BRANTFORD PUBLIC WORKS

NORTH-EAST FLOOD REMEDIATION STUDY
OCTOBER 2020

- FINAL -

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Executive Summary

Introduction

Aquafor Beech Limited (Aquafor) was retained by the City of Brantford (the City) to undertake the Northeast Neighborhood Flood Remediation Study (the study). The City of Brantford experienced basement and surface flooding during a heavy rainfall event in August 11, 2017 that impacted the north east area of the City. The storm event overwhelmed the existing sewers which resulted in numerous basement flooding complaints due to backup of water into houses. Aging infrastructure, extreme rainfall events, population growth and intensification could be some of the factors that contribute to the increased risk of flooding. As a result, the City initiated the Study and retained Aquafor to undertake a localized hydraulic and overland stormwater analysis, examine sewer and overland system performance, investigate the system deficiencies, and recommend remedial plans to improve the level of service of the neighborhood to an acceptable level.

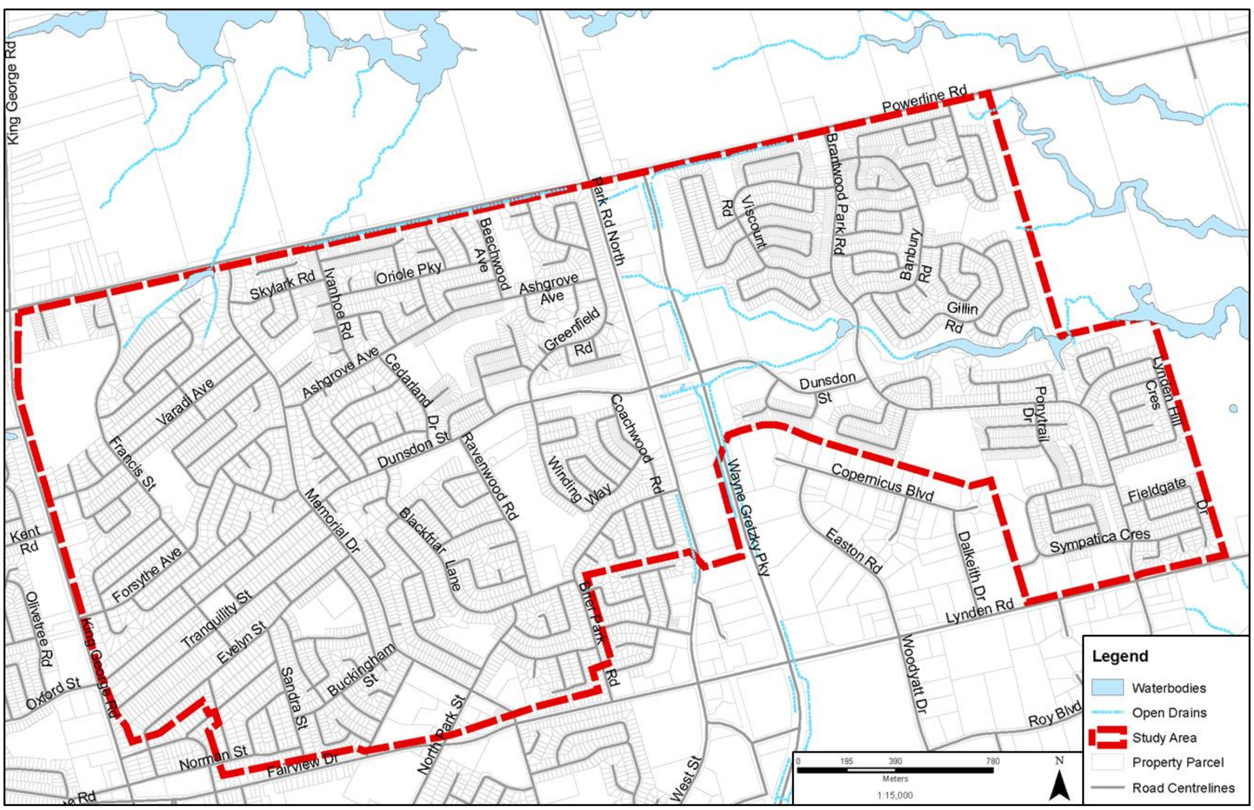

Figure E-1: Study Area

Study Purpose

The primary purpose of the Study is to review the drainage area, undertake minor (sewer) and major (overland) system capacity analysis, investigate the causes of flooding, identify any deficiencies in the drainage system, and recommend solutions to reduce the risk of future flooding in the area.

Municipal Class Environmental Assessment (EA) Process

This study initiated as a flood remediation study with a provisional item to fulfill the Class EA requirements. Due to potential works required in the City's easements on private properties and the unclear easement conditions at the time of alternative development, it was determined to fulfill EA requirements based on discussions with the City. Due to the characteristics of the sewer rehabilitation projects, which are typically Schedule A, A+ or B projects, this study follows the Phases 1 and 2 of the Municipal Class EA Planning and Design Process with Phase 5 to follow at a subsequent phase.

Phase 1 – Problem and Opportunity Definition

A number of locations within the North-East end of Brantford experienced basement flooding and surface flooding during the August 11, 2017 storm event. While the magnitude of the historical storm is comparable to a 5-year design storm, flooding incidents during this specific storm indicate potential deficiencies within the existing drainage system.

The primary types of problems include:

- Surface flooding due to reverse slope driveways or poor lot grading; and
- Basement flooding through floor drains or foundation drain systems.

This study will investigate several opportunities to assess the capacity and performance of the existing drainage system, mitigate the risks of flooding with an integrated solution at flood-prone areas and improve the level of service of the neighborhoods to an acceptable level. Additionally, the localized solutions may also benefit the system performance at areas adjacent to the flood-prone areas.

The opportunities include:

- Propose remedial works to mitigate future flooding;
- Provide a level of service which is consistent with municipal standards; and
- Improve operational and structural conditions of the storm water system.

Phase 2 - Evaluation of Alternative Solutions

Definition of Existing Conditions

A variety of information was collected and reviewed in Phase 1 in order to define the existing conditions. In summary, the following tasks were undertaken to define existing conditions:

1) **Background Data Collection and Review**
   - Relevant background documents addressing the issues primarily from the Northeast Neighborhood perspective with some at the City-wide perspective were reviewed and the relevant findings from the documents were summarized;
2) **Flooding Records and Questionnaire Responses**
   - 48 records historical reported flooding from the City's Customer Contact Centre and 537 responses to the flood questionnaire were received and summarized according to flooding frequency, type (basement of surface flooding), mode of water entry into the home (floor drains, windows, etc.) type of floodwater (clear, dirty, odourous, etc) and condition of the home. The information was used to isolate the areas impacted by the August 11, 2017 event that triggered this study
3) **Additional Data Collection**
   - Additional data that was necessary to bring the system model to reflect the existing conditions include:
     - Verification of sewer inverts and maintenance hole elevations;
     - A survey along Powerline Road to confirm infrastructure and drainage characteristics;
     - Verification of dimensions of storm outfalls and road crossings;
     - Home visits of ten (10) private properties to confirm the type and cause of flooding; and
     - Smoke testing within the storm sewer system to confirm connections for catch basins, foundation drains and other infrastructure.
4) **Model Conversion and Calibration**
   - The City-wide storm sewer model, that was completed and calibration using the InfoSWMM modelling software, was provided by the City. The model was converted to InfoWorks model, re-validated and found to be generally consistent with the original model results. The study area calibration was limited to one flow monitor with available data; thus, emphasis was placed on calibrating to the August 11, 2017 event using the flood records.
5) **Hydrologic and Hydraulic Modelling**

- A hydrologic and hydraulic modelling exercise was undertaken in order to define both the existing level of service together with the frequency, type, extent and location of flooding issues and identify the flood vulnerable areas.

Based on the background data review, flooding records and additional data collection, it was determined that the primary flooding issues were related to the following:

- Undersized storm sewers within the system; and
- The presence of a significant number of reverse-sloped driveways that impact basement flooding and overloading of the sanitary sewer system.

Eight (8) problems areas within the study area were identified as flood-vulnerable and require mitigation measures based on the understanding of existing conditions and model simulation results (see **Figure E-2**).

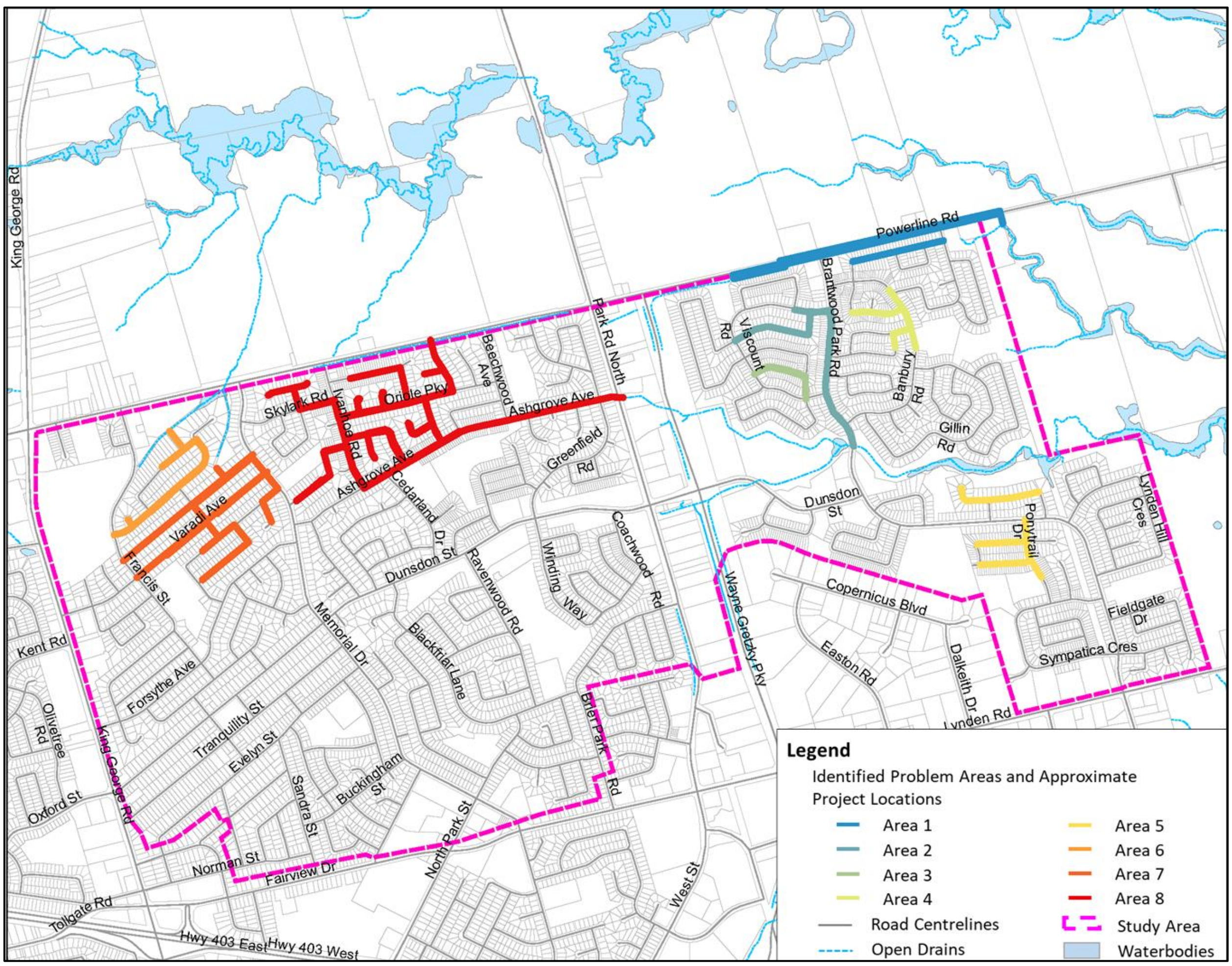

Figure E-2: Extent of Areas Identified as Flood-Vulnerable

Development and Assessment of Alternatives

The following sections outline remedial measures associated with the storm, systems in the study area in order to alleviate basement and surface flooding. The performance of alternatives associated with each system are based on the 1:100-year design storms. This section outlines the evaluation criteria and presents alternative control measures. The outcome of this section is the identification of preferred solutions to address basement and surface flooding within the study area.

Level of Service Criteria

The target level of service for the minor system is to maintain the hydraulic grade line 1.8 m below the ground surface (approximate depth of the basement floor) for events up to the 100year design storm. In addition, for the 100-year storm depths of water on the roadway should not exceed 300 mm in order to prevent flooding of homes from the roadway. The August 11, 2017 event, which is similar to a 5-year design storm, and the 100-year design storm event model results are used as a basis to develop alternatives to alleviate flooding for the remedial measures for the storm sewer (minor) system.

Development of Alternatives

As per **Figure E-2**, the eight flood-vulnerable areas identified also shows the approximate extent of upgrades likely required to meet the targeted level of service for the 100-Year design storm.

Four (4) basic alternatives were developed for Areas 2 through 8 that include:

- Alternative 1 – Do Nothing
- Alternative 2 – Pipe Upsizing within the Existing Storm System
- Alternative 3 – System Storage (In-line / Off-line) within the Existing Storm System
- Alternative 4 – Pipe Upsizing and/or System Storage (In-line / Off-line) within the Existing Storm System

For Areas where an outlet sewer traverses an easement (Areas 5 through 7), consideration was also given to the utilization of pipe upsizing opportunity through the easement to reduce or eliminate the need for a large upstream inline/offline storage.

For Powerline Road (Area 1), separate alternatives were considered that included:

- Alternative A – Do Nothing;

- Alternative B – A combination of new sewers and in-line storage along Powerline Road; and
- Alternative C – Ditching within public road right-of-way along Powerline Road, from approximately 155m west of Brantwood Park Road to the adjacent creek east of Coulbeck Road.

Evaluation Criteria

In order to evaluate the alternative solutions identified in the previous sections, evaluation criteria were established in order to select the preferred alternative. The evaluation criteria include:

- Natural heritage considerations,
- Economic considerations;
- Socio-cultural considerations; and
- Technical considerations.

Public Consultation

A Notice of Project was published in November 2018 on the City's website (https://www.brantford.ca/en/your-government/north-east-flood-remediation-study.aspx). The notice introduced the study, illustrated the study area boundary identifies means of providing public input, and invited the public to attend two (2) Public Information Centres.

A flood questionnaire was mailed to all the properties within the study area. The study team received a total of 537 responses to the questionnaire. Value information such as frequency of historical flooding at the property, type of flooding, water entrance point, existing flood mitigation measures, and so on were collected.

Selection of the Preferred Alternative

Based on the results of the alternatives evaluation and in consultation with the City, agencies and the public, the following alternatives were selected that have a nominal impact on the natural environment, is preferred with respect to impact on adjacent, residents and commuters, is the least costly alternative and is technically feasible. The preferred alternatives along with the estimated cost of implementation is show on **Table E-1**.

Table E-1: Estimated Costs for Preferred Alternatives

Problem Area	Preferred Alternative	Class EA Schedule	Estimated Costs
Area 1 – Powerline Road	Alternative C – Ditching within Public Right-of-Way Along Powerline Road	Schedule A	$ 530,000
Area 2 – Coxwell Crescent / Viscount Road	Alternative 2 – Pipe Upsizing within the Existing Storm System	Schedule A+	$ 2,800,000
Area 3 – White Owl Crescent	Alternative 3 – System Storage (In-line / Off-line) within the Existing Storm System	Schedule A+	$ 400,000
Area 4 – Enfield Crescent / Banbury Road	Alternative 4 – Pipe Upsizing and System Storage (In-line / Off-line) within the Existing Storm System	Schedule A+	$ 2,500,000
Area 5 – Hackney Ridge	Alternative 2 – Pipe Upsizing within the Existing Storm System (Utilizing the Easement and Outlet Sewer)	Schedule A+	$ 1,200,000
Area 6 – Royal Oak Drive	Alternative 2 – Pipe Upsizing within the Existing Storm System (Utilizing the Easement and Outlet Sewer)	Schedule A+	$ 1,800,000
Area 7 – Kensington Avenue / Varadi Avenue	Alternative 2 – Pipe Upsizing within the Existing Storm System (Utilizing the Easement and Outlet Sewer)	Schedule A+	$ 4,200,000
Area 8 – Ashgrove Avenue Area	Alternative 2 – Pipe Upsizing within the Existing Storm System	Schedule A+	$ 10,800,000
		Subtotal	**$ 24,230,000**
Contingency (15%)			$ 3,640,000
Engineering Costs (10%)			$ 2,430,000
		Total	**$ 30,300,000**

Implementation

The next steps for implementation of the preferred alternative will include:

- Conceptual design;
- Detailed design and associated investigations;
- Approvals from municipal, regional, provincial and federal agencies;
- Contract document preparation and tender;
- Implementation Phasing; and
- Construction

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Chapter 1. Introduction

1.1 Study Overview

Aquafor Beech Limited (Aquafor) was retained by the City of Brantford (the City) to undertake the Northeast Neighborhood Flood Remediation Study (the study). The City of Brantford experienced basement and surface flooding during a heavy rainfall event in August 11, 2017 that impacted the north east area of the City. The storm event overwhelmed the existing sewers which resulted in numerous basement and surface flooding complaints. Aging infrastructure, extreme rainfall events, population growth and intensification could be some of the factors that contribute to the increased risk of flooding. As a result, the City initiated the Study and retained Aquafor to undertake a localized hydraulic and overland stormwater analysis, examine sewer and overland system performance, investigate the system deficiencies, and recommend remedial plans to improve the level of service of the neighborhood to an acceptable level. The study area is illustrated on **Figure 1.2.1**.

