.	(Neutral/Positive)	▶ Relatively higher capital costs due to implementation on-site for each individual development area.	(Neutral/Negative)	▶ Relatively low cost to Town for public engagement program ▶ Cost for implementation on properties is comparatively low.	(Positive)	▶ Relatively lower capital costs compared to conventional on-site controls for all new development. ▶ Relatively low cost for to Town for public engagement program to support pilot project. ▶ Cost for implementation of LID BMP's on private properties is comparatively low.	(Neutral/Positive)
	Maintenance Costs	▶ Relatively lower maintenance costs compared to conventional on-site controls due to reduced number of facilities.	(Neutral/Positive)	▶ Relatively higher overall maintenance costs due to number of individual on-site facilities.	(Neutral/Negative)	▶ Relatively lower maintenance costs due to informal nature of stormwater quality management practices.	(Positive)	▶ Relatively lower maintenance costs for retrofit facilities compared to conventional on-site controls due to reduced number of facilities. ▶ Relatively lower maintenance costs for pilot project due to informal nature of stormwater quality management practices on existing residential lots.	(Neutral/Positive)
Overall Ranking			(Neutral)		(Neutral/Negative)		(Neutral)		(Neutral/Positive)

Legend	(Positive symbol)	Positive	(Neutral/Positive symbol)	Neutral/Positive	(Neutral symbol)	Neutral	(Neutral/Negative symbol)	Neutral/Negative	(Negative symbol)	Negative

9.6 Preferred Alternative

The results in Table 9.5.1 indicate that, ***Alternative 5: Combinations*** is the preferred alternative, based upon the following:

n. Ability to meet Provincial Standards for *Enhanced* Standard of Water Quality Treatment for new development areas.
o. Improves conditions within aquatic systems compared to existing conditions.
p. Limited impacts to private property due to location of SWM facilities on fewer sites.
q. Improves upon water quality conditions within residential areas compared to existing conditions.
r. Relatively lower capital costs compared to conventional on-site controls for all new development.
s. Relatively lower cost for town for public engagement program to support pilot project for implementing source controls within existing developments.
t. Relatively lower maintenance costs for retrofit facilities compared to conventional on-site controls due to reduced number of facilities.
u. Relatively lower maintenance costs for pilot project due to informal nature of stormwater quality management practices on existing residential lots.

While the foregoing has outlined the preferred alternative for providing stormwater quality control for the focus area. It is also recognized that opportunities exist to provide stormwater quality treatment for future expansions and enhancements to the Municipal roads within the Focus Area. As noted previously, the existing ditches within the town, shown in Drawings 9.5, are considered to currently provide a form of "informal" stormwater quality treatment. Consequently, where municipal roads are proposed to be rebuilt, it is recommended that consideration be given toward maintaining/enhancing and formalizing the function offered by the existing drainage system of ditches by either preserving their current rural geometry or considering a semi-urban section, in order to utilize the infiltration stormwater quality treatment afforded by the rural ditches. As such, an effort should be made to prevent the rurally serviced roads from being converted to an urbanized cross section where it is unnecessary.

A cost estimate for formalizing the town's ditched roadways has not been developed given the uncertainty regarding the details associated with implementation. Costing will be influenced by multiple factors, including the longitudinal slope, the number of driveway culverts, the geometry of the ditch (width and depth), the infiltration capacity of the soils, the contributing drainage area, and the ability to implement enhanced swales or bioswales.

10.0 Policy Review

The town's current Policies, By-Laws, and Guidelines related to stormwater and environmental protection/management have been reviewed as part of the Stormwater Management Master Plan to identify potential revisions which would support the recommendations advanced in this document, as well as promote compliance with current and emerging Provincial policies and regulations, and build upon current practices within the industry, as applicable to the Town of Oakville. The following provides an overview of the potential policy enhancements/revisions considered to support the foregoing recommendations.

10.1 Cash-In-Lieu of On-Site Stormwater Quality By-Law

The stormwater quality management plan for the focus area is comprised of multiple components to address the need to treat runoff from existing and new development areas; the plan includes:

- Retrofitting existing stormwater quantity management facilities (i.e. dry ponds) to provide stormwater quality treatment
- Building new stormwater management facilities at outfalls which currently have no stormwater quality treatment
- Source controls for infill/intensification (redevelopment)
- Source/conveyance controls for roadway reconstruction
- Preservation and formalization of roadside ditches for stormwater quality treatment.

In addition, where redevelopment (new development) parcels are of sufficient size to practically implement on-site stormwater management (for stormwater quality control specifically), they would be expected to construct those works accordingly.

Notwithstanding the foregoing, there will be circumstances whereby smaller redeveloping areas in the focus area, which are less suited to on-site stormwater management (i.e. for instance parking lot expansions, small scale building additions) or drain directly to a trunk sewer offering no (or limited) benefit to fluvial system habitat, may wish to provide cash in-lieu of on-site stormwater quality management. The revenue generated by this approach can then be targeted toward the retrofit program of stormwater management facilities and outfalls.

