Rethinking Public Green Spaces and Streets in Flood-Vulnerable Neighbourhoods: A Conceptual Planning and Design Study of Rockcliffe-Smythe, Toronto

by

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Abstract

This report demonstrates how green stormwater infrastructure in public streets and green spaces can increase urban capacity to adapt to severe rainfall events and minimize flood risk. A concept plan based on current green stormwater management best practices is included that, if implemented, would transform Rockcliffe-Smythe from being Toronto’s most flood-vulnerable neighbourhood (Plato, 2019) into a more flood-resilient community. The flood mitigation approach proposed in the concept plan focuses on restoring the natural hydrological cycle of the urban landscape by allocating more area for stormwater capture and infiltration. Flood mitigation measures employed include street retrofits and the revitalization of green spaces. This report concludes that neighbourhood-scale retrofit projects can significantly improve stormwater management and build urban resilience to the effects of flooding.

Keywords: Green Infrastructure, Stormwater Management, Urban Flooding, Climate Change Mitigation and Adaptation, Land Use Planning, Urban Environmental Planning, Urban Environmental Design, Resilience.

Foreword

When I began the Master in Environmental Studies in Planning (MES) program, my objective was to understand the socioeconomic and environmental value of nature in cities and how the planning process can strengthen and expand the urban green space system. Over the two year program, my knowledge has expanded on topics within urban planning and with it my research interests have evolved into planning for urban resilience to climate change by working with natural systems. Courses, conferences, workshops, and placements have enabled me to build the theoretical and practical skills required to conduct this research and enter the planning profession as a critical and competent practitioner.

The MES program requires students to create a Plan of Study; a personalized curriculum that includes learning components and learning objectives which must be achieved by the end of the two year program. This report demonstrates my mastery of the three components of my Plan of Study: environmental planning, urban environmental design and urban ecology, and public space and place-making.

Dedication

To the residents of Rockcliffe-Smythe who have experienced flooding, most recently on July 8th, 2020.

Acknowledgements

I acknowledge that this research took place in Toronto on Treaty 13 territory. Toronto has been the site of human activity for thousands of years by the Mississaugas of the Credit, the Anishinabek, the Chippewa, the Haudenosaunee Confederacy, the Huron-Wendat, and Metis, now home to many diverse Indigenous peoples.

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1. Introduction

Cities are vulnerable to climate change. There is a growing need for cities that historically grew around water bodies to plan and implement adaptation measures that build resilience against intensifying extreme weather and flood events. Planners and public policy practitioners are among the core experts who have been called upon to develop adaptation and mitigation solutions to manage climate change impacts in cities. The Canadian Institute of Planners' Policy Statement on Climate Change (2018, p. 2) states that "preparing for the unavoidable impacts of climate change requires a drastic shift in the way our communities are built and function" and requires immediate action at every level of government. My research report responds to the Canadian Institute of Planners' call to action for planners to play a key role in the adaption of communities to environmental changes now and in the future.

For cities like Toronto, where stormwater infrastructure is already operating over its designed capacity, the anticipated increase in rainfall is a serious threat that must be addressed. Without significant increases to the capacity of Toronto's stormwater management system, the risk of flood events and damage will increase. A question I found myself asking is: how can the capacity of Toronto's stormwater management system be increased to ensure the city can adapt to a future with more frequent and severe rainfall events?

As city-builders, we can choose to implement innovative stormwater management solutions that work with natural drainage systems, or we can reinforce the conventional approach to stormwater management that aims to convey runoff away from built-up areas as quickly as possible. This report explores how public spaces, such as streets and parks, could be retrofitted to reduce the number and severity of urban floods by improving overland drainage and infiltration rates, enabling the urban environment to function hydrologically and reduce strain on the existing piped infrastructure system.

To this end, I undertook a conceptual planning and design study of Rockcliffe-Smythe, Toronto's most flood-vulnerable neighbourhood (Plato, 2019), to investigate how green stormwater infrastructure could be used to reduce local vulnerability to riverine flooding and sewer failure by improving urban drainage. The output of the study is a proposed concept plan that transform underutilized public spaces into multifunctional green stormwater management facilities. The plan recommends that all low-traffic and low-volume streets within the neighbourhood should be retrofitted into one of four new street types, referred to in this report as Green Stormwater Streets, that convert portions of the impervious roadway into pervious and/or vegetated cover to increase water infiltration at the source. The second recommendation involves the revitalization of the local green space system to create multifunctional green spaces that fulfil several policy priorities, including stormwater management and recreation objectives.

This research was undertaken to reconcile the disconnection between cities and natural systems by conceptualizing what the flood-vulnerable neighbourhood of Rockcliffe-Smythe could look like if it were retrofitted with the hydrological cycle in mind. I conclude that neighbourhood-scale retrofit projects that implement green stormwater infrastructure are an achievable approach to improving urban resilience to flooding.

1.1: Report Outline

This report is divided into eight main sections, plus additional resources in the appendices, as follows:

1: Introduction

2: Key Issues and Opportunities in Stormwater Management
This section includes background information on the urban challenges caused by stormwater runoff and the different approaches to stormwater management.

3: Concept Plan and Design Methodology
This section outlines my methodological approach to conducting a conceptual planning and design study.

4: The Study Area and Surrounding Geographic Context
This section provides background knowledge of the study area and the surrounding geographic context examined during the conceptual planning and design study.

5: Study Area Challenges: Existing Conditions and Assessment
This section should be consulted to gain an understanding of the current environmental conditions and challenges to stormwater management within the study area. This analysis was used to establish reference conditions consulted when creating and evaluating the proposed concept plan.

6: The Proposed Concept Plan and Designs
This section includes my proposed concept plan and designs that aim to minimize flood risk damage in the study area using green stormwater infrastructure. The proposal includes two types of retrofits: green stormwater streets and public green spaces. The proposed concept plan and designs respond to the City of Toronto's *Official Plan* (2019) and *Green Streets Technical Guidelines* (Schollen & Company Inc. et al, 2017), which encourage the use of green infrastructure to improve the management of stormwater and resilience to climate change.

7: Discussion on the Impact of the Proposed Concept Plan

This section provides my interpretation of the impacts the proposed concept plan would have on mitigating flood risk and damage in the study area. In addition, commentary is included on the limitations of the research project and the current provincial and municipal policy context for green stormwater management and infrastructure.

8: Concluding Remarks

A summary of the research and findings is presented. Several research questions that could extend this project and findings are included for future MES Planning students interested in green infrastructure and stormwater management.

Appendix A: Planning and Policy Framework for the Study Area

Detailed summary of the provincial and municipal public policy that promote the use of green infrastructure and natural vegetative systems to improve stormwater management and forward climate change adaptation.

Appendix B: Green Stormwater Infrastructure Selection Tool for Street Retrofits

The green stormwater infrastructure selection tool used when developing the concept plan and designs for the Green Stormwater Streets retrofits.

2. Key Issues and Opportunities in Stormwater Management

2.1: Overview

This section provides background information on the hydrologic cycle and stormwater generation in natural and urban landscapes (Section 2.2). The grey and green approaches to stormwater management are outlined (Section 2.3), followed by a discussion on green stormwater infrastructure elements used in this report to achieve stormwater management objectives (Section 2.4).

2.2: Stormwater and the Hydrologic Cycle

Stormwater runoff is produced when rain and snowmelt flow along the surface of the Earth. In natural areas, vegetation and natural ground cover—such as trees, shrubs, mosses, and soils—intercept the water, capturing it in depressions where water is filtered and infiltrated. Groundwater levels are stable, supplying water to the trees and microorganisms that keep the soil porous. Water flows through wide and meandering watercourses filled with clean water and abundant marine and terrestrial life (Hough, 1995). Stormwater in this natural hydrologic cycle is a resource that connects all life and natural systems together.

The urban hydrologic cycle, on the other hand, bears little resemblance the natural cycle. The built form and land use within urban areas have significantly altered how water moves through urban landscapes (Li et al, 2019; Larco, 2016). Urbanization replaces vegetated land cover with impermeable surfaces—such as roads, roofs, parking lots and compacted sports fields—that prevent stormwater infiltration into the underlaying soils. Low infiltration rates result in large volumes of fast-moving stormwater flowing along the smooth impervious urban surfaces (Hough, 1995, p. 39). Stormwater, if not managed effectively, can result in serious adverse socioeconomic and environmental impacts, including damage from floods and erosion, poor water quality, watercourse fluctuations, and the depletion of the water table (Li et al, 2019; Marsh, 2010, p. 168; Larco, 2016; Hough, 1995).

Stormwater management is the effort to reduce the volume of stormwater runoff that flow through urban areas and minimize the effects of the runoff that is produced (TRCA, n.d.-c; Larco, 2016). There are different approaches to stormwater management that determines the strategies, design, and effectiveness of the system (Davis et al, 2009; Hough, 1995).

2.3: Approaches to Stormwater Management

Two main types of stormwater management systems are discussed in this report: the conventional grey stormwater approach and the green stormwater approach.

Conventional grey stormwater management systems are designed to convey runoff away from built-up urban areas as quickly as possible (Li et al, 2019; Hough, 1995, p. 39). This is done with engineered infrastructure assets such as storm sewers, culverts, and outfalls. Common practices also include channeling or burring streams, draining wetlands, and constructing dams (Marsh, 2010). Unfortunately, grey stormwater management systems have exacerbated the issues of flooding, erosion, and poor water quality, rather than minimize the damage (Hough, 1995; Marsh, 2010). For example, the risk of riverine flooding is raised by piped drainage systems, which discharge huge quantities of runoff accumulated from impermeable catchment areas directly into local watercourses through outfalls. This raises the peak flow and velocity of the watercourse, which increases the risk of flood and erosion damage. Further, the grey stormwater system decreases local and downstream water quality by discharging large quantities of untreated runoff directly into watercourses through outfalls and combined sewer overflows (Forman, 2014).

Green stormwater management systems are designed to handle runoff where it is generated by harnessing natural processes to restore the hydrological cycle. The green approach utilizes natural and manmade infrastructure—such as *Natural Heritage System* features, permeable surfaces, and bioretention facilities-—to reduce, slow, filter, and infiltrate stormwater runoff. Common practices include the naturalization of developed land and channelized streams, the protection of *Natural Heritage System* features, and the construction of multifunctional ecosystems that provide temporary and/or permanent water storage. Researchers have found the green approach to be an effective tool to manage runoff, reduce peak flow and erosion rates, and improve water quality (Davis et al, 2009; Beatley, 2016; Matthews et al, 2015; Larco, 2015; Higgs 2003 & 2017; Kondo et al, 2015; Chin, 2017). The green approach emphasizes the importance of working with natural systems as opposed to controlling nature under the conventional grey approach (Davis et al, 2009).

In this report, I use the green stormwater management approach to create a concept plan to demonstrate how the natural drainage capacity can be improved in Rockcliffe-Smythe, Toronto's most flood-vulnerable neighbourhood (Plato, 2019), using green stormwater infrastructure. Section 2.4 provides an overview of the green stormwater infrastructure elements that I utilize in the proposed concept plan and designs.

2.4: Green Stormwater Infrastructure

The four primary outcomes that the green approach to stormwater management achieves are to reduce, slow, infiltrate, and filter urban runoff. These outcomes can be achieved by directing runoff into purpose-built infrastructure assets, referred to in this report as green stormwater infrastructure, that use vegetation and soils to manage runoff where it is generated. Green stormwater infrastructure is an effective strategy to maintain natural hydrology in a site undergoing development, or to restore natural hydrology to an urbanized area. Moreover, green stormwater infrastructure is effective at extending the capacity of existing municipal grey stormwater infrastructure by diverting runoff from the sewer system into green stormwater infrastructure elements where it can be infiltrated (Li et al, 2019).

Typical components of a green stormwater infrastructure element include vegetation, depressions, soil or other permeable materials, and inlets. This combination facilitates infiltration and filtration, reducing watercourse velocity, peak flow, erosion and contamination rates. Green stormwater infrastructure elements become more effective over time as vegetation reaches maturity and is less likely to fail during heavy rainfall events (Forman, 2014, p. 172).

There are several green stormwater infrastructure elements that city-builders can implement to achieve stormwater management outcomes. The following green stormwater infrastructure elements are utilized in this report:

Bioretention Facilities are constructed depressions designed to capture, hold, filter, and infiltrate stormwater runoff during rainfall and snowmelt events (Davis et al, 2009; Chin, 2016; Kondo et al, 2015; Trowsdale & Simcock, 2011). Although bioretention systems require site-specific design, a typical facility consists of a grass buffer, a below-grade depression filled with a porous soil mixture of sand and organic matter, and an upper layer of mulch and vegetation (Trowsdale & Simcock, 2011). Bioretention facilities can be incorporated into any green space or street type and can be designed to manage runoff from light to heavy rainfall events through the addition of an underdrain pipe which conveys runoff that reaches the bottom of the facility into another element of the stormwater system (Schollen & Company Inc. et al, 2017; NACTO, 2017; Chin, 2017).

Types of bioretention facilities that are used in the concept plan include bioretention planters, bioretention swales, and bioretention rain gardens.

Bioretention Planters have vertical walled sides, a flat bottom, and are often rectangular in shape. Typically, bioretention planters are located along streets, sidewalks, driveways, and utilities in order to receive and manage runoff from impermeable surfaces through inlets (Schollen & Company Inc. et al, 2017; NACTO, 2017). Bioretention planters are also be referred to as stormwater planters, planter boxes, bioretention cells, raised planters, or roadside planters.

Bioretention Swales are shallow vegetated channels with sloped sides that manage runoff through source control and conveyance. Bioretention swales are an effective method for slowing the velocity of runoff before it engages with other stormwater infrastructure features or watercourses. Bioretention swales can be incorporated into local and connector streets (Schollen & Company Inc. et al, 2017). Bioretention swales are also referred to as dry swales, wet swales, or infiltration swales.

Bioretention Rain Gardens are small-scale sunken planting beds composed of highly permeable soils that receive runoff for temporary storage. Rain gardens can be incorporated into residential street medians and islands, residential lots, and greenspaces (Chin, 2017; NACTO, 2017; Schollen & Company Inc. et al, 2017).

Curb Extensions and Bump-Outs are an expansion of a curb into a portion of the roadway, either at an intersection or mid-block, in order to make space to incorporate green stormwater infrastructure into the roadway. Curb extensions and bump-outs can be incorporated into many street types to receive and manage runoff from adjacent impermeable surfaces (Schollen & Company Inc. et al, 2017; NACTO, 2017). In addition to providing space for green stormwater infrastructure, such as bioretention planters and street trees, curb extensions and bump-outs are an effective traffic-calming feature (Schollen & Company Inc. et al, 2017).

Inlets are openings in a curb that are designed to convey stormwater runoff from the surrounding area into a green stormwater infrastructure feature, such as a bioretention planter or tree cell (NACTO, 2017).

Permeable Pavement can be used as an alternative to impermeable pavement to allow stormwater to infiltrate through the surface material into the underlying soil or reservoir. Permeable pavements include interlocking concrete pavers, pervious concrete, porous asphalt, or other forms of pervious or porous materials. Permeable pavement can be used for walkways in parks or incorporated into urban streets by replacing impermeable sidewalks, on-street parking spaces, cycling lanes, low-traffic vehicle lanes, and parking lots with permeable pavement (Schollen & Company Inc. et al, 2017; NACTO, 2017).

Stormwater Tree Cell are walled cells designed for a single tree to receive runoff from adjacent impervious surfaces (Schollen & Company Inc. et al, 2017). The cells can have an open or closed bottom, dependent on the space available for soil volume. Stormwater tree cells are also referred to as stormwater tree wells and stormwater tree pits.

Stormwater Tree Trenches are designed to connect several stormwater tree cells with a linear underground trench system (Schollen & Company Inc. et al, 2017; NACTO, 2017). Stormwater tree trenches can be incorporated into the medians and sidewalk planting zones of most street types.

3. Concept Plan and Design Methodology

3.1: Overview

This section outlines my methodological approach to conducting this conceptual planning and design study. The approach enabled me to apply the theoretical knowledge I learned throughout the MES program to a real-world environmental planning problem. In doing so, I challenged myself to engage with a critical planning issue and gain experience with geographic information systems (ArcGIS) and graphic design (Adobe Illustrator) software that I had no previous experience using.

3.2: Methodological Approach

3.2.1: Study Area Selection

In order to meet the learning objectives outlined in my Plan of Study, I selected an area within Toronto that has high vulnerability to flooding and has numerous low-quality and underutilized public spaces that could be retrofit using green infrastructure to improve stormwater management. I identified the neighbourhood of Rockcliffe-Smythe as a potential study area following a review of several TRCA resources such as the floodplain map viewer (TRCA, n.d.-a) and the flood vulnerable cluster map (TRCA, 2019, p. 30). Given that developing a concept plan for an entire neighbourhood was beyond my capacity, a subsection of the neighbourhood was selected as the study area for this research project.

3.2.2: Identifying and Assessing Stormwater Management Challenges in the Study Area

Understanding the current organization and conditions of the built and natural environments in the study area was my first step to understanding the stormwater management challenges. My methodological approach to identifying and assessing stormwater management challenges was initially based on strategies for establishing baseline conditions when conducting an environmental assessment. I was introduced to this methodology in ENVS 6186 Theory and Methods of Impact Assessment and have since consulted the assigned text, Kevin Hanna's *Environmental Impact Assessment: Practice and Participation* (2015), several times throughout the MES program. I adapted Hanna's (2015) baseline assessment strategy to fit the scope of this research project using strategies outlined in James LaGro Jr.'s *Site Analysis: Linking Program and Concept in Land Planning and Design* (2013).

Establishing the existing conditions included three steps: (1) information gathering; (2) data organization; and (3) analysis. The information gathering phase included assembling data from my on-site observation and a variety of secondary sources such as City of Toronto and TRCA staff reports, environmental assessments, and open data portals. After collecting the data, I organized the information by creating tables, maps, and sketches to make sense of the information I had gathered. Finally, I reviewed the organized data to identify key challenges to stormwater management at the neighbourhood-level that could be addressed using green stormwater infrastructure.

3.3.3: Developing the Proposed Concept Plan and Designs

Before I could begin designing the concept plan, I first needed to learn about the topics of watershed planning, stormwater management, and green infrastructure. Further, I needed to have a broad understanding of the current best practices within these fields and to examine built precedents. I consulted academic literature, public policy documents, and professional reports in the fields of urban environmental planning and design, landscape architecture, and engineering to compile a list of emerging planning trends and best practices for strengthening urban resilience to climate change and flooding through the use of green stormwater infrastructure within public spaces.

My decision to retrofit the roadways within the study area is because roads are the largest public space asset in most cities, far exceeding the amount of space dedicated to parks, natural areas, or other spaces for social and community connection. Urban roadways, especially low-volume and low-speed roads in residential areas, are an underutilized public space that have the potential to forward environmental and social needs of communities by reallocating how the roadway is used.

My inspiration for how to retrofit the roadways within the study area came primarily from City of Toronto design guideline manuals, including the *Green Streets Technical Guidelines* (Schollen & Company Inc. et al, 2017) and the *Complete Streets Guidelines* (Toronto, 2017a). The *Urban Street Stormwater Guide* (NACTO, 2017) complemented the City of Toronto's design guidelines and provided excellent case study examples from which to draw further real-world examples and lessons learned. From these resources, I created a simplified street classification system and green stormwater infrastructure selection tool (see Appendix B) adapted from the *Green Streets Technical Guidelines* (Schollen & Company Inc. et al, 2017) and *Urban Street Stormwater Guide* (NACTO, 2017).

My decision to revitalize the public green spaces within the study area is because these spaces can be intentionally designed as flood-resilient infrastructure, as well as spaces for active recreation and social connection. My inspiration for how to redesign the publicly owned green spaces within the study area came from both first-hand observations, courses taken during the MES program, and academic research. Government documents, such as the TRCA's *Living Cities Policies* (2014), the City of Toronto's *Official Plan* (2019), and Ontario's *Stormwater Management Planning and Design Manual* (2003), provided context of the scope of this research project. Planning projects that strive to strengthen a cities natural and structural capacity to adapt to flooding as a result of urbanization and climate change through the use of green stormwater infrastructure, such as the Netherlands *Room for the River Programme* (Rijkswaterstaat, 2010; Rotterdam, 2010) and the *Don Mouth Naturalization and Port Lands Flood Protection Project* (Waterfront Toronto, n.d. & 2016), were inspiration for the designs. Lastly, I consulted academic papers while drafting the concept designs to ensure that best practices were being incorporated into the plans.

The planning and design process was lengthy, stretching from March to June 2020. I drafted by hand many versions of each street and green space concept design before settling on the final designs that are included in this report using Adobe Illustrator. Drafting multiple concept plans helped me identify realistic interventions and the different possible configurations that could occur within the sites. Often, the strongest concept designs were created by merging multiple drafts together, pulling inspiration from built precedents, and by soliciting feedback from fellow environmental planning students and professors.

3.3.4: Plan Visualization

Communicating the proposed concept plan through easy-to-understand visuals was an integral component of this project for me. I believe that visual representations of urban planning and design theories, concepts, and visions are essential for community engagement and decision-making purposes. Further, as a student researcher, I felt the only way I could explore the feasibility of my proposed concept plan to mitigate flood risk using green stormwater infrastructure was to illustrate my plan through visual designs.

My lack of experience using design software was a significant challenge that I faced during this research project. I spent many hours learning how to use ArcGIS to display the spatial organization of the study area and my vision for the site. However, following months of effort I was struggling to produce the graphics in a format I was happy with. After testing out other design software, I decided to move forward with Adobe Illustrator as my software of choice. I found Illustrator to be a user-friendly program with several online tutorials available for beginners. Illustrator allowed me to import screenshots of maps into the program and add layers to display the existing conditions and concept plan in a clear and clean format.

This was a time consuming but rewarding process. Without any prior knowledge, I have succeeded in communicating the vision of my concept plan graphically. Further, many job applications for entry-level urban planners highlight as an asset experience using design software, such as ArcGIS and Adobe Illustrator. I am happy that I was able to leverage this research project to develop new design skills, in addition to my much greater understanding of site design, that will serve me in my career as a practicing planner.

4. The Study Area and Surrounding Geographic Context

4.1: Overview

This section should be consulted to gain background knowledge of the study area and the surrounding geographic context examined during the conceptual planning and design study. Section 4.2 provides an overview of the study area, a 1.65 square kilometre area within Toronto's Rockcliffe-Smythe neighbourhood along Black Creek and the Humber River. Section 4.3 provides high-level information on the surrounding geographic area, from a municipal and watershed perspective, to provide context to the stormwater management and environmental challenges that will be examined in subsequent sections of the report.

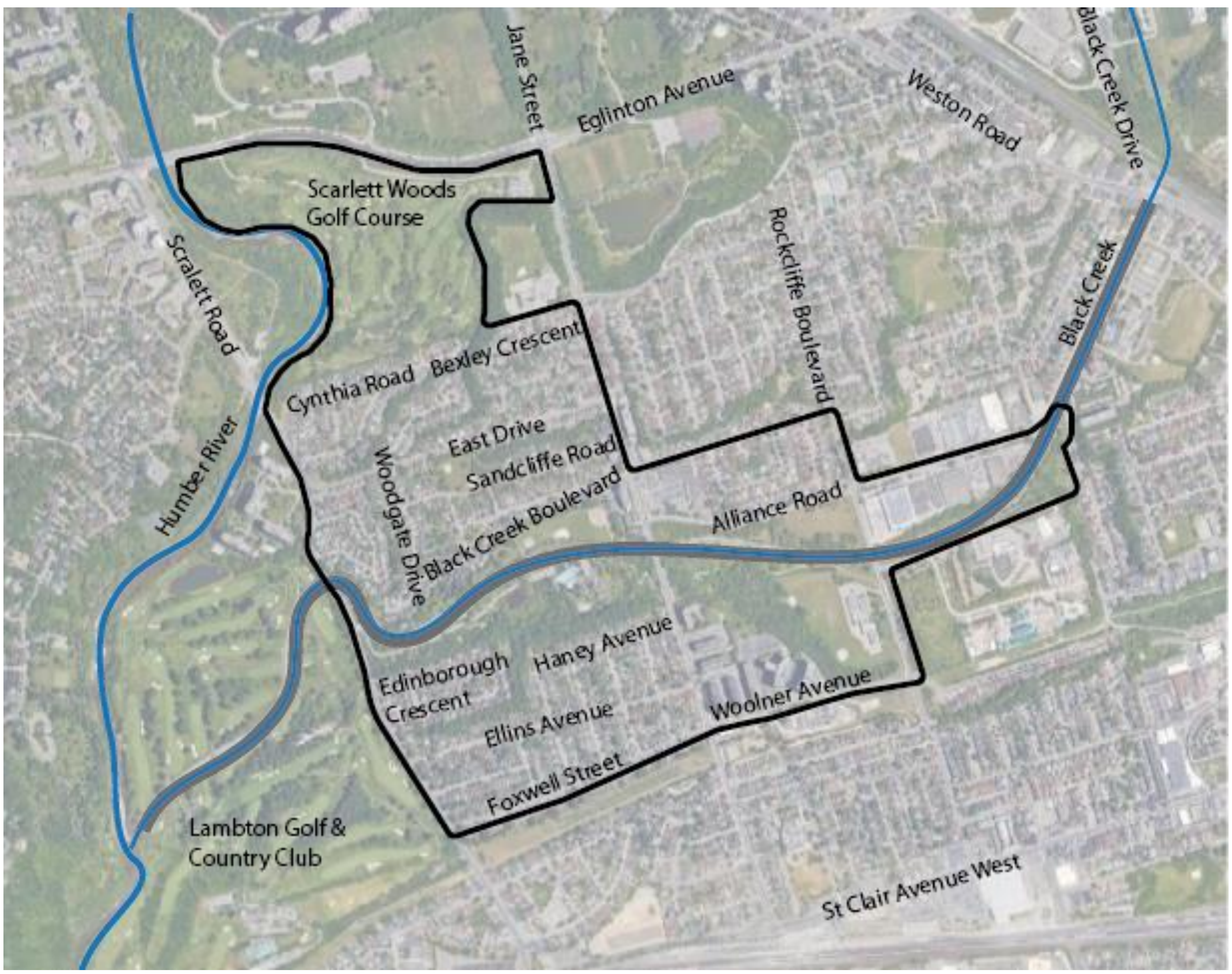


Figure 1: Study Area Context Map

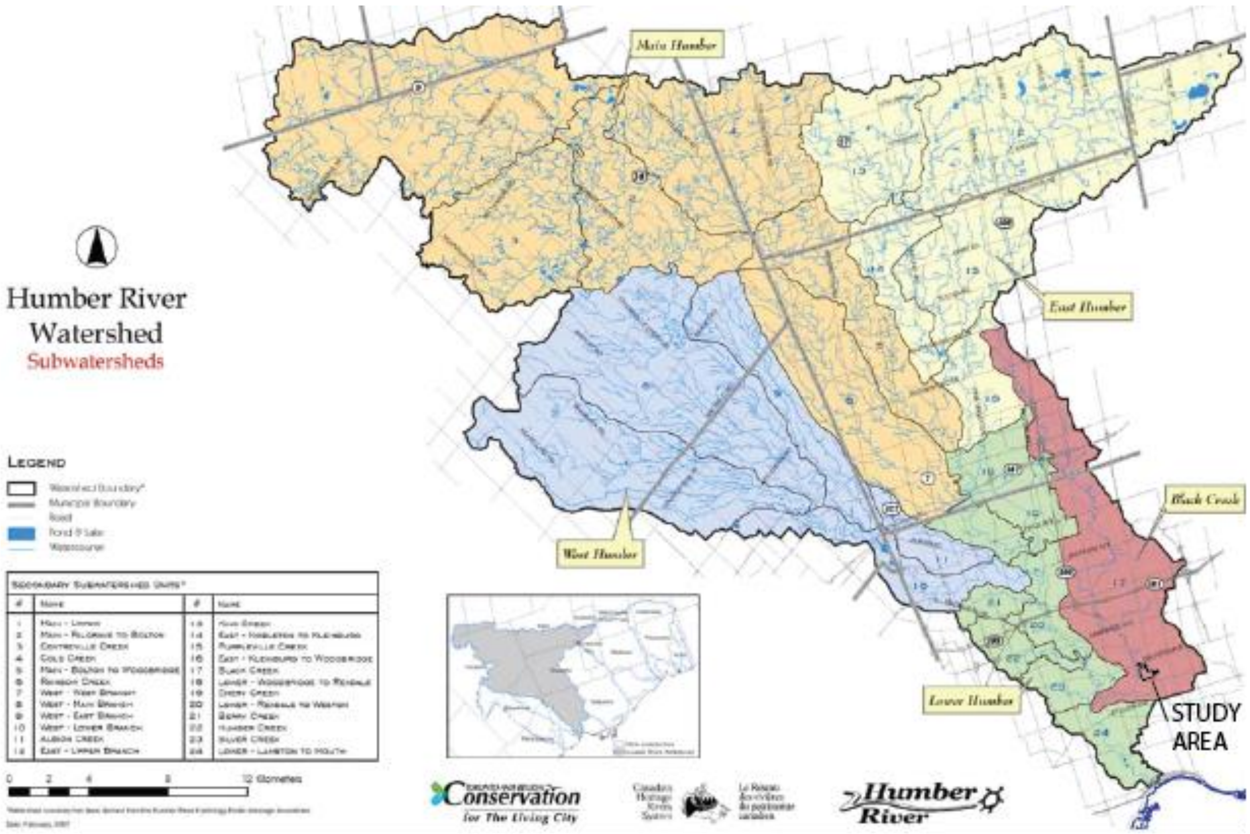


Figure 2: Watershed and Subwatershed Context Map (TRCA, 2008a, p. 22)

4.2: The Study Area

The study area is a 1.65 square kilometre area located within the Rockcliffe-Smythe neighbourhood in the City of Toronto's west end. The study area is bound by Eglinton Avenue West to the north, Jane Street/ Hilldale Road to the east, Foxwell Street/ Woolner Avenue to the south, and Scarlett Road to the west. Located along the regulatory floodplains of Black Creek and the Humber River, the study area has a high vulnerability to flooding. Many sites within the study area have experienced surface and basement flooding during large precipitation events due to riverine flooding and storm sewer overflows (Toronto, 2018b).

The study area includes:

- Seven public parks: Smythe Park, Black Creek Park West, Black Creek Park East, Rose Valley Park, Noble Park, Brendwin Circle Parkette, and Cynthia-Frimette Parkette;
- One publicly owned and operated golf course: Scarlett Woods Golf Course;
- One public school: Rockcliffe Middle School; and
- 30 publicly owned streets.