1.2 Background

In 2014, the City of Brantford completed the Master Servicing Plan that identified infrastructure opportunities and constraints in the City's future growth areas as well as identifying potential bottlenecks within the existing systems that would potentially limit growth opportunities to 2031. The study included the development of City-wide hydraulic and hydrologic models of the storm and sanitary sewer systems. In 2017, the City completed and update to the MSP planning for growth in 2041.

In 2017, Aquafor was retained for flow monitoring and calibration of the City-wide storm drainage network developed in the MSP. In 2018, flow monitoring of the sanitary sewer system was completed by Aquafor as well.

This study will address issues related to basement and surface flooding within the Northeast Neighborhood through a comprehensive review of the sewer system to determine the primary causes of flooding and develop remedial flood mitigation measures.

The objective is to provide a strategic plan, drainage policies and a capital strategy in order to define ongoing capital, operation and maintenance, and the long-term growth and sustainability of the City's drainage system infrastructure.

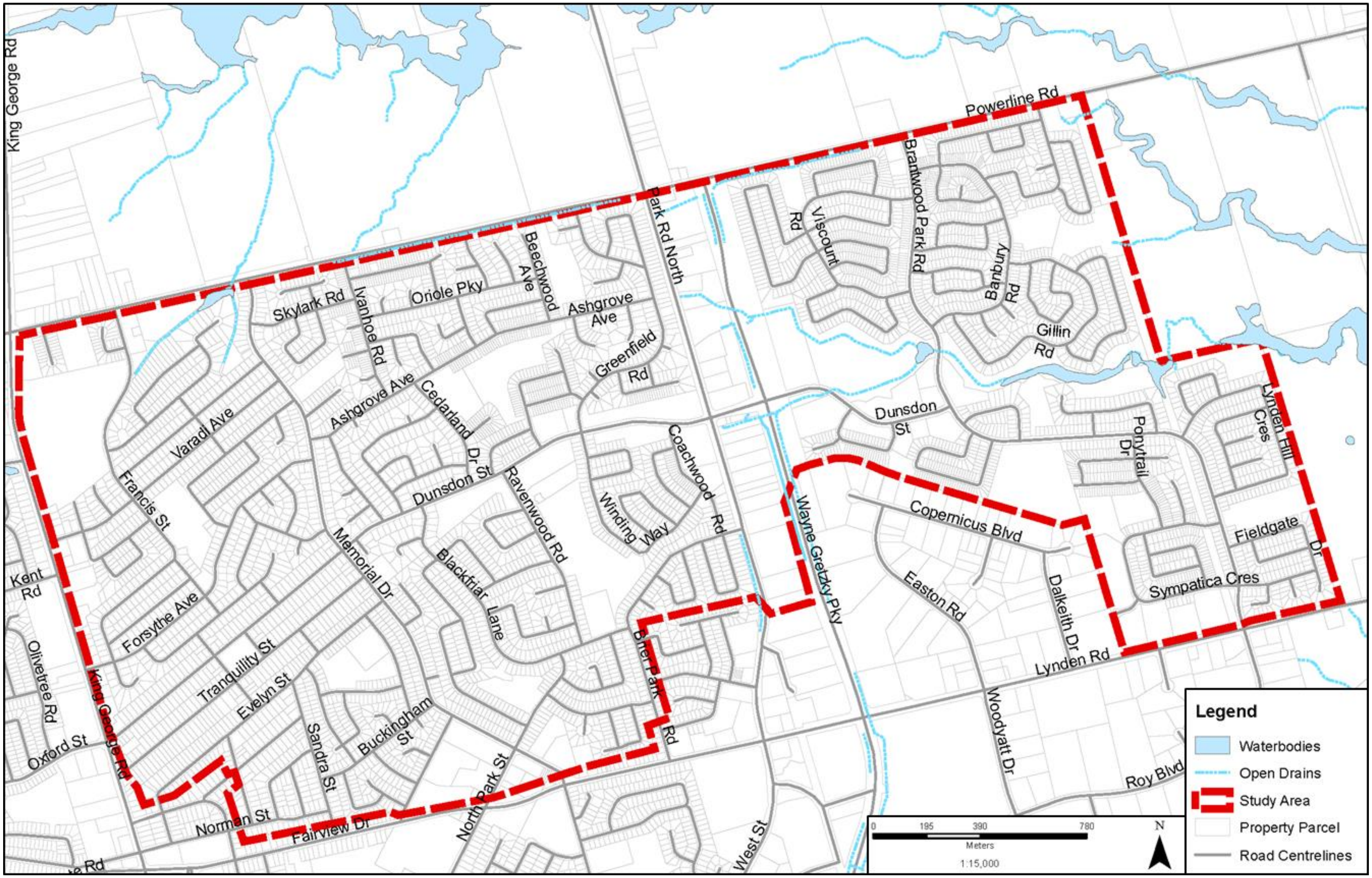


Figure 1.2.1: Study Area Map

1.3 Municipal Class Environmental Assessment Process

This study initiated as a flood remediation study with a provisional item to fulfill the Municipal Class Environmental Assessment (EA) requirements, but it was decided to fulfill the EA requirements based on discussions with the City due to the potential works required in the City's easements on private properties and the unclear easement conditions at the time of alternative development. In turn, this document was developed to satisfy the requirements set out in the Municipal Class EA document dated October 2000, amended in 2007, 2011 and 2015. The Municipal Class EA process provides members of the public and interest groups an opportunity to provide input at key stages of the study.

The Municipal Class Environmental Assessment, Municipal Engineers Association (MEA) document (October 2000, as amended in 2007, 2011 and 2015), describes the process that municipalities must follow in order to meet Ontario's Environmental Assessment requirements for water, wastewater and road projects, including Master Plans. Depending on the individual project or Master Plan to be completed, there are different processes that municipalities must follow to meet Ontario's Environmental Assessment requirements.

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

This Class Environmental Assessment document reflects the following five key principles of successful planning under the Environmental Assessment Act.

- Consultation with affected parties early on, such that the planning process is a cooperative venture.
- Consideration of a reasonable range of alternatives.
- Identification and consideration of the effects of each alternative on all aspects of the environment.
- Systematic evaluation of alternatives in terms of their advantages and disadvantages, to determine their net environmental effects.

- Provision of clear and complete documentation of the planning process followed, to allow "traceability" of decision-making with respect to the project.

The accompanying flow chart (**Figure 1.3.1**) illustrates the process followed in the planning and design of projects covered by this Class Environmental Assessment. The five phases, as defined in the flow chart, are summarized in the document as follows:

Phase 1: Identify the problem or deficiency.

Phase 2: Identify alternative solutions to the problem, by taking into consideration the existing environment, and establish the preferred solution taking into account public and agency review and input. At this point, identify approval requirements (e.g., Ontario Water Resources Act, Lakes and Rivers Improvement Act, and Environmental Protection Act) and determine the appropriate schedule for the project and proceed through the appropriate phases (**Figure 1.3.1**).

Phase 3: Examine alternative methods of implementing the preferred solution, based upon the existing environment, public and government agency input, anticipated environmental effects, and methods of minimizing negative effects and maximizing positive effects.

Phase 4: Document, in an Environmental Study Report, a summary of the rationale and the planning, design, and consultation process of the project as established throughout the above phases, and make such documentation available for scrutiny by review agencies and the public.

Phase 5: Complete contract drawings and documents, and proceed to construction and operation; monitor construction for adherence to environmental provisions and commitments. Where special conditions dictate, also monitor the operation of the completed facilities.

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

The Municipal Engineers Association's Class EA document classifies projects as Schedule A, B or C depending on their level of environmental impact and public concern.

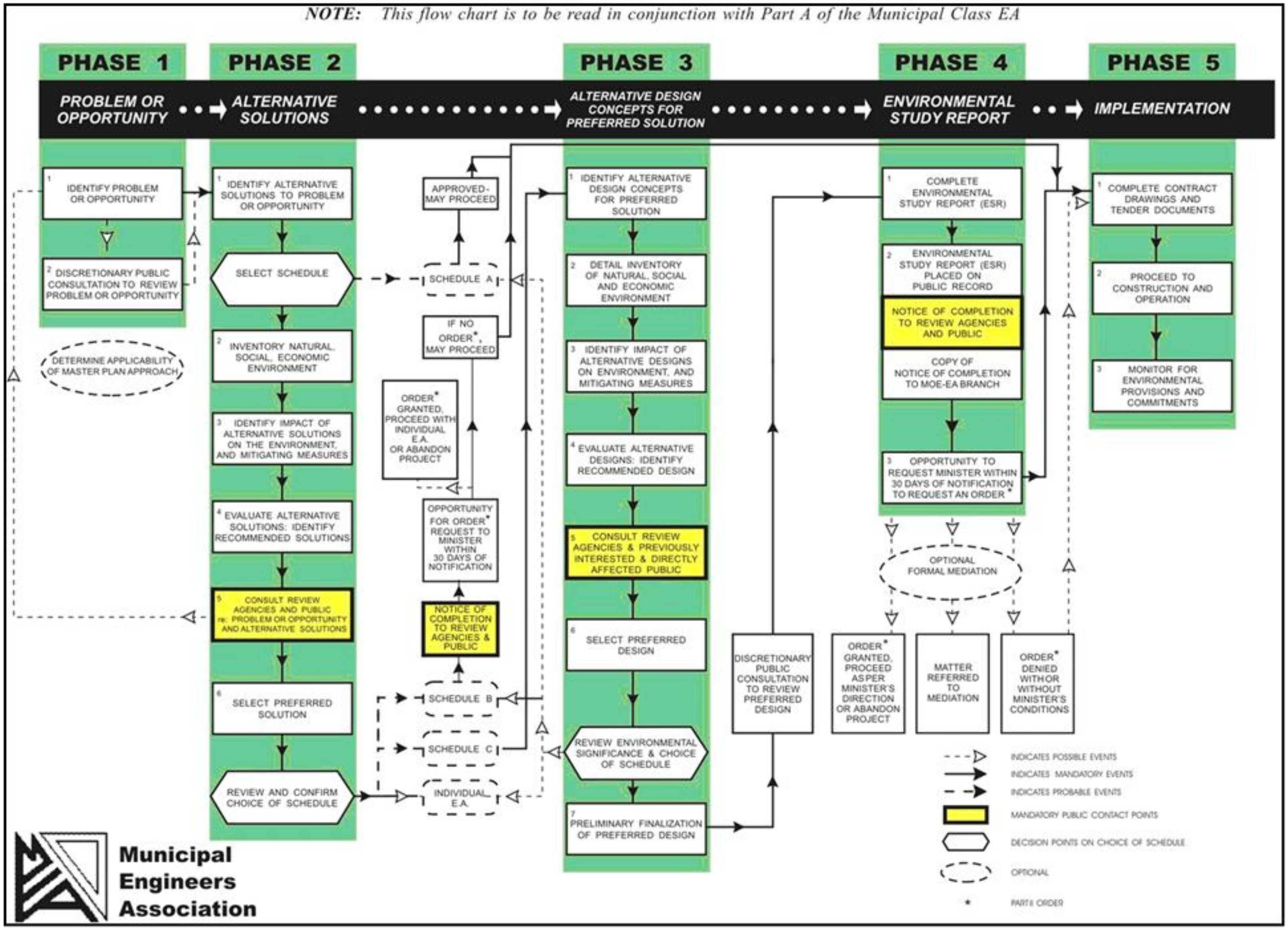


Figure 1.3.1: Municipal Class EA Planning and Design Process

- **Schedule 'A'** projects are generally routine maintenance and upgrade projects; they do not have big environmental impacts or need public input. Schedule 'A' projects are all so routine that they are generally pre-approved without any further public consultation.
- **Schedule 'B'** projects have more environmental impact and do have public implications. Examples would be stormwater ponds, river crossings, expansion of water or sewage plants beyond up to their rated capacity, new or expanded outfalls and intakes, and the like. Schedule 'B' projects require completion of Phases 1 and 2 of the Class EA process.
- **Schedule 'C'** projects have the most major public and environmental impacts. Examples would be storage tanks and tunnels with disinfection, anything involving chemical treatment, or expansion beyond a water or sewage plant's rated capacity. Schedule 'C' projects require completion of Phases 1 through 4 of the Class EA process, before proceeding to Phase 5 implementation.

This study, which started in September 2018, has been undertaken following the Master Plan approach (Approach #2), under the Municipal Class Environmental Assessment process to satisfy the Environmental Assessment requirements for Schedule A and A+ projects.

1.4 Study Purpose and Primary Tasks

The primary purpose of the Study is to review the drainage area, undertake minor (sewer) and major (overland) system capacity analysis, investigate the causes of flooding, identify any deficiencies in the infrastructure, and recommend solutions to reduce the risk of future flooding in the area.

The primary tasks which were undertaken as part of this study and associated chapters in which information is provided are summarized below:

- Chapter 1 – Introduction
  - Provide study background and define the study purpose
- Chapter 2 – Identification of Problems and Opportunities
  - Define the problems and opportunities associated with the study;
- Chapter 3 – Background Data Collection and Review
  - Collect associated background information and undertake data gap analysis;
  - Undertake various field investigations to collect additional information;
- Chapter 4 – Existing Conditions

- Summarize the existing conditions within the study area from physiological, natural environment, social-economical, regulatory and other perspectives;

- Chapter 5 – Existing Storm Sewer Systems
  - Storm system model building and model calibration;
  - Assess the existing storm sewer system and identify system deficiencies under various storm events;
- Chapter 6 – Evaluation of Alternative Solutions
  - Present and evaluate the alternative solutions;
  - Selection of the preferred alternative;
- Chapter 7 – Public Awareness Program
  - Prepare a brochure for enhancing public awareness and provide public education regarding basement flooding and potential mitigation measures;
- Chapter 8 – Implementation Measures
  - Provide implementation considerations including impact mitigation measures, details relating to functional design and detailed design, environmental approvals and permitting, and contract documents and construction;
- Chapter 9 – Conclusions and Recommendations
  - Provide conclusions and recommendations.

Chapter 2. Identification of Problems and Opportunities

2.1 General

Phase 1 of the Municipal Class EA process involves the identification of the problem to be resolved together with the opportunities to resolve the problem. Provided below is a summary of the problems and opportunities.

2.2 Identification of Problems

A number of locations within the North-East end of Brantford experienced basement flooding and surface flooding during the August 11, 2017 storm event. While the magnitude of the historical storm is comparable to a 5-year design storm and the storm sewers are typically designed to convey 5-year storm flows, flooding incidents during this specific storm indicate potential deficiencies within the existing drainage system.

The primary types of problems include:

- Surface flooding due to reverse slope driveways or poor lot grading; and
- Basement flooding through floor drains or foundation drain systems.

2.3 Opportunities

This study will investigate several opportunities to assess the capacity and performance of the existing drainage system, mitigate the risks of flooding with an integrated solution at flood-prone areas and improve the level of service of the neighborhoods to an acceptable level. Additionally, the localized solutions may also benefit the system performance at areas adjacent to the flood-prone areas.

The opportunities include:

- Propose remedial works to mitigate future flooding;
- Provide a level of service which is consistent with municipal standards; and
- Improve operational and structural conditions of the storm water system.

Chapter 3. Background Data Collection and Review

3.1 General

At the onset of the Study, Aquafor reviewed available background information which included:

- Geotechnical and topographic information;
- As-built drawings and plumbing records;
- Closed Conduit Television (CCTV) records;
- Flooding records; and
- Rainfall and flow monitoring data.

3.2 Geotechnical Information

Geotechnical investigations were undertaken by several firms for upgrades to the water and sewer systems within the study area. Geotechnical reports were compiled and the borehole location and soil type findings were summarized in **Section 4.4**. General findings indicated soils ranging from highly permeable in the west and south to low permeability in the east and north within the study area. Evidence of high groundwater was found in boreholes along Buckingham Rd, Belvedere Blvd, Ivanhoe Rd. and Morning Dew Dr.

3.3 Digital Elevation Model (DEM)

The 2015 DEM data and 2017 Lidar data provided by the City were used to develop the ground model using most accurate DEM. Inconsistencies in elevation were observed between the two sources, therefore the two data set were compared against field-surveyed maintenance hole cover and invert elevations as well as the as-built drawing information. Based on the comparative analysis of the data sets with the field-surveyed data and as-built drawings, it was determined that the 2015 DEM provided greater accuracy. The 2015 DEM was used to develop the ground model for the InfoWorks model and updated the maintenance hole cover elevations at maintenance holes within the study area.