In order to implement this process/policy in the town, a number of steps would need to be taken, including:

- establishing a cash-in-lieu rate or fee;
- establishing a drainage area (or other criteria) above which cash in lieu will not be considered (and hence on-site stormwater quality control is to be provided);
- determining preferred locations in the town for cash-in-lieu application, as well as those locations less preferred
- reviewing/confirming applicable current and future regulatory issues;
- appointing Municipal Staff to manage the cash-in-lieu program; and
- coordinating with the review of Site Plan applications by Town staff.

Hence, to facilitate the implementation of the cash-in-lieu approach, the town would require a By-Law to be implemented. As noted, the By-Law should also include requirements to appoint a Municipal Staff member to manage the cash-in-lieu program. This should be coordinated with the review of Site Plan applications by Planning and Engineering staff, and could include developing a spreadsheet and/or GIS structure to track the developments contributing to the cash-in-lieu program.

Retrofit facilities could start to be constructed once sufficient funds are collected through the cash-in-lieu program. For example, small scale developments (e.g. parking lot expansions) and select town capital projects may choose to opt for the cash-in-lieu approach for stormwater management and the Town will collect and "bank" the funds collected. Once sufficient funds are collected to allow for the construction of one or more facilities such as an OGS at a currently untreated outfall, then a capital project can be commenced to do so.

10.2 Stormwater Management Policies for Residential Redevelopment

It is anticipated that much of the future development within the focus area would occur in the form of redevelopment of private residential lots. This type of development has occurred in recent years, and has been largely guided by the town's existing by-laws to determine the permissible size of the dwelling on the site. However, no guidance is currently provided regarding total coverage of redevelopment (including coverage associated with amenity surfaces). As such, it is recommended that the town's current planning and stormwater management policies be updated to provide the appropriate guidance for determining total permissible coverage for residential redevelopments (including permissible coverage for increased amenity surfaces), as well as requiring the implementation of stormwater management for these forms of redevelopment. As outlined in Section 8.8, the requirement to retain and infiltrate 25 mm of stormwater runoff (minimum), as a stormwater practice for mitigating land use intensification and climate change impacts should be required as a minimum standard for all residential redevelopments.

10.3 Low Impact Development and Alternative Design Standards

Stormwater management practices across the Province have evolved from more conventional end-of-pipe techniques (stormwater management facilities) to the suite of practices commonly referred to as Low Impact Development Best Management Practices (LID BMPs) to reduce and treat the volume of storm runoff prior to discharge to receiving systems. The application of LID BMPs on all new redevelopment within the focus area would serve to reduce the demand on the town's drainage infrastructure, thereby maintaining the level of service provided by the existing infrastructure.

Section 3.1.3.01 of the Town of Oakville Development Engineering Procedures and Guidelines makes reference to the use of LID BMPs for stormwater management, however no details are provided within the Guidelines regarding acceptable practices or design standards within the Town of Oakville. As such, it is recommended that the town develop guidelines and standards specific to the application of LID BMPs on private properties and within municipal rights-of-way.

The Town of Oakville Development Engineering Procedures and Guidelines have been supplemented with Addendum #1 (Town of Oakville, January 2017) that provides reference to the application and design of dry wells, also known as soak away pits. The purpose of the dry wells is to reduce runoff volume and increase infiltration where satisfactory infiltration rates exist; dry wells are to be used when conventional stormwater drainage methods are not applicable. The guidelines require the proponent to obtain a report from a qualified professional indicating that the site and soils are suitable, and the design is in accordance with the guidelines.

The relevant policies identified in Section 1.1.1 of this document provide an outline or framework to manage growth and development in a sustainable manner within the town. Several references within those policy documents promote the use and implementation of LID BMPs to support sustainable development. These policies, however, do not explicitly state that the use of LID BMPs or maintaining groundwater recharge are required for every development or redevelopment. As such, it is recommended that procedures be developed by the town to require a greater use of LID BMPs.

The incorporation of the LID BMP guidelines and procedures into the Town of Oakville's policy and guideline documents would further emphasize the balanced approach of "grey" and "green" infrastructure as the preferred mitigation alternative to addressing the impacts on stormwater runoff due to land use intensification and climate change, as well as the existing infrastructure deficiencies. The documents should explicitly state that source controls in the form of LID BMPs should retain a minimum of 25 mm of stormwater runoff on private and public properties, as outlined in Section 8.8.

In addition, it is recommended that the town develop Alternative Design Standards to promote the formal application of rural and hybrid sections within Municipal rights-of-way. These standards would build upon the town's current standards for roads, and would refine them to provide details and guidance for lane widths, placement of sidewalks and bike paths, positioning utilities, and placement of catch basins and sewers within a traditionally rural (i.e. ditched) right-of-way.

10.4 Guidance for Remnant Channels

As noted previously, remnant channels (i.e. those open waterways not regulated by Conservation Halton) within the focus area are predominantly located on private properties, and receive and convey storm runoff from multiple properties and landowners. Currently, these features do not have a dedicated easement to allow the town access for maintenance and management, hence over time have been altered by residents and private landowners. These alterations have, at times, affected the capacity and performance of the remnant channel, altering the extent of flow within the features during storm events.