2.3: The Surrounding Geographic Context

2.3.1: The Rockcliffe-Smythe Neighbourhood

The Rockcliffe-Smythe neighbourhood is situated in the west end of Toronto. The neighbourhood has a population of approximately 22,246 residents with a population density of 4,414 people per square kilometre (Toronto, 2016). The built form of the neighbourhood is predominantly residential, with pockets of mixed-use and employment areas. Black Creek, a channelized watercourse, flows through the centre of the neighbourhood, while the Humber River flows along the northwestern boundary. Several parks and open green space areas are located along the watercourses, while a small number of small parks and parkettes are distributed away from the watercourses within the residential area.

The land that makes up Rockcliffe-Smythe has undergone many land-use changes. In the 1920s, Conn Smythe converted a significant portion of the agriculture land around Smythe Park into a gravel quarry. Residential and associated infrastructure development of the area began following the Second World War to provide housing for veterans and their families (Reeves, 2018). In 1954, less than a decade after the war, Hurricane Hazel hit Toronto, pounding the city with 210 millimetres of rain causing extensive property damage and the loss of 81 lives. Hurricane Hazel altered Toronto's planning direction, leading to the creation of conservation authorities and watershed planning and regulations (TRCA, n.d.-b). Had watershed regulations been in place in the 1940s, the development of Rockcliffe-Smythe within the Black Creek floodplain would have been prevented. Instead, measures, such as the straightening and channeling of Black Creek, were taken to prevent future flooding in the area by installing infrastructure designed to convey stormwater out of the urbanized area as quickly as possible (TRCA, 2008b, p. ii). In hindsight, the channelization of Black Creek, and several other hard engineered stormwater infrastructure projects, have increased flood-risk in Rockcliffe-Smythe. Today, the neighbourhood is considered completely urbanized and is known for riverine flooding and sewer failure (TRCA, 2014a).

Several flood risks studies have been conducted to determine the extent of the issue, including the *Black Creek (Rockcliffe Area) Riverine Flood Management Class Environmental Assessment* (TRCA, 2014a) and the *Basement Flooding Study Area 4 and Combined Sewer Overflow Control Environmental Assessment* (XCG Consulting Ltd., 2014). Rockcliffe-Smythe has the highest flood-risk out of the TRCA's 41 identified Flood-Vulnerable Clusters (Plato, 2019). Riverine flooding of Black Creek within Rockcliffe-Smythe has, and will continue, to cause significant damage to the built-environment and risk the health and wellbeing of the local residents unless substantial efforts to improve the local stormwater management infrastructure is taken (Plato, 2019; TRCA, 2014a).

2.3.2: City of Toronto

The City of Toronto, located in Southern Ontario on the shore of Lake Ontario, is Canada's largest municipality with a population of approximately 2.96 million (Toronto, 2017b). Toronto's land-use and hydrology have undergone significant change from pre-development conditions as a result of urban development and industrialization. The level of urbanized land within the city contributes to several stormwater management problems, including high runoff quantities, high peak flow, combined sewer overflows, poor water quality, and riverine and basement flooding.

In the last decade Toronto has experienced several major flood events, resulting in billions of dollars in flood and erosion damage (Green Communities Canada, 2019, p. 3). The quantity of runoff generated by current rainfall volumes is overwhelming the capacity of Toronto's stormwater infrastructure. Projections estimate that the population of the Greater Toronto Area is going to increase by 49.6 percent between 2018 and 2046 (Ontario, 2019), adding further stress to the local watershed and stormwater management system. To prevent widespread flooding and sewer failure, drastic action will need to be taken by the City's planning and policy departments to increase the capacity of the stormwater management and drainage systems.

2.3.3: Black Creek Subwatershed

Black Creek is the smallest of five subwatersheds that make up the Humber River watershed and has a drainage area of approximately 65 square kilometres. Black Creek flows from the City of Vaughan, near the intersection of Weston Road and Rutherford Road, to the Rockcliffe-Smythe neighbourhood in the City of Toronto, where the creek joins the Humber River in the Lambton Golf course near Scarlet Road and Dundas Street West. The Black Creek subwatershed is almost entirely developed and the limited vegetated area that remains is characterized by low-permeable clay soil (TRCA, 2008b, p. 29). South of the 401 Highway, a significant portion of the creek has been straightened and channelized in an effort to prevent flooding (TRCA, 2008b, p. 28). Today, the Black Creek subwatershed is known for its numerous stormwater management issues including, but not limited to, riverine flooding, flashy storm flows, sewer failure, and poor water quality.

2.3.4: Humber River Watershed

The headwaters of the Humber River begin on the Niagara Escarpment and the Oak Ridges Moraine, a glacially formed hilly landscape north of Toronto, and then flows 126 kilometres south into Lake Ontario. The Humber River watershed is 911 square kilometres which includes 1,800 kilometres of waterways, approximately 600 bodies of water, and is home to more than 850,000 residents across ten municipalities (TRCA, n.d.-c). The river system includes three main branches; the East Humber, West Humber, and

Main Humber, which joins to form a single stream, the Lower Humber, just north of Toronto; and has many tributaries (see Figure 2).

The Humber River watershed consists of both rural and urban ecosystems with a variety of land uses. The northern portion of the watershed is predominantly protected conservation and agricultural lands under the *Niagara Escarpment Planning and Development Act* (Ontario, 1990), *Oak Ridges Moraine Conservation Act* (Ontario, 2001), and the *Greenbelt Act* (Ontario, 2005). Agricultural land-use activities are associated with deforestation in order to make space for crops and grazing land. The effects of agricultural activities on the watershed system include the rise in waterbody temperature due to the loss of tree cover, reduction in water quality due to fertilizer and pesticide use, and in some historical cases, the filling of wetlands and tributaries. The southern portion of the watershed, on the other hand, is characterized by urban land use, especially in the Cities of Brampton, Vaughan, and Toronto. Urbanization of the watershed is associated with significant changes to how water flows through a landscape as a result of the increase in impervious land cover (Forman, 2014). The results of urbanization of the Humber River watershed include an increase in seasonal fluctuation and higher peak flow volumes, increased shoreline erosion potential, decreased water quality from industry, sewage treatment, and untreated runoff, and an increase in flood risk.

5: Study Area Challenges: Existing Conditions and Assessment

5.1: Overview

This section of the report summarizes the current environmental conditions within the study area in order to establish reference conditions to be used when creating and evaluating the proposed concept plan and designs. Section 5.2 describes the existing conditions of the natural and built environments within the study area in the context of stormwater management. Section 5.3 describes my assessment of the existing conditions outlined in Section 5.2. This section outlines the stormwater management challenges within the study area, which the concept plan mitigates using green stormwater infrastructure.

Overall, my assessment of the existing conditions is that the study area does not have adequate natural or engineered infrastructure in place to manage stormwater runoff and mitigate the effects of flooding. Because the study area was developed before floodplain management planning policies and regulations were in place, the neighbourhood was built within the regulatory floodplain. Legacy stormwater management practices have exacerbated riverine flooding and sewer failure within the study area. Without intervention, the study area will continue to experience flooding in the future as heavy rainfall and melt events become more frequent and severe as a result of climate change.

5.2: Existing Conditions

5.2.1: Natural Environment

5.2.1.1: Hydrology/ Topography

The topography in the study area consists of terrain ranging from approximately 100 metres to 129 metres above sea level. Most of the area slopes gently south towards Black Creek, while the northwest portion of the study area slopes gently west towards the Humber River (XCG Consulting Ltd., 2014, p. 31; Topographic-map.com, n.d.). The lowest elevations are observed along the banks of Black Creek and the Humber River, while the highest elevations are observed west of Jane Street between Bexley Crescent and East Drive. The large low-lying areas adjacent to Black Creek and the Humber River are located within the extent of the regulatory floodplain, an area that will flood during a 100-year storm event (TRCA, n.d.-a). The majority of this area is covered by impervious surfaces, in the form of pavement, buildings, and other hardscaping, that generate large volumes of stormwater runoff as a direct result of the low infiltration rate (Larco, 2015; Matthews et al., 2015; Tingsanchali, 2012).

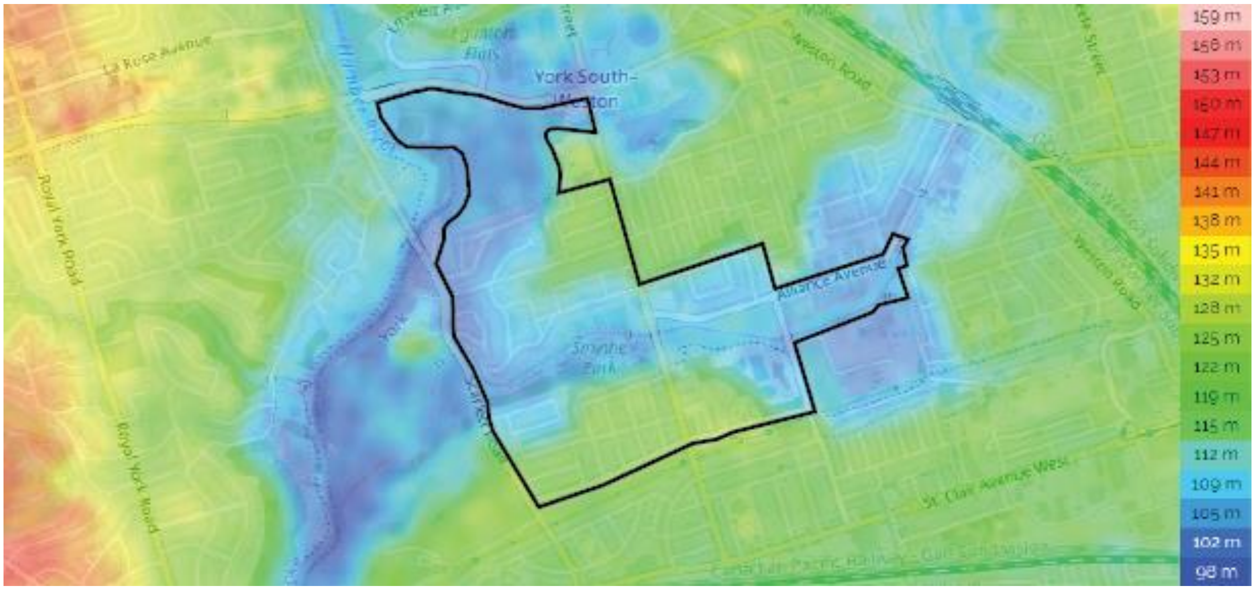


Figure 3: Topography Context Map (Topographic-map.com, n.d.)

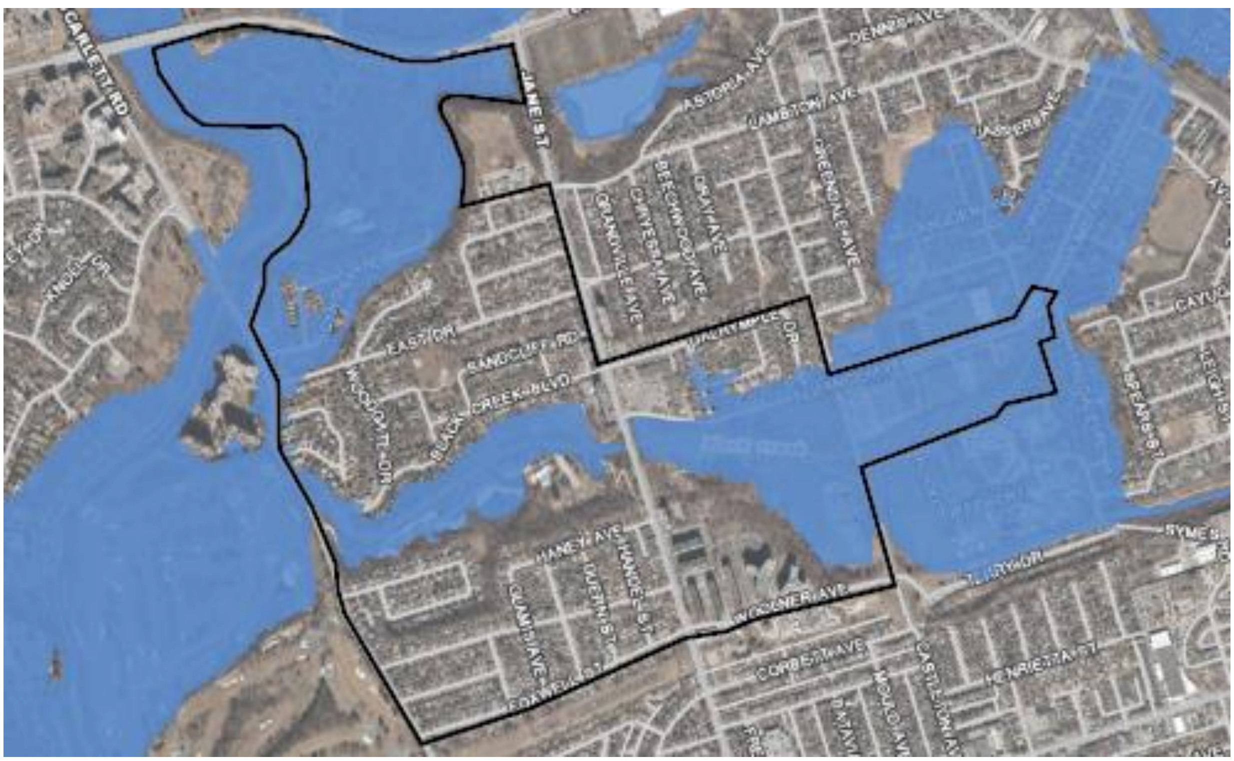


Figure 4: Floodplain Context Map (TRCA, n.d.-a)

5.2.1.2: Vegetation and Habitat

The study area is considered completely urbanized with limited natural vegetation and wildlife habitat (TRCA, 2014a). There are no Environmentally Significant Areas or Significant Wildlife Habitat (Toronto, n.d.), despite that fact that a significant portion of the study area is within the *Natural Heritage*

System. Further, no green infrastructure projects have been completed by the City of Toronto or the TRCA within the study area to my knowledge.

Figure 5: Natural Heritage System Context Map (Toronto, 2019)

4.2.1.3: Green Space System

The study area has a diverse green space system, comprised of sites designated as *Natural Areas*, *Parks*, and *Other Open Space Areas* in Toronto's Official Plan (Toronto, 2019, 4.3.1).

Thirty-four percent of the study area, 560,500 square metres (56.05 hectares), is within the green space system. The green space system consists of nine sites: Cynthia-Frimette Parkette, Brendwin Parkette, Noble Park, Rose Valley Park, Smythe Park, Black Creek Park East, Black Creek Park West, Scarlett Woods Golf Course and the grounds of Rockcliffe Middle School. The general form of the green spaces are lawns with trees and dilapidated recreation amenities. For a detailed description of the existing conditions of each site, see Section 6.3.3.

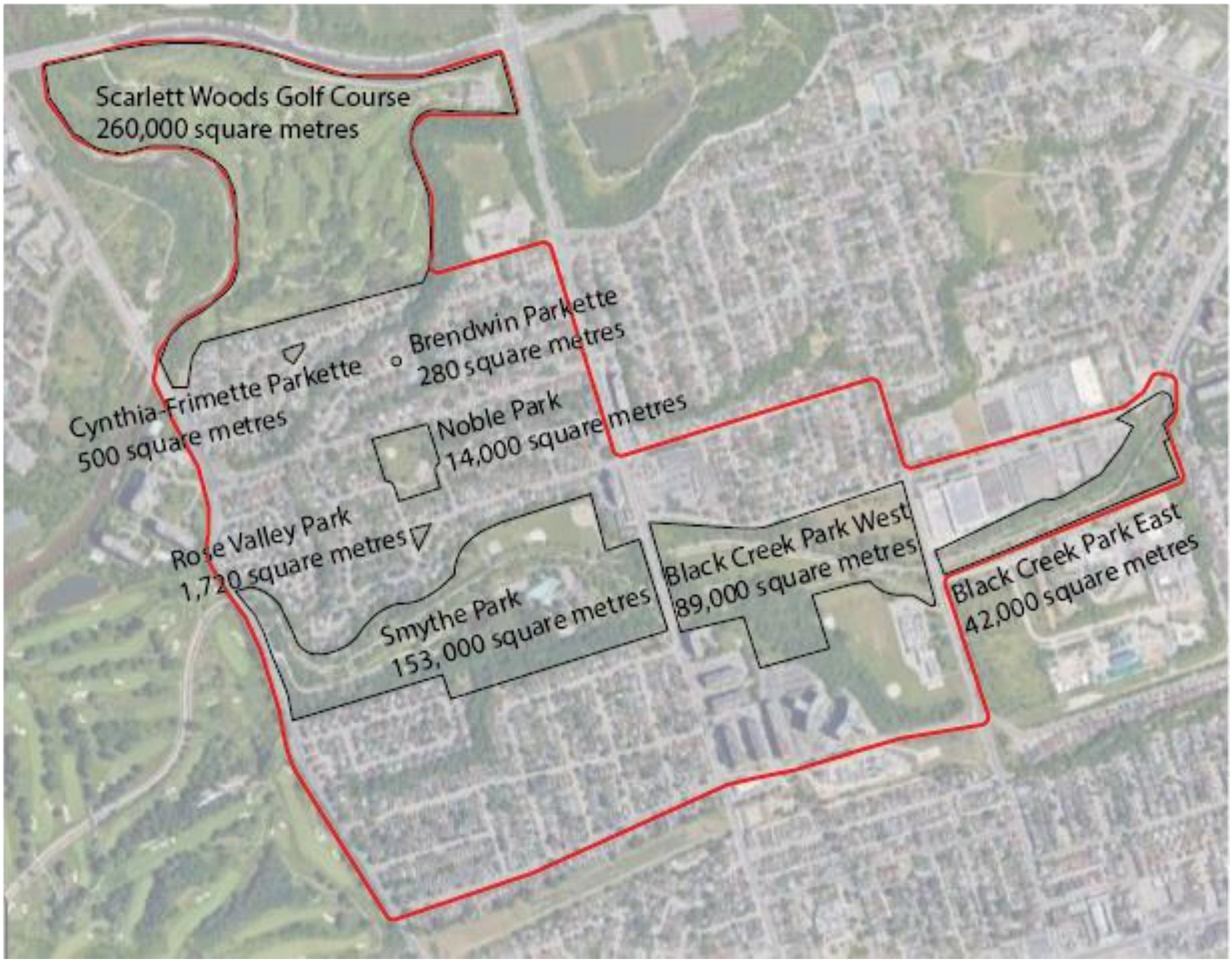


Figure 6: Public Green Spaces within the Study Area

5.2.2: Built Environment

5.2.2.1: Land Use

The study area is considered completely urbanized (TRCA, 2014a) and is composed of a mixture of land use designations, including *Neighbourhoods*, *Apartment Neighbourhoods*, *Mixed Use Areas*, *Natural Areas*, *Parks*, and *Other Open Space Areas* (Toronto, 2019).

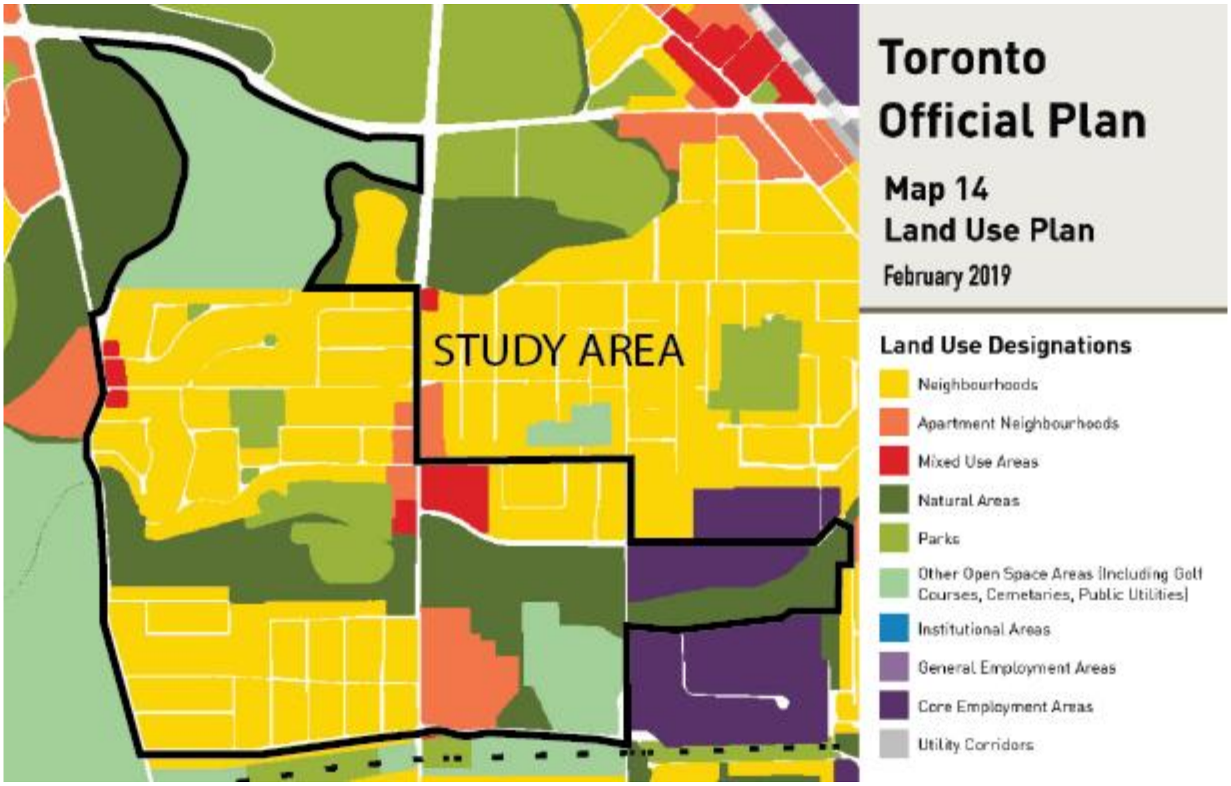


Figure 7: Land Use Context Map (Toronto, 2019)

5.2.2.2: Road Network

The public road network within the study area includes 30 roadways. Of the 30 roads, 24 are local streets, 5 are collector streets, and 1 is a minor arterial street. Table 1 summarizes the City of Toronto's road classification criteria (Toronto, 2018a & 2018c), while Figure 8 and Table 2 display the street classifications for roads within the study area.

The street arrangement includes a combination of grid patterned rights-of-way, typical of pre-1950 planning, and looped crescents, typical of post-1950 road design in Toronto (Toronto, 2017a, p. 34-37; Schollen & Company Inc. et al, 2017, p. 50). The sidewalk arrangement is irregular; streets have either no sidewalks, or a narrow sidewalk on one or both sides. Where there are sidewalks, they are typically directly adjacent to the curb; there is a notable lack of planting/ furnishing zones between the sidewalk and vehicle lane curb. Further, private driveways are common within the residential streets, as is on-street parking on one or both sides of the street. Based on my observations, the typical built design of the streets within the study area are designed mainly to facilitate car movement.

Street Classification	Primary Function	Traffic Volume (vehicles/ day)	Legal Speed Limit (km/hr)	Surface Transit Route (passengers/ day)	Heavy Truck Restrictions
Local	Access to Property	<2,500	40 - 50 km/hr	-	Restrictions preferred
Collector	Access to Property & Traffic Movement	2,500 - 8,000	40 - 50 km/hr	<1,500	Restrictions permitted
Minor Arterial	Traffic Movement	8,000 - 20,000	40 - 60 km/hr	1,500 - 5,000	-
Major Arterial	Traffic Movement	>20,000	50 - 60 km/hr	>5,000	-
Expressway	Traffic Movement	>40,000	80 - 100 km/hr	-	-

Table 1: City of Toronto's Road Classification Criteria (Toronto, 2018a)

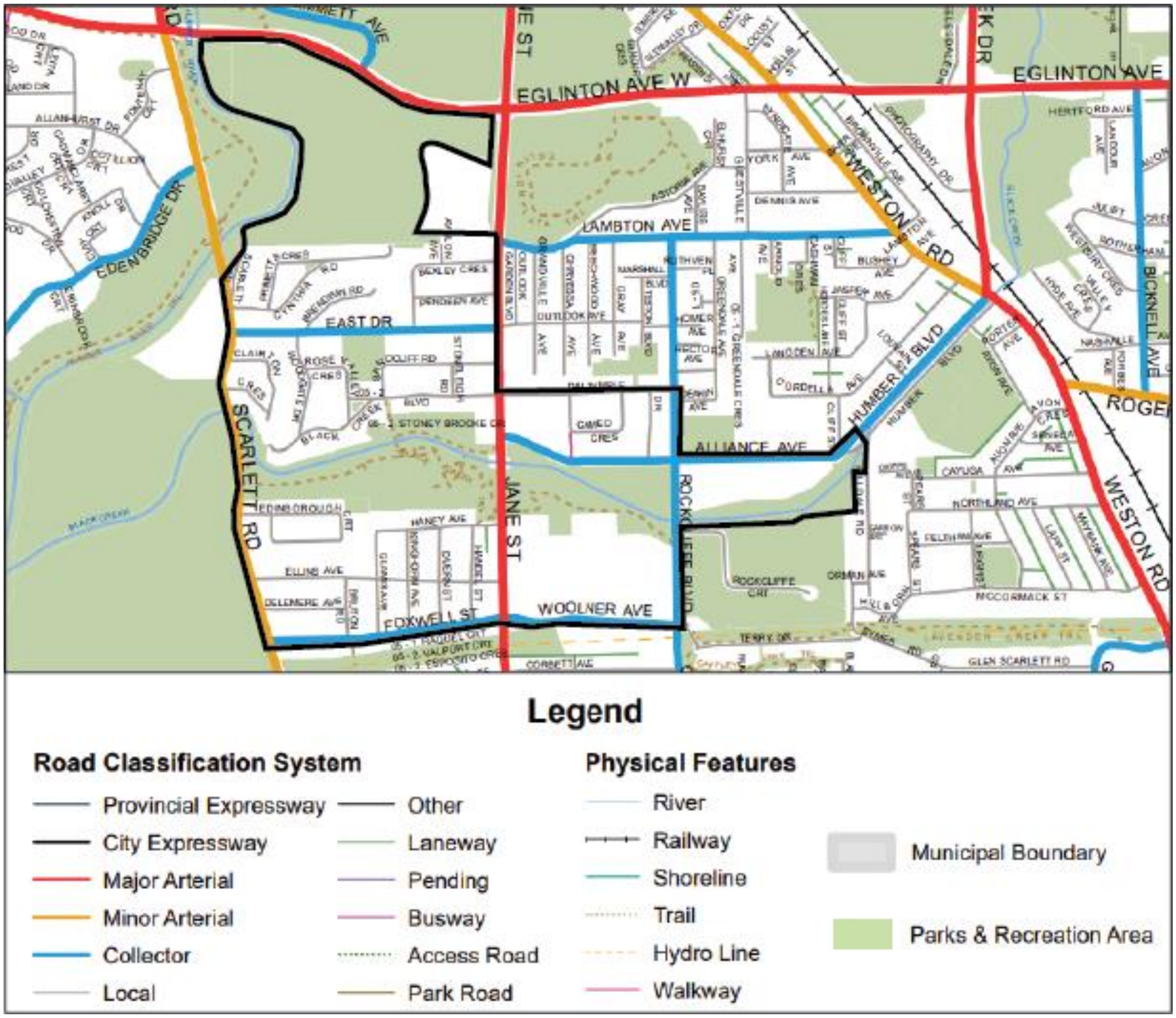


Figure 8: Road Classification System Context Map (Toronto, 2018c).

Street Name	Local	Collector	Minor Arterial
Alliance Avenue		X	
Avalon Avenue	X		
Bexley Crescent	X		
Black Creek Boulevard		X	
Brendwin Road	X		
Bruton Road	X		
Cameo Crescent	X		
Clairton Crescent	X		
Cynthia Road	X		

Dalrymple Drive	X		
Delemere Avenue	X		
Duern Street	X		
East Drive		X	
Edinborough Crescent	X		
Ellins Avenue	X		
Foxwell Street		X	
Frimette Crescent	X		
Glamis Avenue	X		
Handel Street	X		
Haney Avenue	X		
Kinghorn Avenue	X		
Old Scarlett Road	X		
Pendeen Avenue	X		
Rose Valley Crescent	X		
Sandcliff Road	X		
Scarlett Road			X
Stoneleigh Road	X		
Stoney Brooke Drive	X		
Woodgate Drive	X		
Woolner Avenue		X	

Table 2: Classification of Streets in the Study Area (Toronto, 2018c).

5.2.2.3: Stormwater Management Facilities

The study area is serviced by both a separated sanitary and storm sewer system, and a combined system. Storm sewers in the study area discharge into Black Creek or the Humber River through outfalls. There are three combined sewer overflows, all situated along Rockcliffe Boulevard, that are designed to discharge untreated combined wastewater and stormwater into local storm sewers during typical conditions or directly into the watercourses when the infrastructure is over capacity (XCG Consulting Ltd., 2014, p. 6). Within the study area, there are separated sanitary sewers, separated storm sewer, combined sewers, 141 sanitary sewer system manholes, 197 storm sewer system manholes, 113 combined sewer system manholes, 25 storm sewer outfalls, 3 combined sewer control structures and outfalls, and 0 larger storage facilities (XCG Consulting Ltd., 2014, p. 6).

No green stormwater management infrastructure has been installed on public land within the study area. This observation is based on my research and was confirmed via email correspondence with the TRCA on March 12, 2020.