3.4 Rainfall and Flow Monitoring Data

Aquafor Beech was retained by the City of Brantford to conduct rainfall and flow monitoring city-wide for two previous studies:

- Stormwater Flow Monitoring and System Model Calibration Study (2018); and
- Sanitary Sewer Flow Monitoring Study (2018).

Stormwater Flow Monitoring and System Model Calibration Study (2018)

The former study was to facilitate the calibration and validation of the city-wide storm model (using InfoSWMM). Rainfall data was collected and provided by the City from three (3) City-owned rain gauges and are shown in **Table 3.4.1**. The events highlighted in bold are those selected events where the rainfall depth totals exceed 15 mm across all of the rain gauges with relatively high rainfall intensities. The remaining events shown above were used to supplement the calibration exercise for the following monitoring sites where data from four events were not available.

Table 3.4.1: Rainfall Events for City-Wide Storm Model Calibration and Validation

Rain Gauge	Ground Conditions Prior to Event	WTP		PCC		TCT	
Event		Amount (mm)	Peak I (mm/h)	Amount (mm)	Peak I (mm/h)	Amount (mm)	Peak I (mm/h)
2-Oct-16	Wet	23.6	43.2	11.8	9.6	-	-
3-Nov-16	Wet	15.6	16.8	12.6	12	12.4	14.4
20-Apr-17	**Wet**	**43.4**	**60**	**47.8**	**60**	**47.2**	**28.8**
1-May-17	Wet	19	19.2	19.6	31.2	20.4	16.8
21-May-17	**Dry**	**17.8**	**31.2**	**17**	**43.2**	**14.4**	**38.4**
13-Jul-17	**Dry**	**46.2**	**81.6**	**31.2**	**50.4**	**34**	**69.6**
17-Aug-17	**Dry**	**24**	**57.6**	**22.2**	**31.2**	**22.2**	**40.8**

In addition, two (2) flow monitors recorded depth of water only and not flow rate; total volume of flow was calculated for these flow monitors and used in the calibration of the storm model.

For this study, two (2) flow monitors are located within the study area boundary as indicated on **Figure 3.4.1**. Of these two flow monitors, the Northeast Neighborhood storm model was calibrated to FM20 at Dunsdon Street at Edinburgh Crescent as this flow monitor had sufficient data for three (3) events: 1-May-17, 21-May-17 and 13-Jul-17. FM19 was not used as this flow monitor recorded flow depth only.

Further calibration work was completed for the storm system within the study area and is summarized in **Section 5.3**.

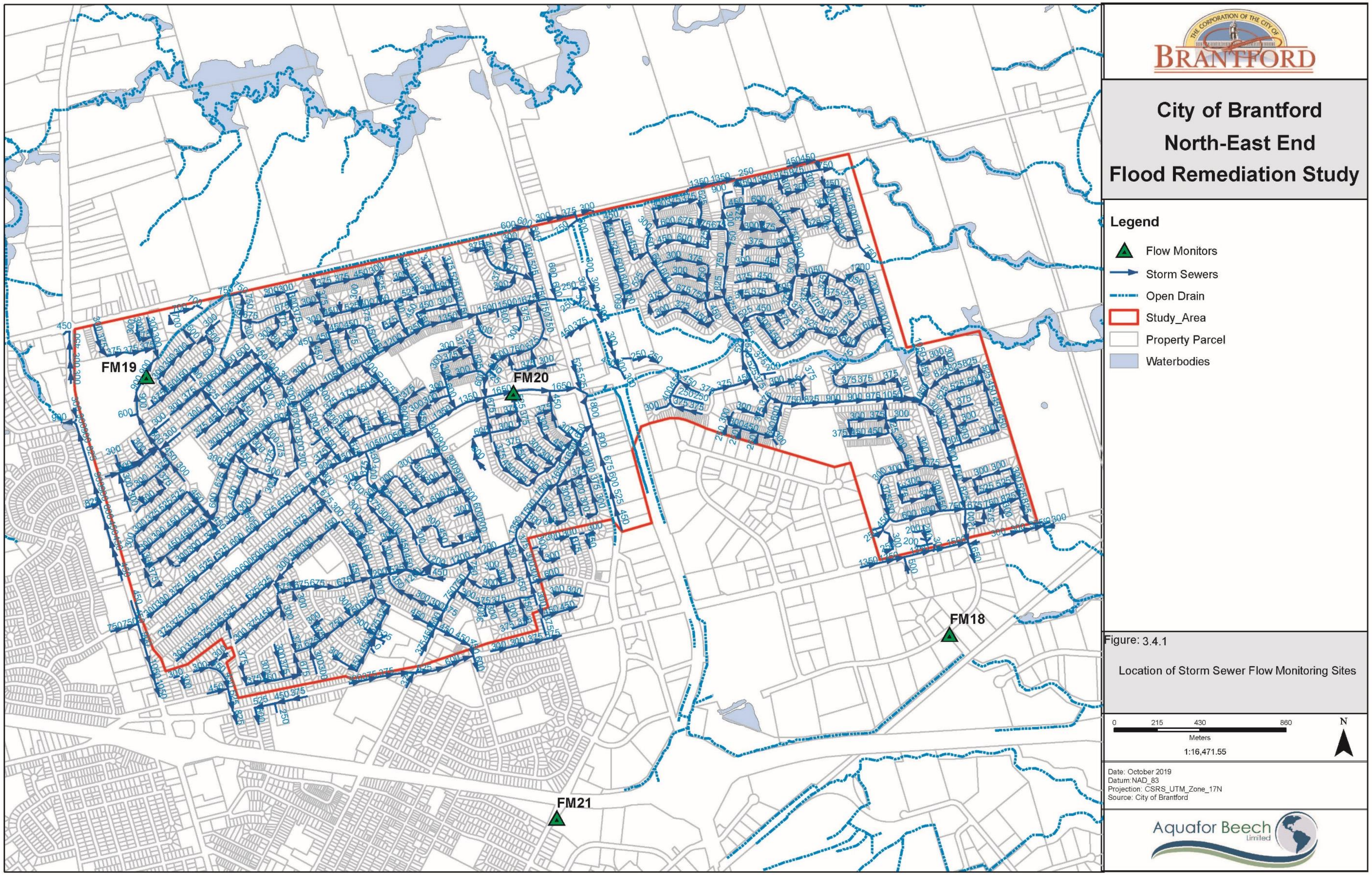


Figure 3.4.1: Locations of Flow Monitoring Sites within the Study Area

Sanitary Sewer Flow Monitoring Study (2018)

The flow monitoring study for the sanitary sewer system was submitted to the City for calibration and validation of the City-wide sanitary sewer model. Sixteen (16) flow monitors were installed at various points of the sanitary sewer system where flow monitoring data was collected between March, 2017 through October, 2017 and complied to establish baseflow and the system response to several large and intense events.

3.5 As-Built Drawings

As-built drawings for the study area were provided by the City that included historical drawings and updated drawings resulting from road reconstruction projects. The study team used the as-built drawings to fill in the identified data gaps where it was applicable to complete the model development. Missing data that was collected from the as-bult drawings area flagged in the model.

3.6 Plumbing Records

The City possesses relatively comprehensive plumbing records and the records for a majority of the properties within the study area were provided. The records contain information such as property address, the depth of sanitary and / or storm service lines at the house and at the street, as well as the dimension of service lines. Nevertheless, there is no definitive record of the foundation drain connection policy. In turn, the plumbing records were used as the primary source to determine the whether the foundation drain is connected to the storm or sanitary sewer.

The study team reviewed the plumbing records at various locations across the study area and the findings are summarized below:

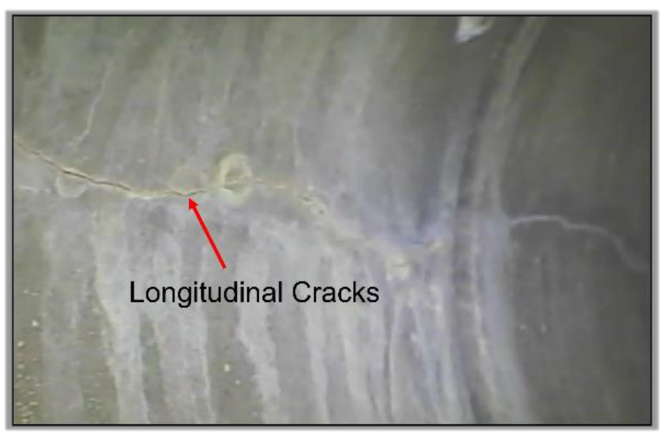
- A majority of the properties constructed prior to 1970 only have record of house sanitary sewer connection. Meanwhile, most of the properties developed post-1970 have records of house storm and sanitary sewer connection.
- For the properties that have both storm and sanitary service line connections, the depths of sanitary and storm service line connections both at the house and at the street are the same for a majority of the properties.
- Of the sampled properties, a majority of the post-1970's properties have storm sewers at or lower than 1.8m below ground, which is the typical level of basement and could allow for foundation drain connection.

Moreover, sections of streets which have only sanitary sewer system were identified within the neighborhoods that were developed prior to 1970, which indicates that the foundation drain would be connected to the sanitary sewer in those areas. Based on the information, it is presumed that the foundation drain is connected to the storm system for properties developed post-1970 and is connected to the sanitary system for pre-1970 properties.

This presumption is further affirmed based on observations and data collected from field investigations which are discussed in **Section 3.9**, and the findings are presented in **Section 3.10**.

3.7 Closed Conduit Television (CCTV) Records

CCTV records were requested in the areas of reported flooding to assess the condition of the sewers and provide guidance in adjusting the model to reflect the pipe condition. Records were received for approximately twenty percent of the study area. The city also provided the locations and approximate percentage of pipe blockage for the areas of calcite build-up within the sewers based on the CCTV zoom camera inspections shown on **Figure 3.7.1**. Upon review of the CCTV videos, a few issues including longitudinal cracks, calcite build-up were observed, which could potentially compromise the conveyance capacity. The sewer segments, length and condition based on CCTV records and location of calcite build-up were complied and the data was used to adjust the roughness value (Manning's N) to reflect the actual condition of the sewer in the model based on percent blockage.



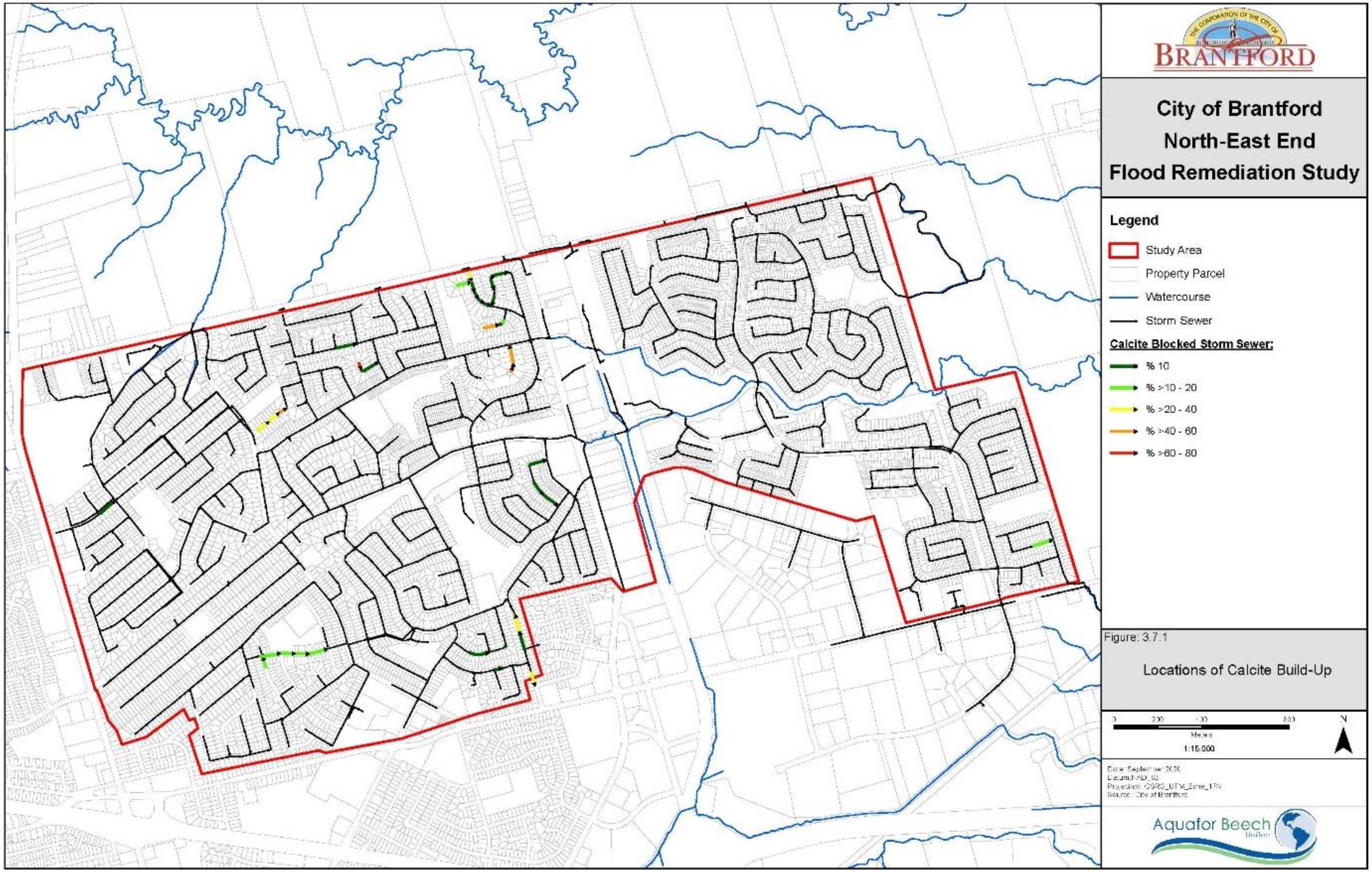


Figure 3.7.1: Locations of Calcite Blockage within the Storm Sewer System

3.8 Flooding Records

Two sources were used to collect historical flooding records – historical flood calls received by the City and a questionnaire customized to this study.

Historical flood calls from the relating to the August 11, 2017 event received at the City's Customer Contact Centre were provided by the City. A total of 48 records, including address and descriptions of flood occurrence, were reviewed to assist with understanding the cause of flooding.

A questionnaire was mailed to all residents within the Northeast Neighborhood in late November 2018 with a submission deadline of January 11, 2019. The objective of the questionnaire was to collect additional information to assist in understanding the type and causes of flooding relevant to the August 11, 2017 storm event that impacted the study area. A sample questionnaire and the compiled questionnaire responses can be found in **Appendix A**. The responses to the questionnaire were also cross-referenced with flood records from the City to supplement the responses (i.e. flooding occurrences and source).

In total, 537 questionnaire responses were received, which were compiled and analyzed. The result analyses are attached to **Appendix A**. A brief response summary is presented below for some of the key questions.

Question: How has your home been impacted by flooding? If so, what type of flooding?

Out of 537 flood records, 179 reported (33%) reported flooding on their properties with the vast majority reporting basement flooding and to a lesser extent, both basement and surface flooding. 11 percent reported surface flooding impacting their properties. The common causes of basement and surface flooding and potential remedial measures are summarized below:

Table 3.8.1: Types of Flooding and Potential Remedial Measures

Type of Flooding	Potential Causes	Primary Remedial Measures
Basement Flooding	Insufficient sewer capacity, presence of reverse-sloped driveways, age of development where storm sewers do not extend fully up the street	Sewer upgrades, in-line or off-line storage, modification of inlet capacity
Surface Flooding	In sufficient sewer capacity, presence of reverse-sloped driveways, lack of major system	Sewer upgrades, in-line or off-line storage, upgrading major

Type of Flooding	Potential Causes	Primary Remedial Measures
		system outlet, modification of inlet capacity
Basement & Surface Flooding	Undersize laterals & trunk combined sewer, improper downspout and/or foundation drain connections	Combination of the above plus addressing reverse-sloped driveway drainage.

Question: How many times have you experienced basement flooding?

One third of the responses indicated one or more occurrence of flooding from approximately 1998 onward with 16 percent reporting two or more occurrences of property flooding. Common responses to the multiple occurrences indicated the following:

- Water backing through floor drains; and
- Water entering the house through windows, walls, doors potentially due to poor grading or reverse-slope driveways.