Recognizing that these features provide a conveyance function for multiple landowners (including often a portion of municipal right-of-way runoff), it is recommended that procedures be developed to preserve this function. Any proposed alterations by local residents to properties adjacent to these remnant channels should be specifically evaluated through the town's Development Engineering Site Process (DESP). The intent of this evaluation is to ensure flood risks are addressed through appropriate measures for sites with higher risks associated with remnant channels. In support of this process, all properties adjacent to the remnant channel systems identified through this study should be flagged within the town's property databases as requiring appropriate analyses related to drainage to demonstrate no impacts result from proposed changes to the subject properties.

10.5 Climate Change

The Town of Oakville defines its current rainfall standard in the *Development Engineering Procedures and Guidelines Manual* and uses the Environment and Climate Change Canada Toronto City (Gauge ID 6158355) station as its basis. The data record for this station spans 1940 to 2018. Based upon the results of the climate change assessment conducted as part of this Master Plan, it is recommended that the town maintain the Toronto City ECCC station as the basis for the Town's design IDF relationship as part of its stormwater management guidelines and policies.

Climate change scenarios have been assessed through this study based upon projections for 2050 and 2080. Both timeframes are considered relevant to assessing potential impacts of climate change to the town's storm infrastructure. It is recommended that the town's guidelines be updated to incorporate provisions for the selection of the temporal projection of rainfall, based upon the life span of the infrastructure under consideration. Furthermore, it is recommended that town procedures be updated to incorporate the following components for monitoring and assessing the impacts of climate change, as part of future projects:

- Base assessments should be completed using climate change influenced rainfall based on scenario RCP 4.5 (representing a moderate scenario with global efforts to reduce emissions).
- Stress testing designs using climate change influenced rainfall based on scenario RCP 8.5 (representing the business-as-usual high-emissions scenario). More generally, a stress testing approach be adopted when the town is considering infrastructure decisions regarding critical and long-lived infrastructure, to improve system resiliency.
- The town continue to monitor developments with regards to emissions scenarios and tracking to periodically re-evaluate the aforementioned modelling approach.

11.0 Summary And Next Steps

11.1 Drainage System Improvements

11.1.1 Phasing and Prioritization for Implementation

The recommendations for improving the municipal drainage systems, as presented herein, have been evaluated to establish a preferred phasing and prioritization plan for implementation. The phasing for implementation has separated the works into "short-term" and "long-term" activities, based upon magnitude, complexity, cost and ease of implementation. The "short-term" works represent those recommendations which are relatively low cost, require little to no additional consultation and/or analysis (i.e. Schedule A/A+ Class EA items), and may thus be implemented in the near term (i.e. notionally within the next five years). The long-term tasks represent those recommendations consisting of larger capital projects, requiring additional stages of study, analysis, design, and consultation (i.e. Schedule B Class EA items); although these works may be initiated in the near-term, these works are anticipated to require additional time for planning and design, and final implementation (i.e. greater than 5 years). The following summarizes the short-term and long-term activities for implementation

Short-Term Works

The short-term works, depicted on Drawing 8.6 as minor capital upgrades, are comprised of the following:

- Install Inlet Control Devices (ICDs) within catch basins in designated areas.
- Improvements to storm sewer inlets at designated locations.
- Install additional catch basins at designated locations to improve upon minor system capture.

Installation of ICDs, and associated uptakes, are recommended by network in Table 11.1.1. The short term work to install ICDs as a storm sewer surcharge mitigation effort, has been recommended based on a percentage of the number of catch basins in the network; 75 % or > 75 % of the catch basins should have ICDs installed. The PCSWMM tested ICD implementation rate used for the networks with a recommendation of > 75 % was for 100 % of the catch basins. However, it should be noted that at the time of design, the ICDs required for implementation should be confirmed as the final implementation rate will likely be between 75% and 100% of the catch basins.

Table 11.1.1 Short-Term Recommended Works by Network

Network ID	Extent of ICD Installation	Additional Considerations/Comments
1	Confirm extent of existing ICDs and verify the existence of the negative sloped pipes near the Lakeshore Road outlet	75 % ICD implementation has been assumed for the existing conditions while >75% implementation has been recommended for the alternative assessment
6	Install ICDs (75% of Sewershed)	This network should be considered for disconnecting the basement connections or foundations drains from the storm sewer system.
8	Install ICDs (>75% of sewershed)	Significant mitigation efforts, other than ICDs, are not required
9	Install ICDs (75% of sewershed)	Instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system. See Table 11.1.2 for additional works required.
12	Install ICDs (>75% of sewershed)	See Table 11.1.2 for additional works required.