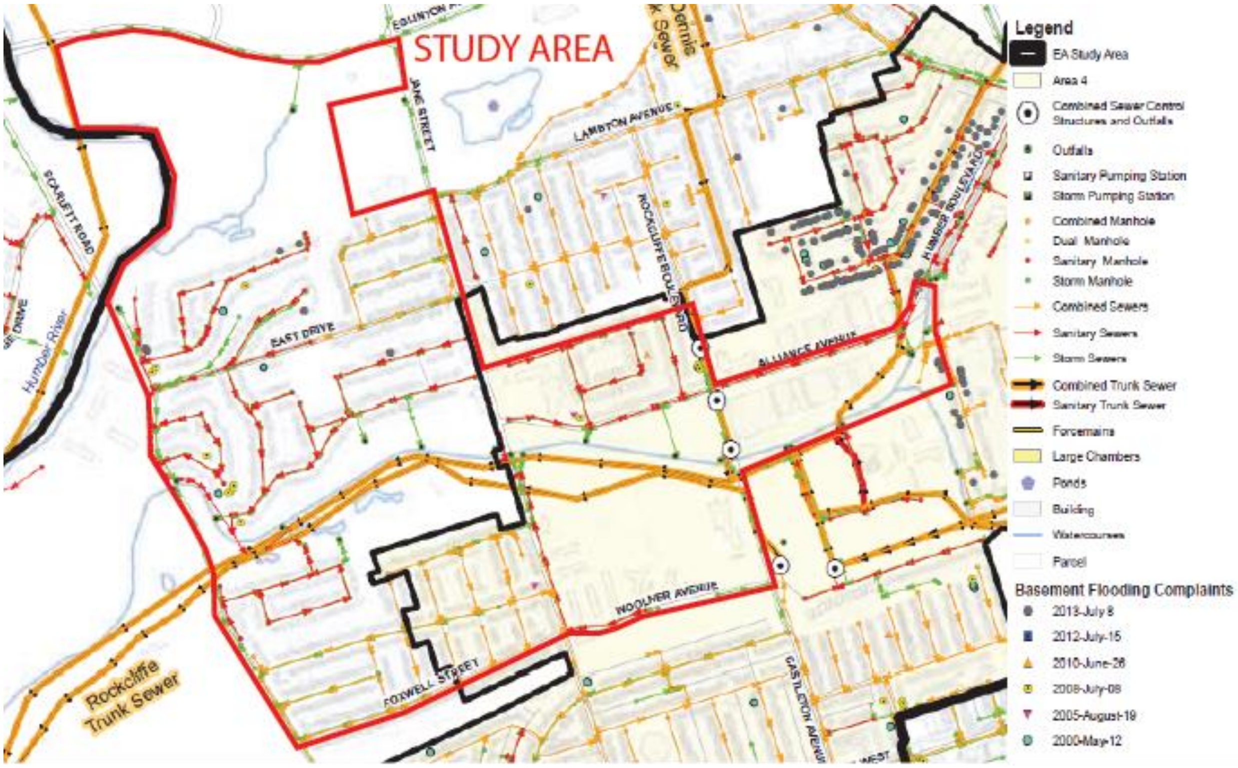


Figure 9: Sewer System Context Map (XCG Consulting Ltd., 2014, p. 6)

5.3: Assessment of the Existing Conditions

5.3.1: Natural Environment

5.3.1.1: Hydrology/ Typography

Riverine flooding—when water flowing in a watercourse spills over their banks and floods adjacent lands—is a high risk within the study area due to the neighbourhood's location with the regulatory floodplain (TRCA, 2014a). In the case of Black Creek, riverine flooding is caused by heavy storms that flow over the channeled banks into the adjacent urbanized floodplain. Riverine flooding is exacerbated by development that limits the capacity for water to flow through a watercourse, such as bridges, culverts, or railroad crossings, which cause blockages and bottlenecks (TRCA, 2014a). The culvert beneath Jane Street, for example, is too small to manage the volume of water that flows through Black Creek which results in significant riverine flooding east of the culvert (see Figure 10).

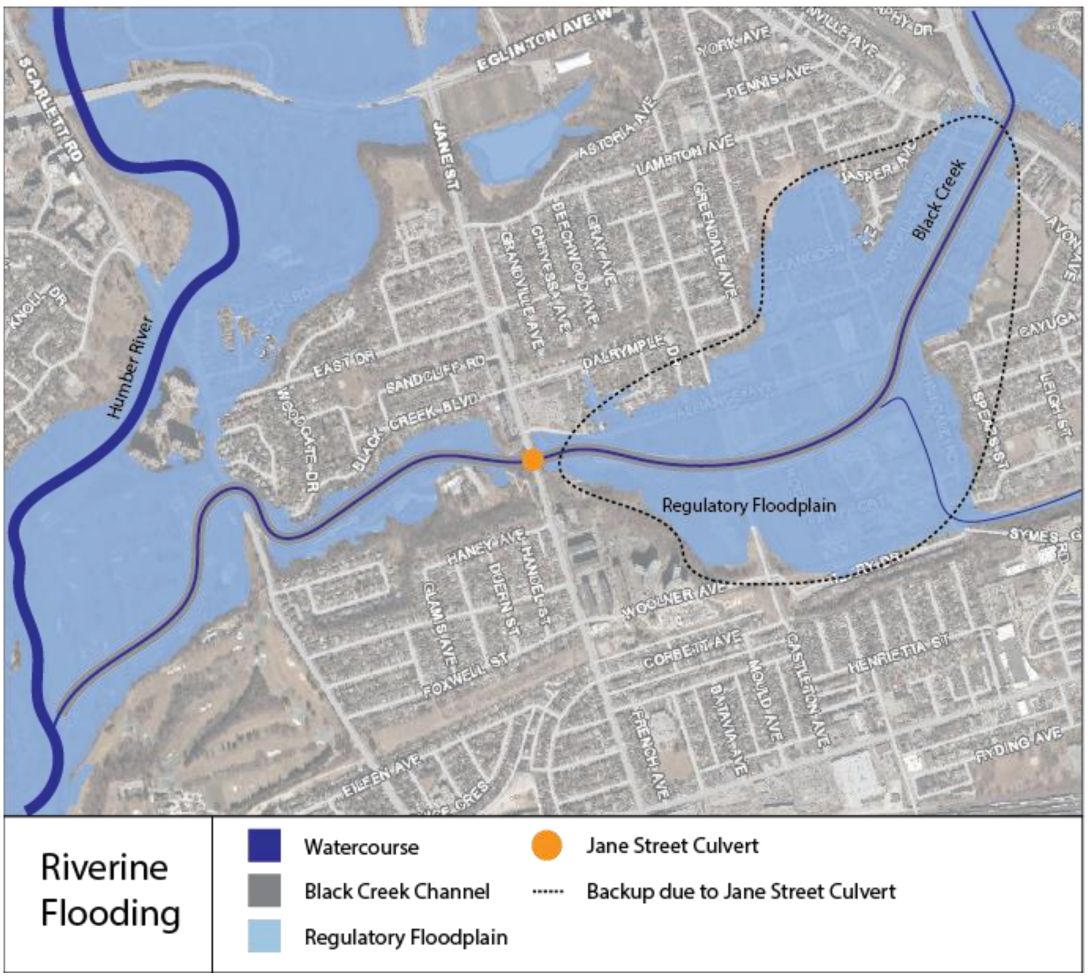


Figure 10: Riverine Flooding of Black Creek due to Grey Stormwater Infrastructure

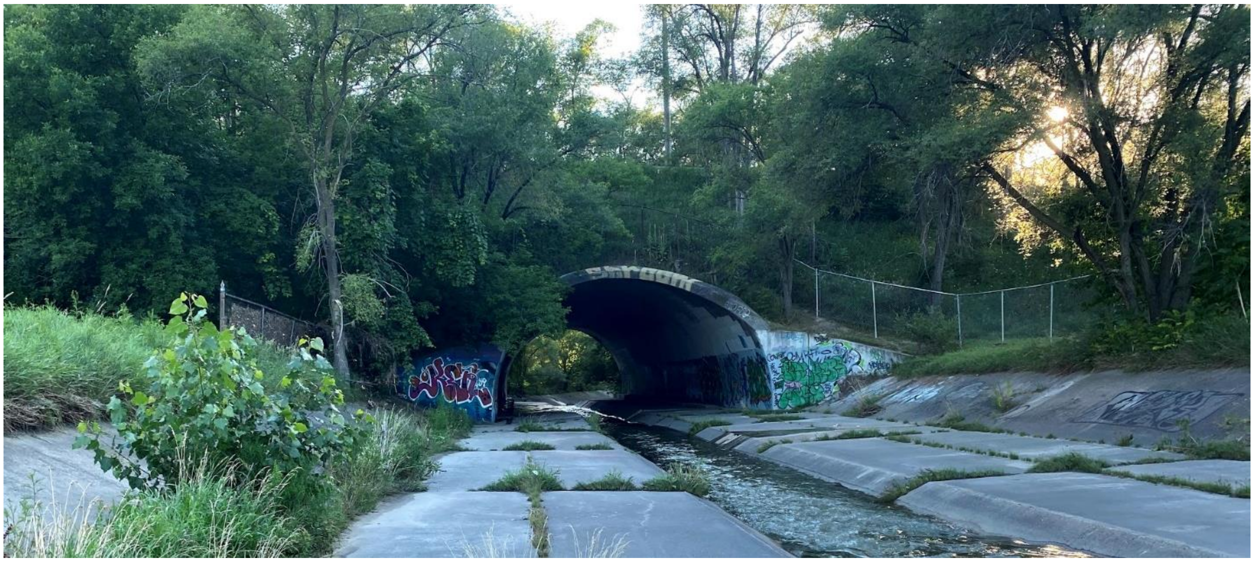


Figure 11: The Jane Street Culvert (Photo Credit: Alana Wittman, July 2020)

5.3.1.2: Vegetation and Habitat

The study area has poor quality vegetation and habitat for plant populations, terrestrial species, and aquatic species. The built-up sites and lack of vegetative cover within the study area adversely affect the infiltration rate, resulting in large quantities of stormwater runoff. Further, the patchy spatial distribution of vegetation affects the movement and distribution of species and limits the opportunity for ecological succession due to land use, the management of public space, and the lack of permeable soils (Forman, 2016).

There are significant opportunities to improve the quality and quantity of vegetation and habitat within the study area. Revitalization of public space within the study area can increase vegetation cover, resulting in higher rates of stormwater capture and infiltration, improve wildlife habitat and mobility, and provide numerous other ecosystem services by reconnecting urban areas with natural systems.

5.3.1.3: Green Space System

The nine green spaces within the study area are an important piece of urban infrastructure, however my observations lead me to conclude that the current design of the sites limits their potential to provide services beyond recreation. Hough (1995, p. 13-14), reflects that “recreation has become the exclusive land use for the city’s public open space[s]” and this design form is a legacy of park planning history and values. The design of parks for recreation often result in large lawn areas that provide “low-structure plant cover” and minimal overland drainage during rainfall or snow melt events compared to predevelopment conditions (Forman, 2016, p. 1659). None of the green spaces in the study area have been designed to reflect natural or semi-natural area, such as healthy woodlands or marine environments. This concerns me, considering six of the nine green spaces are located within the regulatory floodplain will take on riverine floodwater spillover over the banks of the Humber River and/ or Black Creek during heavy rainfall and snow melt events.

The public green spaces within the study area represent untapped potential to manage stormwater naturally. Revitalizing the green spaces based on a green stormwater management approach to design, could strengthen the study areas resilience to riverine flooding (Higgs, 2003; Shannon, 2013).

5.3.2: Built Environment

5.3.2.1: Land Use

Decisions on how land is used and covered is a significant determinant of how water flows on a site (Forman, 2016). The urbanization of the land within the regulatory floodplain was a poor land-use decision that altered water dynamics within the study area and increased the risk of surface flooding for local and downstream communities. In lieu of the acquisition of all privately-owned land within the regulatory floodplain into public ownership, I recommend the land use of publicly owned land within the regulatory floodplain be re-evaluated to determine how green stormwater management objectives can be achieved.

Public parks, streets, and plazas can be redesigned as flood protection infrastructure that will build the resilience to flooding through the revitalization of public spaces. Designing public spaces as sponges to soak up stormwater helps cities mitigate and adapt to heavy rainfall and melt events, while also creating new greenspaces to be enjoyed by all. This approach is referred to as green infrastructure, an ecosystem-based approach to stormwater management, is a key method of building urban resilience to flooding (Pickett and Cadenasso, 2017; Li et al, 2019).

5.3.2.2: Road Network

The street network is a significant contributor to flooding and sewer failure as a direct result of the quantity of stormwater runoff they generate.

Based on my observations, the road network within the study area was designed to facilitate the movement of cars. It appears that few considerations were given to the movement of water over the surface of the roadways. The notable lack of permeable surfaces within the road network results in high surface runoff rates. The generated stormwater runoff from the streets and sidewalks enter the sewer system or is captured in low lying areas, such as underpasses and potholes.

Streets provide a significant opportunity to improve overland drainage when designed, or redesigned, using a green stormwater management approach. Urban roadways, especially low-volume and low-speed residential streets, can be redesigned as multifunctional spaces that deliver mobility and stormwater management requirements. Considering 23 of the 30 streets within the study area are classified as local (Toronto, 2018c), there is significant potential to improve overland drainage and relieve strain on the overburdened sewer system by incorporating green stormwater infrastructure into the road network. Bioretention facilities, for example, are vegetated depressions that can be incorporated into roadways to capture, filter and infiltrate runoff where it is generated (Trowsdale & Simcock, 2011; Chin, 2016; Davis et al, 2009). Bioretention reduces, slows, infiltrates and filters the runoff before it enters local water bodies, reducing the risk of flooding and sewer failure (Trowsdale & Simcock, 2011; Chin, 2016; Davis et al, 2009).

5.3.2.3: Stormwater Management Facilities

The stormwater management system in the study area was designed based exclusively using the grey stormwater approach that aims to convey runoff away from the built-up area as quickly as possible using hard infrastructure. As discussed in Section 2, this approach is problematic because the grey infrastructure results in significant fluctuations in the peak flow and water level (Forman, 2016). In the case of Black Creek, it is common for water to flow over the banks into the floodplain which causes riverine flooding, sewer failure, and combined sewer overflows (XCG Consulting Ltd., 2014).

The local dependence on the conveyance system to manage stormwater runoff causes flooding. The lack of source control infrastructure, that manages stormwater runoff in close proximity to where it is generated through infiltration, is a significant challenge that can be overcome by implementing a hybrid green and grey stormwater management system that balances natural hydrology with human land use and development. Moving away from the structural approach to flood control to a more natural green infrastructure approach can reduce the likelihood of riverine flooding and combined sewer overflows by reducing the strain on municipal stormwater infrastructure (TRCA, 2014a; Kondo et al, 2015).

6. The Proposed Concept Plan and Designs

6.1: Overview:

In this section, I outline my proposed concept plan (Section 6.2) and designs (Section 6.3) that reduce flood risk in the study area. This work is based on my assessment of the existing conditions (Section 5.3) and current best practices for green stormwater management outlined in scholarly and practical studies. Further, the concept plan and designs respond to the City of Toronto's *Official Plan* (2019) and *Green Streets Technical Guidelines* (Schollen & Company Inc. et al, 2017) which encourage the use of green infrastructure to improve the management of stormwater and urban resilience to climate change.

6.2: Concept Plan

6.2.1: Overview:

The concept plan includes two types of retrofits: green stormwater streets (Section 6.2.2) and public green spaces (Section 6.2.3). The concept plan puts forward innovative solutions to local flooding issues that transforms underutilized public lands into multifunctional green stormwater management assets. The proposed 1.65 square kilometre study area provides sufficient scale to implement green stormwater management strategies to achieve ambitious stormwater management and climate change adaptation outcomes that will make Rockcliffe-Smythe a safer and healthier community.

Three principles of planning and design that I considered when developing the concept plan were multifunctionality, connectivity, and resiliency. The proposed concept plan is an attempt to mitigate the impacts of flooding within urban public spaces that have diverse and conflicting uses. Multifunctionality, in the context of this project, refers to interventions that improve stormwater management while simultaneously fulfilling local environmental, community, and economic needs (Rouse & Bunster-Ossa, 2013). Connectivity of the proposed green stormwater infrastructure features need to facilitate system coordination with the existing grey infrastructure network while also reconnecting the city to natural systems (TRCA, 2014b). Finally, green infrastructure that strengthens the resilience of the stormwater management system will enable the system to recover and adapt to external stresses or strains (Heltberg et al, 2009; Pickett et al, 2013; Bohland et al, 2019). The application of these principles allowed me to create a concept plan that reduces local vulnerability to riverine flooding and sewer failure by improving overland drainage.

6.2.2: Street Retrofits

6.2.2.1: Goals, Objectives, and Outcomes

Goal	Restore the ecological and hydrological functions of streets through the incorporation of green stormwater infrastructure into sidewalks and vehicle lanes.
Objective	Retrofit the streets within the study area into Green Stormwater Streets.
Outcomes	• Reduced impervious area by reconstructing streets and the natural drainage system; • Increased source control which reduced runoff quantity and increased infiltration rates; • Increased friction which reduced peak flow and water velocity; • Reduced strain on the existing grey infrastructure system and limit fluctuations in local watercourse levels by reducing the amount of runoff that enters the pipe infrastructure system; and • Expanded urban tree canopy and soil volumes which improve the water quality and recharge rate.

Table 3: Street Retrofit Goals, Objectives and Outcomes

6.2.2.2: Green Stormwater Streets

A Green Stormwater Street, within the context of this paper, are roads that incorporate green stormwater infrastructure to restore the ecological and hydrological functions of streets. The Green Stormwater Streets are designed to complement the existing grey infrastructure by diverting runoff from the sewer system into green stormwater infrastructure assets where it can be captured, filtered and infiltrated. Green Stormwater Streets are an important component of a sustainable stormwater network that balances natural hydrology with human land use and development.

Four Green Stormwater Street types are utilized in this concept plan:

- Residential Green Stormwater Streets;
- Residential Shared Green Stormwater Streets;
- Residential Connector Green Stormwater Streets; and
- Mixed-Use Connector Green Stormwater Streets.

Components of streets discussed in this report which can accommodate green stormwater infrastructure elements include:

- Pedestrian Clearways: the portion of the sidewalk that is clear of obstructions for pedestrian movement;
- Furnishing/ Planting Zones: the portion of the sidewalk between the pedestrian clearway and the curb, designed to accommodate street furniture and/ or green stormwater infrastructure elements;
- Curbside: the edge of the roadway, which can be extended to accommodate green stormwater infrastructure elements;
- Vehicular Lane: the portion of the roadway for vehicle movement;
- Medians/ Raised Islands: a raised area located between vehicle lanes, which can accommodate green stormwater infrastructure elements;
- On-Street Parking: the formal or informal portion of the roadway where vehicles are permitted to park;
- Cycling Lane: a portion of the curbside space identified for cycling, which can be separated or integrated lanes;
- Crosswalks: a designated area for pedestrian movement across other street components, such as vehicle lanes; and
- Intersections: where vehicle lanes intersect with each other.

6.2.2.3: Proposed Green Stormwater Street Retrofits

All streets within the study area will be retrofit into one of the four Green Stormwater Street types, outlined in Table 4.

Proposed Green Stormwater Street Classifications				
Street Name	**Residential Street**	**Residential Shared Street**	**Residential Connector Street**	**Mixed-Use Connector Street**
Alliance Avenue				X
Avalon Avenue		X		
Bexley Crescent	X			
Black Creek Boulevard	X			
Brendwin Road		X		
Bruton Road	X			
Cameo Crescent	X			
Clairton Crescent	X	X		

Cynthia Road	X			
Dalrymple Drive	X			
Delemere Avenue	X			
Duern Street	X			
East Drive			X	
Edinborough Crescent	X			
Ellins Avenue	X			
Foxwell Street			X	
Frimette Crescent	X			
Glamis Avenue	X			
Handel Street	X			
Haney Avenue	X			
Kinghorn Avenue	X			
Old Scarlett Road	X			
Pendeen Avenue	X			
Rockcliffe Boulevard				X
Rose Valley Crescent		X		
Sandcliffe Road	X			
Scarlett Road				X
Stoneleigh Road		X		
Stoney Brooke Drive		X		
Woodgate Drive	X			
Woolner Avenue				X

Table 4: Green Stormwater Street Classifications Proposed in the Concept Plan.

6.2.3: Public Green Space Revitalization

6.2.3.1: Goals, Objectives, and Outcomes

Goal	Restore ecological and hydrological function to public green spaces through the incorporation of green stormwater infrastructure.
Objective	Revitalize the public green spaces within the study area into multifunctional spaces that provides opportunities for stormwater management, nature, and outdoor recreation.
Outcomes	• Manage stormwater runoff by mimicking natural systems to mitigate flood risk and build community resilience; • Mitigation of local and downstream flooding; • Stabilization of soil and watercourse banks with vegetated green infrastructure solutions; • Strengthen environmental resilience to future flooding and climate change; and • Improved flood mitigation, infiltration and drainage rates, and water quality.

Table 5: Public Green Space Revitalization Goals, Objectives and Outcomes

6.2.3.2: Proposed Green Space System Revitalization Projects

The public green spaces within the study area will be revitalized into multifunctional public spaces that function as park space and stormwater management. The scope of each revitalization project was determined based on balancing the possible spatial arrangement of the green stormwater infrastructure elements and my perception of community recreation needs. Table 6 provides a summary of my vision for each public green space undergoing revitalization.

Scope of the Green Space System Revitalization Projects	
Cynthia-Frimette Parkette	The 500 square metre site will undergo a significant transformation from an underutilized public space into a sustainable urban stormwater management parkette that uses bioretention to reduce stormwater runoff volumes and contamination loads from entering the sewer and receiving water systems. A small shaded seating area provides space for passive recreation.
Brendwin Circle Parkette	The 280 square metre site will experience minor design intervention given spatial limitations. A rain garden will use bioretention to capture, treat, and infiltrate stormwater runoff from the adjacent cul-du-sac.

<table>
<tr><td>Noble Park</td><td>The 14,000 square metre park will undergo significant revitalization into a public space that blends active recreation amenities with stormwater management detention and treatment features. The design includes improved active recreation amenities, a new playground, and several green infrastructure elements including bioretention facilities, a detention basin, flood protection berms, and a permeable pavement basketball court and walkways.</td></tr>
<tr><td>Smythe Park</td><td rowspan="3">The 284,000 square metre area will undergo significant revitalization to transform the Black Creek channel and surrounding parkland into the Black Creek Naturalization and Flood Protection Corridor. The design incorporates flood mitigation approaches, inspired by the Dutch Room for the River programme (Rijkswaterstaat, 2010), to convert the constrained channel into a natural and meandering watercourse.</td></tr>
<tr><td>Black Creek Site West</td></tr>
<tr><td>Black Creek Site East</td></tr>
<tr><td>Scarlett Woods Golf Course</td><td>The 260,000 square metre site will undergo significant transformation from a golf course into the Scarlett Woods Wetland Park, a naturalized area for stormwater management, recreation, and environmental education. The design includes a new river channel, wetland habitat, a forested area, flood protection berms, and a new island park. The design incorporates flood mitigation approaches used in Toronto’s Don Mouth Naturalization and Port Lands Flood Protection Project (Waterfront Toronto, 2016) and the Dutch Room for the River programme (Rijkswaterstaat, 2010).</td></tr>
</table>

Table 6: Proposed Green Space System Revitalization Projects.

6.3: Concept Designs

6.3.1: Overview

Section 6.3 is composed of several concept designs that execute the proposed concept plan outlined in Section 6.2. The designs display one of several possible arrangements of green stormwater infrastructure elements within the retrofit green stormwater streets (Section 6.3.2) and the revitalized green space system (Section 6.3.3). The concept designs display how green stormwater infrastructure can be spatially arranged and incorporated into urban public spaces.

6.3.2: Green Stormwater Street Retrofits

6.3.2.1: Residential Shared Green Stormwater Street

OVERVIEW

Six roadways classified as *local streets* in the baseline assessment (Section 5) will be retrofit into Residential Shared Green Stormwater Streets, which includes approximately 0.831 kilometres of roads.

Figure 12: Proposed Residential Shared Green Stormwater Streets

TYPICAL EXISTING CONTEXT

- Short, low-traffic volume streets;
- Parking often permitted on one or both sides of the street;
- Can be two-way or one-way streets;

- Mature trees are common within older neighbourhoods;
- Private driveways are often frequent; and are
- Designated *Neighbourhood* within the *Official Plan* (Toronto, 2019).

RETROFIT OPPORTUNITIES AND CONSTRAINTS

Opportunities:

- Improve local resilience to flooding by integrating green stormwater infrastructure into low-speed and low-traffic streets. Secondary benefits include enhancing the urban tree canopy, traffic calming, and adding natural aesthetic value.
- Revitalize residential streets, often underutilized public spaces, to support the social and environmental needs of the local community rather than exclusively meeting the needs of private vehicles.
- Promote pedestrian and cyclist priority on low-traffic and low-speed streets by creating a uniform grade between the sidewalk and the roadway.
- Incorporate furnishing/ planting zones into streets by removing on-street parking and narrowing vehicle lanes.
- Runoff from higher traffic streets could be conveyed into the green stormwater infrastructure facilities on residential streets to further mitigate flood risk and relieve strain on the grey stormwater sewer system.
- Fulfill, in total or partial, the design objectives outlined in the *Green Streets Technical Guidelines* (Schollen & Company Inc. et al, 2017, p. 51).

Constraints:

- Reducing traffic on some residential streets by transforming them into Residential Shared Stormwater Streets may increase the vehicle traffic volumes on other streets.

Green Stormwater Infrastructure Element	Application Zones
Bioretention Planter	Furnishing / Planting Zones
Bioretention Swale	Furnishing / Planting Zones
Permeable Paving - Pervious Concrete	Vehicular Lanes Sidewalk
Permeable Paving - Porous Asphalt	Vehicular Lanes

Permeable Paving - Interlocking Precast Concrete Pavers	Feature Paving On-Street Parking Sidewalk Crosswalks
Stormwater Tree Pits	Furnishing / Planting Zones
Stormwater Tree Trenches	Furnishing /Planting Zones

Table 7: Potential Green Stormwater Infrastructure Elements for Residential Shared Green Stormwater Streets

DESIGN EXAMPLE - RESIDENTIAL SHARED GREEN STORMWATER STREET

Street Name: Avalon Avenue

Length: 61 metres

Figure 13: Context Map of Avalon Avenue

Avalon Avenue is a low-speed and low-traffic residential street that is bound by Roselands Junior Public School to the north and Bexley Crescent to the south.

Figure 14: Existing Conditions of Avalon Avenue

Figure 15: Avalon Avenue Looking South from the Parking Lot of Roselands Junior Public School (Photo Credit: Alana Wittman, July 2020)

Figure 16: Avalon Avenue Looking North from Bexley Crescent (Photo Credit: Alana Wittman, July 2020)

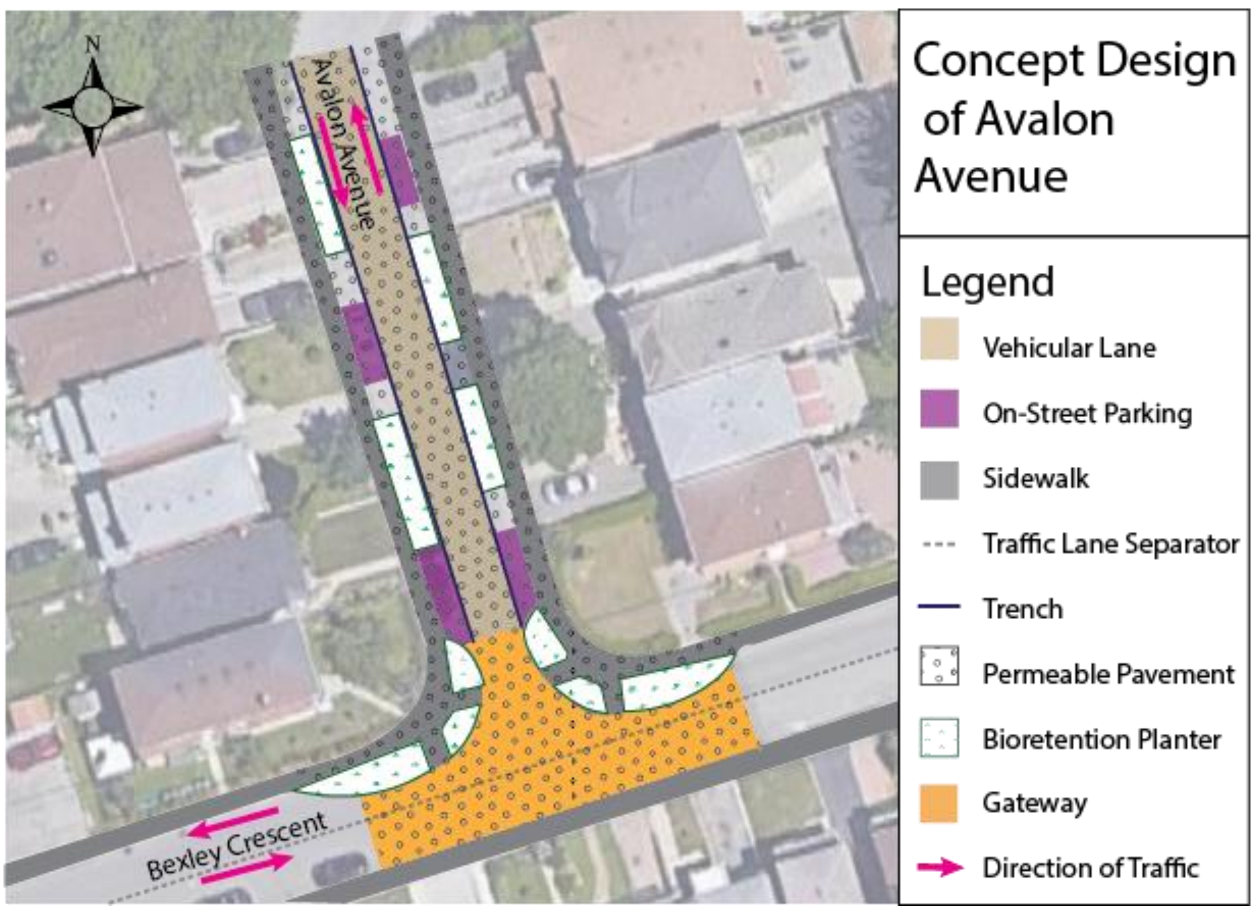


Figure 17: Concept Design of Avalon Avenue as a Residential Shared Green Stormwater Street

The retrofit of Avalon Avenue into a Residential Shared Green Stormwater Street includes:

- Removal of the existing road and sidewalk and replace them with permeable pavement. The sidewalk is flush with the curb to promote the pedestrian priority on the street leading up to the school.
- Narrow the vehicular lane from two distinct lanes into one wide lane that enables traffic calming to improve pedestrian safety near Roselands Junior Public School and provide room for green stormwater management infrastructure within the roadway.
- New curb extensions are constructed at the intersection of Avalon Avenue and Bexley Crescent in order to reduce the road width entering Avalon Avenue, providing space for bioretention and street tree facilities, reduce the distance of the pedestrian crosswalks, and reduce traffic speed in order to reinforce pedestrian priority.
- New stormwater trench drain constructed along the east and west perimeter of the vehicle lane to collect and convey runoff into the bioretention facilities.
- New bioretention planters between the sidewalk and vehicle lane to collect, treat, and infiltrate stormwater runoff generated from the adjacent impervious services.
- New gateway, a raised and textured portion of the roadway, at the intersection of Avalon Avenue and Bexley Crescent to slow traffic at the entrance to the Residential Shared Green Stormwater Street.