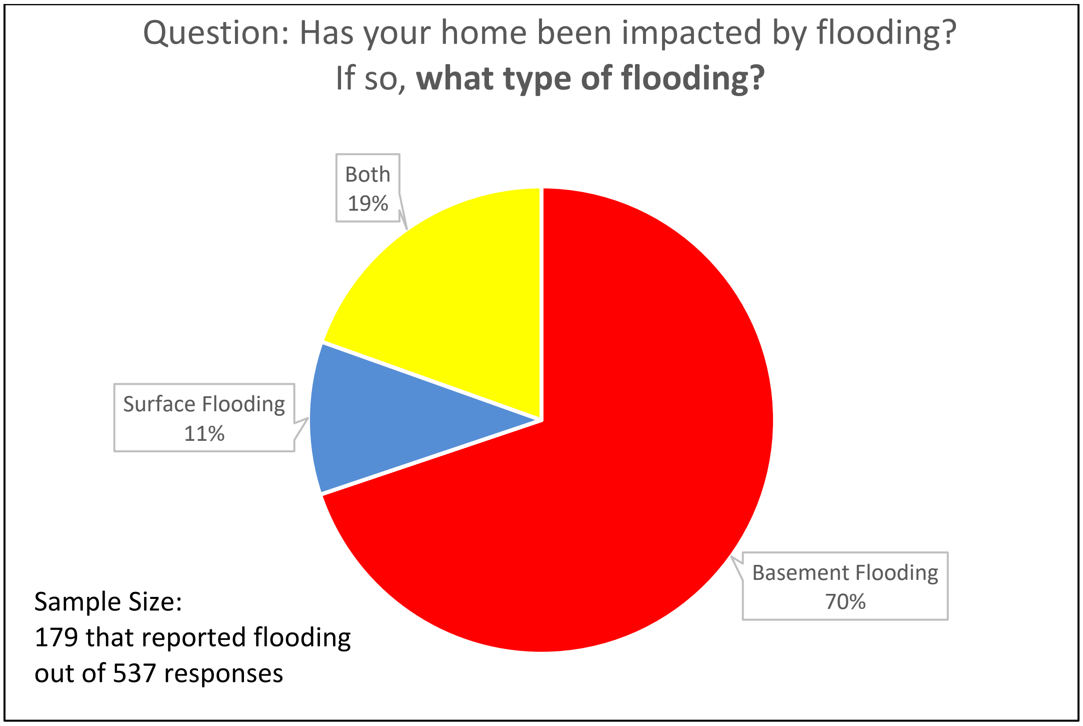
The responses are illustrated in pie chart format shown on **Figure 3.8.1**.

To get a common baseline of the which areas experience flooding, types of flooding and likely cause of flooding, the August 11, 2017 event, which resulted in numerous calls to the City regarding both basement and surface flooding and triggered this study, was chosen for further analysis. Out of the 183 responses that reported occurrence of flooding, 56 responses indicated flooding as a result of the August 11, 2017 event.

Some of the responses from the 56 properties that reported flooding associated with the August 11, 2017 event are discussed below.

Question: Did the water entering your basement appear to come from any of the following: floor drains, walls, windows, doors and/or sump?

Almost half of the responses indicated the floor drain as the source of water entering the basement while just under 30 percent indicated water entering through the wall, windows and doors. The remainder did not indicate a response to the source. The mode of entry indicates that the foundation drains are likely a primary mode of entry of water into the home. The locations of flooding and mode of entry are shown on **Figure 3.8.1** which provided guidance on the background data review, additional data collection and field survey to determine the root cause of the flooding issues.



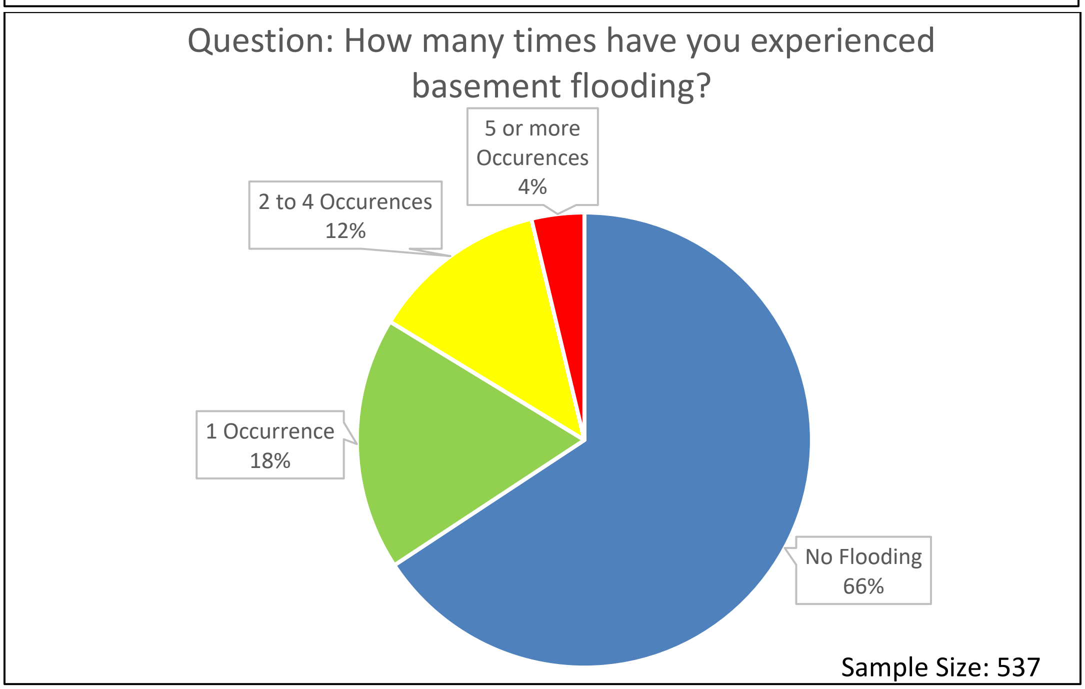
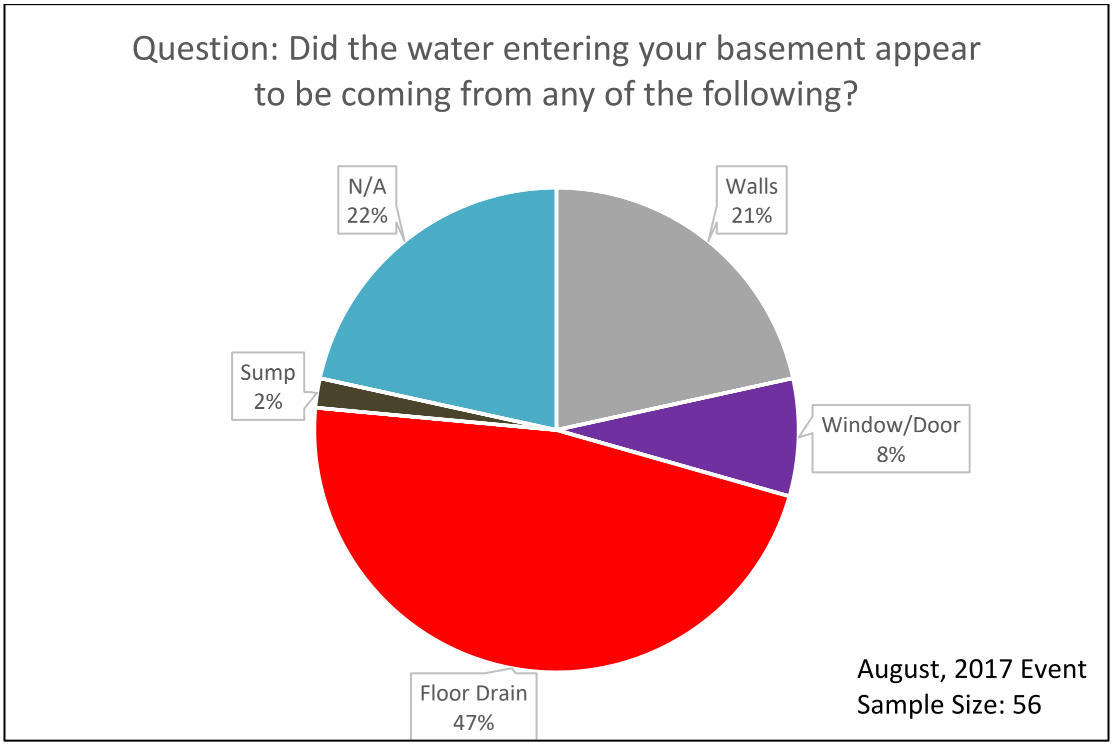


Figure 3.8.1: Northeast Neighborhood Questionnaire Responses (based on sample size of 537)

Question: If there was an odour, what did it smell like? and Question: How did the water appear?

The majority of the 56 property owners indicated either clear water or brown/dark or dirty/muddy water entering the home while another 10% indicated a sewage odour emanating from the flood water. The locations of the flooded properties were mapped provided guidance on the background data review, additional data collection and field survey to determine the root caused of flooding issues. It was noted that all homes with reverse-sloped driveways also reported sewage odour; this suggests overloading of the sanitary system from water entering the basement through the garage and overloading the sanitary system.

Figure 3.8.2 illustrates the pie-chart distribution of the responses to three questions. The information collected from the flood records was summarized into general areas of flooding as shown in **Figure 3.8.3**; this figure was used to guide isolate the areas for additional data collection.



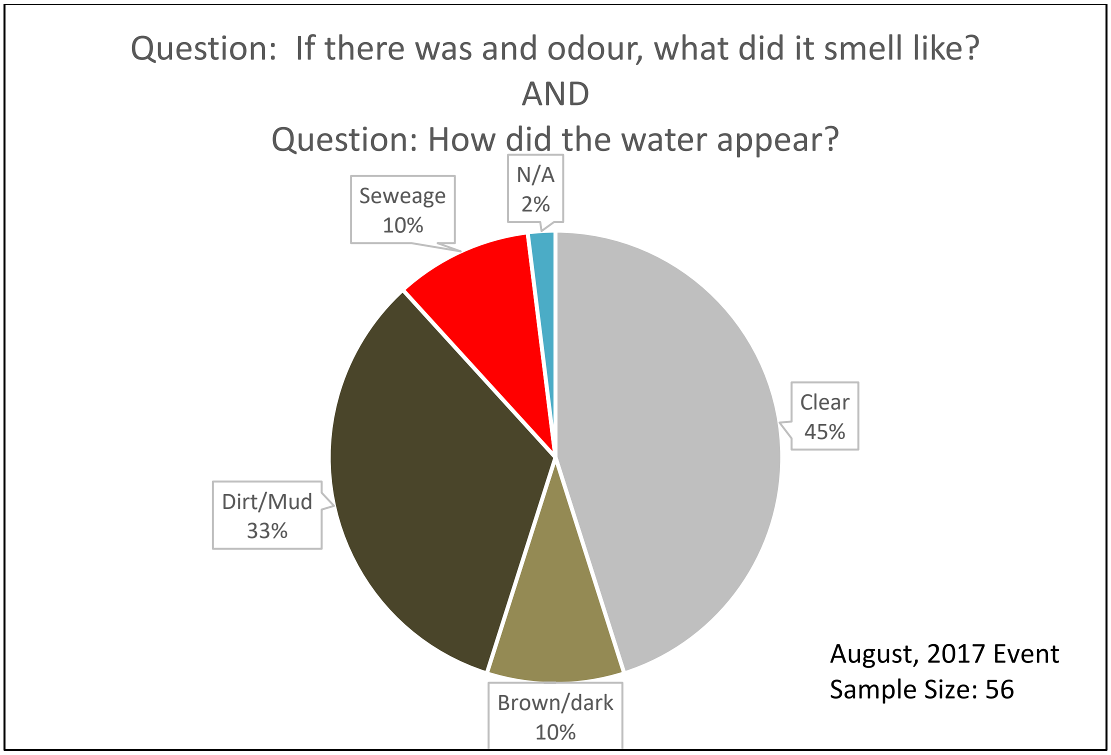


Figure 3.8.2: Northeast Neighborhood Questionnaire Response for August 11, 2017 Event

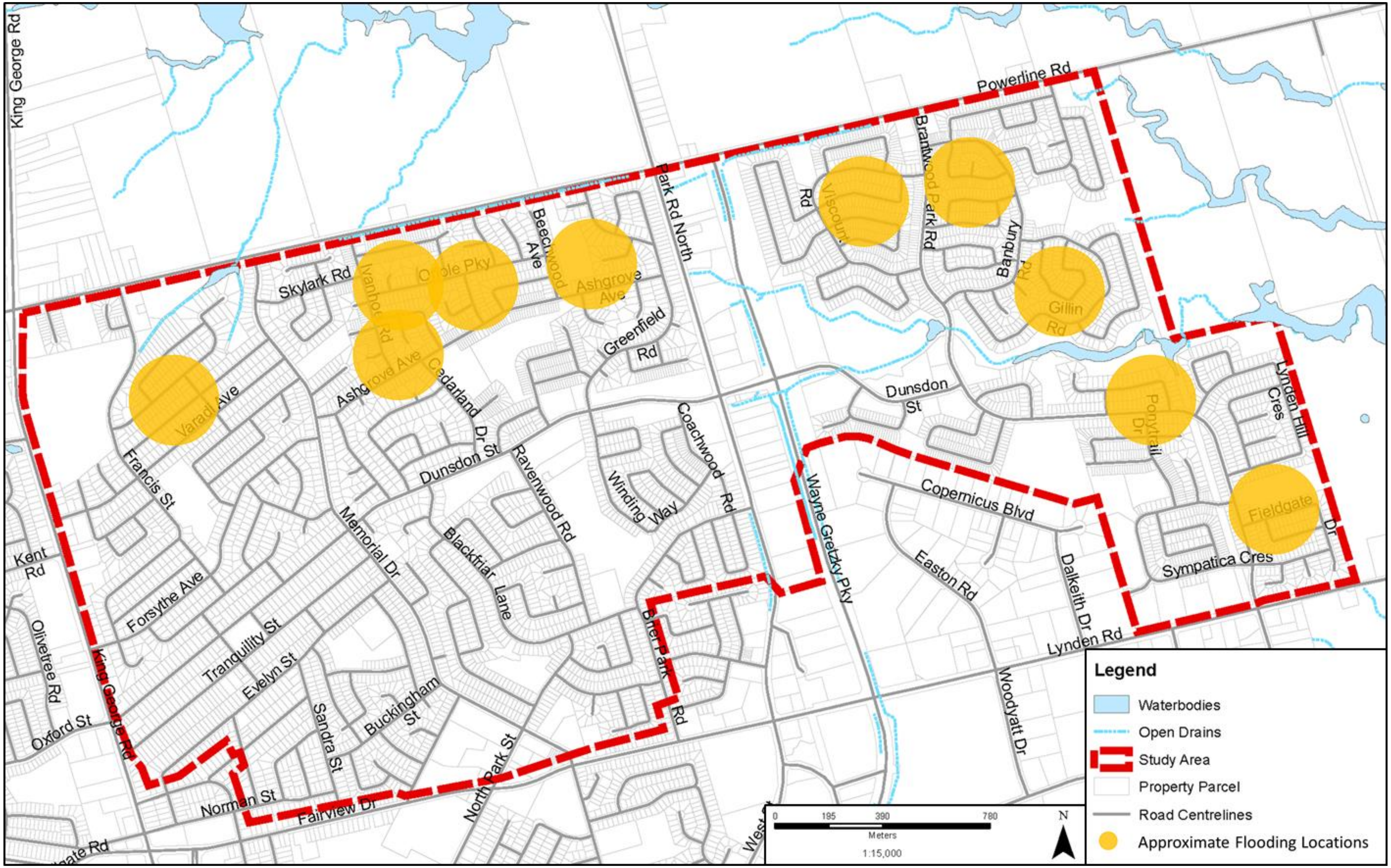


Figure 3.8.3: Approximate Locations of Reported Flooding Incidents

3.9 Additional Data Collection

The study team identified a number of data gaps and inconsistencies in the data provided. Consequently, the study team undertook field investigations to fill the data gaps and confirm data accuracy. The field work included:

- Verification of sewer inverts and maintenance hole elevations;
- A survey along Powerline Road to confirm infrastructure and drainage characteristics;
- Verification of dimensions of storm outfalls and road crossings;
- Home visits of ten (10) private properties to confirm the type and cause of flooding; and
- Smoke testing within the storm sewer system to confirm connections for catch basins, foundation drains and other infrastructure.

The detailed procedures and findings for each type of survey are presented in the sub-sections below.

3.9.1 Sewer Inverts & MH Elevation Verification Survey

Inconsistencies were observed for the MH lid elevations in the existing storm and sanitary sewer systems amongst the different data sources including the InfoWorks ICM model, the 2015 DEM data, the 2017 LiDAR data, as well as as-built drawings. In addition, the study team was advised by the City that the sewer inverts may be estimated in the existing model. As a result, the study team undertook the sewer invert and MH lid elevation survey to confirm data accuracy and determine the most suitable source of topographic data.

A total of 29 MH locations across the study area were selected and the sewer inverts, pipe diameters as well as the MH lid elevations were surveyed using GPS survey equipment. The collected data were then compared to the existing information from the various sources. The existing sewer invert information in the model is generally consistent with as-built and surveyed information. It was determined that the topographic data from the 2015 DEM corresponded better to the as-built and surveyed information than the 2017 LiDAR data and the existing InfoWorks model, and it is used to update the ground elevations in the model.

3.9.2 Powerline Road Survey

Due to the flooding issues along Powerline Road and limited background information available for investigation, a field survey along Powerline Road was warranted to confirm existing infrastructure and drainage characteristics. A number of road cross sections including the dimensions of the road-side ditches, drainage direction, and dimensions of existing infrastructure were collected and utilized to update the model.

3.9.3 Verification of Dimensions of Storm Outfalls and Road Crossings;

Storm outfalls including the outfall invert, dimension, headwall, as well as outfall condition were surveyed. Locations of the storm outfalls are illustrated on **Figure 3.9.1**.