Table 11.1.1 Short-Term Recommended Works by Network

Network ID	Extent of ICD Installation	Additional Considerations/Comments
13	Install ICDs (75% of sewershed)	Instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system. See Table 11.1.2 for additional works required.
16	Install ICDs (75% of sewershed)	Significant mitigation efforts, other than ICDs, are not required
29	Install ICDs (>75% of sewershed)	See table 11.1.2 for additional works required.
31	Install ICDs (75% of sewershed)	This network should be considered for disconnecting the basement connections or foundations drains from the storm sewer system.
32	Install ICDs (75% of sewershed), pipe replacement	Minor instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system or addressed as part of future long-term maintenance.
33	Install ICDs (>75% of sewershed)	See Table 11.1.2 for additional works required
35	Install ICDs (>75% of sewershed)	Significant mitigation efforts, other than ICDs, are not required
37	Install ICDs (75% of sewershed),	Minor instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system or addressed as part of future long-term maintenance. See Table 11.1.2 for additional works required.
47	Install ICDs (>75% of sewershed)	Significant mitigation efforts, other than ICDs, are not required
50	Install ICDs (>75% of sewershed)	Significant mitigation efforts, other than ICDs, are not required
51	Install ICDs (75% of sewershed)	See Table 11.1.2 for additional works required.
53	Confirm extent of existing ICDs	The existing ICDs have not been modelled for the existing condition scenario as the town confirmed their presence following the initial assessment. However, 75 % implementation has been used for the alternative assessment, which mitigates the minor system to the town's LOS criteria.
54	Confirm extent of existing ICDs	The existing ICDs have not been modelled for the existing condition scenario as the town confirmed their presence following the initial assessment. However, 75 % implementation has been used for the alternative assessment, which mitigates the minor system to the town's LOS criteria.
55	Install ICDs (75% of sewershed)	See Table 11.1.2 for additional works required.
56	Install ICDs (>75% of sewershed)	Significant mitigation efforts, other than ICDs, are not required

Long-Term Works

The long-term works represent those recommendations comprised of more significant capital works for implementation, depicted on Drawing 8.1 as major capital sewer upgrades. The long-term recommendations and associated networks are summarized in Table 11.1.2.

Table 11.1.2 Long-Term Recommended Works by Network

Network ID	Recommended Capital Works	Additional Considerations/Comments
1	See comments	No Long-term works have been recommended.
2	See comments	No Long-term works have been recommended.
3	See comments	No Long-term works have been recommended.
4	See comments	No Long-term works have been recommended.
5	See comments	No Long-term works have been recommended.
6	See comments	No Long-term works have been recommended.
7	Pipe replacement	Confirm and replace pipes with negative slope to mitigate the surcharging in the minor system.
8	See comments	No Long-term works have been recommended
9	Pipe replacement	Minor Pipe replacement upgrades are recommended in addition to pipe upgrades as per the Lakeshore Road (Draft) Class EA. Future study recommended with additional investigation to address residual data gaps and to validate alternatives.
10	Pipe Replacement	Pipe replacement recommended to improve upon major system performance (ref. Table 8.2.1).
11	See comments	No Long-term works have been recommended
12	See comments	Upgrade pipes per recommendations of Lakeshore Road (Draft) Class EA.
13	See comments	Upgrade pipes per recommendations of Lakeshore Road (Draft) Class EA.
14	Pipe replacement, online/offline storage	Further mitigation possible through lowering inverts and increasing sizes (to be considered at next stages of planning and design). Future study recommended with additional investigation to address residual data gaps and to validate alternatives due to the extent of recommended works.
15	Pipe replacement, online/offline storage	Further mitigation possible through lowering inverts and increasing sizes (to be considered at next stages of planning and design). Future study recommended with additional investigation to address residual data gaps and to validate alternatives due to the extent of recommended works.
16	See comments	No Long-term works have been recommended.
17	Diversion, pipe replacement, online storage	Diversion and pipe replacement per recommendations of Coronation Park Class EA and the Lakeshore Road (Draft) Class EA.
18	Diversion, pipe replacement, online/offline storage	Diversion, pipe replacement, and online/offline storage per recommendations of Coronation Park Class EA. Future study recommended with additional investigation to address residual data gaps and to validate alternatives. Additional storage could be considered as part of a future study rather than upsizing storm sewers on private property.

Table 11.1.2 Long-Term Recommended Works by Network		
Network ID	**Recommended Capital Works**	**Additional Considerations/Comments**
19	Diversion, pipe replacement	Diversion and pipe replacement per recommendations of Coronation Park Class EA and the Lakeshore Road (Draft) Class EA. Instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system.
20	Pipe replacement	Further mitigation possible through lowering inverts and increasing sizes (to be considered at next stages of planning and design). Future study recommended with additional investigation to address residual data gaps and to validate alternatives due to the extent of recommended works.
21	Pipe replacement	Pipe replacement does not mitigate major system flooding on Speers Road. The major system should be considered for regrading or reprofiling at the time of other road works to mitigate the major system performance.
22	Pipe replacement and new sewers	Pipe replacement recommended to improve upon major system performance (ref. Table 8.2.1), install pipes as per the Lakeshore Road (Draft) Class EA.
23	Pipe replacement	Further mitigation possible through lowering inverts and increasing sizes (to be considered at next stages of planning and design).
24	Diversion, pipe replacement	Diversions pipe to Network 25 to provide mitigation from tailwater conditions in remnant channel.
25	Pipe replacement	Upgrade pipes per recommendations of Lakeshore Road (Draft) Class EA, and diversion from Network 24.
26	See comments	No Long-term works have been recommended. Instances of surcharge due to tailwater condition at outlet proximate to McCraney Creek are not mitigable through capital works.
27	Pipe replacement, online/offline storage	Further mitigation possible through lowering inverts and increasing sizes (to be considered at next stages of planning and design); future study recommended with additional investigation to address residual data gaps and to validate alternatives due to the extent of recommended works. This network should be considered for disconnecting the basement connections or foundations drains from the storm sewer system.
28	Pipe replacement	Upgrade pipes per recommendations of Lakeshore Road (Draft) Class EA.
29	Pipe replacement	Upgrade storm sewers per Lakeshore Road (Draft) Class EA. Remnant channel upgrades are recommended as per the ongoing study for the St. Jude's Cemetery and are subject to revision.
30	Pipe replacement, online/offline storage	Pipe replacement and offline/online storage to mitigate both major and minor systems; future study recommended with additional investigation to address residual data gaps and to validate alternatives due to the extent of recommended works. Incidences of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system.