PERFORMANCE

- Impervious surfaces are reduced by 100% as a result of the incorporation of bioretention facilities and permeable pavement sidewalks and vehicle lane.
- Approximately 150 square metres of dedicated bioretention systems within the mid-block and intersection curb extensions will manage runoff generated from the adjacent impermeable surfaces, such as the Roselands Junior Public School's parking lot and private residential driveways.

6.3.2.2: Residential Green Stormwater Street

OVERVIEW

20 roadways classified as *local streets* in the baseline assessment (Section 5) will be retrofit into Residential Green Stormwater Streets, which includes approximately 1.536 kilometres of roads.

Figure 18: Proposed Residential Green Stormwater Streets

TYPICAL EXISTING CONTEXT

- Streets are within the area designated *Neighbourhood* within Toronto's *Official Plan* (Toronto, 2019);
- Short, low-traffic volume streets;
- Sidewalks can either be on both, one, or neither side of the street;
- Parking is often permitted on one or both sides of the street;
- Street can have either two-way or one-way traffic;
- Mature trees often exist within older neighbourhoods; and
- Private driveways are often frequent.

RETROFIT OPPORTUNITIES AND CONSTRAINTS

Opportunities:

- Improve local resilience to flooding by integrating green stormwater infrastructure into streets. Secondary benefits include street calming, enhancing the urban tree canopy, and adding natural aesthetic value.
- Revitalize residential streets, often underutilized public spaces, to support the social and environmental needs of the local community rather than exclusively meet the needs of private vehicles.
- Runoff from higher traffic streets could be conveyed into the green stormwater infrastructure facilities on residential streets to further mitigate flood risk and relieve strain on the grey stormwater sewer system.
- Where space is limited, two-way traffic residential streets could be converted into one-way traffic streets to provide more space for green stormwater infrastructure, wider sidewalks, furnishing/ planting zones, and bicycle lanes.
- Fulfill, in total or partial, the design objectives outlined in the *Green Streets Technical Guidelines* (Schollen & Company Inc. et al., 2017, p. 50).

Constraints:

- Frequency of driveways can limit the ability to incorporate bioretention facilities into the furnishing/ planting zone.

Green Stormwater Infrastructure Element	Application Zones
Bioretention Curb Extension / Bump-out	Intersections Mid-block Transit Stops
Bioretention Planter	Furnishing / Planting Zones
Bioretention Rain Gardens	Furnishing / Planting Zones Medians / Raised Islands
Bioretention Swale or Enhanced Grass Swale	Furnishing / Planting Zones Medians / Raised Islands
Permeable Paving - Pervious Concrete	On-street Parking Sidewalk
Permeable Paving - Porous Asphalt	Vehicular Lanes

Permeable Paving - Interlocking Precast Concrete Pavers	On-street Parking Crosswalks
Permeable Paving - Interlocking Precast Concrete Pavers	Crosswalks

Table 8: Green Stormwater Infrastructure Elements for Green Stormwater Residential Streets

DESIGN EXAMPLE: RESIDENTIAL GREEN STORMWATER STREET

Street: Kinghorn Avenue

Length: 290 metres

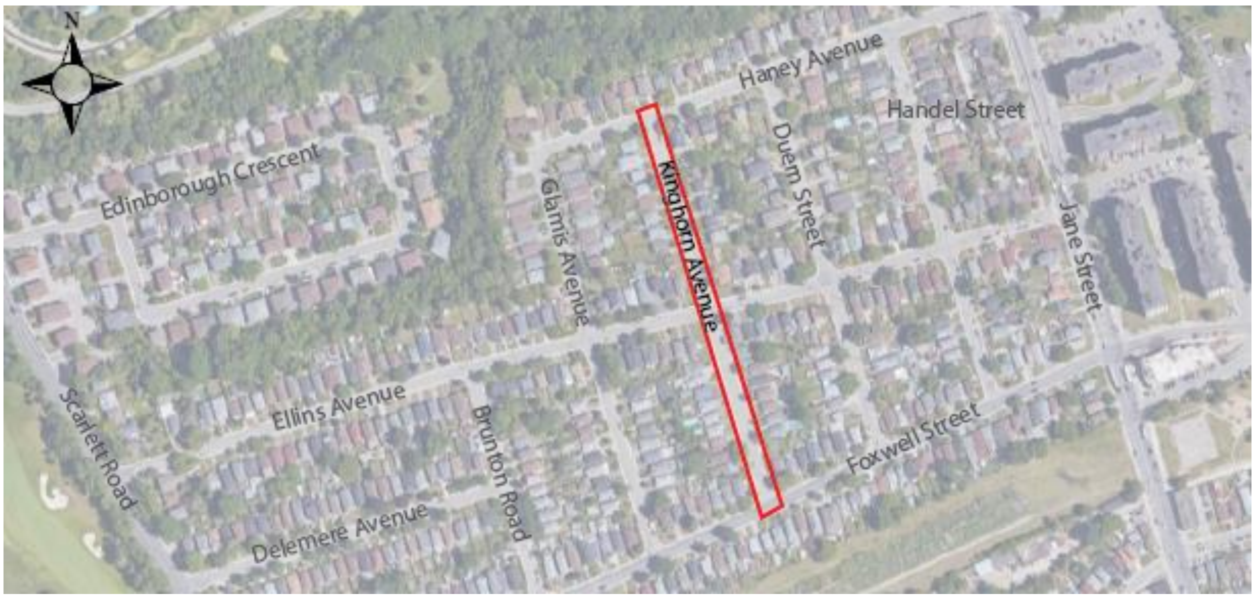


Figure 19: Context Map of Kinghorn Avenue

Kinghorn Avenue is a low-speed and low-traffic residential street that is bound by Haney Avenue to the north and Foxwell Street to the south.

Figure 20: Existing Conditions of Kinghorn Avenue

The existing design of Kinghorn Avenue includes impermeable sidewalks on both sides of the street, a vehicular lane with two-way traffic, and on-street parking is permitted on the both sides of the vehicle lane. The current street does not have a furnishing/ planting zone, resulting in a low-quality urban forest canopy.

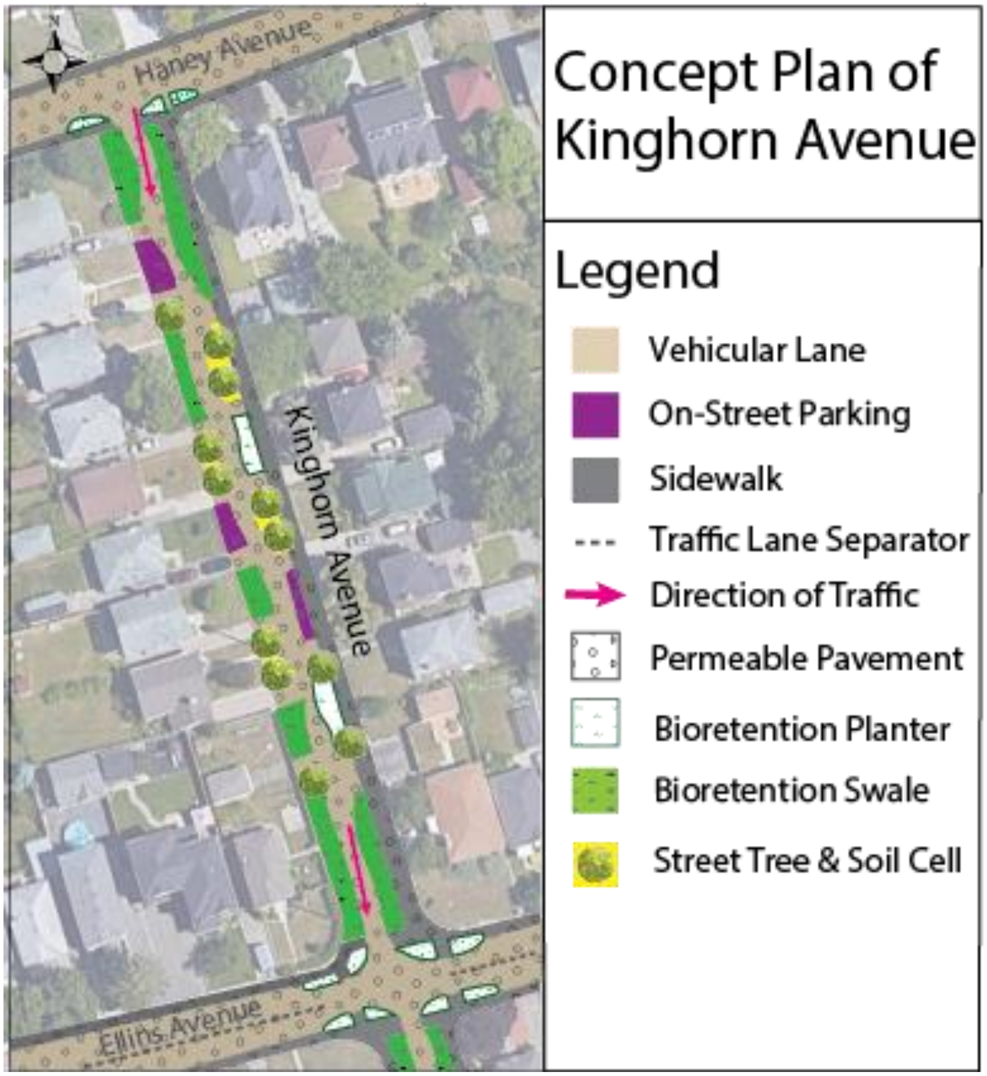


Figure 21: Concept Design of Kinghorn Avenue as a Residential Green Stormwater Street

Concept design to transform Kinghorn Avenue into a Residential Green Stormwater Street incorporates green stormwater infrastructure elements that fit the built form context of the existing street. The design is based on the City of Seattle's Street Edge Alternatives street pilot project (Seattle, 2001; NACTO, 2017, p. 56) but was adapted to incorporate design objectives for Residential Streets from the City of Toronto's *Green Streets Technical Guidelines* (Schollen & Company Inc. et al., 2017, p. 50).

The retrofit of Kinghorn Avenue into a Residential Green Stormwater Street includes:

- Removal of the existing road and sidewalk and replace them with permeable pavement with a flush curb.
- Reduce the width of the roadway to a one-lane, one-way vehicle lane in order to provide space for green stormwater infrastructure along both sides of the street.

- Increase the width of the sidewalk on the east side of the street to accommodate higher pedestrian volumes.
- New furnishing/ planting zones are constructed between the vehicle lane and the sidewalk on the east side of the street, and residential lots to the west. This provides a safety buffer for pedestrians and space for green stormwater infrastructure.
- Vegetated bioretention swales, rain gardens, and street trees in soil cells are constructed within the new furnishing/ planting zones that collects, treats, and infiltrates runoff from the adjacent permeable surfaces and water that infiltrates through the permeable sidewalk and vehicle lane pavement.
- New curb extensions are constructed at all intersections to provide space for bioretention facilities, reduce the road width and vehicle speed entering local streets, and reduce the distance of the pedestrian crosswalks.
- On-street angled parking spaces have been constructed to meet local needs.

PERFORMANCE

- Impervious surfaces are reduced by 100% as a result of the incorporation of bioretention facilities and the permeable pavement sidewalk, vehicle lane, and on-street parking.
- Approximately 650 square metres of dedicated bioretention facilities within the furnishing/ planting zone and curb extensions manage runoff generated on Kinghorn Avenue and the adjacent streets and sidewalks.

6.3.2.3: Residential Connector Green Stormwater Street

OVERVIEW

Two roadways classified as *connector streets* in the baseline assessment (see Section 5) will be retrofitted into Residential Connector Green Stormwater Streets, which includes approximately 1.413 kilometres of roads.

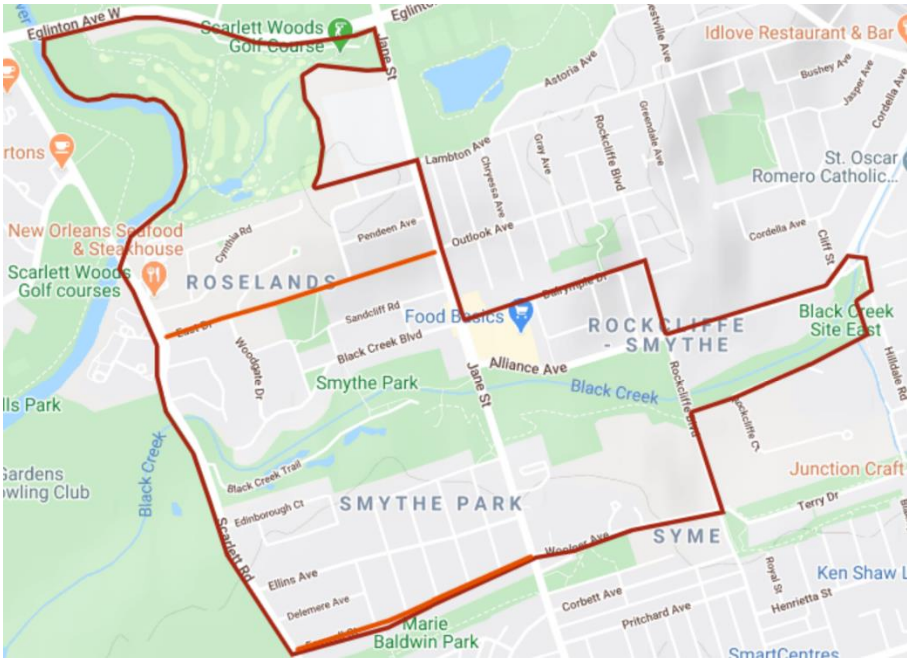


Figure 22: Proposed Residential Connector Green Stormwater Streets

TYPICAL EXISTING CONTEXT

- Streets are within areas designated *Neighbourhood* within Toronto's *Official Plan* (Toronto, 2019);
- Sidewalks can either be on one or both sides of the street;
- Parking is often permitted on one or both sides of the street;
- Streets often have two-way traffic;
- Streets can have either surface transit stops or no transit stops;
- Mature trees often exist within older neighbourhoods; and
- Driveways are often frequent.

RETROFIT OPPORTUNITIES AND CONSTRAINTS

Opportunities:

- Improve local resilience to flooding by integrating green stormwater infrastructure into streets. Secondary benefits include enhancing the urban tree canopy and adding natural aesthetic value.
- Incorporate furnishing/ planting zones to streets by removing on-street parking or narrowing vehicle lanes where possible.
- Fulfill, in total or partial, the design objectives outlined in the *Green Streets Technical Guidelines* (Schollen & Company Inc. et al, 2017, p. 51).

Constraints:

- Frequency of driveways can limit the ability to incorporate bioretention facilities into the furnishing/ planting zone.
- Retrofit without expropriation of portions of private land, in my opinion, makes meeting all the design objectives for Residential Connector Streets in the *Green Streets Technical Guidelines* (Schollen & Company Inc. et al., 2017, p. 51) improbable to achieve.

Green Stormwater Infrastructure Element	Application Zones
Bioretention - Cell	Furnishing / Planting Zones Medians / Raised Islands
Bioretention Rain Gardens	Furnishing / Planting Zones Medians / Raised Islands
Bioretention Swale / Enhanced Grass Swale	Furnishing / Planting Zones Medians / Raised Islands
Permeable Paving - Pervious Concrete	Cycling Infrastructure Sidewalk
Permeable Paving - Porous Asphalt	On-street Parking Cycling Infrastructure
Stormwater Tree Pits	Furnishing / Planting Zones Medians / Raised Islands
Stormwater Tree Trenches	Furnishing /Planting Zones Medians / Raised Islands

Table 9: Potential Green Stormwater Infrastructure Elements for Residential Connector Green Stormwater Streets

DESIGN EXAMPLE - RESIDENTIAL CONNECTOR GREEN STORMWATER STREET

Street Name: East Drive

Length: 747 metres

Figure 23: Context Map of East Drive

East Drive is a residential connector street that enables pedestrian and vehicle mobility between Scarlett Road and Jane Street.

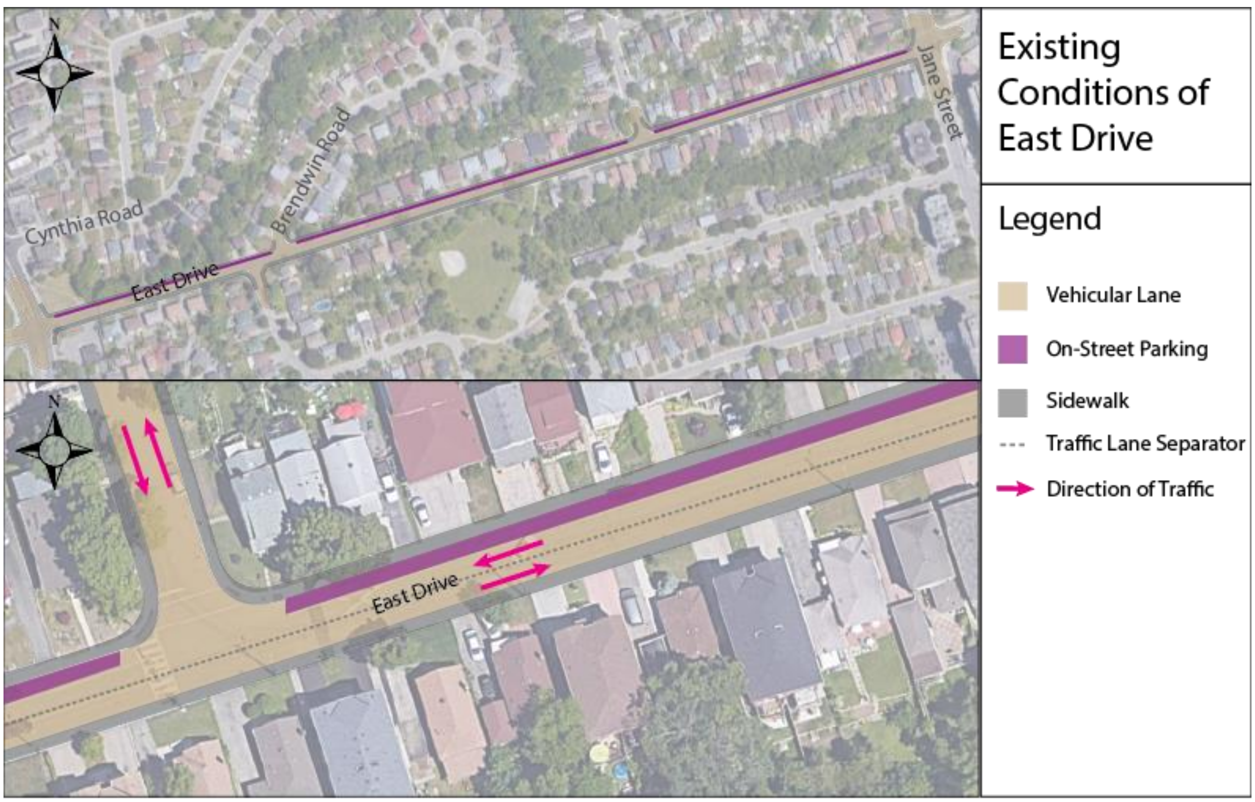


Figure 24:Existing Conditions of East Drive

Figure 25: East Drive Looking West (Photo Credit: Alana Wittman, July 2020)

Figure 26: East Drive Looking East

The current design of East Drive includes impermeable sidewalks on both sides of the roadway, a vehicular lane with two-way traffic, and a dedicated on-street parking lane. The current sidewalk design does not include a furnishing/ planting zone, resulting in a low-quality urban tree canopy along the roadway.

Figure 27: Concept Design of East Drive as a Residential Connector Green Stormwater Street

The retrofit of East Drive into a Residential Connector Green Stormwater Street includes:

- Removal of the existing road and sidewalk and replace them with permeable pavement.
- Removal of the on-street parking to provide space for green stormwater infrastructure.
- New furnishing/ planting zones are constructed between the sidewalk and the vehicle lanes to provide both a safety buffer for pedestrians and space for green stormwater infrastructure.
- New stormwater tree trench and soil cells are constructed within the new furnishing/ planting zones that treat runoff from the adjacent impermeable surfaces, such as driveways, and water that infiltrates through the permeable sidewalk and vehicle lane pavement.
- New curb extensions are constructed at all intersections to provide space for bioretention facilities, reduce the road width and vehicle speed entering local streets, and reduce the distance of pedestrian crosswalks.

PERFORMANCE

- Impervious surfaces are reduced by 100% as a result of the incorporation of a permeable pavement sidewalk and the removal of the on-street parking lane which made up 33% of the roadway.
- 747 metres of underground stormwater tree trenches which capture and convey runoff to the newly planted street trees in soil cells. The street trees enhance the urban tree canopy, infiltrate runoff water, improve air quality, and reduce urban temperatures.
- Approximately 2,400 square metres of dedicated bioretention systems within the curb extensions manage runoff generated on East Drive and the adjacent streets and sidewalks.

6.3.2.4: Mixed-Use Connector Green Stormwater Street

OVERVIEW

Four roadways classified as *connector streets* in the baseline assessment (Section 5) will be retrofit into Mixed-Use Connector Green Stormwater Streets, which includes approximately 3.29 kilometres of roads.

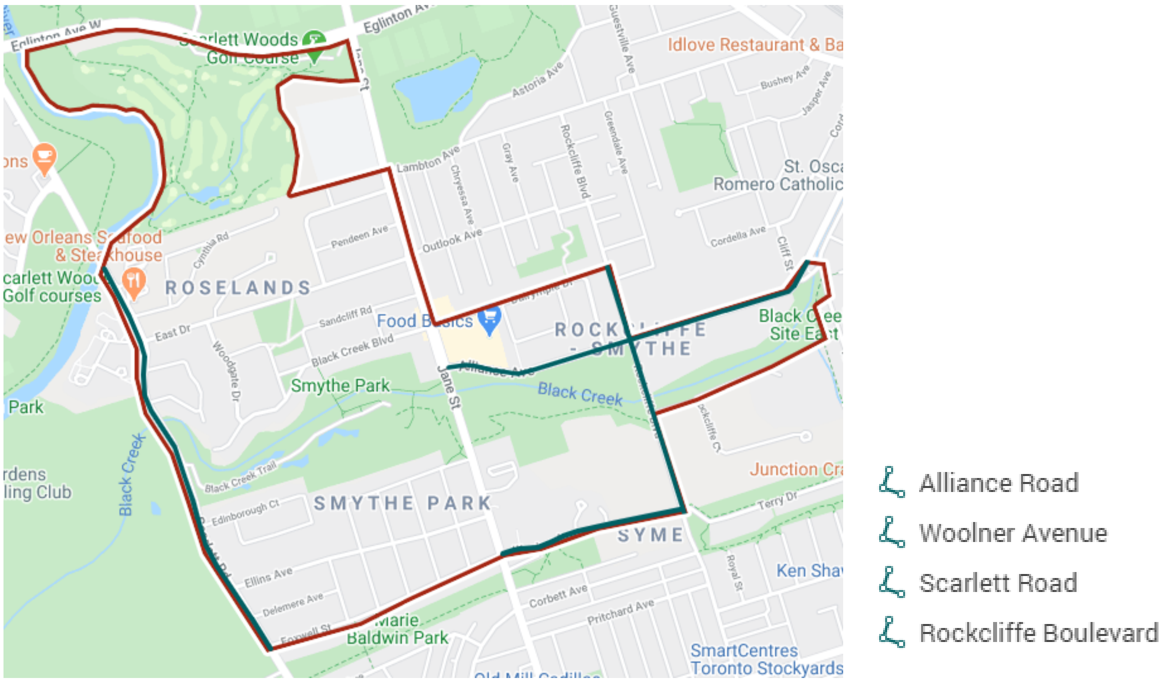


Figure 28: Proposed Mixed-Use Connector Green Stormwater Streets

TYPICAL EXISTING CONTEXT

- Streets travel through different land uses and built form types.
- Longer, more continuous, and higher speed roads in comparison to residential streets.
- Enables direct mobility and connections between higher volume roads and between different communities.
- Common travel routes for pedestrians, cyclists, transit users, private cars, and cargo trucks.
- Transit stops and stations are common, and the street may include transit priority lanes.
- Efficient vehicle travel is a priority for this street type.

RETROFIT OPPORTUNITIES AND CONSTRAINTS

Opportunities:

- Improve local resilience to flooding by integrating green stormwater infrastructure into streets.

- Incorporate bioretention facilities and stormwater tree infrastructure into the furnishing/ planting zone, around transit stops, and in medians to improve drainage while providing a safety buffer for pedestrians and cyclists.
- Incorporate permeable pavement into sidewalks and bicycle lanes to improve surface drainage.
- Expand the tree canopy and soil quantity with stormwater tree facilities and soil cells.
- Expand space for people and nature by removing all on-street parking.
- Fulfill, in total or partial, the design objectives outlined in the *Green Streets Technical Guidelines* (Schollen & Company Inc. et al., 2017, p.50).

Constraints:

- Conflicting multimodal transportation types and priorities can make it challenging to meet the transportation and safety needs of all users while also incorporating green stormwater infrastructure into the public space.
- Retrofits, without expropriation of portions of private land, in my opinion, makes meeting all the design objectives for Mixed-Use Connector Streets in the *Green Streets Technical Guidelines* (Schollen & Company Inc. et al., 2017, p. 50) improbable to achieve.

Green Stormwater Infrastructure Element	Application Zones
Bioretention Planter	Furnishing / Planting Zones Medians / Raised Islands
Bioretention Rain Gardens	Furnishing / Planting Zones Medians / Raised Islands
Bioretention Swales / Enhanced Grass Swale	Furnishing / Planting Zones Medians / Raised Islands
Permeable Paving - Pervious Concrete	Cycling Infrastructure Sidewalks
Permeable Paving - Porous Asphalt	Cycling Infrastructure
Stormwater Tree Pits	Furnishing / Planting Zones Medians / Raised Islands
Stormwater Tree Trenches	Furnishing /Planting Zones Medians / Raised Islands

Table 10: Potential Green Stormwater Infrastructure Elements for Mixed-Use Connector Green Stormwater Street

6.3.3: Green Space Revitalization

6.3.3.1: Scarlett Woods

SITE CONTEXT

Area: 260,000 square metres (26 hectares)

Topography: Drains southwest towards the Humber River with a maximum elevation of 107 metres and minimum elevation of 99 metres.

Within the Regulatory Floodplain: Yes

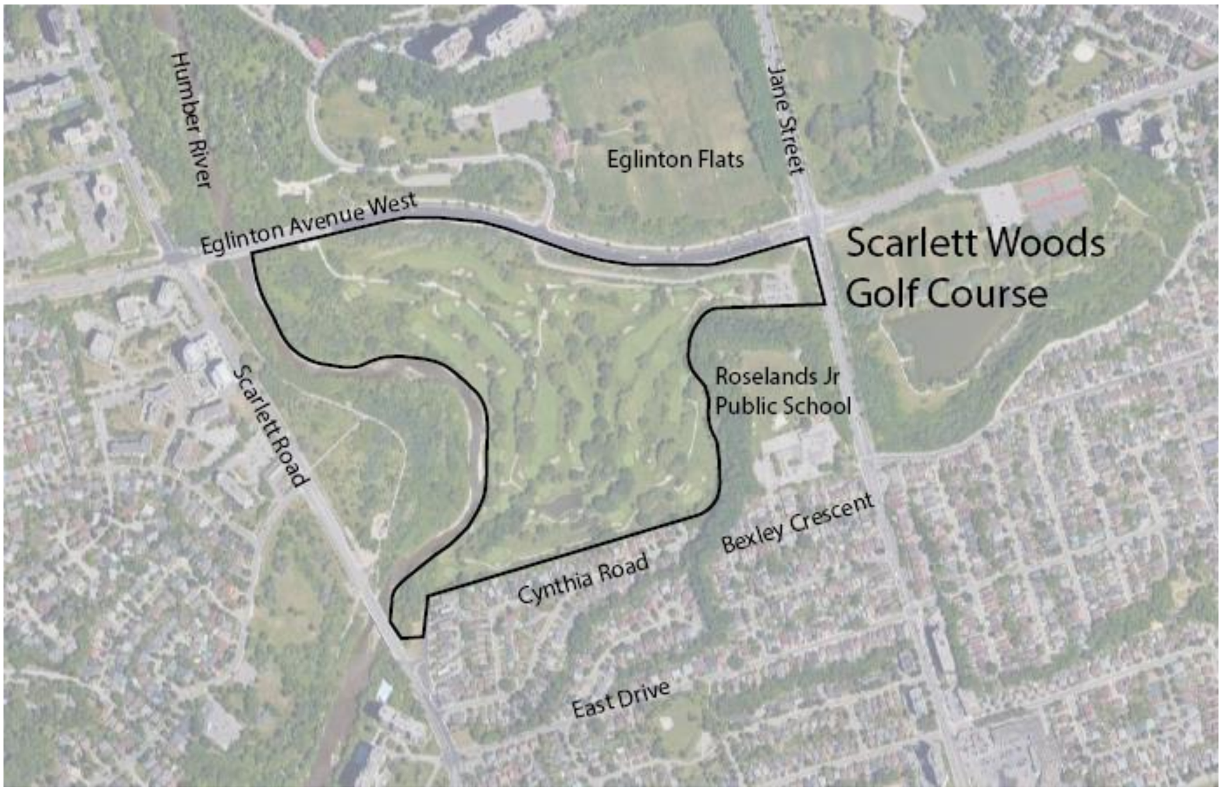


Figure 29: Context Map of Scarlett Woods Golf Course

Scarlett Woods Golf Course is located south of Eglinton Avenue West, west of Jane Street and Roseland Junior Highschool, east of the Humber River, and north of the backyards of houses along Cynthia Road.