Representative road crossings were surveyed and the information was used to update the overland system in the model.

3.9.4 Home visits

During the first PIC, a total of ten (10) private property owners requested home visits to be undertaken by the consultant team to inspect the property and investigate the flooding issues. Home visits were completed in May and June of 2019; survey results are summarized in **Table 3.9.1**.

Based on property owner’s description, field observations and best engineering judgement, it is inferred that only five of the properties experienced flooding due to private property issues while the other five experienced flooding potentially due to municipal infrastructure limitations.

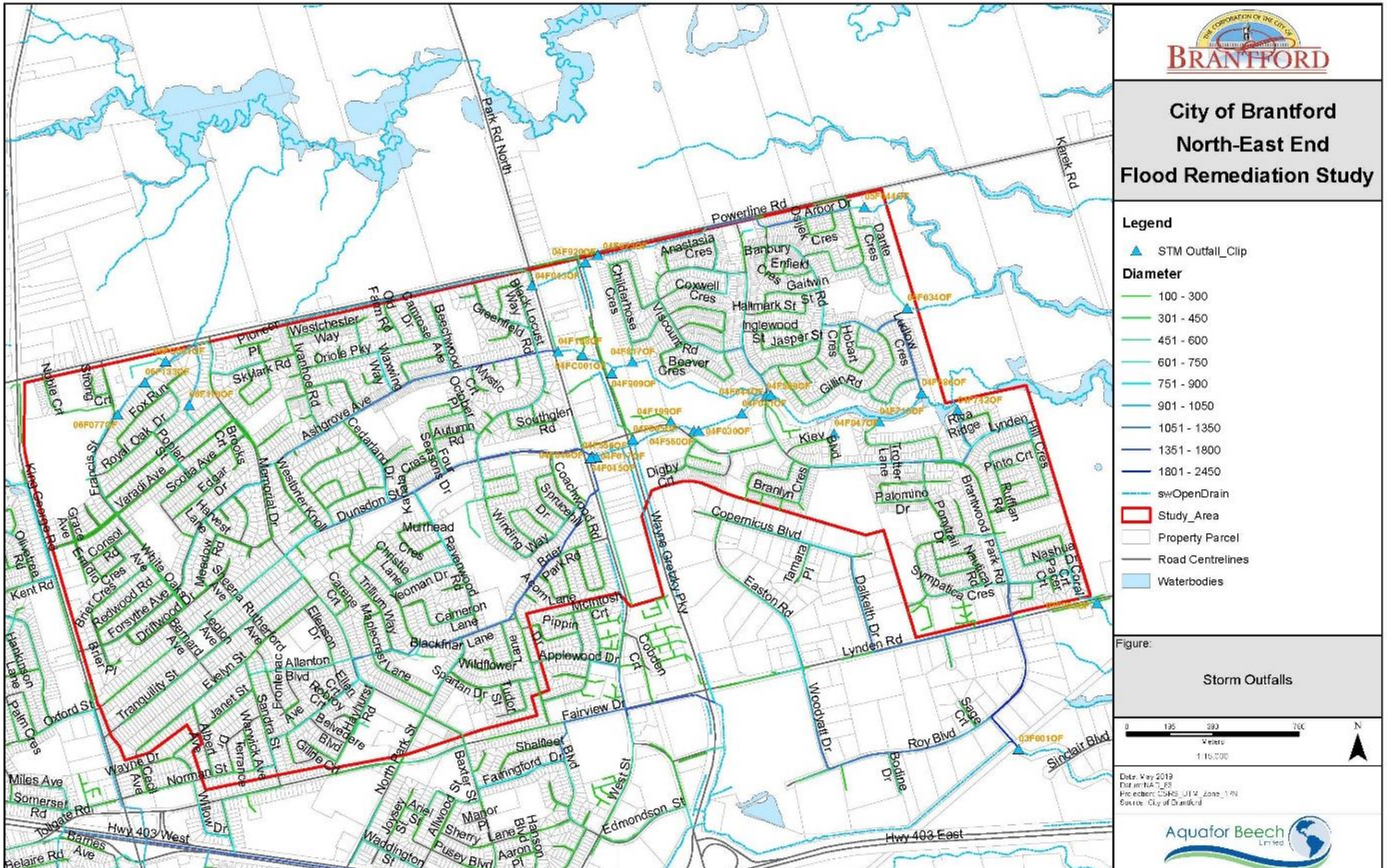


Figure 3.9.1: Storm Outfall Locations

Table 3.9.1: Summary of Home Visits

Approximate Location	Property Conditions				Additional Notes	Potential Cause of Flooding
	Flooded in Aug 2017?	Downspouts Disconnected?	Lot Grading?	Reverse Slope Driveway?		
Anastasia Cres	Yes	Yes	Good	No	Backyard was flooded due to water ponding on Powerline Road.	Surface flooding from Powerline Road
Ashgrove Ave	Yes	Yes	Good	No	Water entered through floor drain and walls during the Aug 2017 storm. Back-water valve put in place since the flood.	Potentially caused by overwhelmed municipal sewer system during the storm event.
Bell Manor Crt	Yes	Yes	Good	No	Water entered from hairline cracks on basement floor and no water entered floor drain during the Aug 2017 event.	Potentially caused by overwhelmed storm sewer system through connected foundation drain during the storm event.
Brookhaven Crt	No	Yes	Good	No	Water entered from the sump in the basement during winter 2018 with a malfunctioning pump during the time.	Most likely a private property issue.
Fieldgate Dr	Yes	Yes	Fair	No	Poor drainage on property. Flooded through window well during every rainfall previously; window well cover installed in 2018. Potentially receives overland flow from the park behind the property based on visual inspection. No water overflow from park's berm during Aug 2017 event.	Most likely a private property issue.

Approximate Location	Property Conditions				Additional Notes	Potential Cause of Flooding
	Flooded in Aug 2017?	Downspouts Disconnected?	Lot Grading?	Reverse Slope Driveway?		
Kensington Ave	Yes	Yes	Fair	No	Water entered through sump pump in Aug 2017 due to malfunctioning pump. In May 2019, water likely entered from basement floor/wall edges and no water back-up from floor drain.	Potentially caused by overwhelmed municipal sewer system during the storm event.
Nautical Rd	No	Yes	Good	No	Water infiltrated through walls and hairline cracks on basement floor in spring 2018.	Most likely a private property issue.
Royal Oak Dr	Yes	Yes	Good	No	Water entered through sump in the basement. Back flow from floor drain and shower drain was also observed, but it is not the main source of the flooding.	Potentially caused by overwhelmed municipal sewer system during the storm event.
Sulky Rd	Yes	Yes	Good	No	Water enters from the wall corner in basement during some rain events.	Most likely a private property issue.
Tanglewood Terr	Yes	Yes	Fair	No	Constantly flooded and the property owner has done a number of measures to alleviate flooding issue: 1) downspouts connect to rain barrels; 2) 3 pumps in basement; 3) a drainage ditch installed to direct backyard runoff to street.	Most likely a private property issue.

3.9.5 Smoke Test

Thompson Flow Investigation (TQI), retained by Aquafor, undertook smoke testing in September 2019 at ten (10) selected problem locations within the study area. The tests were carried out within the storm sewer system in order to confirm the connections for catchbasins (CBs), foundation drains and any potential cross connections. A detailed smoke test report is included in **Appendix B** and a brief summary of the findings for each location are presented in **Table 3.9.2** and representative photos are shown on **Figure 3.9.2**.

Table 3.9.2: Summary of Smoke Test

Key Findings	Locations									
	Skylark Rd	Oriole Pkwy	Royal Oak Dr	Canary Dr	Hemlock Crt	Wedgewood Dr	White Owl Cres	Enfield Cres	Palomino Dr	Thicketwood Crt
Evidence of direct connection between reverse slope driveway drains and the storm sewer	✓				✓	✓				✓
Evidence of direct connection between foundation drain and storm sewer	✓	✓	✓	✓						
Evidence of direct connection between sump pit / cleanout and storm sewer				✓	✓	✓	✓	✓	✓	
Evidence of connected downspout	✓					✓				
Evidence of cross connection between plumbing and storm sewer	✓	✓			✓	✓	✓	✓	✓	✓
Unknown downspout connections			✓	✓			✓	✓		

It should be noted that the smoke test results are not definitive and generally indicate a direct or indirect connection. A dye test from the source to the sewer system is required to confirm the connection.

Smoke at reverse-sloped driveway CB indicating a direct connection with storm sewer.

Smoke out of downspout indicating a direct connection with storm sewer.

Smoke out of sump pit / cleanout in the basement indicating a connection with the storm sewer via foundation drain and storm lateral.

Smoke out of plumbing vent and internal plumbing indicating a connection with storm sewer.

Figure 3.9.2: Smoke Testing Photos

3.9.6 Property Survey

A property survey was completed for 29 streets within the study area. Information including estimated downspout disconnection rate, lot grading, reverse slope driveways, road grading, and local low points were collected and used to assist in the development of the InfoWorks model and alternatives. The key findings are summarized below:

- A majority of the downspouts are disconnected within the surveyed area;
- A number of reverse slope driveways are identified within the study area (see **Figure 3.9.3**) and most of them have a catchbasin or drain trench in front of the garage door;
- Five (5) low points were identified based on visual inspections; and
- A majority of the properties have average to good lot grading.

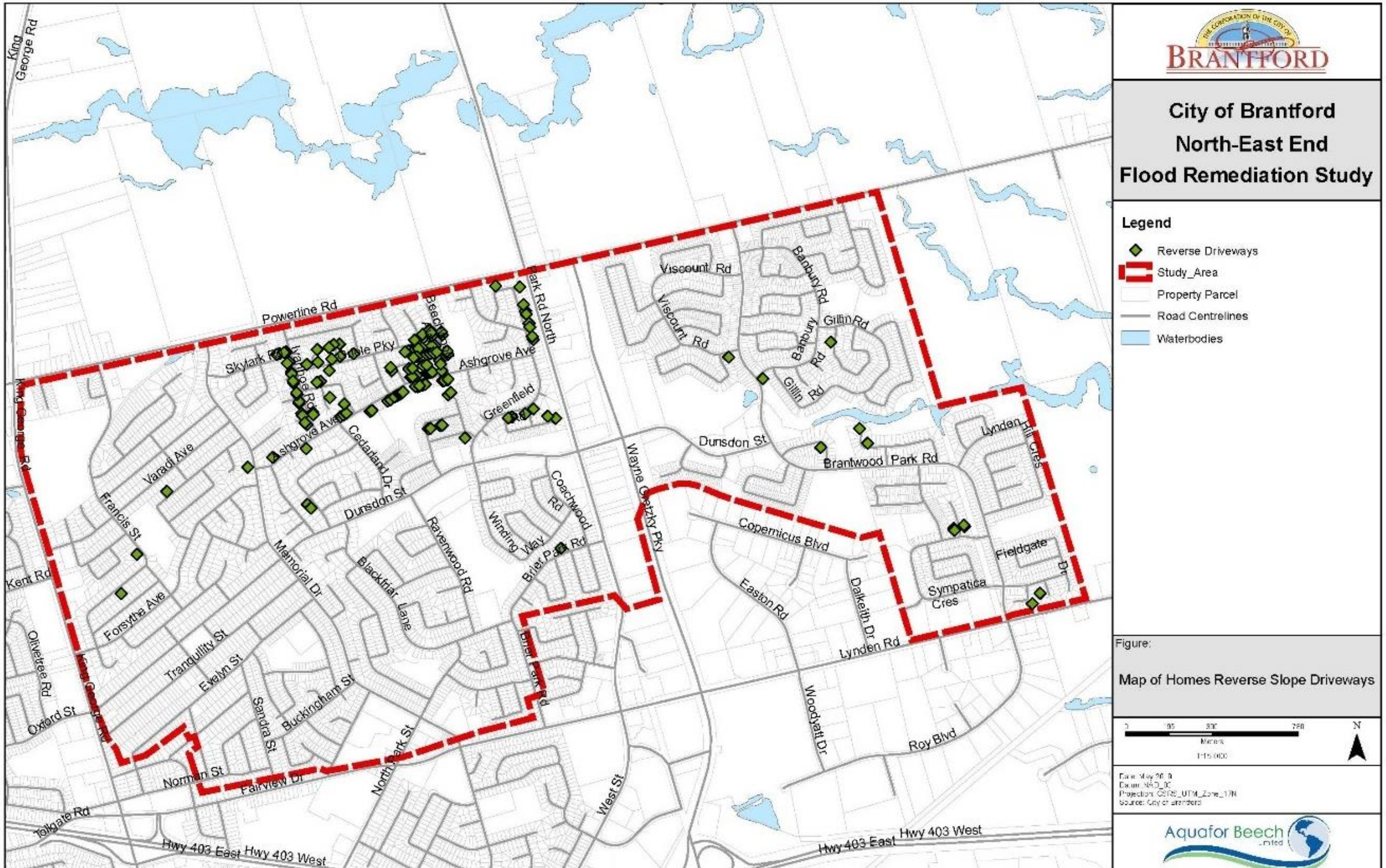


Figure 3.9.3: Properties with Reverse Slope Driveways

3.10 Conclusions

As smoke emanated from the sump pits / cleanouts in the basement of various properties during the smoke testing, it is evident that the foundation drains are directly connected to the sewer storm system. This confirms the presumption reached based on the plumbing records review. A number of the residents informed the survey crew that water entered from their sump pits when their basements were flooded. Furthermore, a number of the properties that reported basement flooding through floor drain were also visited during the survey. Through discussion with the residents, it was clarified that the water in fact entered through the sump pits instead floor drain as they indicated is the questionnaire response. Considering that a majority of the flooding as a result of the August 2017 event occurred in the areas that were developed post 1970, it is concluded that storm sewer surcharging during extreme storm events is one of the main causes of basement flooding within the area. As a result, the study team focused subsequent efforts on the assessment of the storm sewer system.

The field program was used to supplement existing sources of data. With the available background information, the study team completed the development, validation and calibration of the storm system computer model, as well as sewer system capacity and performance analysis for the various storm events.

Chapter 4. Existing Conditions

4.1 General

Existing conditions within the study area from various perspectives including geotechnical, physiological, natural environment, social-economical, and regulatory were investigated and summarized in the sections below.

4.2 Study Area Conditions

The study area is serviced by a separated sewer system where storm and sanitary flows are conveyed in separate storm and sanitary sewers. Sanitary flows are conveyed to the wastewater treatment facility. The storm sewer is a system designed to carry rainfall runoff and other drainage (excess rain and ground water from impervious surfaces such as paved streets, parking lots, sidewalks and roofs). A schematic illustrating a typical separated sewer system is provided below on **Figure 4.2.1** that shows the foundation weeping tile connected to the storm sewer system. It was found in some cases that homes constructed in pre-1970 had the foundation drain connected to the sanitary system.

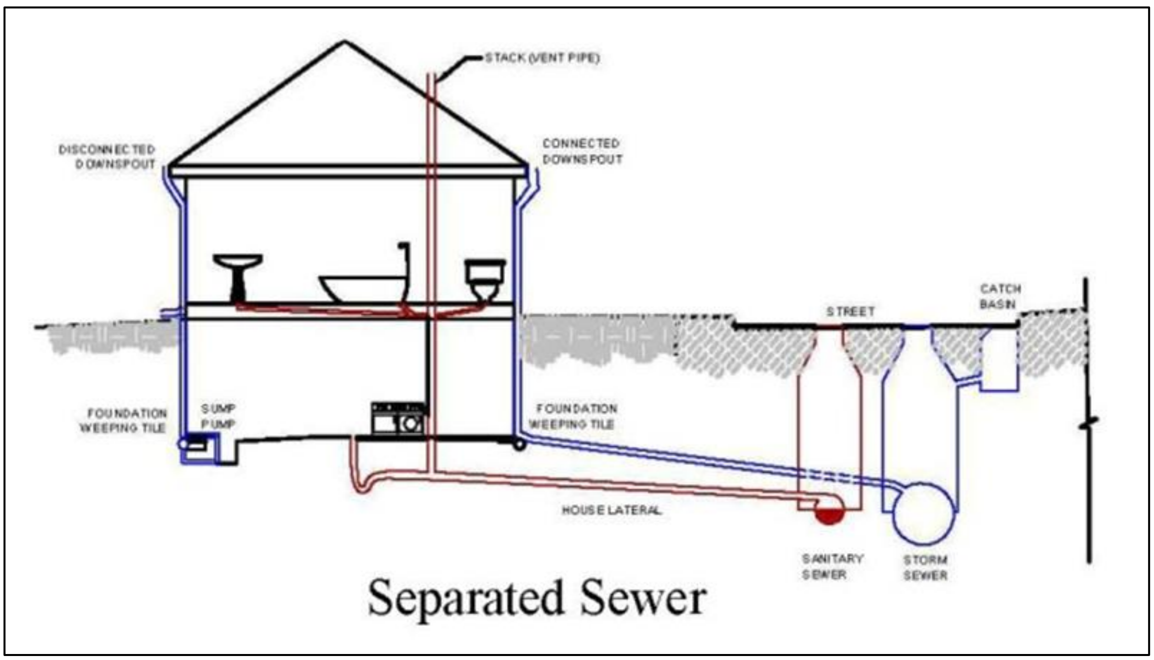


Figure 4.2.1 Technical Schematic of the Sewer System

The entirety of the stormwater collection and conveyance system within the study area consists of a gravity system that follows the local topography and drains to local streams as shown in **Figure 4.2.2**. The sanitary sewer system consists of gravity sewers and forcemains that drain to the Brantford Wastewater Treatment Plant.