Table 11.1.2 Long-Term Recommended Works by Network		
Network ID	**Recommended Capital Works**	**Additional Considerations/Comments**
31	See comments	Future study recommended with additional investigation to address residual data gaps and to validate alternatives as implementing ICDs does not fully mitigate to the town's standards due to tailwater conditions from Network 30. This network should be considered for disconnecting the basement connections or foundations drains from the storm sewer system.
32	Pipe replacement	Minor pipe replacement recommended in addition to ICDs.
33	Offline storage	Offline storage near water treatment plant as well as increasing pipe sizes through water treatment plant are recommended.
34	Pipe replacement	Pipe replacement to mitigate both the major and minor systems.
35	See comments	No Long-term works have been recommended.
36	Pipe replacement, online storage	Instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system.
37	Pipe replacement	Pipe replacement recommended in addition to ICDs.
38	Pipe replacement	Instances of surcharge due to tailwater condition at outlet to Lower Morrison Creek. This network should be considered for disconnecting the basement connections or foundations drains from the storm sewer system. There is an ongoing fluvial study for Lower Morrison Creek; a future study should be considered for this network following the recommendations of the fluvial study with a study cost to be determined.
39	Pipe replacement, diversion	Pipe replacement mitigates surcharging.
40	Pipe replacement	Pipe replacement mitigates surcharging.
41	Pipe replacement	Pipe replacement mitigates surcharging. Minor instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system or addressed as part of future long-term maintenance.
42	Offline storage, pipe replacement	Storage and upgrades per recommendations of Cornwall Road Class EA, have been completed. As such, these works have not been included in the cost estimate for this study. Nevertheless, there continue to be instances of surcharge within the minor system due to tailwater condition at outlet to Lower Morrison Creek. This network should be considered for disconnecting the basement connections or foundations drains from the storm sewer system. There is an ongoing fluvial study for Lower Morrison Creek; a future study should be considered for this network following the recommendations of the fluvial study with a study cost to be determined.
43	Pipe replacement	Storage and upgrades per recommendations of Cornwall Road Class EA, have been completed. As such, these works have not been included in the cost estimate for this study. Additional

Network ID	Recommended Capital Works	Additional Considerations/Comments
		pipe replacement has been recommended to mitigate residual surcharging.
44	Pipe replacement	Pipe replacement mitigates major and minor systems. Minor instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system or addressed as part of future long-term maintenance.
45	Pipe replacement	Pipe replacement mitigates minor system surcharging; limited cover on pipes at the Lower Wedgewood Creek outlet necessitates the use of box culverts for the storm sewer.
46	Pipe replacement	Minor instances of surcharge at isolated locations with basement connections or foundations drains should be considered for disconnection from the storm sewer system or addressed as part of future long-term maintenance.
47	See comments	No Long-term works have been recommended.
48	Pipe replacement	Pipe replacement recommended to mitigate instances of surcharging.
49	Pipe replacement	Pipe replacement recommended to mitigate instances of surcharging. Flow conveyed to the 3000 mm x 1500 mm drop inlet structure, south of the rail corridor, causes surcharging in the minor system. Future study recommended with additional investigation to address residual data gaps and to validate alternatives.
51	Pipe replacement	Minor pipe replacement recommended to mitigate minor instances of surcharging.
52	Pipe replacement	Pipe replacement recommended to mitigate instances of surcharging. Sump pumps have been identified on town drawings, however, sump pump presence should be confirmed as part of future analysis.
53	Pipe replacement	Verify existence of negative sloped pipes and confirm the extent of the existing ICDs.
54	Pipe replacement	Implement pipe replacement to mitigate instances of surcharging.
55	Pipe replacement	Some additional pipe replacement recommended to mitigate instances of surcharging
56	See comments	No Long-term works have been recommended.

Table 11.1.2 Long-Term Recommended Works by Network

The long-term works have been prioritized based upon the results of the minor system performance assessment during the 100 year design storm event for the storm sewers with assumed basement connections, the minor system performance assessment during the 5 year storm event for the storm sewers that are assumed to not have basement connections, and the major system performance during the 100 year design storm event. The evaluation criteria for determining whether these systems meet the town's standards are presented in Table 11.1.3, as previously outlined in Section 7.2.