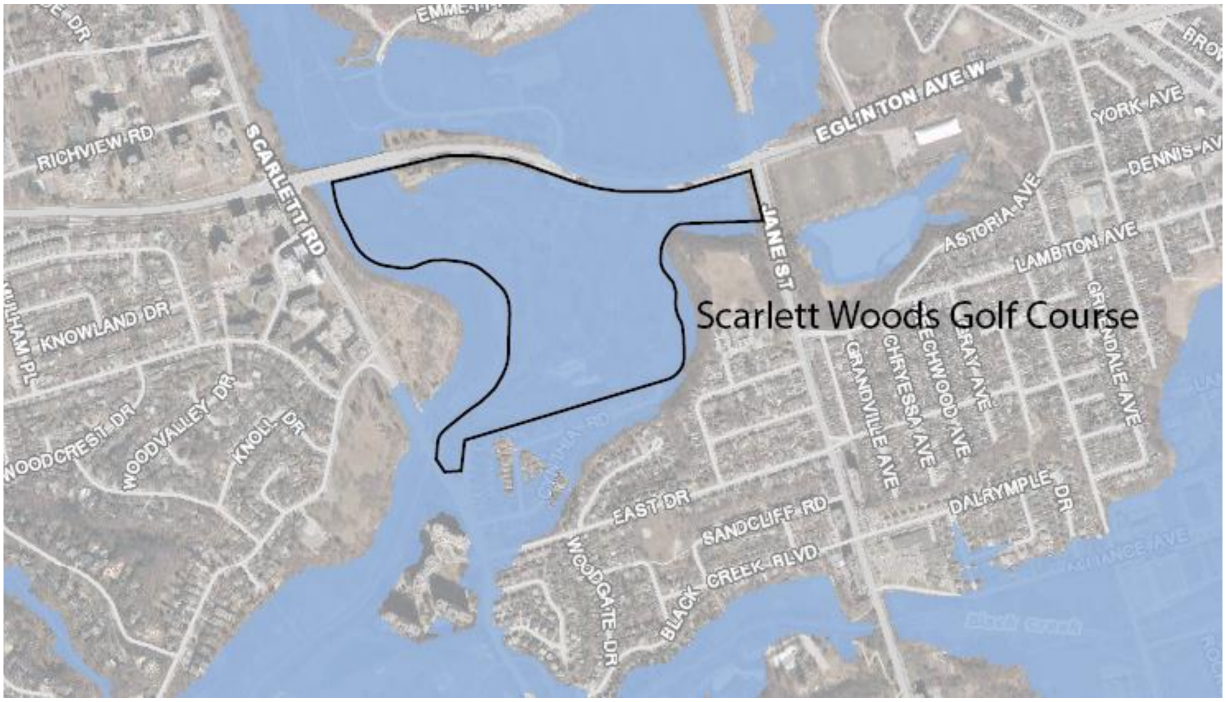


Figure 30: Floodplain Context of Scarlett Woods Golf Course (TRCA, n.d.-a)

Figure 31: Topographic Context of Scarlett Woods Golf Course (Topographic-map.com, n.d.)

Figure 32: Sewer System Context of Scarlett Woods Golf Course (XCG Consulting Ltd., 2014, p. 6)

Stormwater runoff from Jane Street and Eglinton Avenue West, between Scarlett Road and Gilmour Place, enters a Storm Sewer that is conveyed to an outfall located within the Scarlett Woods Golf Course.

EXISTING SITE DESCRIPTION

Scarlett Woods Golf Course is a City of Toronto owned and operated 18-hole golf course situated within the Humber River floodplain. The course opened in 1974 following its approval by Council in 1972 as a feature of the South Humber regional park system plan (Toronto, n.d.). The current design of the site consists of a parking lot and clubhouse; several grasses that make up the fairway, rough, and greens; sand traps; rows of trees separating the fairways; two ponds at the southern end of the site; and forested buffers along the northwest and eastern boundaries of the site. Public vehicle access to the site is from Eglinton Avenue West, and an additional pedestrian access point is located at the intersection of Eglinton Avenue West and Jane Street.

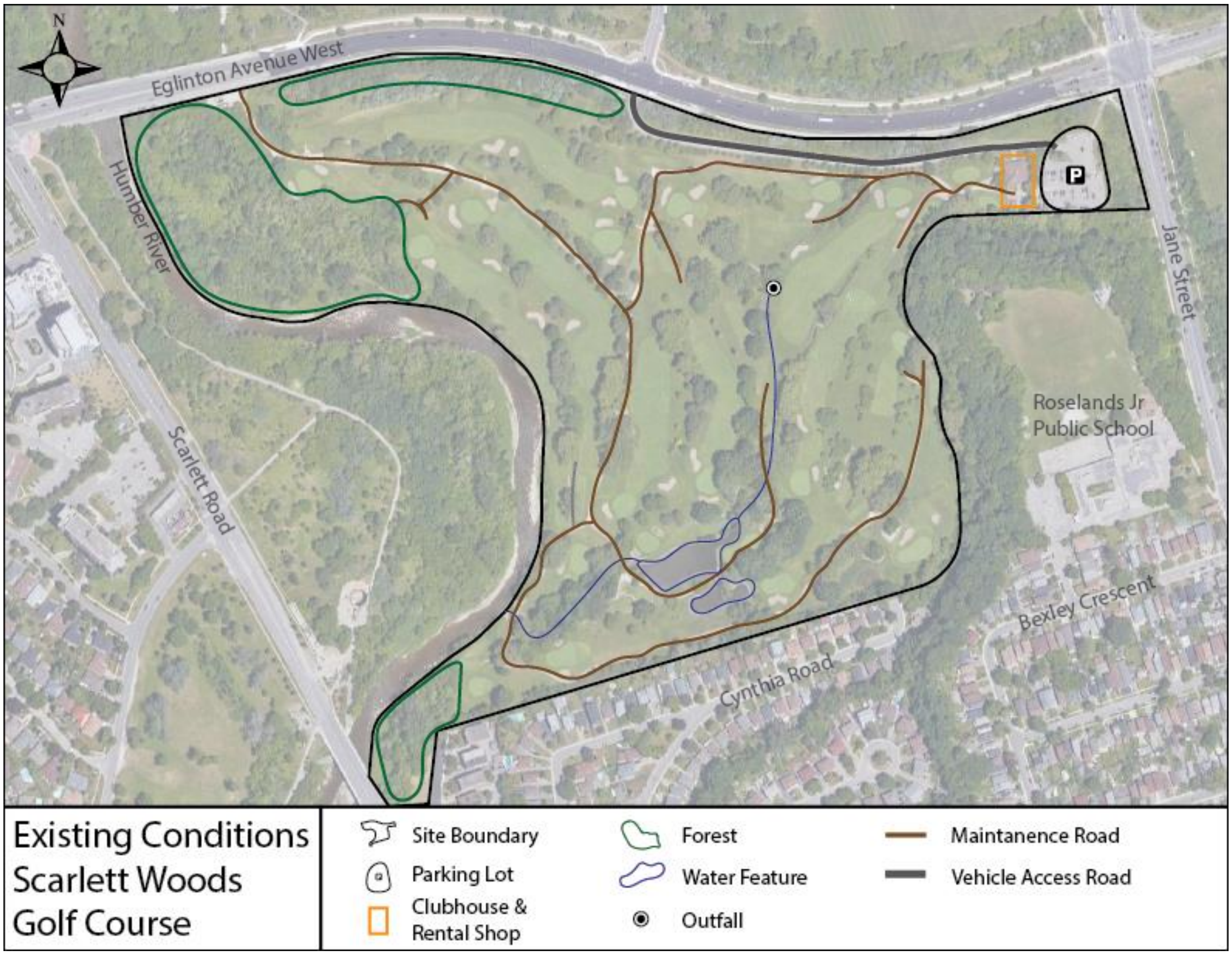


Figure 33: Existing Conditions of Scarlett Woods Golf Course

REVITALIZATION OPPORTUNITY

Scarlett Woods, a substantial parcel of public land situated within the Humber River floodplain, has unrealized potential for stormwater management and flood protection. Further, the golf course is operating under a net loss due to declining public interest and participation in golf (Toronto, 2014), making the site an excellent candidate for renewal into a public area that is accessible to the general public free of charge.

DESIGN APPROACH AND VISION

- Integrate green stormwater infrastructure into the park to achieve stormwater management and flood mitigation benefits.
- Apply relevant *Room for the River* approaches into the design, which includes:
    - Diversion measures, such as creating a new overland river channel route within the floodplain.

    - Conveyance measures, such as lowering the floodplain by excavating a portion of the floodplain in order to increase space for the river to flow during high water events.
    - Detention measures, such as designing wetland areas for temporary water storage and to control peak flow rates during high water events and restoring riparian zones for absorption and bank stabilization.
- Design the site to include both permanent and temporary water storage, this includes enabling the entire site to be able to take on flood water.
- Dual functional design that achieves stormwater management and recreation objectives, while creating an attractive public space for community use.
- Establish clear entrances for park access and to park activity spaces using structural and vegetative buffers to reduce safety hazards for park users.
- Improve public access to the site by creating a new pedestrian access points between the park and the community at Cynthia Road and the western bank of the Humber River.
- Integrate the existing stormwater outfall into the design.

CONCEPT DESIGN

Scarlett Woods Golf Course will be converted into the Scarlett Woods Wetland Park, composed of both green stormwater management infrastructure and recreation amenities. The design incorporates flood mitigation approaches used for Toronto's *Don Mouth Naturalization and Port Lands Flood Protection Project* (Waterfront Toronto, n.d. & 2016) and the Dutch *Room for the River* programme (Rijkswaterstaat, 2010; Rotterdam, 2010).

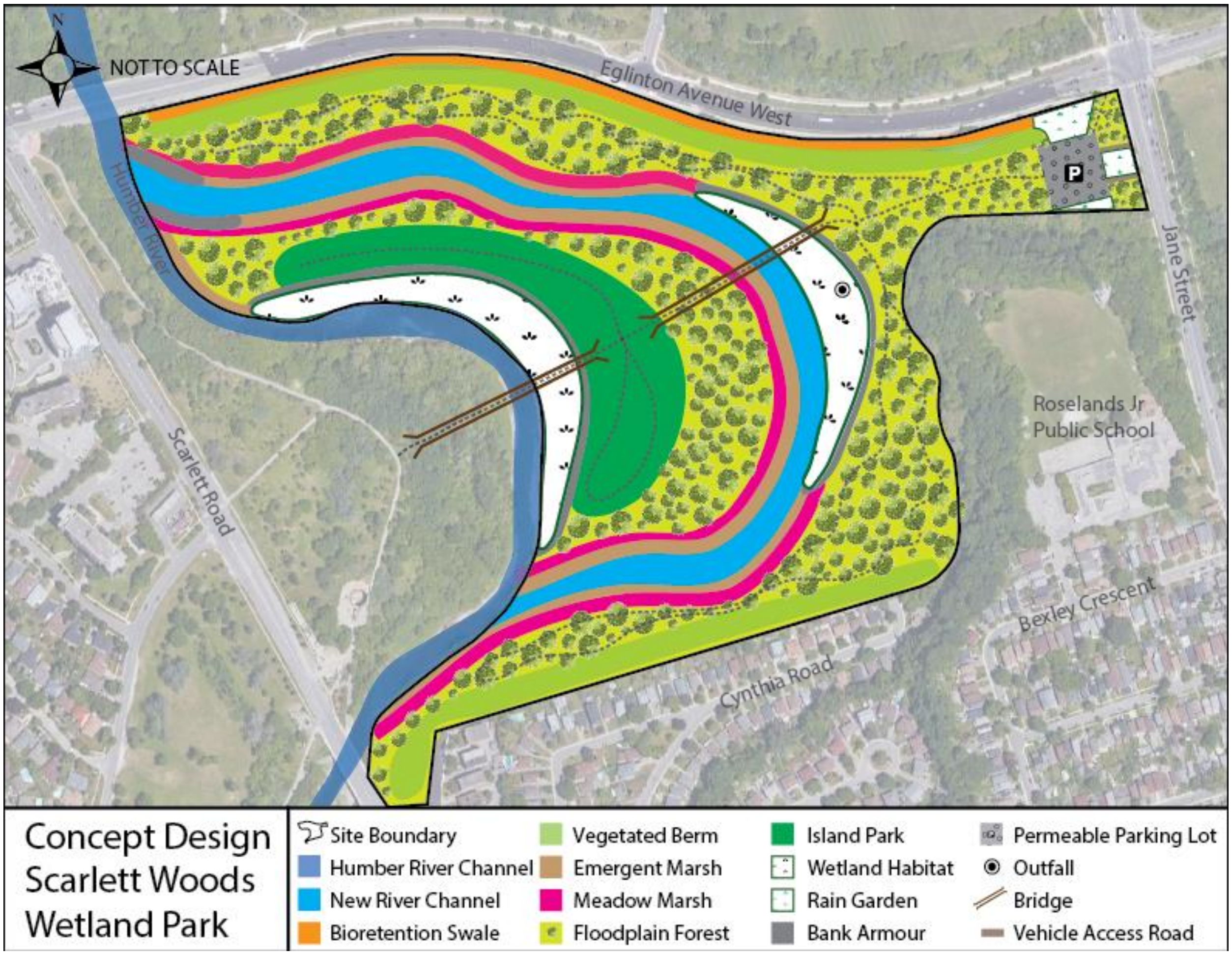


Figure 34: Concept Design of Scarlett Woods Island Park

A new river channel will be constructed in order to provide a bypass route for water flowing down the Humber River during both normal and high-water conditions. By providing more space for the Humber River to flow, the new 1,200 metre river channel provides a significant amount of permanent and temporary storage space for water during high flow events. Further, the channel enables the creation of 122,000 metres squared of multifunctional wetland and marsh habitat that provides additional storage capacity during high flows and improves water quality.

Island Park, situated between the Humber River and the new river channel, creates a new publicly accessible open space for exploration, outdoor education, and flood protection. The centre of Island Park consists of space for both passive and active recreation space through the incorporation of pedestrian and cycling multiuse-trails, shaded picnic areas, and viewpoints of the river and wetland ecosystems. The pathways are designed to minimize impacts to natural areas and are wide enough to accommodate a maintenance vehicle. The perimeter of Island Park consists of green stormwater and flood protection infrastructure for flood mitigation. This includes the creation of wetland and riparian zones for water absorption and filtration; bank stabilization facilitated by exposed stone armouring and bioengineered banks to prevent erosion; and a vegetated floodplain through the planting of a floodplain forests to provide natural and structural capacity to mitigate riverine flooding (Hough, 1995, p. 34).

Vegetated flood protection berms have been used along the northern and southern perimeter of the site to raise the grade of the land. The berms increase the structural capacity to temporarily hold large quantities of riverine flood waters within the site, protecting the surrounding community from riverine flooding. The inclusion of the berms is critical since the entire site is within the Humber River floodplain and is designed to function as a green spillway during high water events. The southern berm provides flood protection for the residential area south of the site. A pedestrian access point between the park and the community at Cynthia Road has been added via a staircase along the flood protection berm. The berm at the northern extend of the site prevents riverine flood water flowing from the park onto Eglinton Avenue West, while also preventing untreated runoff from Eglinton Avenue West from entering the park. The berm, in combination with the adjacent bioretention swale, will collect, filter and infiltrate the runoff from Eglinton Avenue West.

Design Element	Description
New River Channel	The new 1,200 metre river channel will act as a diversion channel to provide more room for the Humber River during both normal and high-water conditions. The banks of the new channel will be bioengineered with stone armouring and wetlands that enable the channel to withstand fast moving floodwaters.
Flood Protection Berms	The berms provide flood protection for the areas adjacent to the site by raising the grade of land along the edges of the park. The berms increase the structural capacity of the site to temporarily hold large quantities of riverine flood waters during high water events.
Island Park	Island Park is created by the new river channel. The grade of the land will be elevated and reinforced with exposed stone armour on the southern portion of the island, and with a bioengineered wetland bank on the northern portion. Island Park will offer recreational amenities, viewpoints of the river and wetland ecosystem, and wildlife habitat.
Emergent Marsh	The emergent wetland zone is the saturated portion of the riverbank where riparian vegetation that thrive in shallow water and/or water edge conditions grow, such as

	grasses and woody shrubs. This zone is important for flood-flow storage, slowing water velocity rates, and bank stabilization.
Meadow Marsh	The meadow wetland is the uppermost portion of a riverbank, comprised of flood tolerant grasses, that infiltrated runoff and riverine floodwater during high-water conditions, but is dry in typical conditions.
Exposed Stone Armour and Wetland Habitat	Exposed stone armour will protect the river channel and bank from erosion and fast-flowing waters during high-water events. Wetland habitat has been incorporated into this design, between the river channel and the stone armour to provide additional storage capacity for water, improve water quality, and create habitat.
Floodplain Forest	A floodplain forest will be planted to slow and infiltrate rainwater. This will lower water level fluctuations in the Humber River and reduce the risk of riverine flooding and erosion (Forman, 2014, p. 171; Hough, 1995, p. 34). An additional benefit is that densely wooded areas around the perimeter of a wetlands will deter geese from colonizing (Ontario, 2003).
Bioretention Swale	The swale will collect, filter and infiltrate the runoff from Eglinton Avenue West. The swale is 4 to 6-meters-wide and is composed of wetland vegetation, shallow check dams, and an under drainpipe that drains into one of the wetlands for further filtration before being conveyed into the new river channel.
Permeable Pavement Parking Lot	A permeable pavement parking lot, with adjacent bioretention rain gardens, will provide bicycle and vehicle parking for park users. The parking lot will be designed to meet the City of Toronto's '*Greening' Surface Parking Lots Guidelines* (Toronto, 2013).
Maintenance Access Road	The main paths and the pedestrian bridge that connect to Island Park will be wide enough to accommodate City of Toronto and TRCA maintenance vehicles.
Green Spillway	The entire site will function as a spillway, an area that provides additional space for flood water capacity, during flooding events. During regular conditions, the spillway will perform its primary function as a naturalized open space for stormwater management and recreation use.

Table 11: Green Stormwater Infrastructure Elements within the Concept Design of Scarlett Woods Wetland Park

PERFORMANCE

- The project includes (1) a new naturalized river channel, which is approximately 1,200 metres in length and 30 metres wide, provides more room for the Humber River to flow during normal and high water conditions; (2) approximately 30,000 square metres of dedicated wetland ecosystem and 92,000 square metres of emergent and meadow marsh ecosystem, providing permanent and temporary storage capacity for riverine water and slows water flow during flood events; and (3) approximately 70,000 metres squared of floodplain forest habitat that slows and captures water during flood events.

- The entire 260,000 metres squared site functions as a spillway during riverine flooding events.
- The swale along Eglinton Avenue West will prevent polluted stormwater runoff from entering the sewer system while the attached vegetated berm protects riverine flood water from spilling out of the parkland and onto the road.

6.3.3.2: Black Creek Naturalization and Flood Protection Corridor

SITE CONTEXT

Area: Approximately 284,000 square metres (28.4 hectares)

Topography: Black Creek flows southwest towards the Humber River.

Within the Regulatory Floodplain: Yes

Figure 35: Context Map of the Black Creek Channel

The Black Creek Naturalization and Flood Protection Corridor project include the revitalization of Black Creek between Scarlett Road and Hilldale Road, inclusive of Smythe Park, Black Creek Park West, and Black Creek Park East.

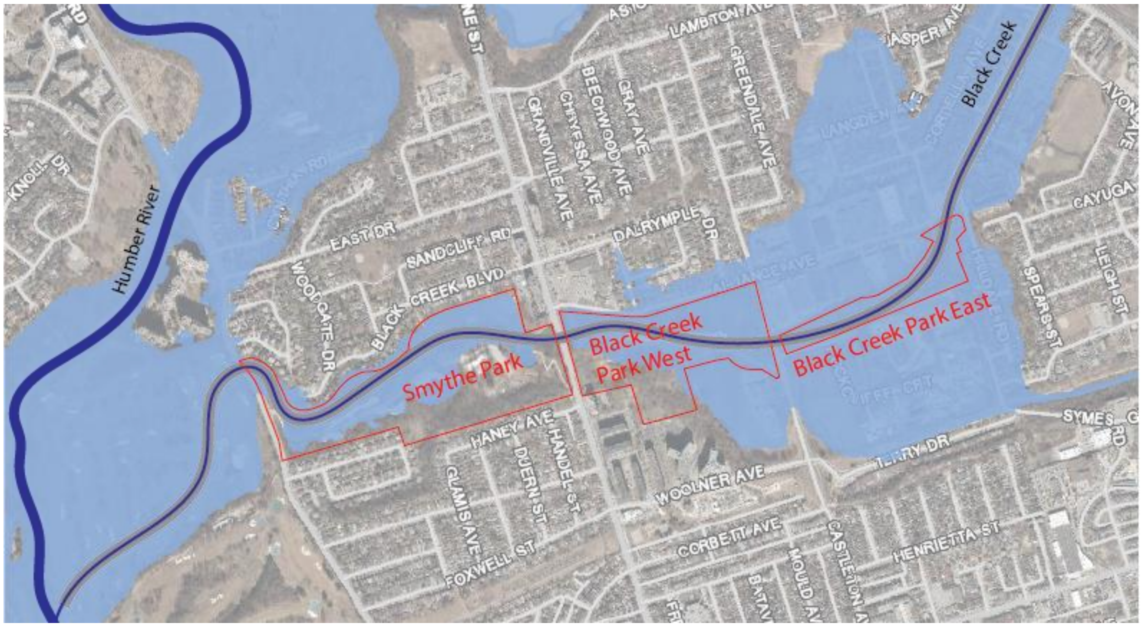


Figure 36: Floodplain Context of Black Creek (TRCA, n.d.-a)

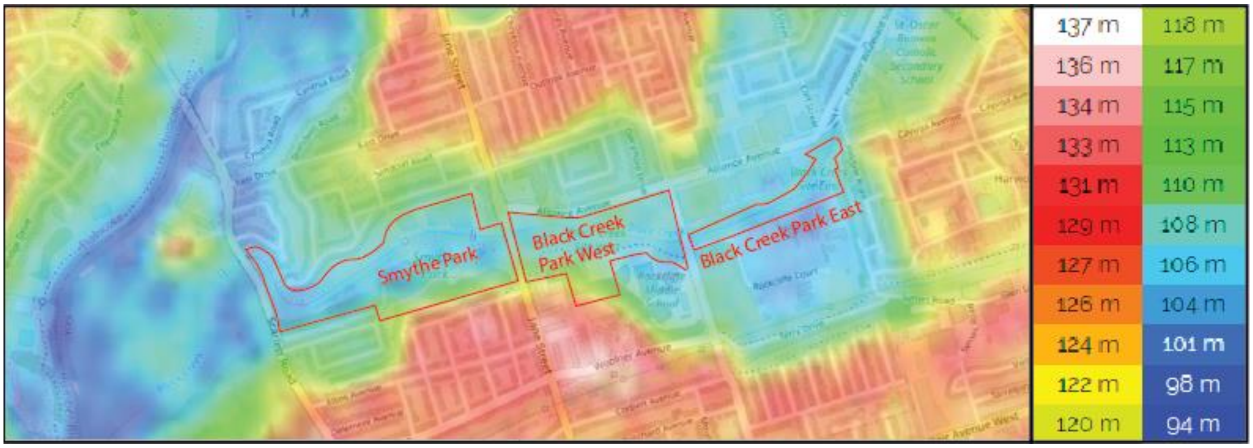


Figure 37: Topographic Context of Black Creek (Topographic-map.com, n.d.)

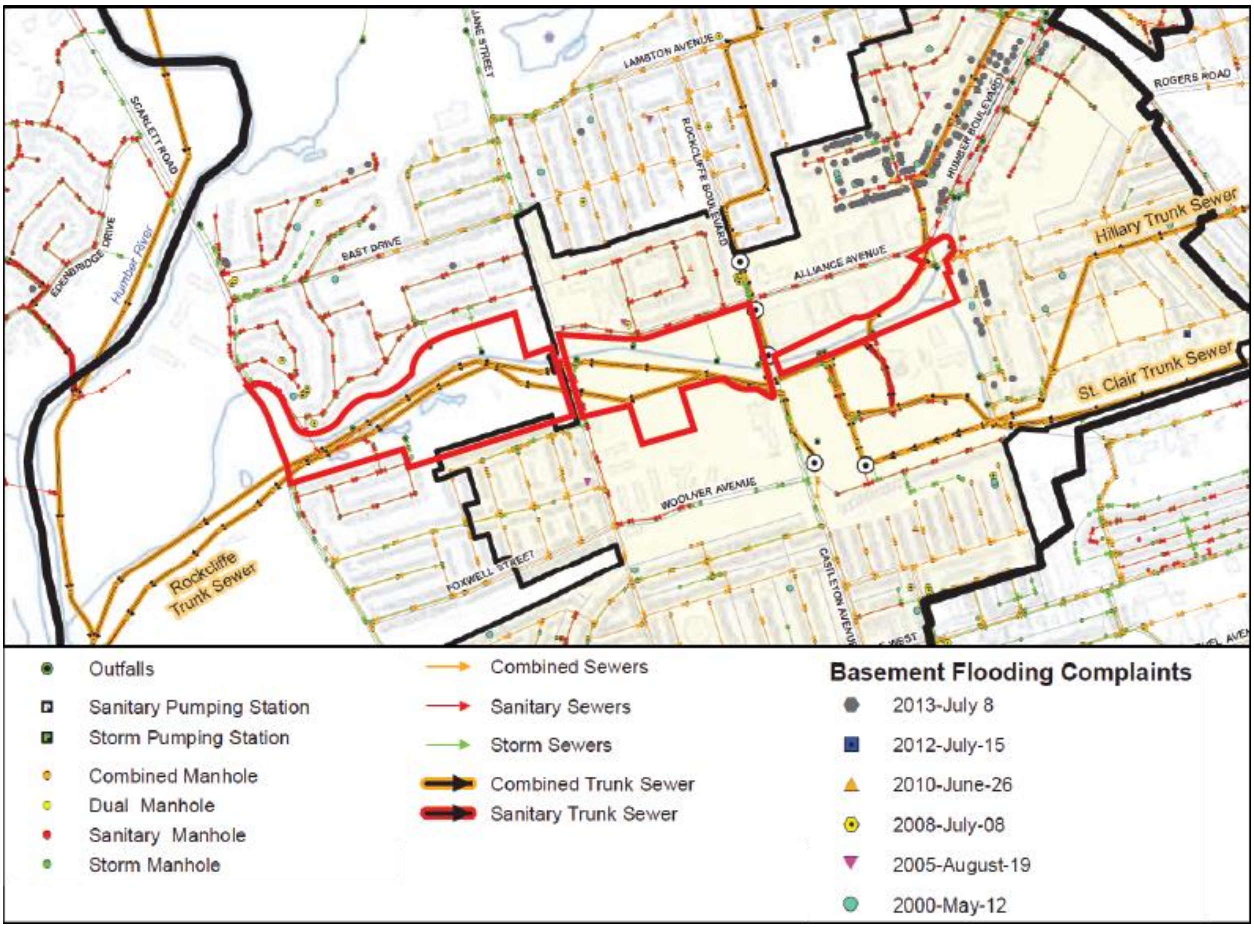


Figure 38: Sewer System Context of Black Creek (XCG Consulting Ltd., 2014, p. 6)

EXISTING SITE DESCRIPTION

The Black Creek Naturalization and Flood Protection Corridor project consists of three green space areas, including Smythe Park, Black Creek Park West, and Black Creek Park East. Black Creek flows through an engineered concrete channel constructed throughout the 1950s and 60s following Hurricane Hazel in 1954 (Reeves, 2018). Instead of functioning as a natural creek system, Black Creek is a grey infrastructure element designed to convey stormwater away from the built-up urbanized area as quickly as possible. Several outfalls and combined sewer overflow structures discharge untreated stormwater and wastewater into the Black Creek channel, which flows at high volumes and velocity during rainfall events. It is common for Black Creek to flow over the concrete banks, causing flooding of the grounds of Rockcliffe Middle School and the surrounding parkland and residentials streets within the floodplain.

The current design of Black Creek Site East and West consists of mature trees and open lawn areas that follow the Black Creek concrete channel. Smythe Park consist of mature trees, open lawn areas, a vehicle access road from Scarlett Road, three parking lots, and several recreation amenities, including three baseball diamonds, an outdoor pool and splash pad, and multiuse trails.

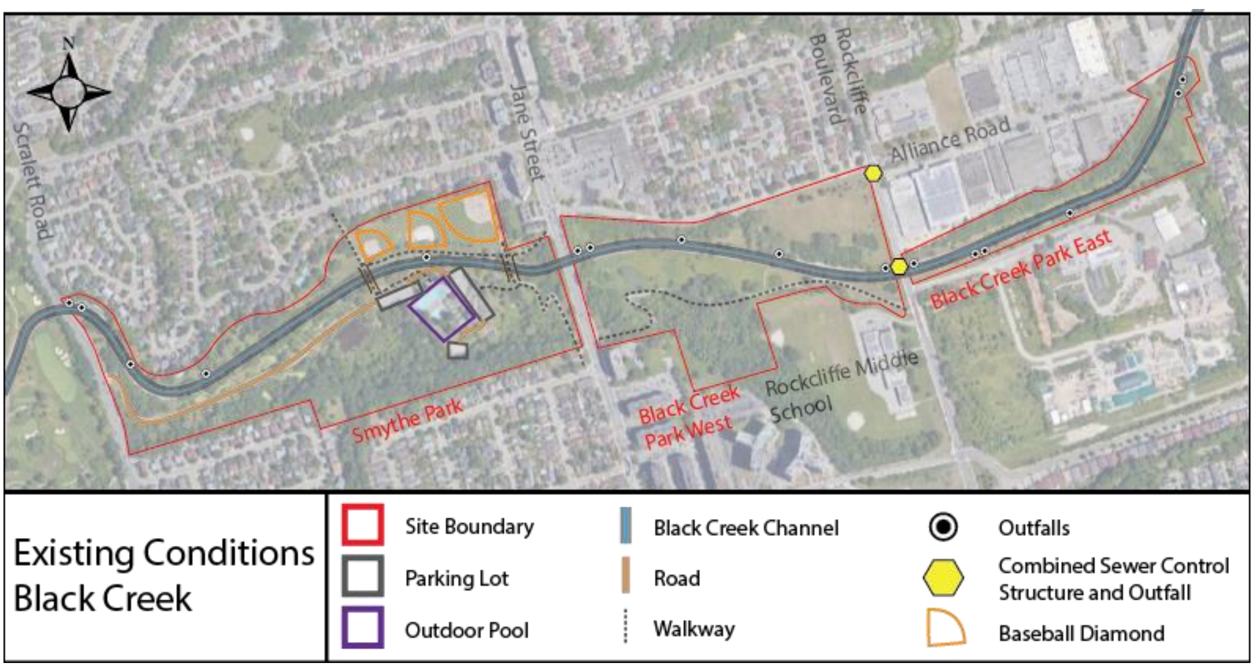


Figure 39: Existing Conditions of Black Creek

Figure 40: Black Creek Flows within a Concrete Channel Through Smythe Park, Black Creek Park West and Black Creek Park East (Photo Credit: Alana Wittman, July 2020)

Figure 41: Combined Sewer Control Structure and Outfall in Black Creek Park West (Photo Credit: Alana Wittman, July 2020)

Figure 42: The Jane Street Culvert within Black Creek Park West (Photo Credit: Alana Wittman, July 2020)

Figure 43: Open Green Space within Black Creek Park West (Photo Credit: Alana Wittman, July 2020)

Figure 44: City of Toronto Flood Risk Warning Sign in Black Creek Park East (Photo Credit: Alana Wittman, July 2020)

REVITALIZATION OPPORTUNITY

The subject area is a substantial parcel of public land situated within the Black Creek floodplain that has unrealized potential for stormwater management and flood protection. Planning and design interventions can transform Black Creek from a constrained concrete channel into a naturalized watercourse with wetlands and a vegetated floodplain that reduce, capture, filter and infiltrate rainwater and runoff.