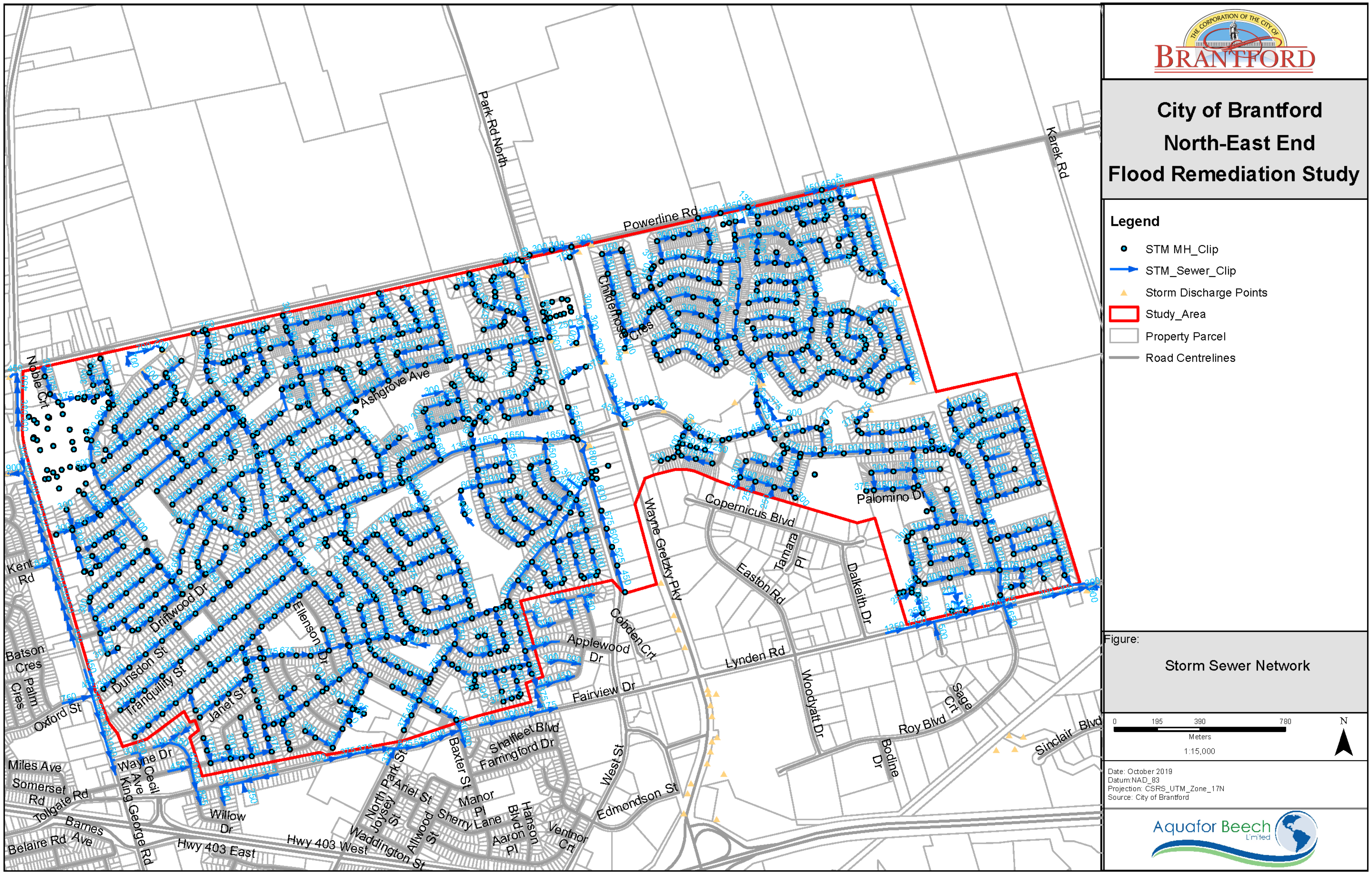


Figure 4.2.2: Northeast Neighborhood Storm Sewer Network

4.3 Policy Review

The following presents a summary of key federal, provincial and local acts and regulations relevant to the stormwater related issues within the study area. These include:

4.3.1 Planning Act

The Planning Act promotes sustainable economic development in a healthy natural environment. The Act enables municipalities to regulate land use and development at the local or regional level, subject to a provincial policy framework.

A few provisions in the Planning Act are relevant to stormwater management. They include:

- Ensuring adequate provision of sewage and water services, ensuring the orderly development of safe and healthy communities, and protecting public health and safety (Section 2);
- Enabling the provincial government to issue policy statements on matters of provincial interest, and requiring municipalities to have regard for such policy statements (Section 3), and
- Empowering municipalities to prohibit or restrict the use of land, or the erection or use of buildings or structures, particularly in areas containing significant natural heritage or land that is "a sensitive groundwater recharge area, or headwater area, or land that contains a sensitive aquifer" (Section 34(1)).

4.3.2 Conservation Authorities Act

The Conservation Authorities Act was established by the Province of Ontario in 1946 and gave CAs jurisdiction over natural areas based on delineation by watershed (MOE and MNR, 1993). Accordingly, water and related land management are the responsibility of CAs working in conjunction with the municipalities. The CAs are to establish regulations dealing with environmental protection of their watershed's resources. Regulations made under the Conservation Authorities Act must be consistent across the province and be compliant with the Planning Act.

4.3.3 Drainage Act

The Drainage Act provides a procedure for the construction, improvement and maintenance of drainage works. Not all ditches and buried pipes in a city are considered municipal drains. An engineer's report generally classifies a ditch or pipe as a municipal drain. Under Section 74 of the Drainage Act, municipalities are responsible to maintain municipal drainage systems within their jurisdiction (Ontario, 1990e).

4.3.4 Species at Risk Act

The federal Species at Risk Act (SARA) and provincial Endangered Species Act (ESA) perform a similar function of protecting at-risk plant and wildlife species and their habitats, and providing a basis for the recovery or maintenance of species that are in decline. Under these Acts, it is prohibited to kill, harm, harass, or capture regulated species, and to destroy their critical habitats. Species which have been identified under these Acts are designated as Endangered, Threatened, or Special Concern based on their current status (e.g., degree of decline, severity or immediacy of threats). Related to the current study, stormwater runoff from farm operations, lawns, golf courses, urbanization, and other pollution sources may carry contaminants, adversely affecting critical habitat and water quality for aquatic SAR (Department of Justice Canada, 2002). Decreases in water quality are a common threat affecting many aquatic SAR. Terrestrial species, similarly, are often affected by habitat alteration or loss which can occur through construction and development.

4.3.5 Fisheries Act

The Fisheries Act focuses on the protection of fish and aquatic habitat. It prohibits the deposit (direct discharging, spraying, releasing, spilling, leaking, seeping, pouring, emitting, emptying, throwing, dumping or placing) of harmful substances into waters frequented by fish, such as oceans, rivers, lakes, creeks, and streams, or into storm drains that lead to such waters. A harmful substance would alter or degrade water quality such that it would harm fish or fish habitat. A harmful substance can also be stormwater, wastewater, or other effluent that contains a substance in such quantity or concentration that it would, if deposited to waters frequented by fish, degrade or alter fish or fish habitat (DFO, 2006).

4.3.6 Municipal Planning Polices / Guidelines

4.3.6.1 Master Servicing Plan – MSP (GM Blue Plan 2014, 2016)

GM Blue Plan completed the City of Brantford 2014 Master Servicing Plan (MSP). The purpose of the MSP is to provide a review, evaluation and development of water, wastewater and stormwater servicing strategies to support existing needs and projected growth within the City. The report established the existing infrastructure conditions and capacities from a master plan perspective using an un-calibrated sanitary and storm model, assessed opportunities and constraints for the minor system and developed strategies for stormwater management for future conditions at an EA level. In 2016, an update to the MSP included adjustment to future population growth from 2031 to 2041.

Figure 4.3.1 from the MSP update study illustrates the proposed growth areas and intensification corridors together with the projected population growth. The projected land-use changes include development of the annexed lands to the north of Powerline Road and development intensification along King George Road and Wayne Gretzky Parkway have potential impacts to the study area. The majority of the study area is projected to remain at the existing level of development.

Overall, the MSP identified key opportunities and constraints that included:

- Future servicing of the expansion lands to include new pump stations, trunk sewers and stormwater conveyance and storage infrastructure isolated from the existing systems;
- Management of wet weather flow and system resilience to climate change;
- Determination of system bottlenecks and the preferred infrastructure upgrades that achieve long-term Level of Service targets; and
- Storm sewer capacity needs to support intensification corridors.

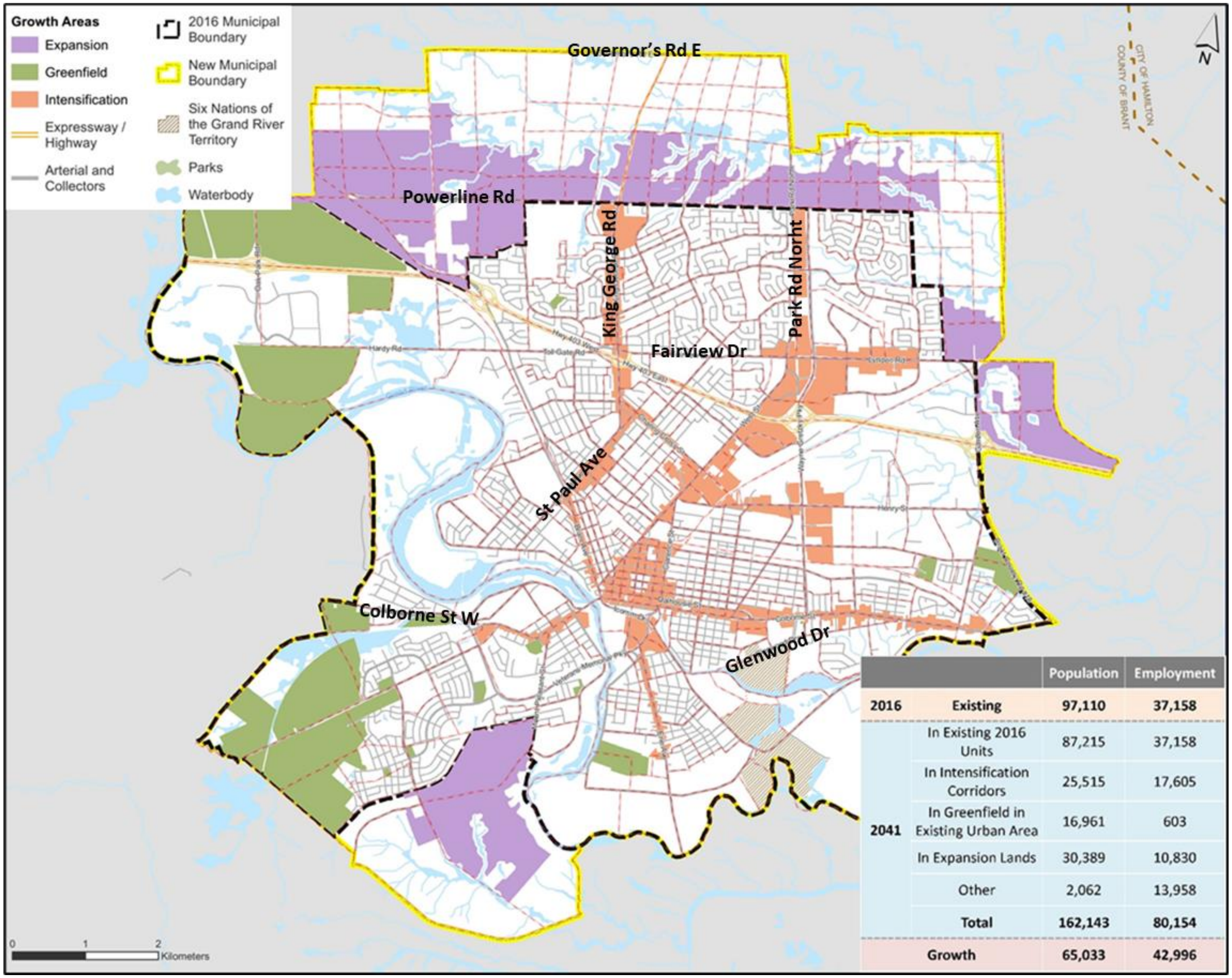
4.3.6.2 City of Brantford Official Plan (2015)

The City's Official Plan provides a framework for the development and redevelopment of lands and guide growth and development within the City and was updated to reflect the annexed lands for development and intensification corridors for future growth to 2041. The Northeast Neighborhood is largely unchanged from the existing land use (primarily residential with some commercial and mixed-use corridors).

4.3.6.3 City of Brantford Design and Construction Manual – Linear Municipal Infrastructure Standards – Storm Sewers (December, 2018)

The Design and Construction Linear Municipal Infrastructure manual is to provide the City staff, consulting engineers, contractors, developers and the general public with a common reference to ensure the consistent application of design and construction practices of linear municipal infrastructure within the City. The manual is intended to aid in the planning, design and construction and maintenance and operation activities of linear infrastructure for new subdivision developments and the retrofit of existing infrastructure.

The key guiding principles underlying the storm sewers manual are to:



		Population	Employment
2016	Existing	97,110	37,158
2041	In Existing 2016 Units	87,215	37,158
	In Intensification Corridors	25,515	17,605
	In Greenfield in Existing Urban Area	16,961	603
	In Expansion Lands	30,389	10,830
	Other	2,062	13,958
	Total	162,143	80,154
	Growth	65,033	42,996

Figure 4.3.1: Excerpt from MSP Update Study (GM Blue Plan, 2016) – Projected Growth Areas

- Undertake sustainable planning of the Storm Sewer System;
- Preserve and / or establish a more natural hydrologic cycle;
- Reduce impacts to the natural environment and protect against erosion;
- Improve runoff water quality to protect surface and groundwater supply; and
- Promote and implement shared responsibility between the City and stakeholder.

All storm sewers and appurtenances shall be designed and constructed in accordance with the latest versions of this manual as well as industry standards and best practices, including but not limited to:

- Ontario Provincial Standard Specifications (OPSS) and Ontario Provincial Standard Drawings (OPSD);
- MECP Design Guidelines for Sewage Works;
- MECP Stormwater Management Planning and Design Manual;
- Grand River Conservation Authority (GRCA) Stormwater Management Guidelines;
- MTO Highway Drainage Design Standards;
- Low Impact Development Stormwater Management Planning and Design Guide (TRCA, CVC); and
- Official Plan of the City of Brantford.

4.4 Soils and Groundwater

Soil and groundwater information was reviewed to determine general permeability and groundwater conditions within the study area that may impact basement and surface flooding risk. The Ontario GeoHub GIS data along with geotechnical reports from several firms that had conducted borehole sampling within the study area were compiled and reviewed for the soil and groundwater conditions; the findings are summarized below.

4.4.1 Surficial Geology

Figure 4.4.1 shows the study area soils are dominated by two types of geologic deposits:

- Sand and some silt from Glaciolacustrine shallow water and deltaic sediments that is highly permeable in approximately the western half of the study area; and,
- Stratified to varved silt and clay, minor sand (locally overlain by veneer of sand) from Glaciolacustrine deep water sediments that has low permeability in approximately the eastern half of the study area and along most of Powerline Road. There is also an area of silt, sand, gravel and clay with variable permeability along Fairchild Creek.