Table 11.1.3 The Required Major and Minor System Performance for a Pass Condition			
System	**Basement Connections**	**Design Storm Event**	**Performance Criteria**
Minor System	Yes	100 Year	The hydraulic grade line is less than 50 % surcharged between the pipe obvert and the rim elevation
	No	5 Year	The hydraulic grade line is surcharged less than the rim elevation
Major System	N/A	100 Year	The surface flow is less than 50% of the distance between the right-of-way and the main property structure

As discussed in Section 7.2 weighting factors have been developed to prioritize mitigating impacts for those networks with basement connections to storm sewers, where there is potential for the minor system to surcharge to the basement elevation. Storm sewers that do not have basement connections, and typically only convey surface runoff, have been assigned a lower weighting due to their reduced risk potential for adverse impacts. Major systems that have the potential to convey surface flow greater than 50 % beyond the ROW have been assigned a moderate prioritization. The prioritization for implementing the long-term capital works is summarized in Table 11.1.4. Following the implementation of the short-term works, it is recommended that the long-term works be re-prioritized based on the existing conditions weighted net score for each network. As shown in Table 11.1.4, there are 13 networks that are low priority, 17 networks that are medium priority, and 12 networks that are high priority for a total of 42 networks; 14 networks do not require long-term works.

Table 11.1.4 Prioritization for Long-Term Capital Works		
Network ID	**Score**	**Priority**
7	2.55	high
9	1.91	high
10	0.28	low
12	0.29	low
13	1.51	medium
14	2.15	high
15	2.63	high
17	1.35	medium
18	2.23	high
19	1.85	high
20	1.67	medium
21	0.77	low
22	1.42	medium
23	1.96	high
24	1.55	medium
25	1.75	medium
27	1.47	medium
28	1.74	medium

Table 11.1.4 Prioritization for Long-Term Capital Works

Network ID	Score	Priority
29	0.59	low
30	1.39	medium
31	2.32	high
32	0.74	low
33	0.68	low
34	1.31	medium
36	1.24	medium
37	0.94	low
38	2.27	high
39	1.37	medium
40	2.26	high
41	0.99	low
42	1.64	medium
43	1.97	high
44	1.74	medium
45	2.32	high
46	1.03	low
48	0.73	low
49	1.58	medium
51	1.15	low
52	1.14	low
53	1.56	medium
54	0.92	low
55	1.40	medium

11.2 Cost Estimates

Cost estimates have been developed for the recommended works to address the existing deficiencies within the major and minor drainage systems in the focus area. The total costs by network are presented in Table 11.2.1. Detailed cost estimates for the proposed improvements to the drainage systems within the focus area are provided in Appendices H and J.

Table 11.2.1 Estimated Costs for Recommended Works by Network

Network	Minor System		Major System[3]	Weighted Net				Existing Conditions Net LOS	Recommended Works Net LOS	Number of Private Properties	Total Capital Works and Detailed Future Studies Costs	Unitary Capital Cost Per Network ($/Private Properties)
	Connected[1]	Not Connected[2]		Score								
	LOS	LOS	LOS	1	2	3	Total Score					
1	A	A	A	0.21	0.00	0.09	0.30	D	A	299	$ 380,222	$ 1,272
2	A	A	A	0.00	0.00	0.34	0.34	A	A	263	$ 205,090	$ 780
3	A	B	A	0.05	0.10	0.04	0.19	A	A	599	$ 332,572	$ 555
4	A	A	A	0.05	0.00	0.04	0.09	A	A	563	$ 496,016	$ 881
5		A	A	0.00	0.12	0.14	0.26	A	A	27	$ 167,360	$ 6,199
6	D	A	A	0.94	0.00	0	0.94	B	B	25	$ 44,156	$ 1,766
7	D	A	B	2.03	0.00	0.52	2.55	D	B	79	$ 160,888	$ 2,037
8	D	A	A	2.33	0.00	0.34	2.67	D	A	480	$ 369,819	$ 770
9	D	A	A	1.72	0.02	0.18	1.91	C	C	298	$ 1,126,126	$ 3,779
10		A	A	0.00	0.08	0.2	0.28	A	A	137	$ 300,768	$ 2,195
11	D	A	B	0.78	0.00	0.42	1.20	B	B	74	$ 190,137	$ 2,569
12		B	A	0.00	0.29	0	0.29	A	A	33	$ 605,302	$ 18,342
13	D	A	A	1.27	0.02	0.22	1.51	C	B	680	$ 1,498,925	$ 2,204
14	D	A	B	1.71	0.02	0.42	2.15	D	B	1164	$ 37,196,937	$ 31,956
15	D	B	B	1.92	0.11	0.6	2.63	D	B	752	$ 25,095,207	$ 33,371
16	D	A	A	1.91	0.00	0	1.91	C	A	51	$ 19,845	$ 389
17	C	B	B	0.58	0.18	0.6	1.35	B	B	179	$ 2,122,589	$ 11,858
18	D	B	C	1.22	0.17	0.84	2.23	D	B	586	$ 12,197,654	$ 20,815
19	C	C	C	0.30	0.41	1.14	1.85	C	B	436	$ 7,691,647	$ 17,641
20	D	B	B	0.98	0.21	0.48	1.67	C	B	969	$ 24,141,342	$ 24,914
21	C	A	B	0.11	0.00	0.66	0.77	B	B	63	$ 1,661,966	$ 26,380
22		A	D	0.00	0.00	1.42	1.42	B	B	80	$ 308,063	$ 3,851
23	D	C	C	0.77	0.31	0.88	1.96	C	B	449	$ 2,888,241	$ 6,433
24	D	A	A	1.35	0.04	0.16	1.55	C	A	420	$ 5,308,289	$ 12,639
25	D	A	B	1.22	0.06	0.48	1.75	C	B	415	$ 4,658,950	$ 11,226
26	D	A	B	0.43	0.10	0.5	1.03	B	B	153	$ 173,625	$ 1,135
27	D	B	B	0.83	0.20	0.44	1.47	B	B	824	$ 33,722,243	$ 40,925
28	D	A	B	1.04	0.07	0.62	1.74	C	B	190	$ 1,782,935	$ 9,384
29	C	A	A	0.41	0.05	0.12	0.59	B	A	167	$ 7,111,743	$ 42,585
30	D	A	A	0.87	0.14	0.38	1.39	B	B	572	$ 14,199,762	$ 24,825
31	D	B	A	2.07	0.11	0.14	2.32	D	D	100	$ 110,772	$ 1,108
32	D	A	A	0.44	0.12	0.18	0.74	B	A	125	$ 239,896	$ 1,919
33	D	A	A	0.38	0.03	0.28	0.68	B	A	402	$ 4,855,809	$ 12,079
34	D	B	A	0.85	0.18	0.28	1.31	B	A	578	$ 6,297,048	$ 10,895
35	C	A	A	0.80	0.04	0.1	0.94	B	A	368	$ 757,479	$ 2,058
36	D	A	B	0.68	0.12	0.44	1.24	B	B	436	$ 6,622,650	$ 15,190