DESIGN APPROACH AND VISION

- Integrate green stormwater infrastructure in the site to achieve stormwater management and flood mitigation benefits, while creating an attractive public space for community use.
- Increase water storage capacity and groundwater recharge through a naturalized watercourse, wetland habitat, vegetated soils, and woodland areas (Hough, 1995, p. 77).
- Design the site to include both permanent and temporary water storage, this includes enabling the entire site to take on flood water during high-flow events.
- Lower the floodplain by designing the Black Creek to be deeper and wider than its current built form, allowing larger volumes of water to flow through the waterway during high-flow events (Rijkswaterstaat, 2010; Rotterdam, 2010).
- Use vegetation to stabilize the naturalized creek bank, control peak flow rates, and restore riparian zones within the floodplain.
- Establish clear entrances for park access and to park activity spaces using structural and vegetative buffers to reduce safety hazards for park users.
- Integrate the existing stormwater outfall and combined sewer overflows into the design.
- Incorporate design recommendations from the TRCA's (2014) *Black Creek (Rockcliffe Area) Riverine Flood Management Class Environmental Assessment*, including the flood protection berms east of Scarlett Road and north of Rockcliffe Middle School.

CONCEPT DESIGN

The Black Creek Naturalization and Flood Protection Corridor project transforms Black Creek from a constrained concrete lined channel into a natural and meandering watercourse, substantially reducing the risk of riverine flooding in the Rockcliffe-Smythe neighbourhood. Green stormwater infrastructure will be incorporated into Smythe Park, Black Creek Park West, and Black Creek Park East to achieve stormwater management objectives, while creating an attractive public space for community use. The design incorporates flood mitigation approaches used for Toronto's *Don Mouth Naturalization and Port*

Lands Flood Protection Project (Waterfront Toronto, n.d. & 2016) and the Dutch *Room for the River* programme (Rijkswaterstaat, 2010; City of Rotterdam, 2010).

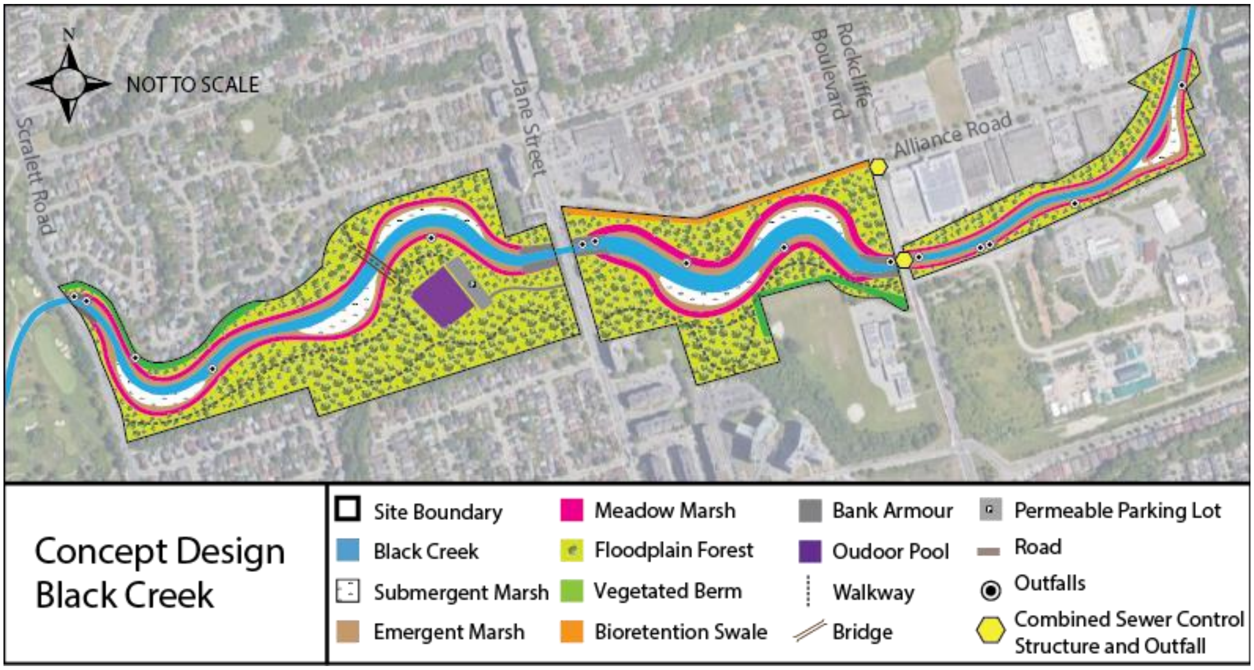


Figure 45: Concept Design of the Black Creek Naturalization and Flood Protection Corridor Project

A new naturalized creek channel will be constructed, replacing the existing concrete channel. The new 2,000 metre Black Creek channel will include a rocky creek bed and bioengineered banks, providing more space for Black Creek to flow during typical and high-water conditions. The wide and meandering creek provides a significant amount of permanent and temporary storage space for water, reduces peak flow and velocity rates and enabled the creation of approximately 104,000 metres squared of multifunctional wetlands and marsh habitat. The width and meander of the creek within each park was determined by the available space within each site. For example, the creek channel is much wider in Black Creek Park West than in Black Creek Park East due to the limited area and configuration of the site.

Two vegetated berms have been incorporated into the revitalization project to provide 100-year flood protection (XCG Consulting Ltd., 2014, p. 11). A berm will be constructed on the northern extent on Smythe Park from Scarlett Road to Jane Street to protect the adjacent residential area from flooding during high-flow events (TRCA, 2014, p. E-2-3). The second berm will be constructed along the southeastern extent on Black Creek Park West, protecting Rockcliffe Middle School for riverine flood water events (TRCA, 2014, p. E-2-3). The berms would permanently remove Rockcliffe Middle School and the homes along Black Creek Drive from the floodplain (TRCA, 2014, p. E-4).

A floodplain forest will be planted within the remaining parkland area. The floodplain forest slows, filters and infiltrated rain and riverine flood water, strengthening the natural and structural capacity of the parkland to mitigate the effects of flooding (Hough, 1995, p. 34). Multiuse recreation trails, shaded picnic areas, and viewpoint of the creek and wetland ecosystems will be constructed to provide space for both active and passive recreation within the parkland. The pathways are designed to minimize impacts to natural areas and are wide enough to accommodate a maintenance vehicle.

Design Element	Description
Naturalized Black Creek Channel	The new 2,000 metre naturalized Black Creek channel will be designed to provide significantly more room for the creek to flow in comparison to the existing concrete channel. The banks of the new channel will be bioengineered with stone armouring and wetlands that enable the channel to withstand fast moving floodwaters. Further, the wide and meandering creek provides space for permanent and temporary water storage, reduces peak flow and velocity rates.
Flood Protection Berms	The berms provide flood protection for the areas adjacent to the site by raising the grade of land along the edges of the parks.
Submergent Wetland	Wetland habitat has been incorporated along the meanders of the watercourse, between the creek channel and emergent marsh, to provide additional water storage capacity, improve water quality, and create habitat.
Emergent Marsh	The emergent wetland zone is the saturated portion of the creekbank where riparian vegetation that thrive in shallow water and/or water edge conditions grow, such as grasses and woody shrubs. This zone is important for flood-flow storage, slowing water velocity rates, and bank stabilization.
Meadow Marsh	The meadow wetland is the uppermost portion of a creekbank, comprised of flood tolerant grasses, that infiltrated runoff and riverine floodwater during high-water conditions, but is dry in typical conditions.
Bank Armour	Exposed stone armour has been incorporated into the creek bank where water flows through culverts underneath bridges. The armour will protect the creek channel and bank from erosion and fast-flowing waters during high-water events.
Floodplain Forest	A floodplain forest will be planted to slow and infiltrate rainwater. This will lower water level fluctuations in Black Creek and reduce the risk of riverine flooding and erosion (Forman, 2014, p. 171; Hough, 1995, p. 34). An additional benefit is that

	densely wooded areas around the perimeter of a wetlands will deter geese from colonizing (Ontario, 2003).
Bioretention Swale	The swale is a shallow vegetated channel with sloped sides that collects and manages runoff from Alliance Avenue.
Permeable Pavement Parking Lot	A permeable pavement parking lot, with adjacent bioretention rain gardens, will provide bicycle and vehicle parking for park and pool users. The parking lot will be designed to meet the City of Toronto's '*Greening' Surface Parking Lots Guidelines* (Toronto, 2013).
Access Road	The road leading to the parking lot and outdoor pool is accessible from Jane Street.
Green Spillway	The entire site, apart from the outdoor pool, will function as a spillway—an area that provides additional space for flood water capacity—during flooding events. During regular conditions, the spillway will perform its primary function as a naturalized waterway and woodland area for stormwater management and recreation use.

Table 12: Green Stormwater Infrastructure Elements within the Concept Design of The Black Creek Naturalization and Flood Protection Corridor

PERFORMANCE

- The project includes (1) a new naturalized river channel, which is approximately 2,000 metres in length, provides more room for Black Creek to flow during normal and high water conditions; (2) approximately 31,000 square metres of dedicated submergent wetland ecosystem, 24,000 square metres of emergent marsh, and 49,000 square metres of meadow marsh ecosystem, providing permanent and temporary storage capacity for riverine water and slows water flow during flood events; and (3) approximately 152,000 metres squared of floodplain forest habitat that slows and captures water during flood events.
- The entire site 284,000 metres squared, apart from the outdoor pool, functions as a spillway during riverine flooding events.
- The two vegetated berms will provide flood protection by preventing flood water from spilling out of the parkland and into the residential neighbourhood and Rockcliffe Middle School.

6.3.3.3: Noble Park

SITE CONTEXT

Area: Approximately 14,000 square metres (1.4 hectares)

Topography: A maximum elevation of 121 metres is observed at the northwest corner of the site, where the grade slopes south towards Black Creek with a minimum contour level of 114 metres.

Within the Regulatory Floodplain: No

Figure 46: Context Map of Noble Park

Noble Park is located south of East Drive, west of Sandcliffe Road, and east of Rose Valley Crescent in a low-density residential area.

Figure 47: Floodplain Context of Noble Park (TRCA, n.d.-a)

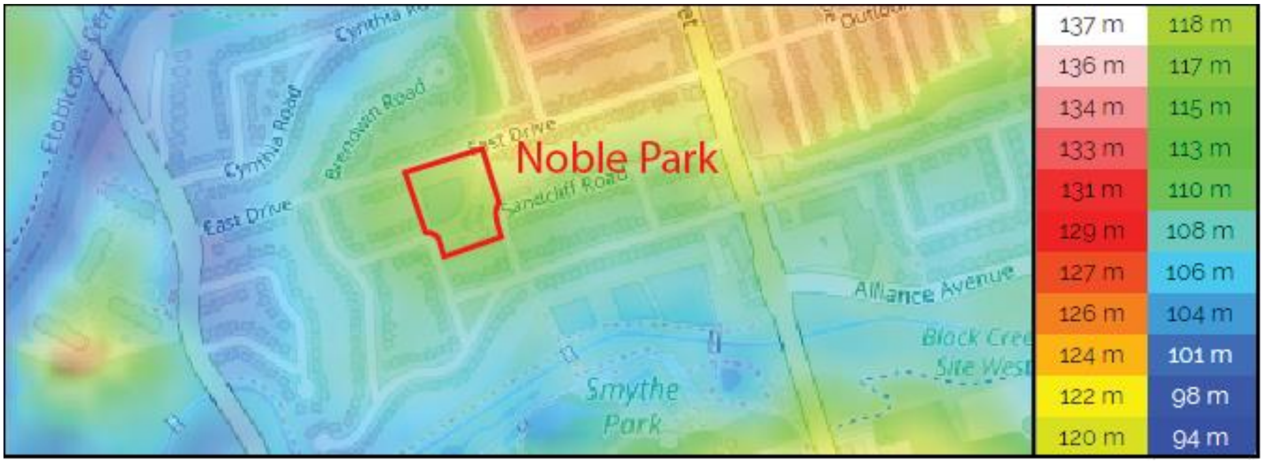


Figure 48: Topographic Context of Noble Park (Topographic-map.com, n.d.)

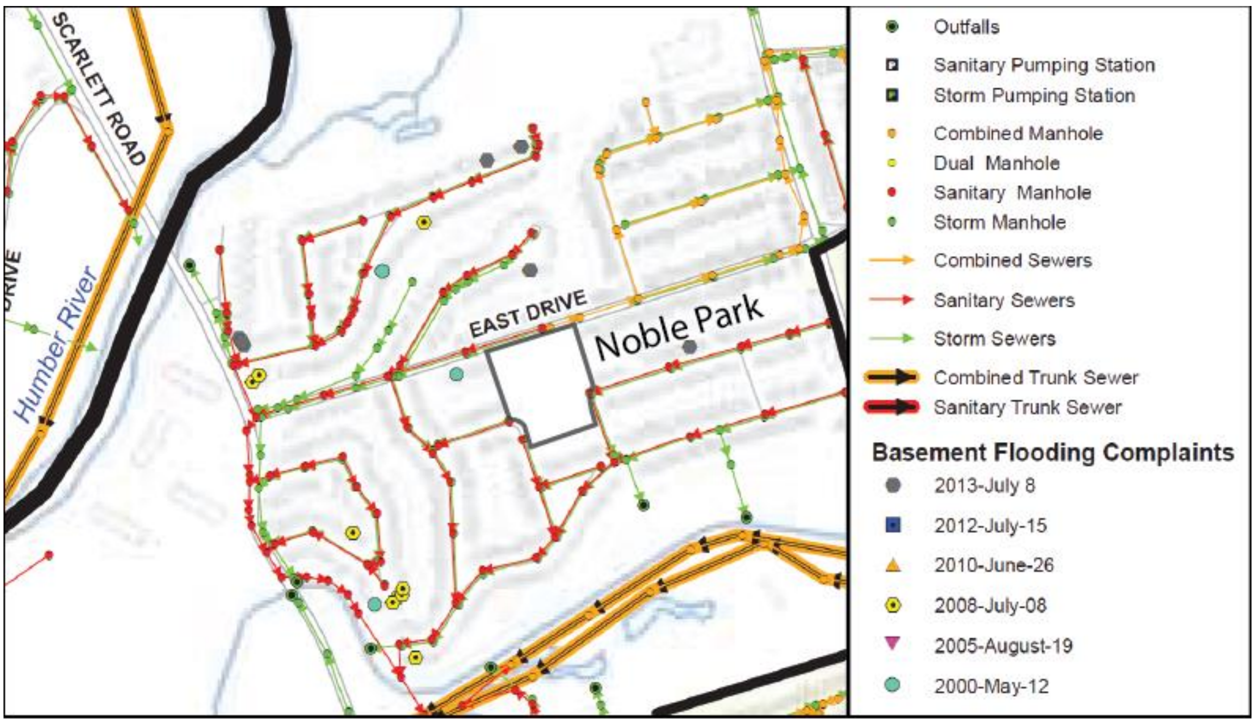


Figure 49: Sewer System Context of Noble Park (XCG Consulting Ltd., 2014, p. 6)

Noble Park is situated within an area that has both combined and separated sewer systems. Stormwater runoff that enter the separated stormwater sewer is conveyed to outfalls that discharge into Black Creek, while the runoff that enters the combined system, northeast of the site, is conveyed into the Mt. Dennis Trunk Sewer.

EXISTING SITE DESCRIPTION

Noble Park is located on the south side of East Drive and extends south to Rose Valley Crescent to the west and Sandcliffe Road to the east. Low-density detached residences are directly adjacent to the site on the eastern, southern, and western site boundaries. The current design of the park caters exclusively to active recreation, which include a baseball diamond, basketball court, and playground. The recreation amenities are in disrepair despite the park being an important location for active recreation for the local community. Additional amenities include two pedestrian walkways and many mature trees along the perimeter of the site and along the north-south walkway.

Figure 50:Exisiting Conditions of Noble Park

Figure 51: Noble Park Looking South from East Drive (Photo Credit: Alana Wittman, July 2020)

Figure 52: Basketball Court in Noble Park (Photo Credit: Alana Wittman, July 2020)

Figure 53: Access Point to Noble Park from Rose Valley Crescent (Photo Credit: Alana Wittman, July 2020)

REVITALIZATION OPPORTUNITY

In recognition that Noble Park is an important space for active recreation within the local area, the redesign is an opportunity to replace the dilapidated active recreation amenities with multifunctional amenities that fulfils recreation and stormwater management objectives. The incorporation of bioretention into the site provides the opportunity to capture stormwater runoff that is generated northeast of the site as it drains southwest towards Black Creek and the Humber River.

DESIGN APPROACH AND VISION

- Integrate green stormwater infrastructure in the park to achieve stormwater management benefits.
- Dual functional design of the recreation amenities in order to achieve stormwater management and recreation objectives, while creating an attractive public space.
- Provide permeable walkways and shaded seating areas throughout the park for passive recreation.
- Establish clear entrances for park access and to amenity spaces through planting, grading, and walkways.
- Improve public access to the site by creating a new pedestrian access point on the northwestern edge of the site along East Drive.
- Provide planted tree buffers along the edge of the park and adjacent private property.
- Preserve existing mature trees when possible.

CONCEPT DESIGN

Noble Park, an important space for active recreation in the community, will be revitalized into a public space that blends recreational amenities with stormwater management detention and treatment features. The design includes improving recreational amenities and the playground, and the construction of new pedestrian walkways, landscaped berms, and two rain gardens.

Figure 54: Concept Design of Noble Park

Two rain gardens will be constructed that use bioretention to collect, store, treat, and infiltrate stormwater runoff that is generated northeast of the site, where the elevation is higher. Runoff enters the park through inlets that convey the stormwater into the rain gardens during rainfall and snowmelt events. The soils and vegetation within the rain gardens cleans pollutants from the runoff, prevents the soil from compacting, and allows water to infiltrate back into the ground (Chin, 2017). The rain garden just south of East Drive is situated beside the sidewalk at street level. When this rain garden reaches its storage capacity, runoff will flow over the check-dam and into the vegetated swale that conveys the excess water south into the baseball diamond that functions as a detention basin during flooding events. The rain garden just west of Sandcliffe Road is designed with elevated walkways to provide viewing opportunities to park users. Where the walkway passes over the rain garden, the path will be elevated, and handrails will be installed to ensure user safety and to protect the integrity of the bioretention facility.

Vegetated berms are a multifunctional element that have been used within and along the perimeter of the site. The berms direct water flow to the green stormwater management features, provide physical barriers to separate different activity spaces and the park from the adjacent private residences, and can be utilized by park users as viewing and picnic spaces. The most unique berm incorporated in the site is located just south of East Drive, between the rain garden and the baseball diamond. This berm not only enables the baseball diamond to function as a temporary stormwater detention basin during flooding events, but also provides seating space for spectators and park users through its terraced slope.

The walkways, seating/ gathering area, and the multiuse sports court will be constructed with permeable and porous pavement to improve surface drainage. The north-south walkways that provide community access to the park along East Drive are now gently meandered to blend into the landscape while still being situated along pedestrian desire lines. Trees, both existing and newly planted, line the walkways to provide shaded walking and seating areas for passive recreation.

The location of the playground has been moved approximately 20 metres west to make room for a rain garden that uses bioretention to capture and treat stormwater runoff from Sandcliffe Road. The revitalized playground includes natural play features, such as a logs and boulders for climbing and seating. A new multiuse sports court, which includes two basketball hoops and small skateboard platforms, will replace the existing basketball court. The new court will be constructed from permeable pavement which not only allows stormwater to infiltrate into the underlying soil, but also enables the court to dry faster for recreational use.

Design Element	Description
Bioretention Rain Garden	Two rain gardens, sunken vegetation filled planting beds, have been incorporated into the design to collect, temporarily store, and infiltrate stormwater runoff from adjacent roads and sidewalks. The rain gardens will improve street drainage, restore a natural water cycle, and reduce strain on the existing grey stormwater system by reducing the quantity of runoff entering the system.
Permeable Pavement Walkway	Pervious interlocking concrete pavers are used to form the pedestrian walkway and seating area. The pavers will allow water to infiltrate into the underlying soil.
Porous Basketball Court	Although the footprint of the existing basketball court will remain, the court will be replaced with a porous asphalt surface with an underground stormwater storage system that will allow stormwater to infiltrate into the soil below.

Baseball Diamond / Stormwater Detention Basin	The existing baseball diamond will be surrounded by raised berms, enabling the diamond to function as a temporary stormwater detention basin during heavy rainfall events.
Trees	In addition to preserving the existing mature trees within the park, additional trees have been planted to provide shaded walkways and seating area; establish clear entrances to the park and park amenity spaces; provide a visual and noise buffers between the park and adjacent private property.
Vegetated Berm / Buffer	The berms surrounding the baseball diamond enable the sports field to function as a stormwater detention basin during flood-events, while the berms adjacent to private residential lots provide visual and noise buffers between the park and adjacent private property.
Natural Playground	A playground that contains play elements made from natural materials or incorporated into the natural landscape. Natural playgrounds could include trees, logs, stumps, boulders, sand, water, vegetation, or other natural materials. Research suggests that natural playgrounds stimulate the creative and imagination of children more than traditional playgrounds.
Inlet	Inlets are openings within the roadway curb that conveys stormwater runoff from the surrounding area into the rain gardens.
Swale/ Spillway	The swale is a shallow grass channel that is integrated into the terraced berm and rain garden. The swale conveys excess stormwater runoff from the rain garden into the baseball diamond, which functions as a temporary stormwater detention basin during flood events.

Table 13: Green Stormwater Infrastructure Elements within the Concept Design of Noble Park

PERFORMANCE

- The park includes approximately 2,000 metres squared of bioretention facilities.
- Overflow drains and a spillway have been incorporated into the design in order to manage high volumes of stormwater runoff.

6.3.3.4: Cynthia - Frimette Parkette

SITE CONTEXT

Area: Approximately 500 square metres (0.05 hectares)

Topography: Generally flat, with a maximum elevation of 104 metres

Within the Regulatory Floodplain: Yes

Figure 55: Context Map of Cynthia-Frimette Parkette

Cynthia-Frimette Parkette is located at the intersection of Cynthia Road and Frimette Crescent in a low-density residential area.

Figure 56: Floodplain Context of Cynthia-Frimette Parkette (TRCA, n.d.-a)

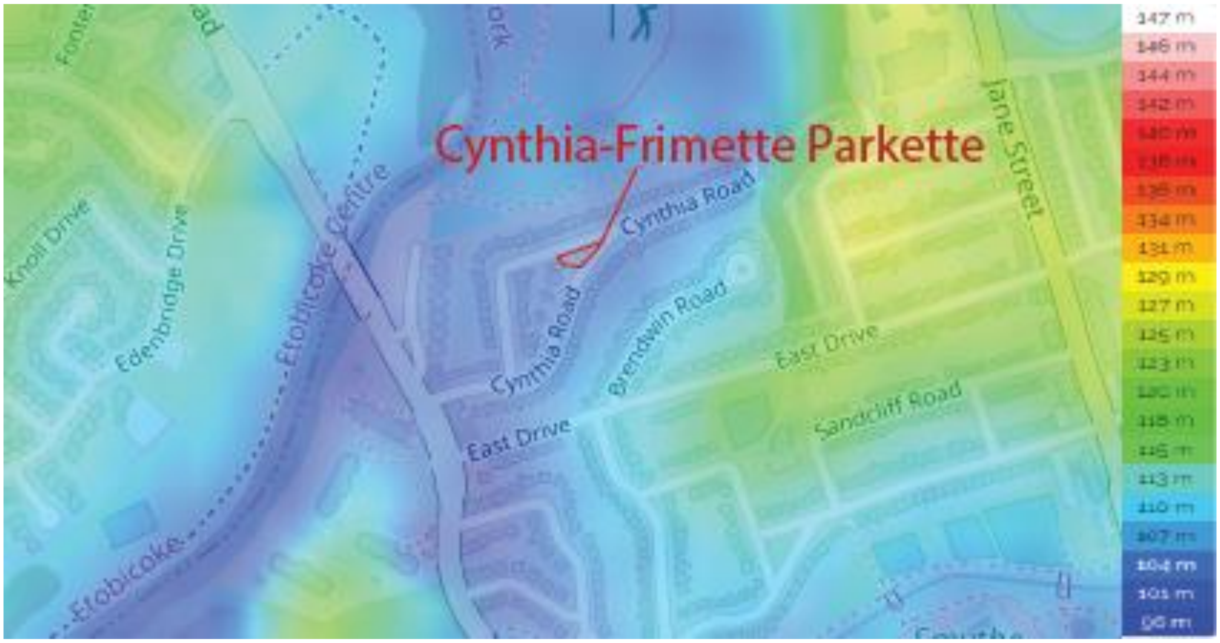


Figure 57: Topographic Context of Cynthia-Frimette Parkette (Topographic-map.com, n.d.)

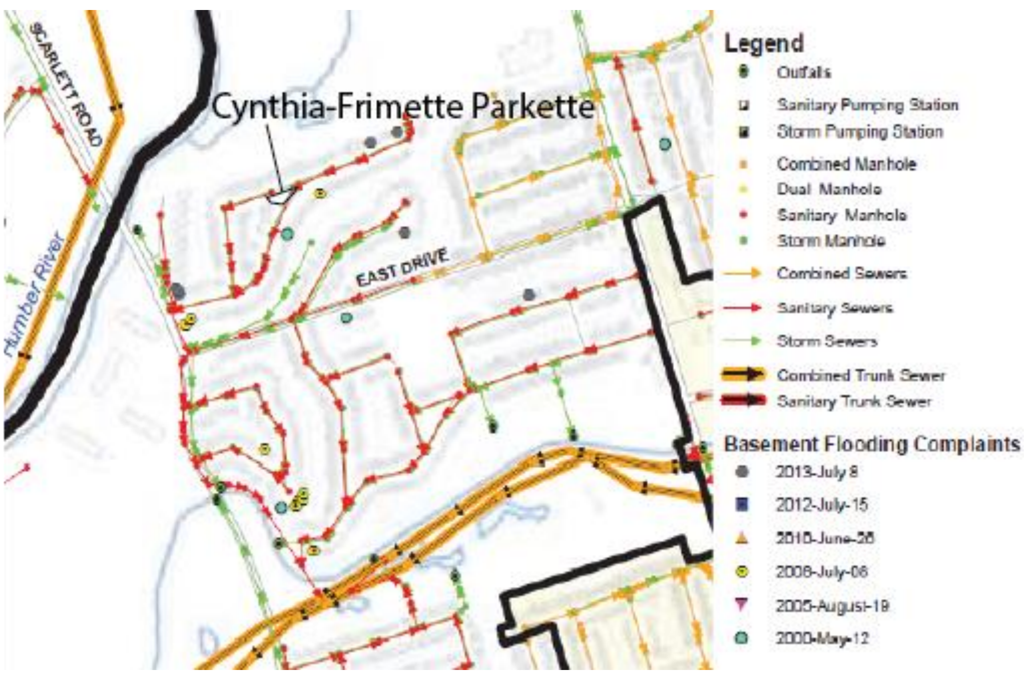


Figure 58: Sewer System Context of Cynthia-Frimette Parkette (XCG Consulting Ltd., 2014, p. 6)

Cynthia-Frimette Parkette is situated within an area that has a separated sanitary and storm sewer system. The storm sewer collects and conveys stormwater runoff from Cynthia Road and Frimette Crescent to an outfall that discharges into Black Creek.

EXISTING SITE DESCRIPTION:

Cynthia-Frimette Parkette is an irregular piece of land at the intersection of Cynthia Road and Frimette Crescent that makes up a small portion of Toronto's public green space system. The current design of the site consists of a maintained grassed lawn, four mature trees, a bench, and a garbage bin. Given the site's location within the floodplain and the number of basement flooding events that have occurred, the parkette has untapped potential to support stormwater management through green stormwater infrastructure.

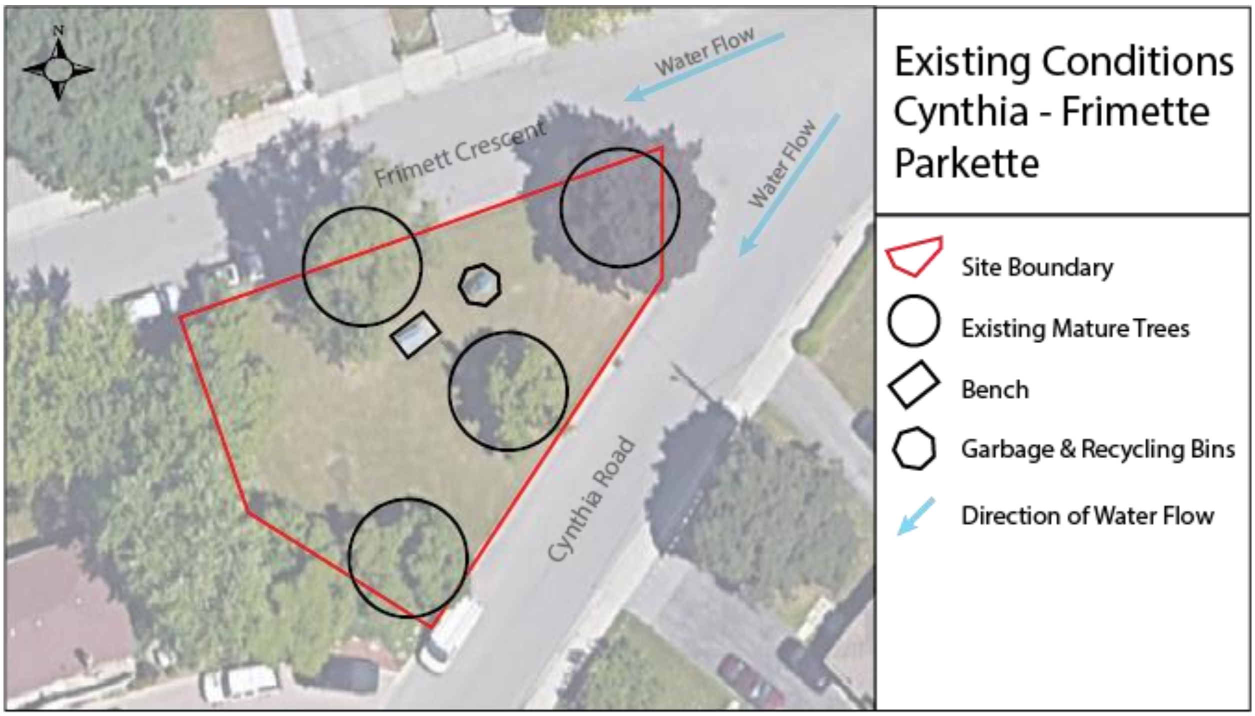


Figure 59: Existing Conditions of Cynthia-Frimette Parkette

Figure 60: Cythia-Frimette Parkette Looking West (Photo Credit: Alana Wittman, July 2020)

Figure 61: Cynthia-Frimette Parkette Looking Southwest (Photo Credit: Alana Wittman, July 2020)

REVITALIZATION OPPORTUNITY

Cynthia-Frimette Parkette provides an opportunity to revitalize an underutilized public space and transform the site into a lush green space for stormwater management and passive recreation through the incorporation of green stormwater infrastructure into the design.