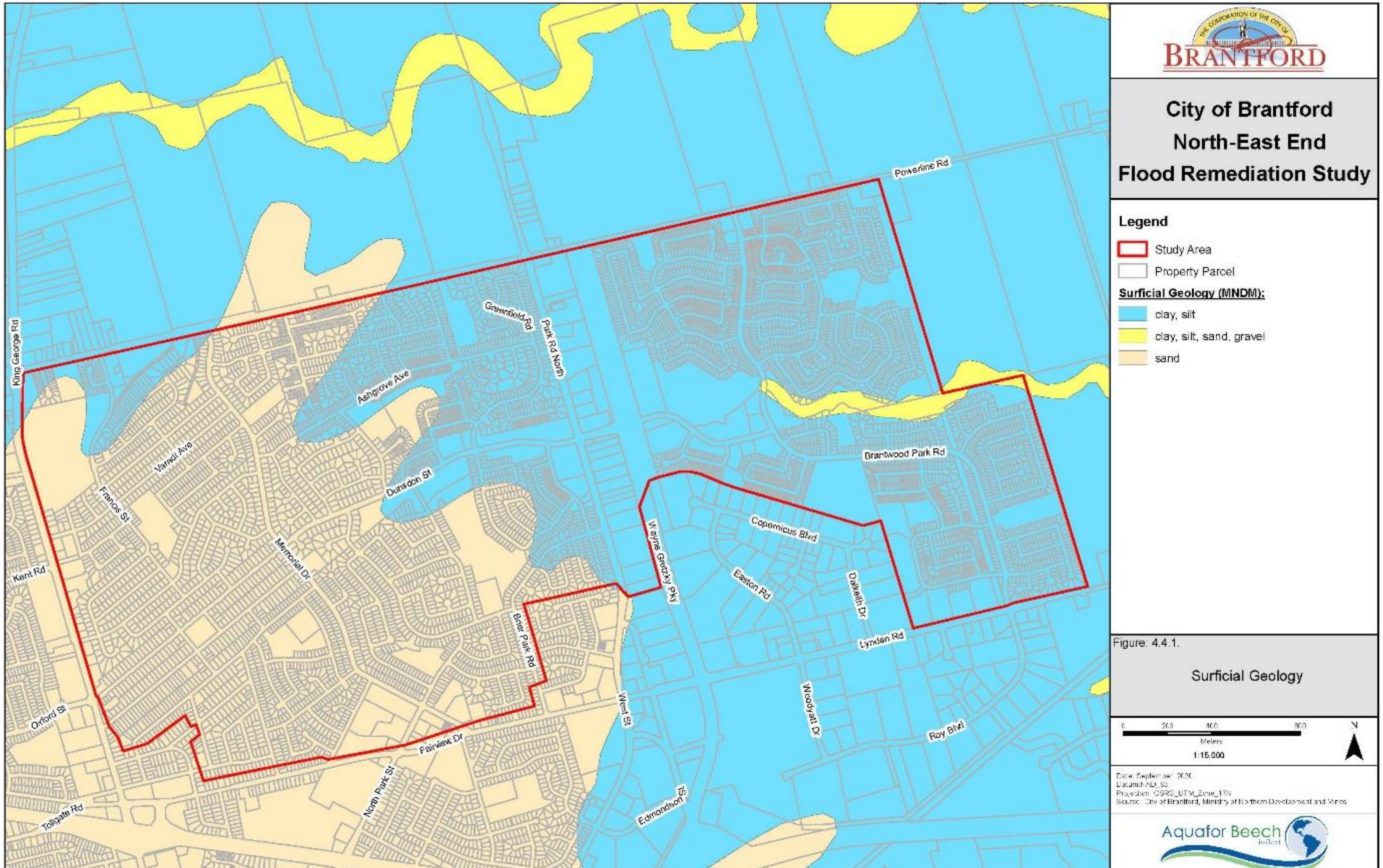


Figure 4.4.1: Surficial Geology

Geotechnical investigations were undertaken by several firms for upgrades to the water and sewer systems within the study area. Geotechnical reports were compiled and the borehole location and soil type findings are summarized in **Figure 4.4.2**. In total, borehole investigations at 30 sites were identified within the study area. The general findings summarized below:

4.4.2 Sub-Grade Soil Conditions

The subgrade soils encountered in the boreholes are generally consistent with the background information and are shown on **Figure 4.4.2**.

4.4.3 Groundwater

The findings in the reports indicate that groundwater conditions are expected to vary according to the time of the year and seasonal precipitation levels. The areas of Buckingham Rd, Belvedere Blvd, Ivanhoe Rd. and Morning Dew Dr. indicated the presence of a high groundwater table. In all areas during wet weather, seasonal fluctuations in groundwater levels are expected. The locations of boreholes showing evidence of groundwater is shown in **Figure 4.4.3**.

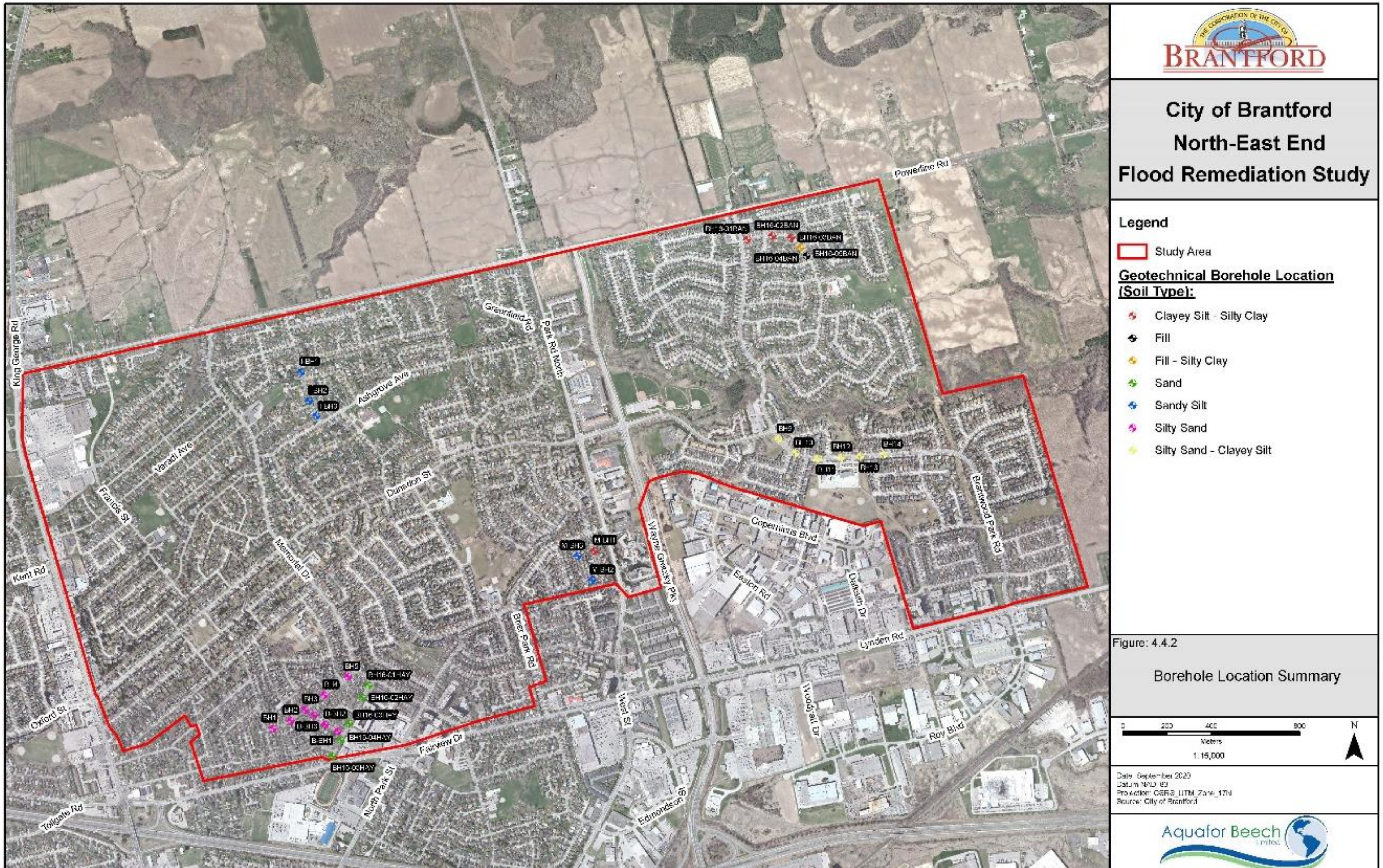


Figure 4.4.2: Borehole Location Summary

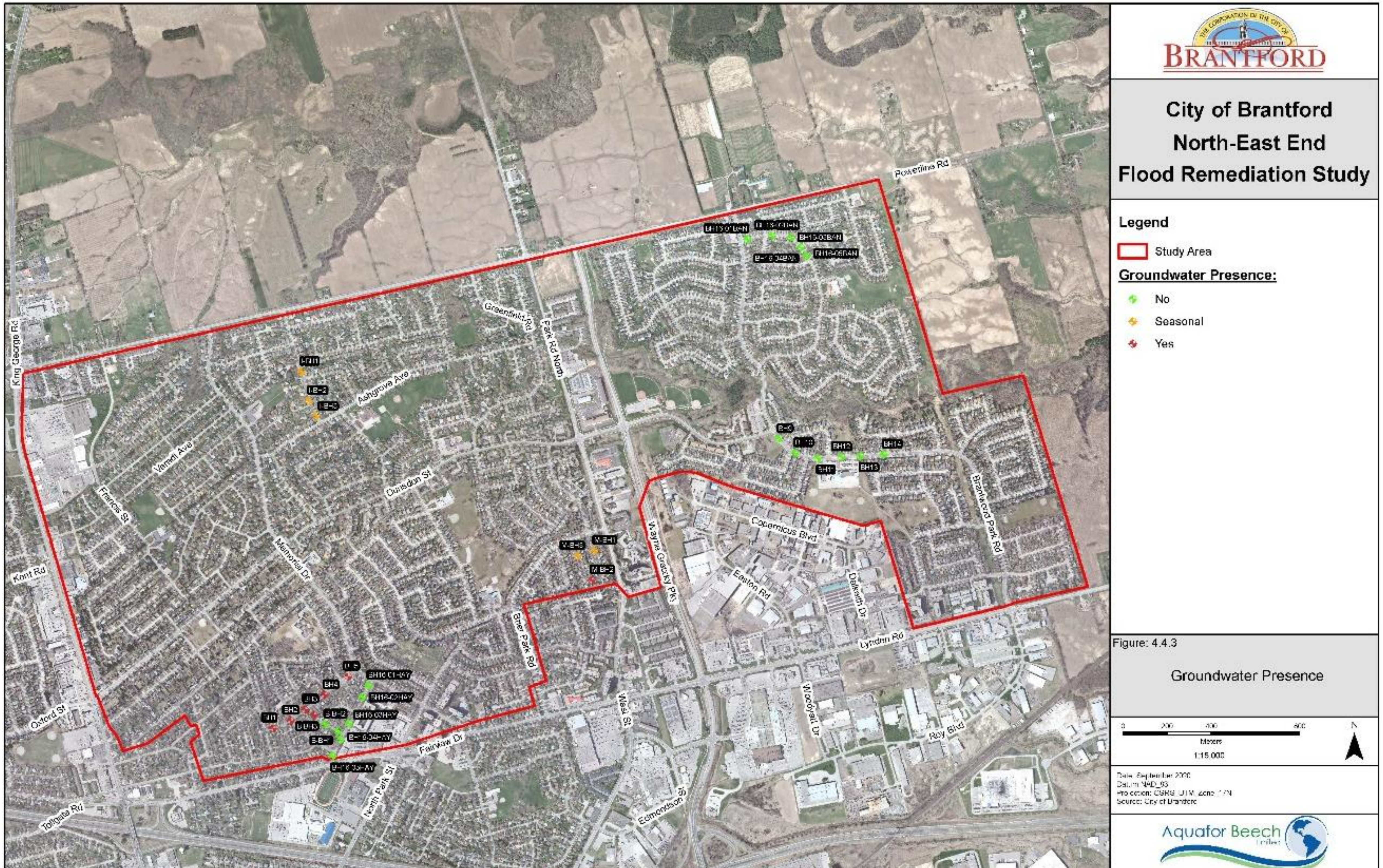


Figure 4.4.3: Location of Ground Water Presence above 3.0 m below Ground

4.5 Natural Environment

4.5.1 Aquatic Ecology

A number of aquatic features fall within the study area depicted in **Figure 1.2.1**, including drainage features contributing to Jones Creek to the north of Power Line Road and drainage features which contribute to Fairchild Creek to the east of the study area. This area falls within the greater Fairchild Creek subwatershed and is considered a major and priority tributary to the Grand River Watershed (MacVeigh, Zammit, & Ivey, 2016).

The Fairchild Creek headwaters are located near the Provincially Significant Wetland Beverly swamp, draining the eastern portion of the Norfolk Sand Plain region, in the Peter's Corners, Ancaster and Cainsville area and confluences with the Grand River near Onondaga (MacVeigh, Zammit, & Ivey, 2016). The Fairchild Creek Subwatershed Characterization Study (MacVeigh, Zammit, & Ivey, 2016) notes that the subwatershed is a largely agricultural subwatershed (68% agricultural land cover) with urban centres, including the northeast corner of the City of Brantford, contributing to 12% urban land cover. 22% of the subwatershed cover is contributed by natural areas such as wetland complexes and forested areas.

The subwatershed groundwater recharge areas support baseflows in Jones Creek to the north of the City which is referenced as a cool water stream that support Brown trout and the provincially vulnerable American brook lamprey (MacVeigh, Zammit, & Ivey, 2016). Drainage features that support this creek are located to the north of Power Line Road and are contributed to by Flood Areas 6, 7 & 8. The mid-reaches of Fairchild Creek located to the east of the study area where the subwatershed is dominated by agricultural land use activities and receives urban drainage from the City, including Flood Areas 1 through 5. This area supports a warmwater fish community (MacVeigh, Zammit, & Ivey, 2016). The Fisheries and Oceans Canada (DFO) aquatic species at risk (SAR) mapping tool also notes that Rainbow mussel (*Villosa iris*), a species listed as Special Concern, is found (or potentially found) within Fairchild Creek to the east of the study area.

Impacts from current and future development are cites as main driving factors for the future conditions of the Fairchild Creek subwatershed, with direct reference made to the resulting impacts on water balance of the subwatershed and Jones Creek to the north of the City (MacVeigh, Zammit, & Ivey, 2016). Ongoing water quality issues within the subwatershed and into the Grand River watershed and greater Lake Erie watershed include high levels of Phosphorus and sediment concentrations, with Fairchild Creek noted as a key driver to these contributions (MacVeigh, Zammit, & Ivey, 2016). The Characterization Study notes that, "key non-point sources of sediment and phosphorus are expected to be in-stream and bank erosion, and runoff from agricultural areas; point sources include discharges from [the] wastewater treatment facilities."

Impacts to the aquatic resources from the proposed flood remediation works will remain consistent with current conditions, with works targeted at existing infrastructure and outside of the natural area. In order to lessen the extent of impacts from additional construction work in the drainage area(s), detailed mitigation plans should include enhanced erosion and sediment control to limit Phosphorus and sediment contributions to Jones and Fairchild Creek. Other considerations should include the MNRF In-Water Timing Restrictions and mitigation measures outlined by the DFO in respect to "Projects near water".

4.5.2 Terrestrial Ecology

The study area is heavily dominated by urban development. Background information, aerial photography, and mapping resources including the City's Official Plan (OP), the MNRF's online mapping website and species occurrence database, and GRCA's mapping website were reviewed in order to identify and characterize remnant terrestrial natural heritage features and functions within the study area limits. Please note that terrestrial Species at Risk (SAR) have been discussed separately in **Section 4.5.3**.

As illustrated on **Figure 4.5.1** the City's OP does not indicate the presence of any Environmental Protection Policy Areas in the study area. Three small areas are mapped as Environmental Control Policy Areas; per the OP, this designation includes "*sensitive natural features such as steep slopes, streams, wetlands, areas of groundwater discharge and representative tree cover, and are designated on the basis of being comprised of fish habitat, significant woodlands, significant wildlife habitat, significant Areas of Natural and Scientific Interest, natural linkages, and locally significant prairies and savannahs*". Aerial photo review indicates that the three indicated Environmental Control Policy Areas are associated with woodlands, and that two are named parks (Royal Oak Park in the northwest and Forestwood Park in the center north). The indicated three areas, plus portions of the Fairchild Creek tributary corridor in the eastern half of the study area, represent the largest remaining woodlands within the project limits.

Figure 4.5.2 illustrates wetlands within the study area per the City's OP. This mapping was confirmed to be consistent with GRCA and MNRF wetland mapping with one exception: the small wetland shown in the center top of the study area per **Figure 4.5.2** is not present in either GRCA or MNRF mapping. None of the three mapping resources indicate the presence of Provincially Significant Wetlands (PSWs) in the study area, although portions of the Cold Spring

Creek Wetland Complex PSW are found a short distance from the study area to the north and west.