Table 11.2.1 Estimated Costs for Recommended Works by Network													
Network	Minor System		Major System[3]	Weighted Net					Recommended Works Net LOS	Number of Private Properties	Total Capital Works and Detailed Futune Studies Costs	Unitary Capital Cost Per Network ($/Private Properties)
	Connected[1]	Not Connected[2]		Score				Existing Conditions Net LOS				
	LOS	LOS	LOS	1	2	3	Total Score					
37	D	A	A	0.74	0.04	0.16	0.94	B	B	440	$ 791,513	$ 1,799
38	D	B	B	1.59	0.16	0.52	2.27	D	D	153	$ 1,238,071	$ 8,092
39	C	A	C	0.37	0.16	0.84	1.37	B	B	378	$ 3,957,802	$ 10,470
40	D	B	B	1.61	0.13	0.52	2.26	D	B	138	$ 1,358,072	$ 9,841
41	D	B	A	0.63	0.21	0.16	0.99	B	B	146	$ 2,580,624	$ 17,676
42	D	B	B	0.92	0.16	0.56	1.64	C	C	173	$ 545,931	$ 3,156
43	D	A	B	1.27	0.03	0.68	1.97	C	B	140	$ 1,956,303	$ 13,974
44	D	A	B	1.27	0.02	0.46	1.74	C	B	267	$ 3,818,715	$ 14,302
45	D	C	B	1.57	0.13	0.62	2.32	D	B	319	$ 2,807,587	$ 8,801
46	D	A	A	0.61	0.06	0.36	1.03	B	B	385	$ 5,347,342	$ 13,889
47	D	C	A	1.89	0.10	0.38	2.37	D	A	503	$ 609,552	$ 1,212
48	B	A	A	0.67	0.00	0.06	0.73	B	B	282	$ 252,136	$ 894
49	D	A	A	1.23	0.02	0.34	1.58	C	C	516	$ 1,602,674	$ 3,106
50	D	A	A	2.38	0.02	0.08	2.47	D	A	368	$ 434,780	$ 1,181
51	C	A	A	1.06	0.01	0.08	1.15	B	A	151	$ 205,631	$ 1,362
52	B	A	A	1.00	0.00	0.14	1.14	B	B	2100	$ 11,328,738	$ 5,395
53	D	A	A	1.36	0.01	0.18	1.56	C	A	672	$ 809,270	$ 1,204
54	C	B	A	0.56	0.13	0.22	0.92	B	B	1432	$ 2,399,050	$ 1,675
55	D	B	A	1.12	0.16	0.12	1.40	B	B	640	$ 937,239	$ 1,464
56	D	A	A	1.49	0.03	0.16	1.69	C	A	984	$ 1,280,024	$ 1,301
LMC			A	0.00	0.00	0.29	0.29	A	A	201	$ 250,403	$ 1,246
LWC			A	0.00	0.00	0.32	0.32	A	A	323	$ 127,413	$ 394
Other[1]										1[1]	$ 17,500[1]	$ 17,500[1]

Note [1]: An inlet has been identified for improvement in the vicinity of South Service Road West and McPherson Road. While this location is within the focus area, it is not within a defined network and has been identified as Other.