DESIGN APPROACH AND VISION

- Integrate green stormwater infrastructure in the parkette to achieve stormwater management benefits.
- Dual functional design that achieves parkette and stormwater management objectives, while creating an attractive public space.
- Provide walkways through the parkette, a shaded seating area, and a planted tree buffer along the edge of the site and the adjacent private property.
- Preserve the existing mature trees.

CONCEPT DESIGN

Cynthia-Frimette Parkette will be transformed into a sustainable urban stormwater management parkette that uses bioretention to reduce stormwater runoff volumes and contamination loads from entering the sewer and receiving water systems.

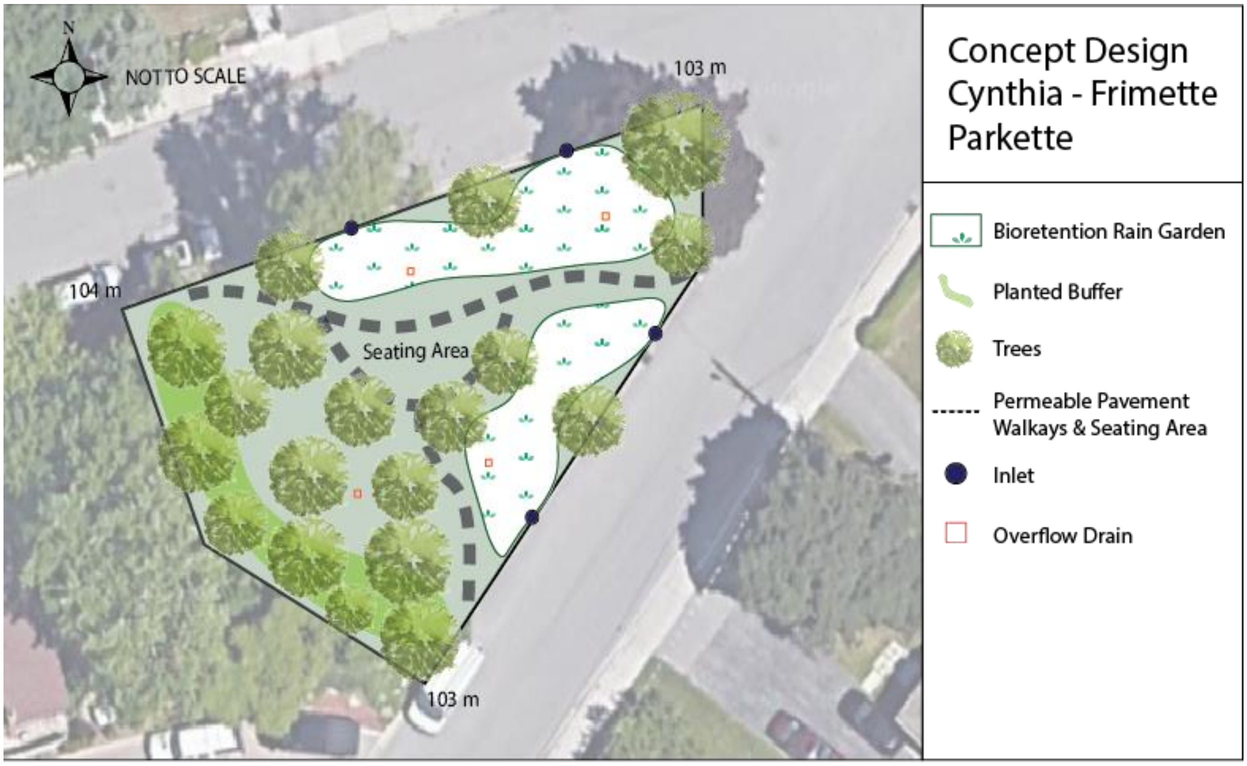


Figure 62: Concept Design for Cynthia-Frimette Parkette

The Cynthia-Frimette Parkette consists of two bioretention rain gardens that treat and infiltrate stormwater runoff from the adjacent roads. Runoff enters the parkette through inlets that convey runoff from the surrounding roadway into the rain gardens during rainfall and snowmelt events. The soils and vegetation within the rain gardens clean pollutants from the runoff, prevent the soil from compacting, and allows water to infiltrate back into the ground (Chin, 2017). In addition to green stormwater infrastructure, the parkette includes seating and a pervious concrete walking path for passive recreational use. The design improves local stormwater management, natural aesthetic, and functionality of the public space.

Design Element	Description
Bioretention Rain Gardens	Two rain gardens, sunken vegetation filled planting beds, provide temporary storage, clean, and infiltrate stormwater runoff from adjacent roads and sidewalks. The rain gardens improve street drainage, restore a natural water cycle within the site, and reduce strain on the existing grey stormwater system by reducing the quantity of runoff entering the system.
Permeable Pavement	Pervious interlocking concrete pavers are used to form the pedestrian walkway and seating area. The pavers allow water to infiltrate into the underlying soil.
Trees	In addition to preserving the existing mature trees, additional trees have been planted. Trees perform several stormwater management services, including the interception of rainwater and increasing soils infiltrate rate. Additionally, trees provide shade for the seating area and a privacy and noise reduction buffer between the park and surrounding uses.
Inlet	Inlets are openings within the roadway curb that conveys stormwater runoff from the surrounding area into the rain gardens.
Overflow Drain	Overflow drains enable excess runoff to be conveyed into the conventional storm sewer when the quantity of runoff within the rain gardens exceeds their designed storage and soil infiltration capacity.

Table 14: Green Stormwater Infrastructure Elements within the Concept Design of Cynthia-Frimette Parkette

PERFORMANCE

- The parkette includes approximately 200 metres squared of bioretention facilities.
- Overflow drains have been incorporated into the design to manage high volumes of stormwater runoff.

6.3.3.4: Brendwin Circle Parkette

SITE CONTEXT

Area: Approximately 280 square metres (0.028 hectares)

Topography: Consistent grade, with a maximum elevation of 100 metres

Within the Regulatory Floodplain: No

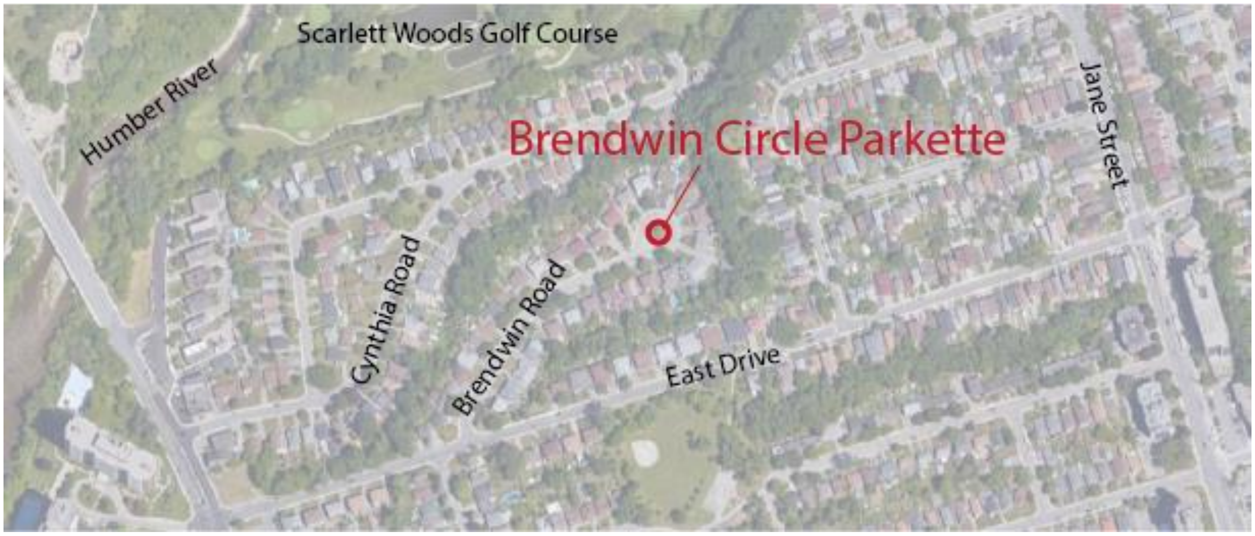


Figure 63: Context Map of Brendwin Circle Parkette

Brendwin Circle Parkette is located at the northern extent of Brendwin Road in the centre of a residential cul-de-sac.

Figure 64: Floodplain Context of Brendwin Circle Parkette (TRCA, n.d.-a)

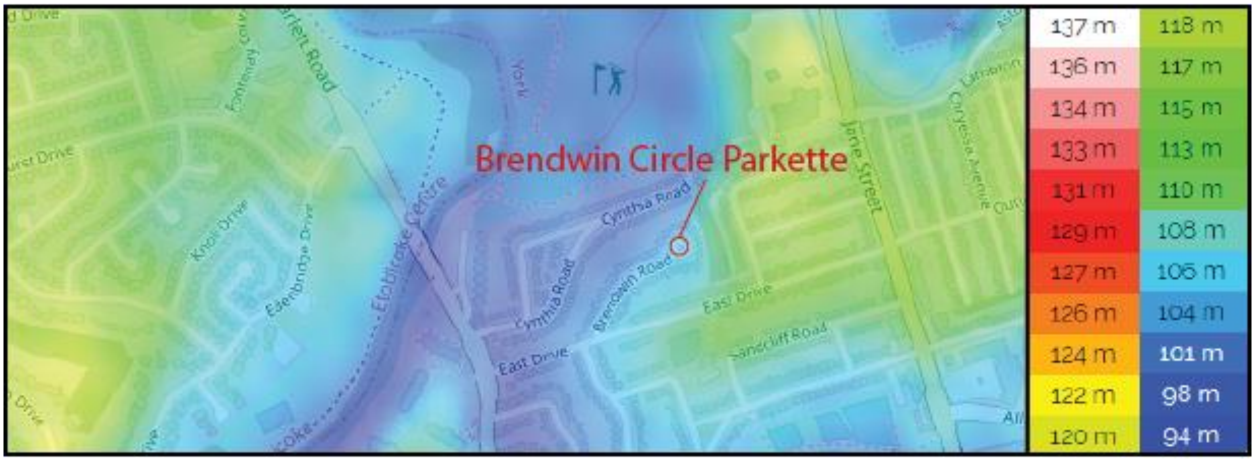


Figure 65: Topographic Context of Brendwin Circle Parkette (Topographic-map.com, n.d.)

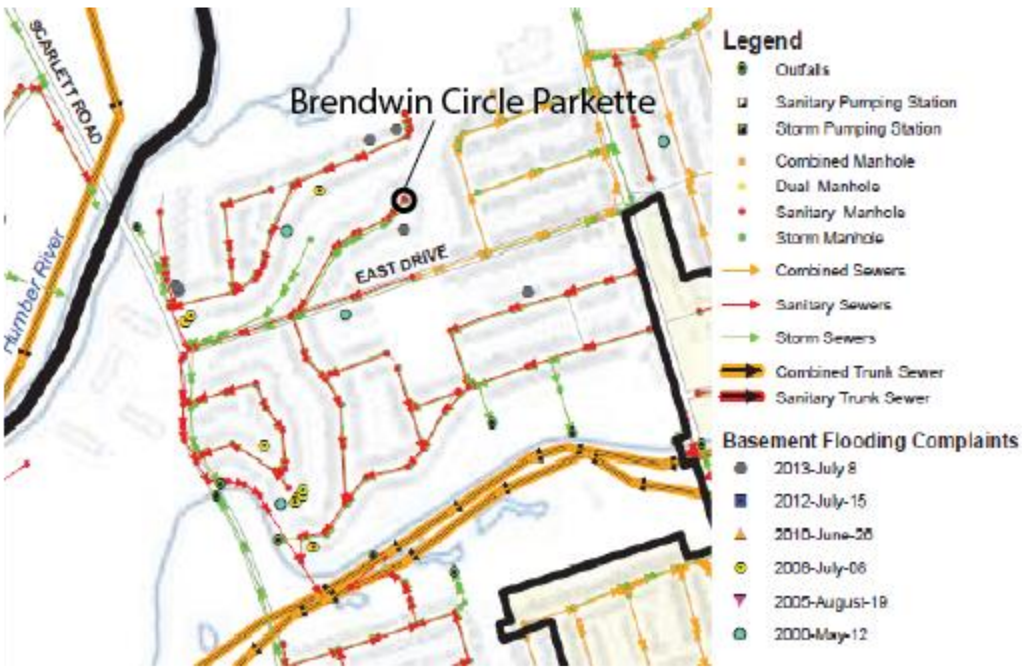


Figure 66: Sewer System Context of Brendwin Circle Parkette (XCG Consulting Ltd., 2014, p. 6)

Brendwin Circle Parkette is situated within an area that has a separated sanitary and storm sewer system. The storm sewer collects and conveys stormwater runoff from Brendwin Road to an outfall that discharges into Black Creek.

EXISTING SITE DESCRIPTION

Brendwin Circle Parkette is the center island of a cul-de-sac which is directly adjacent to the roadway. The current design of the site consists of a single mature tree with three paved pathways leading up to the tree from the roadway. The small size of the site and the location of the existing mature tree limits the number of design interventions that are possible.

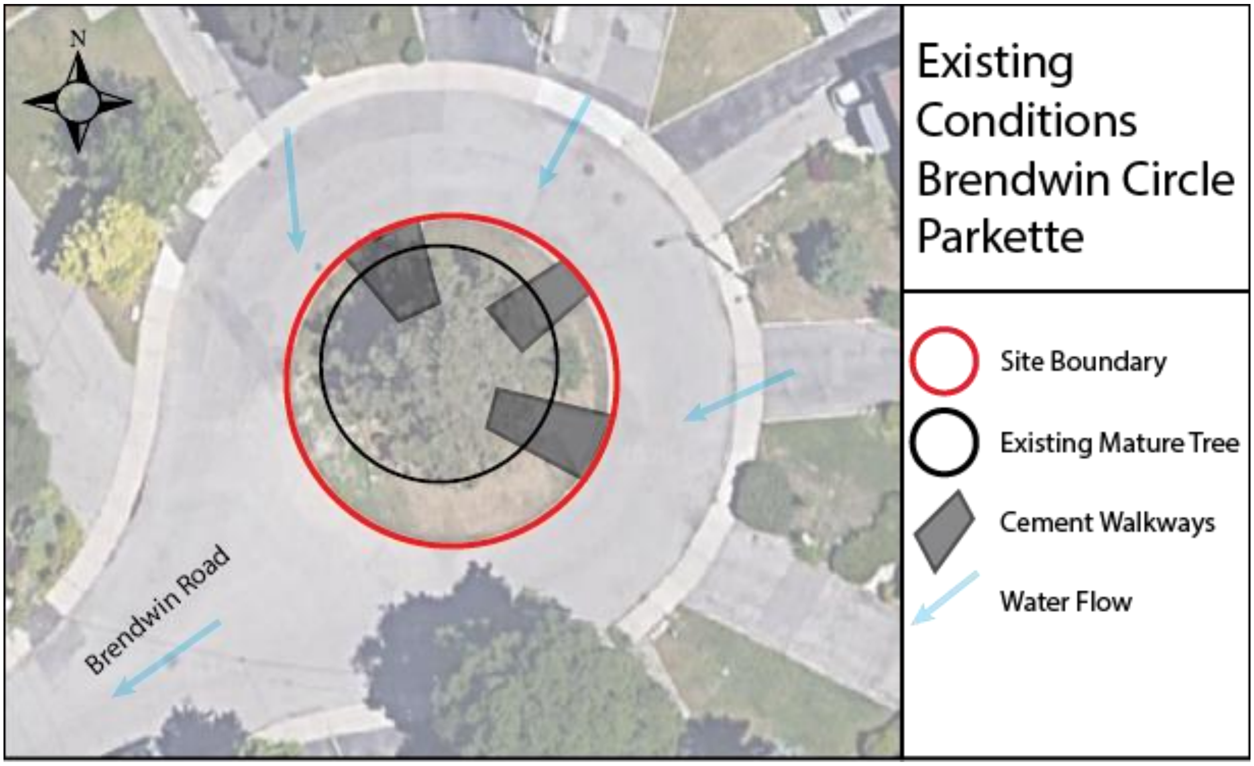


Figure 67: Existing Conditions of Brendwin Circle Parkette

Figure 68: Brendwin Circle Parkette Looking North (Photo Credit: Alana Wittman, July 2020)

REVITALIZATION OPPORTUNITY

Brendwin Circle Parkette provides an opportunity to revitalize an underutilized public parkette and transform the site into a space that improves local stormwater management.

DESIGN APPROACH AND VISION

- Integrate green stormwater infrastructure in the parkette to achieve stormwater management benefits.
- Preserve the existing mature tree.
- Replace the existing grass and concrete walkways with a rain garden.
- Designed space to meet the City of Toronto's *Green Streets Technical Guideline* (Schollen & Company Inc. et al, 2017).

CONCEPT DESIGN

Brendwin Circle Parkette will be transformed into a sustainable urban stormwater management parkette that uses bioretention and the existing mature tree to reduce stormwater runoff volumes and contamination loads from entering the storm sewer and receiving water systems.

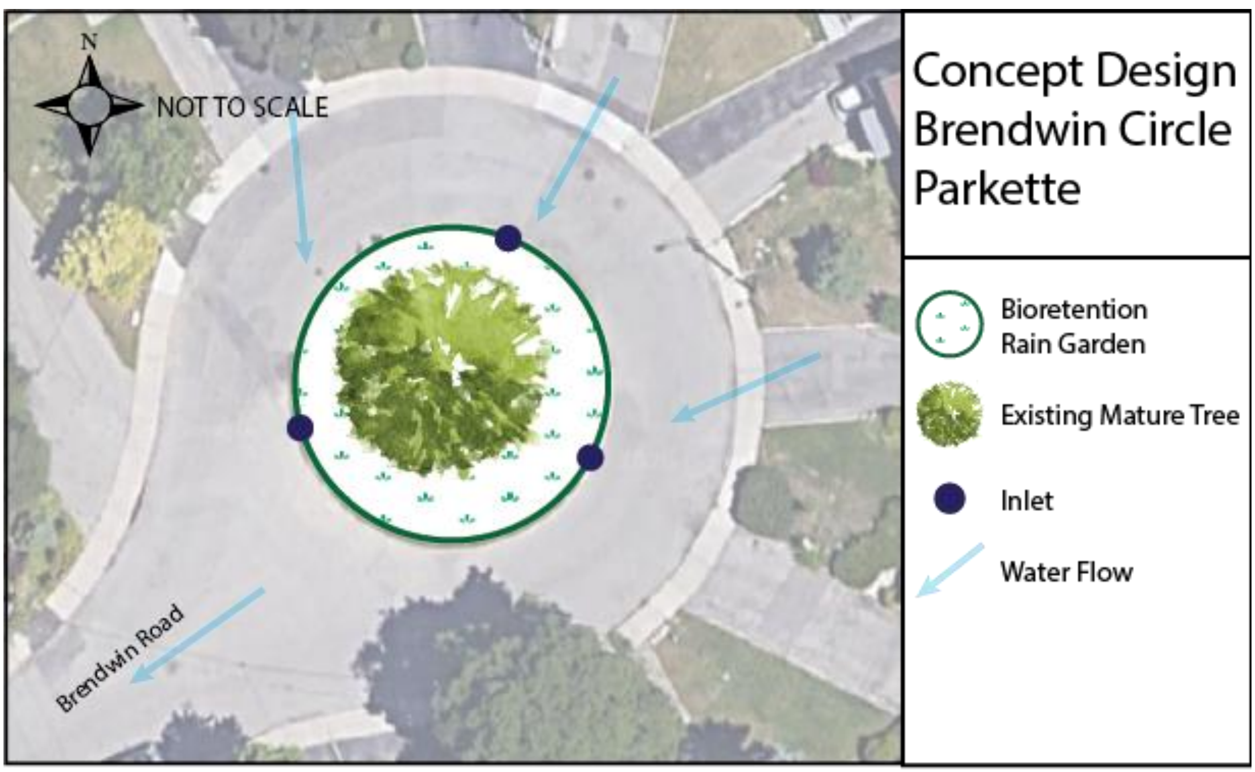


Figure 69: Concept design for Brendwin Circle Parkette.

The Brendwin Circle Parkette consists of one bioretention rain garden that surrounds the trunk of the existing mature tree. Runoff enters the parkette through inlets that convey runoff from the surrounding impermeable surfaces, such as the adjacent buildings, driveways, and roadway, into the rain garden during rainfall and snowmelt events. The soils and vegetation within the rain garden filter pollutants from the runoff, prevent the soil from compacting, and facilitates the infiltration of water into the ground (Chin, 2017). The design improves local stormwater management and natural aesthetics through the revitalization of this small public space.

Design Element	Description
Bioretention Rain Garden	The rain garden, a sunken vegetation filled planting bed, improves street drainage, restores the natural water cycle within the site, and reduces strain on the existing grey stormwater system by reducing the quantity of runoff entering the system.
Inlet	Inlets are openings within the roadway curb that convey stormwater runoff from the surrounding area into the rain garden.
Tree	The existing mature tree is a multifunctional green stormwater infrastructure element that captures rainwater by allowing water infiltrate into the soil, filters pollutants, and enhances the urban tree canopy.

Table 15: Green Stormwater Infrastructure Elements within the Concept Design of Brendwin Circle Parkette

Performance:

- The parkette includes approximately 140 metres squared of bioretention facilities.

7. Discussion on the Impacts of the Proposed Concept Plan

7.1: Impact of the Proposed Concept Plan

In this report, I proposed a concept plan that improves stormwater management on a neighbourhood-scale by reducing runoff rates and mitigating the runoff that is generated. Green stormwater infrastructure is used to reduce, slow, infiltrate, and filter runoff. The transformation of impermeable streets into Green Stormwater Streets is an effective strategy to divert significant volumes of runoff from the sewer system and increase water storage and infiltration capacity. Retrofitting green space would increase overland drainage capacity and reconcile the design disparity between stormwater management and recreation functions.

The movement of water through the landscape would change following implementation of the proposed concept plan. Stormwater runoff would no longer flow over streets and into the pipe drainage system at a volume that overwhelms the system's capacity causing sewer failure and riverine flooding. Instead, stormwater runoff would be conveyed into green stormwater infrastructure where it would be captured, infiltrated and filtered through soils and vegetation. Water would be less likely to break the banks of Black Creek's concrete channel; it will flow through a vegetated and meandering naturalized water channel. If planners treat the "role and dynamics of water" (Shannon, 2013, p. 163) as a principal design consideration, then stormwater management systems could be implemented to restore the natural hydrological cycle to urban areas.

For residents and business owners, the implementation of the proposed concept plan would significantly change the built form and function of their neighbourhood. Reduced stormwater runoff rates would alleviate much of the anxiety and fear caused by flood risk that has become pervasive in this community. The restoration of natural processes into the built environment will be visible everywhere: the expanded tree canopy provides shaded sidewalks; the vegetated curb extensions make crossing the street safer; the revitalized green spaces promote connection to nature and space for active recreation. Beyond flood mitigation, the restoration of the natural hydrological processes in the neighbourhood will lead to many other benefits, including but not limited to: stress reduction (Feda et al, 2015; Orsega-Smith et al, 2004); improved mental health, self-esteem, and mood (Orsega-Smith et al, 2004); improved physical health (Jennings et al, 2017); and crime reduction (Cozens, 2002; Kondo et al, 2015). The proposal uses stormwater management design to create usable and attractive public spaces for the community to enjoy.

Trade-offs are required to reduce runoff rates, mitigate the effects of flooding and build urban resilience to climate change. The proposed retrofit projects require that public space be reallocated to green stormwater infrastructure. Examples of trade-offs include reduced on-street parking spaces, narrowed vehicle lanes on residential and connector streets, and reduced open greenspace in parks. Reallocations such as these would require community consultation, however, if well-informed, I predict the community would agree that the damage caused by floods greatly outweighs the cost of these trade-offs.

7.2: Limitations

Several limitations impacted the outcomes of this research project.

First, although a strong green stormwater management system requires the implementation of green stormwater infrastructure on both public and private land, I only considered the use of green stormwater infrastructure on public streets and green spaces. Future studies should consider how public buildings and privately-owned sites could improve on-site stormwater management through the implementation of green stormwater infrastructure during rehabilitation projects. Further, to create the greatest impact, future studies should be examined at a watershed-scale rather than a neighbourhood-scale.

Second, scenario planning and modeling were not possible to evaluate the performance of the proposed concept plan and designs. I decided not to model the designs due to the technical complexity of the hydrological engineering and statistics that I would have had to learn for an evaluation of this scope. With more time, I would have worked with a technical expert to conduct the modeling based on both historical data and anticipated future risk in order to create evidence-based designs and recommendations for long-term planning (Harris, 2019, p. 129-130). Without knowing how much stormwater the proposed retrofits would capture, I do not know the measurable impact the concept plan would have on flood mitigation in the Rockcliffe-Smythe neighbourhood.

Third, I did not take cost and the politics of infrastructure investment into consideration when developing the proposed concept plan and designs. Politically motivated decisions, rather than evidence-based decision-making, have been known to influence public infrastructure priorities and investment. Although it is out of the scope of this research project, the politics of infrastructure investment needs to be researched to determine if and how a green stormwater approach could be widely embraced and implemented in Ontario. The Government of Canada has created new infrastructure investment programs, such as the Investing in Canada Infrastructure Program (2016) and the Disaster Mitigation and Adaptation Fund (2018), that give municipalities a unique opportunity to use green infrastructure to strengthen urban resilience to the impacts of climate change and extreme weather events. As the announcements of funded projects are released, I can only hope that evidence-based decision-making will forward innovative green stormwater management rather than the traditional grey stormwater approach.

Lastly, I wanted to include more design examples as set out in my overly ambitious research proposal, however time constrains prevented me from completing these designs. For example, I intended to create a design for the revitalization of Rose Valley Park and a design example of a Mixed-Use Connector Green Stormwater Street.

7.3: Provincial and Municipal Policy Context

Public policy is a critical component of implementing urban planning projects and building sustainable cities (Cohen, 2018). Policy drives decision-making by setting priorities to bring about built form change and establishes a framework for how and where urbanization will take place. In order to implement an effective alternative stormwater management system, such as the one I have envisioned, there needs to be legislative and regulatory support via public policy (Kondo et al, 2015).

I reviewed the key policy documents and confirmed that policies are in place that support the use of green infrastructure to improve stormwater management and mitigate the effects of climate (see Appendix A for detail). Generally, the *Provincial Policy Statement* (Ontario, 2014), the *Growth Plan for the Greater Golden Horseshoe* (Ontario, 2019), and the City of Toronto *Official Plan* (Toronto, 2019) support the use of green infrastructure to improve stormwater management and mitigate the effects of climate change.

8. Concluding Remarks

In this report, I propose design interventions that use a green stormwater infrastructure approach to reduce runoff volumes in Toronto's Rockcliffe-Smythe neighbourhood. The design interventions focus on reducing impermeable surface cover by constructing vegetated green stormwater infrastructure ecosystems within streets and public green spaces. The addition of vegetation and soil volume to urban areas has a strong positive impact on the volume of stormwater runoff that is generated and mitigated. Moreover, I demonstrate that the green approach to stormwater management can reduce strain on existing grey stormwater infrastructure assets, reducing the likelihood of their failure during severe rainfall events.

This report is a call to action for all levels of government to update their stormwater management approach to include green infrastructure. For residents and business owners in severely flood-vulnerable areas like Rockcliffe-Smythe, the implementation of strong stormwater management solutions needs to happen now. Upgrades to decaying grey stormwater infrastructure alone will not solve the flooding challenge. The total area of permeable surfaces needs to significantly increase for cities to mitigate the current flood risk and adapt to a future of more severe and frequent rainfall events.

Finally, for future MES Planning students looking for a major research topic, I encourage you to extend the research that I have started in this report. I strongly believe that further research and subsequent implementation of green stormwater management systems is necessary to effectively adapt to and mitigate the effects of climate change related extreme weather events in urban areas. Example research questions that I encourage students to consider include:

1. *What is the performance of this proposed concept plan based on historical data and anticipated future risk models? For example, what percentage of average annual rainfall is captured and how much runoff would be diverted from the sewer system in a typical year?*
2. *What would a watershed-scale green stormwater management retrofit project look like?*
3. *How can public-private partnerships help extend the green public space and green stormwater management systems?*
4. *What process needs to take place to create a paradigm shift among city-building professionals to make green infrastructure the new standard for stormwater management system development and revitalization projects?*

Bibliography

Beatley, T. (2016). *Handbook of biophilic city planning and design*. Island Press.

Bohland, J. R., Davoudi, S., & Lawrence, J. L. (Eds.). (2019). *The resilience machine*. Routledge, Taylor & Francis Group.

Canadian Institute of Planners. (2018). *Canadian Institute of Planners Policy on Climate Change Planning*. Retrieved from https://www.cip-icu.ca/getattachment/Topics-in-Planning/Climate-Change/policy-climate-eng-FINAL.pdf.aspx

Chin, D. A. (2017). Designing Bioretention Areas for Stormwater Management. *Environmental Processes*, *4*(1), 1–13. Retrieved from https://doi.org/10.1007/s40710-016-0200-0

Davis, A., Hunt, W., Traver, R., & Clar, M. (n.d.). Bioretention technology: Overview of current practice and future needs. *Journal of Environmental Engineering*, *135*(5). Retrieved from https://ascelibrary-org.ezproxy.library.ubc.ca/doi/full/10.1061/%28ASCE%290733-9372%282009%29135%3A3%28109%29

Davis, A. P., Hunt, W. F., Traver, R. G., & Clar, M. (2009). Bioretention Technology: Overview of Current Practice and Future Needs. *Journal of Environmental Engineering*, *135*(3), 109–117. Retrieved from https://doi.org/10.1061/(ASCE)0733-9372(2009)135:3(109)

Feda, D. M., Seelbinder, A., Baek, S., Raja, S., Yin, L., & Roemmich, J. N. (2015). Neighbourhood parks and reduction in stress among adolescents: Results from Buffalo, New York. *Indoor and Built Environment*, *24*(5), 631–639. Retrieved from https://doi.org/10.1177/1420326X14535791

Forman, R. T. T. (2014). *Urban ecology: Science of cities*. Cambridge University Press.