The estimated costs for implementing the recommended improvements including storm flow control and stormwater quality management under both short and long term timeframes, as per the recommendations contained in the Stormwater Master Plan are summarized in Tables 11.2.2, 11.2.3, 11.2.4, and 11.2.5, while the associated study costs for the recommended works are provided in Table 11.2.6.

Table 11.2.2 Short-term Capital Works for Flow Conveyance Mitigation

Recommended Work	Capital Cost ($)
Inlet Control Devices	$ 1,000,000
High Capacity Inlets (23 Locations)	$ 260,000
Inlet Improvements (8 Locations)	$ 140,000
Design	$ 120,000[2]
Staff Time	$ 80,000[2]
Total	**$ 1,600,000**

Note [2]: The town provided estimates for design and staff time for this Table. These costs have not been incorporated into the network cost summary sheet (Appendix J) on a network basis.

Table 11.2.3 Long-term Capital Works for Flow Conveyance Mitigation

Recommended Work	Capital Cost ($)
Sewer Upgrades	$ 138,186,000[3]
System Storage (Online/Offline)	$ 50,262,000[3]
Diversions	$ 6,836,000
Remnant Channels (Diversions, Storage, Channel Works)	$ 12,584,000
Private Driveway Culverts	$ 2,611,000
"Green Infrastructure" (by town)	$ 15,275,000
Re-sectioning of Road Side Ditches	$ 2,245,000
Road Reprofiling	To be completed at the time of roadway reconstruction
Total	**$ 227,999,000**

Note [3]: The supply and construction premium (i.e. the difference in supply and construction cost between the recommended pipe upgrades and replacement of the existing storm sewer pipes with like sized pipes at the end of their engineered life cycle) has been estimated at $ 45,198,000. This value is relevant only for the storm sewer pipe upgrades and online storage and does not include sewer upgrades for diversions or offline storage which are considered new storm sewer pipe installations.

Table 11.2.4 Short-term Capital Works for Water Quality Mitigation	
Recommended Works	**Capital Cost ($)**
Neighbourhood Scale BMPs (Pilot Study Project)	$ 145,000

Table 11.2.5 Long-term Capital Works for Water Quality Mitigation	
Recommended Works	**Capital Cost ($)**
Retrofit of Existing Stormwater Management Facilities	$ 1,516,000
New Stormwater Management Facilities	$ 1,093,000
Formalization/Improvement of Roadside Ditches	Based on local designs/Not costed
Total	**$ 2,608,000**

Table 11.2.6 Future Studies for the Recommended Works (ref. Section 11.2.1)	
Study Type	**Capital Cost ($)**
Schedule A/A+ Works	$ 15,504,000
Schedule B Works	$ 1,187,000
Detailed Network Analyses	$ 1,000,000
Total	**$ 17,691,000**

The total estimated cost for all the recommended works and studies as summed from the preceding tables is $ 250,043,000.

11.2.1 Process and Proponency

The recommended capital works to improve the performance and sustainability of the town's drainage system should be completed under either a Schedule A+, Schedule A, or a Schedule B MEA Class Environmental Assessment, depending upon the location, nature, and extent of works recommended. The following summarizes the applicable Class EA Schedule for the associated works:

Nature/Extent of Works:	Applicable Class EA Schedule
Install ICDs in catch basins	Schedule A
Storm sewer replacement	Schedule A
Implementation of storage online	Schedule A+
Implementation of storage offline within public spaces	Schedule B
Regrading/reprofiling of major system	Schedule A+/Schedule B
Drainage diversions	Schedule B
SWM Retrofits for Water Quality Management	Schedule B

Future studies for regrading/re-profiling of major overland systems should include an assessment of potential spill locations under existing and future conditions with recommended regrading works. Where spill beyond the right-of-way may be anticipated following regrading works, consideration should be given toward completing two-dimensional hydraulic analyses localized to the network, in order to determine the extent of spill under existing and proposed conditions, and thereby verify that the proposed works would provide improved flood protection for adjacent private properties.

11.2.2 Financing

The recommended works to improve upon the town's drainage infrastructure would traditionally be funded through the town's capital budget. Under this approach, the works would be financed by a portion of the town's tax base, which may result in necessary works being deferred in the interest of other capital project or priorities. However, it should also be recognized that the financing through the capital budget may be incorporated into other capital projects (i.e. road works), to leverage efficiencies and economies.

An alternative approach to financing the recommended drainage improvements would involve establishing a stormwater management utility for the Town of Oakville. Under the stormwater management utility, funds would be collected as a separate item as part of the town's tax collection, and would be saved separately for a dedicated source of funding. Under this approach, funds would be collected and specifically dedicated toward financing the required upgrades to the town's drainage systems.

Appendix A

Consultation and Correspondence

Appendix B

Background Information

Appendix C

Livable Oakville Schedules

Appendix D

Photo Reconnaissance

Appendix E

PCSWMM Model

Appendix F

Existing Conditions Capacity Assessment Results

Appendix G

IDF Relationships for Climate Change Scenario and Summary Results

Appendix H

Preferred Alternative Summary Drawings

Appendix I

Stormwater Quality Retrofit Design Drawings

Appendix J

Cost Estimates

Appendix K

Remnant Channel Alternative Assessment