Forman, R. T. T. (2016). Urban ecology principles: Are urban ecology and natural area ecology really different? *Landscape Ecology*, *31*(8), 1653–1662. Retrieved from https://doi.org/10.1007/s10980-016-0424-4

Green Communities Canada. (2019). *Ready set rain: Urban flood resilience in Ontario*. Retrieved from http://www.raincommunitysolutions.ca/wp-content/uploads/2019/05/ReadySetRainApril2019.pdf

Hanna, K. S. (2015). *Environmental impact assessment: Practice and participation* (Third edition). Oxford University Press.

Heltberg, R., Siegel, P. B., & Jorgensen, S. L. (2009). Addressing human vulnerability to climate change: Toward a 'no-regrets' approach. *Global Environmental Change*, *19*(1), 89–99. Retrieved from https://doi.org/10.1016/j.gloenvcha.2008.11.003

Higgs, E. (2017). Novel and designed ecosystems. *Restoration Ecology*, *25*(1), 8–13. Retrieved from https://doi.org/10.1111/rec.12410

Higgs, E. S. (2003). *Nature by design: People, natural process, and ecological restoration*. MIT Press.

Hough, M. (1995). *Cities and natural process*. Routledge.

Jennings, V., Floyd, M. F., Shanahan, D., Coutts, C., & Sinykin, A. (2017). Emerging issues in urban ecology: Implications for research, social justice, human health, and well-being. *Population and Environment; New York*, *39*(1), 69–86. Retrieved from http://dx.doi.org.ezproxy.library.ubc.ca/10.1007/s11111-017-0276-0

Kondo, M. C., Low, S. C., Henning, J., & Branas, C. C. (2015). The impact of green stormwater infrastructure installation on surrounding health and safety. *American Journal of Public Health (1971)*, *105*(3), e114–e121. Retrieved from https://doi.org/10.2105/AJPH.2014.302314

LaGro, J. A. (2013). *Site analysis: Informing context-sensitive and sustainable site planning and design* (Third Edition.). Wiley.

Larco, N. (2016). Sustainable urban design – a (draft) framework. *Journal of Urban Design*, *21*(1), 1–29. Retrieved from https://doi.org/10.1080/13574809.2015.1071649

Li, C., Peng, C., Chiang, P.-C., Cai, Y., Wang, X., & Yang, Z. (2019). Mechanisms and applications of green infrastructure practices for stormwater control: A review. *Journal of Hydrology*, *568*, 626–637. Retrieved from https://doi.org/10.1016/j.jhydrol.2018.10.074

Marsh, W. M. (2010). *Landscape planning: Environmental applications* (5th ed.). Wiley.

Matthews, T., Lo, A. Y., & Byrne, J. A. (2015). Reconceptualizing green infrastructure for climate change adaptation: Barriers to adoption and drivers for uptake by spatial planners. *Landscape and Urban Planning*, *138*, 155–163. Retrieved from https://doi.org/10.1016/j.landurbplan.2015.02.010

National Association of City Transportation Officials (Ed.). (2017). *Urban street stormwater guide*. Island Press.

Ontario, Government of. (1990). *Niagara Escarpment Planning and Development Act*. Ontario.ca. Retrieved from https://www.ontario.ca/laws/view

Ontario, Government of. (2001). *Oak Ridges Moraine Conservation Act*. Ontario.ca. Retrieved from https://www.ontario.ca/laws/view

Ontario, Government of. (2005). *Greenbelt Act*. Ontario.ca. Retrieved from https://www.ontario.ca/laws/view

Ontario, Government of. (2019). *Ontario Population Projections, 2018–2046*. Ministry of Finance: Government of Ontario. Retrieved from https://www.fin.gov.on.ca/en/economy/demographics/projections/

Ontario, Government of. (2003). *Stormwater management planning and design manual: [Report prepared for Ontario Ministry of Environment*. Queen's Printer for Ontario. Retrieved from https://www.ontario.ca/document/stormwater-management-planning-and-design-manual-0

Orsega-Smith, E., Mowen, A., Payne, L., & Godbey, G. (2004). The Interaction of Stress and Park Use on Psycho-physiological Health in Older Adults. *Journal of Leisure Research; Urbana*, *36*(2), 232–256.

Pickett, S., & Cadenasso, M. (2017). How many principles of urban ecology are there? *Landscape Ecology; Dordrecht*, *32*(4), 699–705. Retrieved from http://dx.doi.org.ezproxy.library.ubc.ca/10.1007/s10980-017-0492-0

Plato, N. (2019). *Flood risk assessment and rankings of flood vulnerable clusters*. Retrieved from https://conservationontario.ca/fileadmin/pdf/conservation_authorities_tech_transfer/TechTransfer2019_10_Plato_Flood_Risk_Assessment_and_Ranking.pdf

Reeves, A. (2018). Before the flood. *West End Phoenix*. Retrieved from https://www.westendphoenix.com/stories/before-the-flood

Rijkswaterstaat. (2010). *Room for the River*. Retrieved from https://www.rijkswaterstaat.nl/english/about-us/gems-of-rijkswaterstaat/room-for-the-river/index.aspx

Rotterdam, City of. (2010). *Rotterdam Climate Change Adaption Strategy*. Retrieved from http://www.urbanisten.nl/wp/wp-content/uploads/UB_RAS_EN_lr.pdf

Rouse, D. C., & Bunster-Ossa, I. F. (2013). *Green Infrastructure: A landscape approach*. American Planning Association.

Schollen & Company Inc., Urban Forest Innovations, TMIG, & DPM. (2017). *Toronto Green Streets Technical Guide*. City of Toronto.

Seattle, City of. (2001). *Street Edge Alternatives Project*. Retrieved from http://www.seattle.gov/utilities/neighborhood-projects/street-edge-alternatives

Tingsanchali, T. (2012). Urban flood disaster management. *Procedia Engineering*, *32*, 25–37. Retrieved from https://doi.org/10.1016/j.proeng.2012.01.1233

Topographic-map.com. (n.d.). *Toronto topographic map*. Retrieved from https://en-ca.topographic-map.com/maps/q4v/Toronto/

Toronto, City of. (n.d.). *Toronto Maps v2*. Retrieved from https://map.toronto.ca/maps/map.jsp?app=TorontoMaps_v2

Toronto, City of. (2013). *"Greening" Surface Parking Lots Guidelines*. Retrieved from https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/design-guidelines/greening-surface-parking-lots/

Toronto, City of. (2014). *Golf Marketing Incentive* [Staff report]. Retrieved from https://www.toronto.ca/legdocs/mmis/2014/pe/bgrd/backgroundfile-68576.pdf

Toronto, City of. (2016). *Neighbourhood Profile: Rockcliffe-Smythe*. Retrieved from https://www.toronto.ca/ext/sdfa/Neighbourhood%20Profiles/pdf/2016/pdf1/cpa111.pdf

Toronto, City of. (2017a). *Toronto complete streets guidelines: Making streets for people, placemaking and prosperity*. Retrieved from https://www.toronto.ca/services-payments/streets-parking-transportation/enhancing-our-streets-and-public-realm/complete-streets/complete-streets-guidelines/

Toronto, City of. (2017b). *Toronto at a Glance*. Retrieved from https://www.toronto.ca/city-government/data-research-maps/toronto-at-a-glance/

Toronto, City of. (2018a). *About the Road Classification System*. Retrieved from https://www.toronto.ca/services-payments/streets-parking-transportation/traffic-management/road-classification-system/about-the-road-classification-system/

Toronto, City of. (2018b). *Sewer System Flood Reduction Measures in the Rockcliffe Area* (PW28.6; p. 9). Retrieved from https://www.toronto.ca/legdocs/mmis/2018/pw/bgrd/backgroundfile-113634.pdf

Toronto, City of. (2018c). *Toronto Road Classification System* [Map]. https://www.toronto.ca/wp-content/uploads/2019/09/9072-TS_RCS_2019-City-Wide.pdf

Toronto, City of. (2019). *Toronto Official Plan.* Retrieved from https://www.toronto.ca/wp-content/uploads/2019/06/8f06-OfficialPlanAODA_Compiled-3.0.pdf

Toronto and Region Conservation Authority. (n.d.-a). *Flood Plain Map*. Toronto and Region Conservation Authority (TRCA). Retrieved from https://trca.ca/conservation/flood-risk-management/flood-plain-map-viewer/

Toronto and Region Conservation Authority. (n.d.-b). *History*. Toronto and Region Conservation Authority (TRCA). Retrieved from https://trca.ca/conservation/flood-risk-management/history/

Toronto and Region Conservation Authority. (n.d.-c). *Stormwater Management*. Toronto and Region Conservation Authority (TRCA). Retrieved from https://trca.ca/conservation/stormwater-management/

Toronto and Region Conservation Authority. (n.d.-d). *Watershed Features—Humber River*. Toronto and Region Conservation Authority (TRCA). Retrieved from https://trca.ca/conservation/watershed-management/humber-river/watershed-features/

Toronto and Region Conservation Authority. (2008a). *Humber River State of the Watershed Report—Aquatic System*. Retrieved from http://trca.on.ca/dotAsset/82106.pdf

Toronto and Region Conservation Authority. (2008b). *Humber River State of the Watershed Report—Surface Water Quantity* (p. 64). Retrieved from http://www.trca.on.ca/dotAsset/50155.pdf

Toronto and Region Conservation Authority. (2014a). *Black Creek (Rockcliffe area) riverine flood management class environmental assessment*. Retrieved from https://trca.ca/app/uploads/2018/03/2014-March-Black-Creek-Updated-Final-Downsized.pdf

Toronto and Region Conservation Authority. (2014b). *The living city policies for planning and development in the watersheds of the Toronto and Region Conservation Authority*. Retrieved from https://drive.google.com/file/d/0BxjqkzmOuaaRYWxqSGdUaHp5UE0/view?usp=sharing&usp=embed_facebook

Toronto and Region Conservation Authority. (2019). *2019 Flood Contingency Manual* (p. 32). Retrieved from https://s3-ca-central-1.amazonaws.com/trcaca/app/uploads/2016/02/23195030/TRCA-2019-Contingency-Manual_WEB.pdf

Trowsdale, S. A., & Simcock, R. (2011). Urban stormwater treatment using bioretention. *Journal of Hydrology*, *397*(3), 167–174. Retrieved from https://doi.org/10.1016/j.jhydrol.2010.11.023

Waterfront Toronto. (n.d.). *The Port Lands*. Waterfront Toronto. Retrieved from https://portlandsto.ca/

Waterfront Toronto. (2016). *Port Lands flood protection and enabling infrastructure due diligence report*. Retrieved from https://portlandsto.ca/wp-content/uploads/due_diligence_report_october_20_2016_1.pdf

XCG Consulting Ltd. (2014). *Environmental study report: South class environmental assessment area combined sewer overflow control and basement flooding Areas 4 and 5*. Toronto and Region Conservation Authority.

Appendix A: Planning and Policy Framework for the Study Area

A.1: Overview

As outlined below, the concept plan is consistent with the policies and provisions of the *Provincial Policy Statement* (Ontario, 2014), the *Growth Plan for the Greater Golden Horseshoe* (Ontario, 2019), and the City of Toronto *Official Plan* (Toronto, 2019), all of which encourage and support the use of green infrastructure to improve stormwater management and mitigate the effects of climate change.

A.2: Provincial Policy Statement (2014)

The current Provincial Policy Statement (PPS) came into effect as of April 30, 2014. The PPS is issued under the authority of section 3 of the Planning Act (1990).

The concept plan is consistent with the policy direction outlined in the 2014 Provincial Policy Statement to build strong communities by promoting efficient land use and development patterns. To that end, the PPS contains several policies that promote the use of natural vegetative systems to better manage stormwater and for climate change adaptation.

In particular, the PPS supports the use of vegetation and *green infrastructure* to build strong, sustainable, livable, and resilient communities. Policy 1.6.2 provides that "planning authorities should promote *green infrastructure* to complement *infrastructure*". Policy 1.6.6.7(d) and (e) provides that "planning for stormwater management shall maximize the extent and function of vegetative and pervious surfaces" and "promote stormwater management best practices, including stormwater attenuation and re-use, and low impact development".

In addition, Policy 1.8.1(f.1) and (g) provides that "planning authorities shall support energy conservation and efficiency, improved air quality, reduced greenhouse gas emissions, and climate change adaptation through land use and development patterns which: promote design and orientation which maximizes energy efficiency and conservation, and considers the mitigating effects of vegetation" and "maximize vegetation within settlement areas, where feasible".

With respect to natural features, Policy 2.1.2 provides that "the diversity and connectivity of natural features in an area, and the long-term ecological function and biodiversity of *natural heritage systems*, should be maintained, restored or, where possible, improved, recognizing linkages between and among *natural heritage features and areas*, *surface water features* and *ground water features*".

With respect to natural hazards, Policy 3.1.3 provides that "planning authorities shall consider the potential impacts of climate change that may increase the risk associated with natural hazards".

A.3: Growth Plan for the Greater Golden Horseshoe (2019)

The current Growth Plan for the Greater Golden Horseshoe came into effect as of May 16, 2019. The Growth Plan is issued under the authority of section 7 of the Places to Grow Act (2005).

Similar to the PPS, the Growth Plan supports the use of *green infrastructure* and *low impact development*, particularly in *settled areas*.

Chapter 3 (Infrastructure to Support Growth) outlines the role of infrastructure in creating safe, prosperous, and thriving communities. It recognizes that:

> *"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"* (Ontario, 2019, p. 30).

To that end, Policy 3.2.7.1(a), (d), (e), (f), and (h) provides that "municipalities will develop *stormwater management plans* or equivalent for survived *settlement areas* that: are informed by *watershed planning* or equivalent;...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; incorporate appropriate *low impact development* and *green infrastructure*; identify the need for stormwater retrofits, where appropriate;... and include an implementation and maintenance plan".

Chapter 4 (Protecting What is Valuable) outlines the importance of protecting natural and cultural heritage features within the region. It recognizes that:

> "*The [Greater Golden Hourseshoe] contains a broad array of important hydrologic and* natural heritage features and areas*, a vibrant and diverse agricultural land base, irreplaceable* cultural heritage *resources, and valuable renewable and non-renewable resources. These lands, features and resources are essential for the long-term quality of life, economic prosperity, environmental health, and* ecological integrity *of the region. They collectively provide essential ecosystem*

services, including water storage and filtration, cleaner air and habitats, and support pollinators, carbon storage, adaptation and resilience to climate change" (Ontario, 2019, 4.1).

To that end, Policy 4.2.1.3(d) and (d) provides that "*watershed planning* or equivalent will inform…the protection, enhancement, or restoration of the *quality and quantity* of water;" and "planning for water, wastewater, and stormwater *infrastructure*."

A.4: City of Toronto Official Plan (2019)

The current Official Plan for the City of Toronto came as of February 2019 (Chapters 1-5 and Schedules 1-4) and June 2015 (Chapters 6 and 7). The origin version of the current Official Plan was approved by the Ontario Municipal Planning Board on July 6, 2006 (Toronto, 2019). The Official Plan is issued under the authority of Section 17 of the Planning Act (Ontario, 1990).

Green Infrastructure and Stormwater Management Policies

Chapter 2 (Shaping the City) outlines the strategy for directing growth to specific areas of the city in order to accommodate forecasted population growth while protecting other areas, such as green spaces, from development pressure. It recognizes that:

> *"Other infrastructure is needed to provide clean water to everyone, to manage sewage and stormwater and treat it before it goes into the lake. Water and wastewater services are important foundations for growth in the City, as well as for maintaining the quality of life in areas that will not see much growth. This may mean bigger pipes and treatment plants in some areas, but it is also important to use less water in our homes and businesses, to absorb rainwater where it falls and to use our streams and rivers more effectively to control flooding"* (Toronto, 2019, p. 2-5).

Policy 2.2.2(h) provides that "growth will be directed to the *Centres*, *Avenues*, *Employment Areas* and the *Downtown*...in order to improve surface and groundwater quality and restore the hydrological function and habitat of streams, rivers and wetlands".

Policy 2.3.1.6 provides that "environmental sustainability will be promoted in *Neighbourhoods* and *Apartment Neighbourhoods* by investing in naturalization and landscaping improvements, tree planting and preservation, sustainable technologies for stormwater management and energy efficiency and programs for reducing waste and conserving water and energy".

Policy 2.3.1.7(a) and 2.3.1.8(a) and (b) indicate that improving and expanding park space and the public realm contributes to the health, well-being, and sustainability of communities.

Chapter 3 (Building a Successful City) outlines the strategy for integrating social, economic, and environmental perspectives into the city-building process. It recognizes that "we must meet the needs of today without compromising the ability of future generations to meet their needs" (Toronto, 2019, p. 3-1).

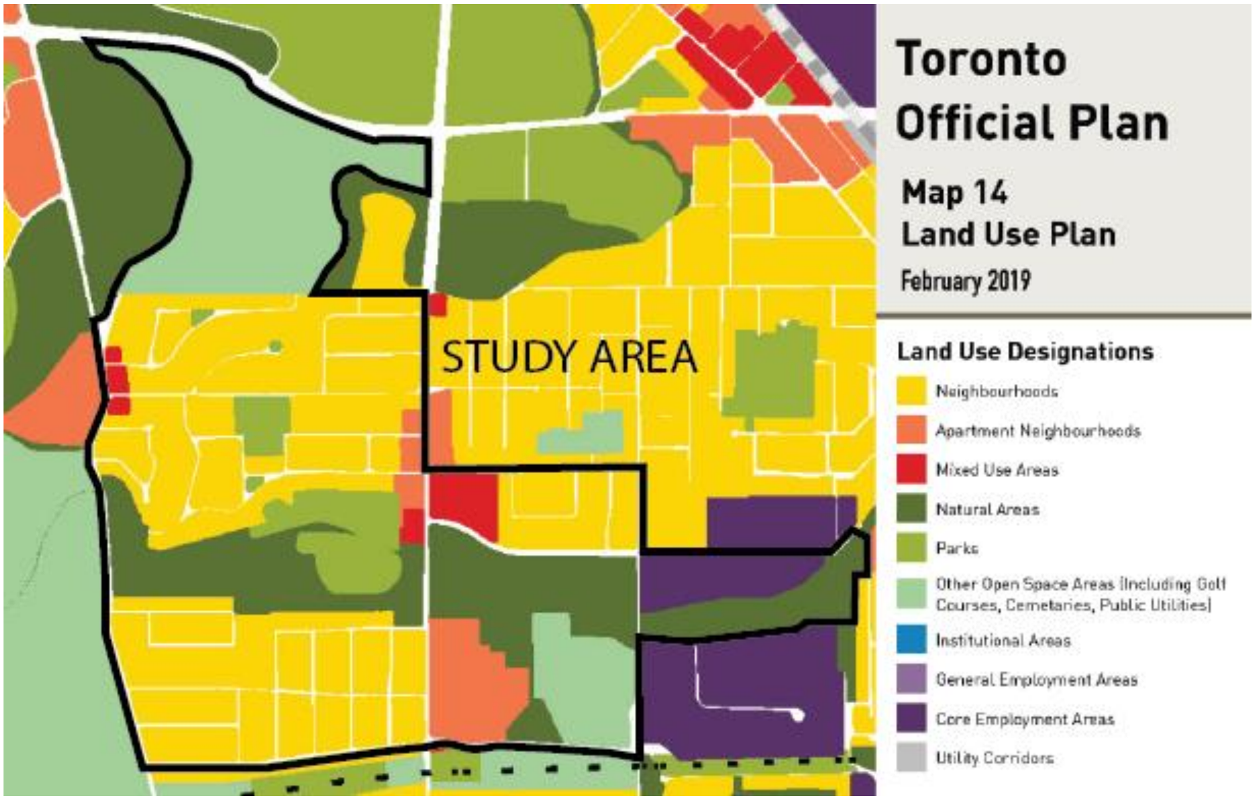
Policy 3.1.1.5(a.ii) recognizes the "city streets are significant public open spaces which connect people and places and support the development of sustainable, economically vibrant and complete communities" and that new and existing streets should be designed to have "space for other street elements, such as utilities and services, trees and landscaping, green infrastructure, snow and stormwater management," in addition to other features. Further, Policy 3.1.1.16(g) and (h) provides that "new streets will be designed to…implement the Complete Streets approach to develop a street network that balances the needs and priorities of the various users and uses within the right-of-way;" and "improve[s] the visibility, access and prominence of unique natural and human-made features".

Policy 3.2.3.1(b) and (c) provides that "Toronto's system of parks and open spaces will continue to be a necessary element of city-building as the City grows and changes. Maintaining, enhancing and expanding the system requires the following actions:…designing high quality parks and their amenities to promote user comfort, safety, accessibility and year-round use and to enhance the experience of "place", provide experiential and educational opportunities to interact with the natural world" and " protecting access to existing publicly accessible open spaces, as well as expanding the system of open spaces and developing open space linkages".

Policy 3.4.1 provides that city-building "will be environmentally friendly". This policy recognizes the importance of managing stormwater runoff and snow melt sustainably, the adverse effects of flood events, and the ability for green infrastructure to complement the existing grey infrastructure system.

Land Use Designation

The study area includes several land use designations including *Neighbourhoods, Apartment Neighbourhoods*, *Mixed Use Areas*, *Natural Areas*, *Parks*, *Other Open Space Areas*.



Neighbourhoods are made up of low scale residential buildings, including detached houses, semi-detached houses, duplexes, triplexes, townhouses, and apartment buildings of four storeys or less. In addition to residential uses, *Neighbourhoods* can also include parks, local institutions, schools, small-scale stores and services that meet the needs of the area (4.1).

Apartment Neighbourhoods are made up of rental apartment and condominium buildings that are taller than the four-storey buildings in *Neighbourhoods*. In addition to residential uses, *Apartment Neighbourhoods* can also include parks, local institutions, cultural and recreation facilities, small-scale stores and services that meet local needs (4.2)

Mixed Use Areas are made up of a variety of planning objectives, such as residential uses, offices, retail and services, institutions, entertainment, recreation and cultural activities, and parks and open spaces (4.5).

Parks and Open Space Areas are outdoor spaces, such as parks and open spaces, valleys, waterways, ravines, golf courses, and cemeteries, that make up Toronto's *Green Space System*. Specifically, the *Green Space System* is comprised of *Natural Areas, Parks,* and *Other Open Spaces Areas* (4.3.1). *Natural Areas* are an area that is maintained primarily in a natural state (4.3.3). *Parks* are an area that are used primarily to provide public park and recreational opportunities (4.3.4). Lastly, *Other Open Space Areas* are areas that are used primarily for golf courses, cemeteries, and open spaces associated with utilities and other specialized uses and facilities (4.3.5).

Appendix B: Green Stormwater Infrastructure Selection Tool for Street Retrofits

The City of Toronto's Green Streets Technical Guidelines (2017) includes a green infrastructure and vegetation selection tool for city-builders to use for road construction and rehabilitation/retrofit projects. I adapted and simplified the Green Streets Technical Guidelines (2017) selection tool to reflect the scope of this research project.

Green Stormwater Infrastructure Options for Street Retrofit Projects		*Green Stormwater Street Types*			
Green Stormwater Infrastructure Element	**Street Component**	**Residential Street**	**Residential Shared Street**	**Residential Connector Street**	**Mixed-Use Connector Street**
Bioretention Planter w/o Pre-treatment or Underdrain	Furnishing / Planting Zones		x		x
Bioretention Planter with Pre-treatment w/o Underdrain	Furnishing / Planting Zones		x		x
Bioretention Planter with Underdrain	Furnishing / Planting Zones		x		x
Bioretention Planter with Pre-treatment & Underdrain	Furnishing / Planting Zones		x		x
Bioretention Planter w/o Pre-treatment or Underdrain	Medians / Raised Islands				x
Bioretention Planter with Pre-treatment w/o Underdrain	Medians / Raised Islands				x
Bioretention Planter with Underdrain	Medians / Raised Islands				x
Bioretention Planter with Pre-treatment & Underdrain	Medians / Raised Islands				x

Stormwater Planter w/o Pre-treatment or Underdrain	Frontage / Marketing Zones		x		
Stormwater Planter with Pre-treatment w/o Underdrain	Frontage / Marketing Zones		x		
Stormwater Planter with Underdrain	Frontage / Marketing Zones		x		
Stormwater Planter with Pre-treatment & Underdrain	Frontage / Marketing Zones		x		
Bioretention Curb Extension/Bump-out w/o Pre-treatment or Underdrain	Intersections	x			
Bioretention Curb Extension/Bump-out with Pre-treatment w/o Underdrain	Intersections	x			
Bioretention Curb Extension/Bump-out with Underdrain	Intersections	x			
Bioretention Curb Extension/Bump-out with Pre-treatment & Underdrain	Intersections	x			
Bioretention Curb Extension/Bump-out w/o Pre-treatment or Underdrain	Mid-block	x			
Bioretention Curb Extension/Bump-out with Pre-treatment w/o Underdrain	Mid-block	x			
Bioretention Curb Extension/Bump-out with Underdrain	Mid-block	x			
Bioretention Curb Extension/Bump-out with Pre-treatment & Underdrain	Mid-block	x			
Bioretention Curb Extension/Bump-out w/o Pre-treatment or Underdrain	Transit Stops	x			
Bioretention Curb Extension/Bump-out with Pre-treatment w/o Underdrain	Transit Stops	x			
Bioretention Curb Extension/Bump-out with Underdrain	Transit Stops	x			
Bioretention Curb Extension/Bump-out with Pre-treatment & Underdrain	Transit Stops	x			
Bioretention - Cell w/o Pre-treatment or Underdrain	Furnishing / Planting Zones	x		x	x
Bioretention - Cell with Pre-treatment w/o Underdrain	Furnishing / Planting Zones	x		x	x
Bioretention - Cell with Underdrain	Furnishing / Planting Zones	x		x	x

Bioretention - Cell with Pre-treatment & Underdrain	Furnishing / Planting Zones	x		x	x
Bioretention - Cell w/o Pre-treatment or Underdrain	Medians / Raised Islands			x	x
Bioretention - Cell with Pre-treatment w/o Underdrain	Medians / Raised Islands			x	x
Bioretention - Cell with Underdrain	Medians / Raised Islands			x	x
Bioretention - Cell with Pre-treatment & Underdrain	Medians / Raised Islands			x	x
Bioretention Rain Gardens	Furnishing / Planting Zones	x		x	x
Bioretention Rain Gardens	Medians / Raised Islands	x		x	x
Bioswale w/o Pre-treatment or Underdrain	Furnishing / Planting Zones	x	x	x	x
Bioswale with Pre-treatment w/o underdrain	Furnishing / Planting Zones	x	x	x	x
Bioswale with Underdrain	Furnishing / Planting Zones	x	x	x	x
Bioswale with Pre-treatment & Underdrain	Furnishing / Planting Zones	x	x	x	x
Bioswale with Pre-treatment, Underdrain & Impermeable Liner	Furnishing / Planting Zones	x	x	x	x
Bioswale w/o Pre-treatment or Underdrain	Medians / Raised Islands	x		x	x
Bioswale with Pre-treatment w/o underdrain	Medians / Raised Islands	x		x	x
Bioswale with Underdrain	Medians / Raised Islands	x		x	x
Bioswale with Pre-treatment & Underdrain	Medians / Raised Islands	x		x	x
Bioswale with Pre-treatment, Underdrain & Impermeable Liner	Medians / Raised Islands	x		x	x
Infiltration Trench	Vehicular Lanes				

Infiltration Trench	Cycling Infrastructure			x	x
Infiltration Trench	On-street Parking	x			
Infiltration Trench	Furnishing / Planting Zones	x	x	x	x
Infiltration Trench	Medians / Raised Islands			x	x
Permeable Paving - Pervious Concrete	Vehicular Lanes		x		
Permeable Paving - Pervious Concrete	On-street Parking	x			
Permeable Paving - Pervious Concrete	Cycling Infrastructure			x	x
Permeable Paving - Pervious Concrete	Sidewalks	x	x	x	x
Permeable Paving with underdrain - Pervious Concrete	Vehicular Lanes		x		
Permeable Paving with underdrain - Pervious Concrete	On-street Parking	x			
Permeable Paving with underdrain - Pervious Concrete	Cycling Infrastructure			x	x
Permeable Paving with underdrain - Pervious Concrete	Sidewalks	x	x	x	x
Permeable Paving - Porous Asphalt	Vehicular Lanes	x	x		
Permeable Paving - Porous Asphalt	On-street Parking			x	
Permeable Paving - Porous Asphalt	Cycling Infrastructure			x	x
Permeable Paving - Porous Asphalt	Sidewalks				
Permeable Paving with underdrain - Porous Asphalt	Vehicular Lanes	x	x		
Permeable Paving with underdrain - Porous Asphalt	On-street Parking			x	
Permeable Paving with underdrain - Porous Asphalt	Cycling Infrastructure			x	x
Permeable Paving with underdrain - Porous Asphalt	Sidewalks				
Permeable Paving - Interlocking Precast Concrete Pavers	Feature Paving		x		
Permeable Paving - Interlocking Precast Concrete Pavers	On-street Parking	x	x		
Permeable Paving - Interlocking Precast Concrete Pavers	Sidewalks		x		
Permeable Paving - Interlocking Precast Concrete Pavers	Crosswalks	x	x		
Permeable Paving - Interlocking Precast Concrete Pavers	Vehicular Lanes				
Permeable Paving with underdrain - Interlocking Precast Concrete Pavers	Feature Paving		x		
Permeable Paving with underdrain - Interlocking Precast Concrete Pavers	On-street Parking	x	x		
Permeable Paving with underdrain - Interlocking Precast Concrete Pavers	Sidewalks		x		

Permeable Paving with underdrain - Interlocking Precast Concrete Pavers	Crosswalks	x	x		
Permeable Paving with underdrain - Interlocking Precast Concrete Pavers	Vehicular Lanes				
Stormwater Tree Pits	Furnishing / Planting Zones		x	x	x
Stormwater Tree Pits	Medians / Raised Islands			x	x
Stormwater Tree Trenches	Furnishing /Planting Zones		x	x	x
Stormwater Tree Trenches	Medians / Raised Islands			x	x

Table 16: Green Stormwater Infrastructure Options for Street Retrofit Projects