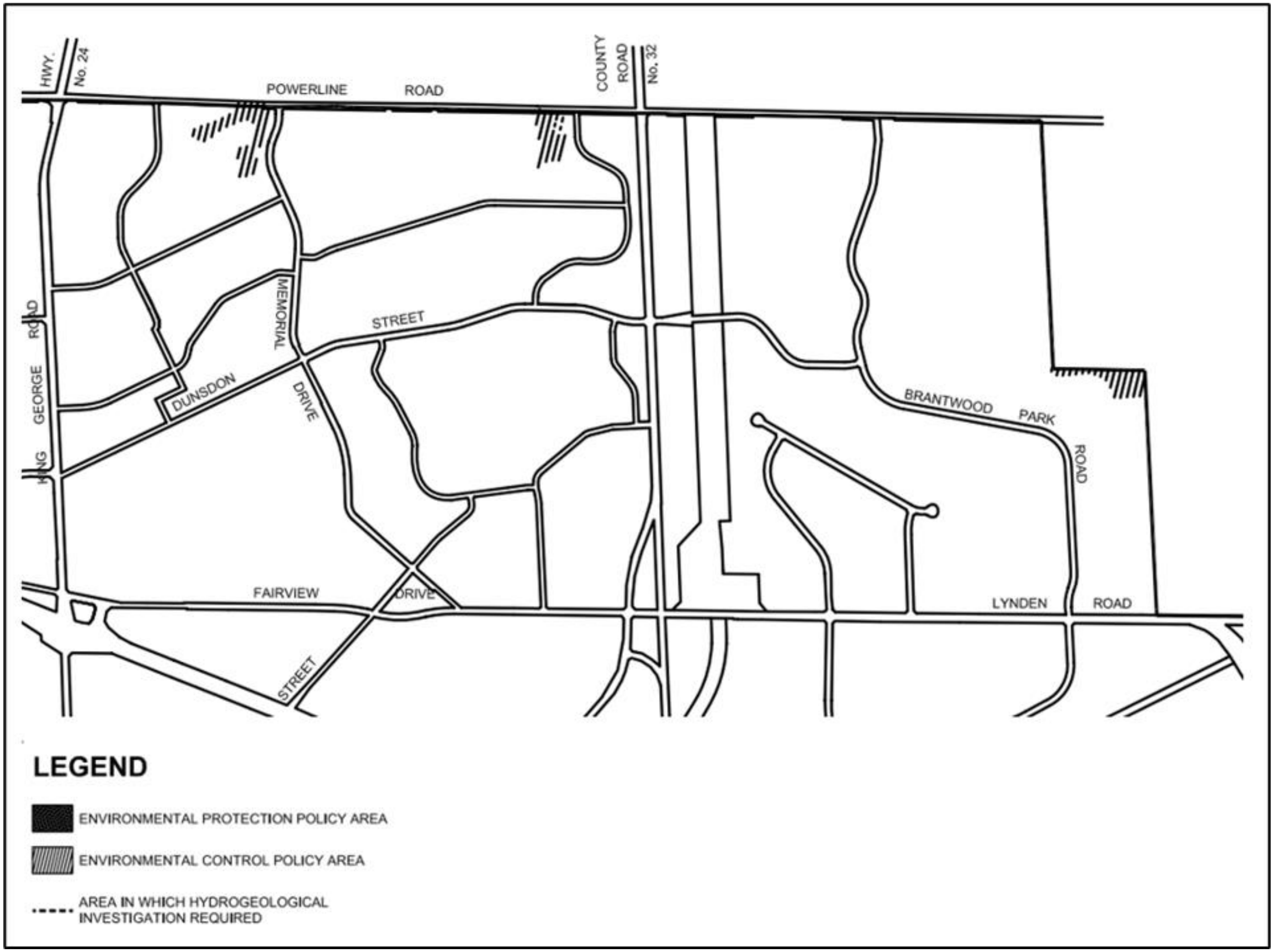


Figure 4.5.1: Excerpt of City of Brantford Official Plan, Schedule 3-1 - "Natural Heritage: Environmental Areas"

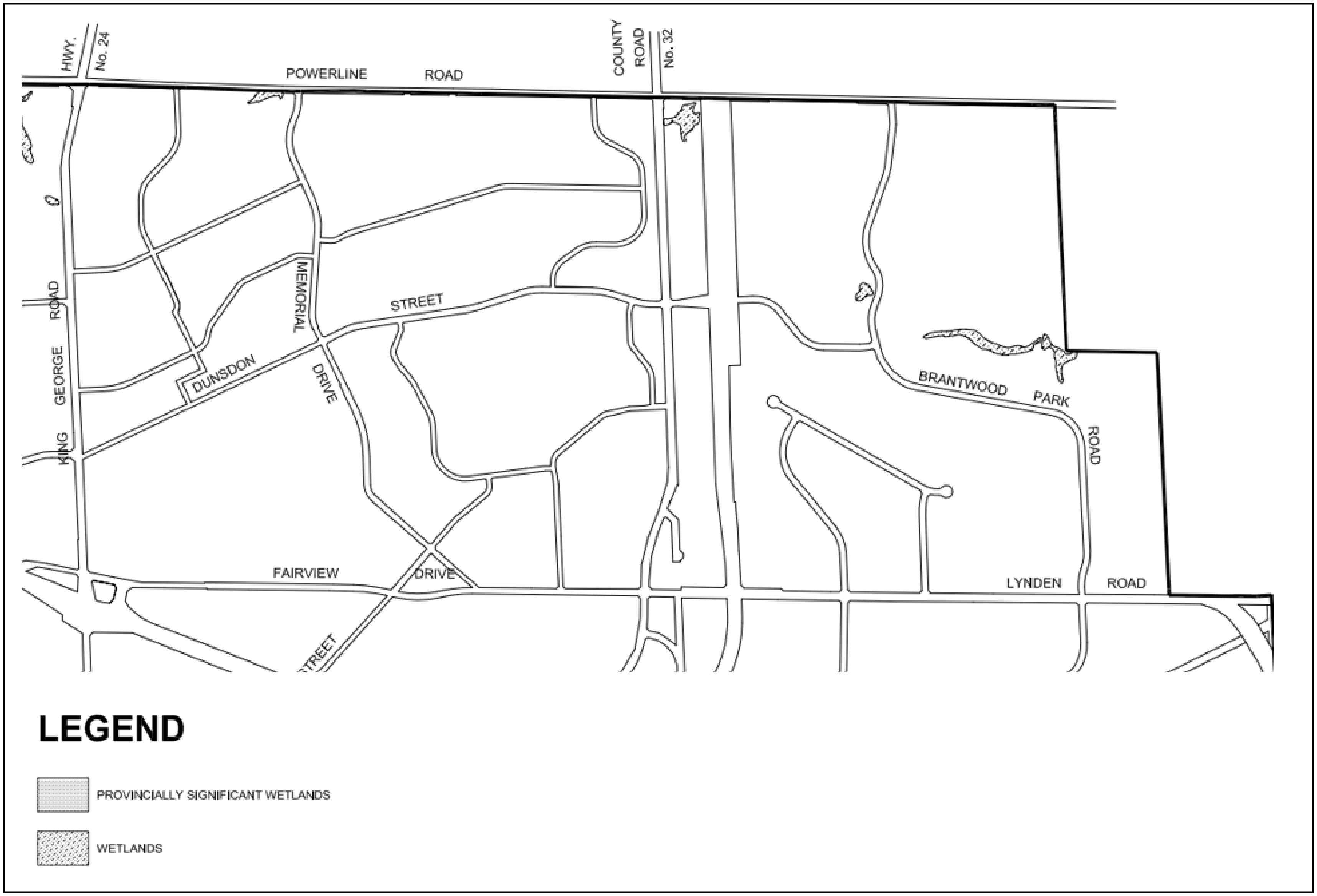


Figure 4.5.2: Excerpt of City of Brantford Official Plan, Schedule 3-3 – "Natural Heritage: Wetland Areas"

4.5.3 Species at Risk

Table 4.5.1 provides an overview of Species at Risk (SAR) associations that were investigated for the study area based on background information including the MNRF's Natural Heritage Information Center (NHIC) online database, DFO online aquatic SAR mapping, the Fairchild Creek Subwatershed Characterization Study (MacVeigh, Zammit, & Ivey, 2016), public species atlases, and 'citizen science' databases (e.g., eBird, iNaturalist).

Table 4.5.1: Species at Risk Review

Species	Status	Data Source	Discussion
Fish and Mussels			
Rainbow Mussel (*Villosa iris*)	Special Concern	DFO	Mapped as found or potentially found in Fairchild Creek, east of the study area, although critical habitat is not indicated to be present. Prefers small to medium-sized rivers with a moderate to strong current and sand, rocky, or gravel bottoms.
Northern Brook Lamprey (*Ichthyomyzon fossor*)	Special Concern	Fairchild Creek Subwatershed Characterization Study	Noted in association with Jones Creek. Habitat includes clear, coolwater streams.
Plants			
American Columbo (*Frasera caroliniensis*)	Endangered	NHIC	Grows in open deciduous forest habitat, most commonly in dry upland woods. Could feasibly be found in remnant forest patches in the study area.
Butternut (*Juglans cinerea*)	Endangered	iNaturalist	Confirmed observation records from wooded areas along Fairchild Creek tributary corridor; potential to occur in remnant natural wooded areas throughout.
Green Dragon (*Arisaema dracontium*)	Special Concern	NHIC	Grows in moist to wet conditions in deciduous forests along streams. Could feasibly be found in remnant forest patches in the study area.
Birds			
Barn Swallow (*Hirundo rustica*)	Threatened	eBird	This species is known to nest on human-built structures including culverts, bridges, and buildings. It will

Species	Status	Data Source	Discussion
			forage in open spaces, including suburban parks.
Eastern Meadowlark (*Sturnella magna*)	Threatened	NHIC	This species requires large contiguous areas of open grassland habitat which is not present in the study area. Therefore, Eastern Meadowlark is unlikely to be relevant to this assignment.
Eastern Wood-pewee (*Contopus virens*)	Special Concern	NHIC, eBird	Potential habitat is present in remnant woodlands in the study area; past observation records specifically associated with Fairchild Creek tributary corridor near Jaycee Sports Park.
Wood Thrush (*Hylocichla mustelina*)	Special Concern	eBird	Potential habitat is present in remnant woodlands in the study area; past observation records specifically associated with Fairchild Creek tributary corridor near Jaycee Sports Park.
Insects			
Monarch (*Danaus plexippus*)	Special Concern	iNaturalist	Requires the presence of milkweed (*Asclepias* sp.) plants as larval food source; relatively common species, likely to be encountered in urban gardens, unmown boulevards, old fields, etc.

Provincially rare but unregulated plant species (i.e., species with a subnational rarity ranking of S1, S2, or S3 which are not listed as Endangered, Threatened, or Special Concern per provincial or federal SAR legislation) were also noted in the proximity of the study area.

In all cases, a comprehensive screening and assessment could be required at later project stages to assess species presence/absence and confirm habitat suitability for SAR if the selected alternative could impact any areas of remnant natural vegetation or have a significant impact on aquatic systems. However, it is anticipated that proposed alternative solutions will be primarily situated within existing development footprints, in which case impacts to potential SAR habitat would likely be avoided or easily mitigated with standard environmental mitigation and protection measures during construction.

4.6 Archaeological Assessment

The Stage 1 archaeological assessment property inspection was conducted on the Preferred Alternatives under the direction of Archeological Services Incorporated (ASI) for Aquafor, in April, 2020, in order to gain first-hand knowledge of the geography, topography, and current conditions and to evaluate and map archaeological potential of the Study Area. It was a visual inspection only and did not include excavation or collection of archaeological resources. The archeological assessment report is attached in **Appendix C**, and the findings and recommendations are summarized below.

The Stage 1 background study determined that 31 previously registered archaeological sites are located within one kilometre of the Study Area. The property inspection determined that part of the Study Area exhibits archaeological potential and will require Stage 2 assessment while the remainder does not retain archeological potential within the right-of-way. The findings and recommendations are summarized below:

1. Area 1 east of Coulbeck Road as shown on **Figure 4.6.1** exhibits archaeological potential. These lands require Stage 2 archaeological assessment by test pit survey at five metre intervals, where appropriate, prior to any proposed impacts to the property;
2. The remainder of the Study Area does not retain archaeological potential on account of deep and extensive land disturbance or low and wet conditions. These lands do not require further archaeological assessment; and,
3. Should the proposed work extend beyond the current Study Area, further Stage 1 archaeological assessment should be conducted to determine the archaeological potential of the surrounding lands.

Figure 9: North-East Flood Remediation - Results of Stage 1 (Sheet 1)

Figure 4.6.1: Area Recommended for Stage 2 Archeological Survey

4.7 Utilities

The existing conditions InfoWorks model includes storm and sanitary sewer infrastructure was provided by the City, expanded and augmented by the background information, additional investigations and field survey and discussed in **Section Chapter 5**.

Locations of existing subsurface utilities including watermain, hydro and communication infrastructure and overhead hydro utilities (locations of hydro poles / towers) will be requested at detailed design pertaining to the implementation of solutions.

4.8 Socio-Economic Environment

4.8.1 Land Use

The existing land use throughout the study is predominantly low-density residential with area of medium to high-density residential and commercial closer to the arterial and collector routes as shown on **Figure 4.8.1**. As noted from the MSP (2018), several changes to the land-use include the development of lands annexed from the County of Brant north of Powerline Road as well as intensification corridors along King George Road and Wayne Gretzky Parkway. The projected land-use changes are expected to impact the existing stormwater conveyance along these corridors and will be taken into consideration during alternative development and selection.

4.8.2 Transportation

The City of Brantford's road classification through the study area is summarized in **Figure 4.8.2**. The road classification was reviewed to determine the characteristics of the overland drainage system as well as the critical routes required by the City's emergency services that may be impacted by flooding. **Figure 4.8.2** shows three general classification groups: major and minor arterial, major and minor collector, and local.

Wayne Gretzky Parkway is the major arterial road that bisects the study area with Powerline Road and Dunsdon Street as the primary feeder routes to both Wayne Gretzky Parkway and King George Road to the west of the study area. The north-south major collector routes include Memorial Drive that connects Powerline Road Dunsdon Street and Fairview Drive and Brantwood Park Road connecting Powerline Road, Dunsdon Road and Lynden Drive. Minor collector routes feed traffic from the local roads to the major collectors and arterial routes were also considered as critical access routes.

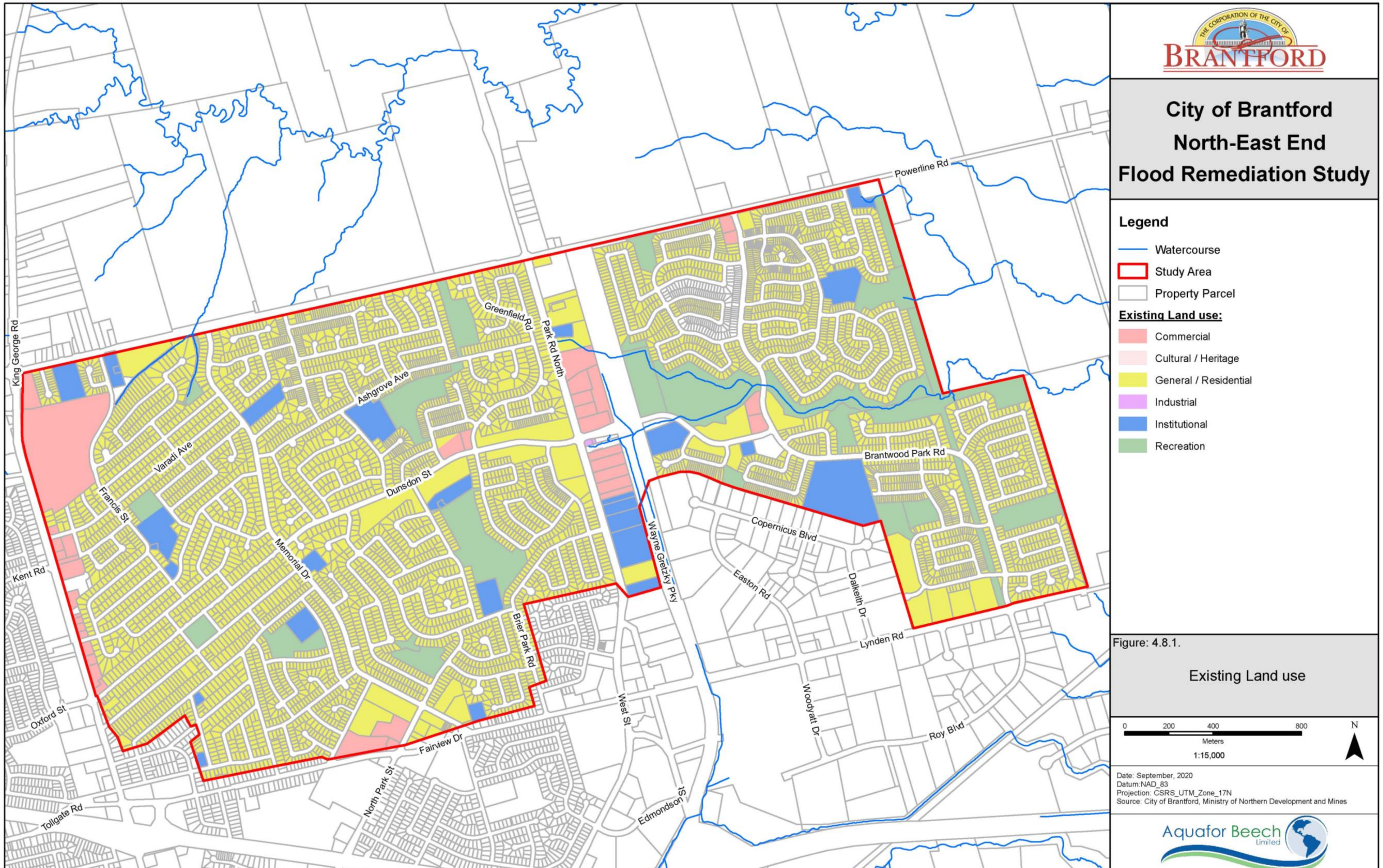


Figure 4.8.1: Study Area Existing Land-Use

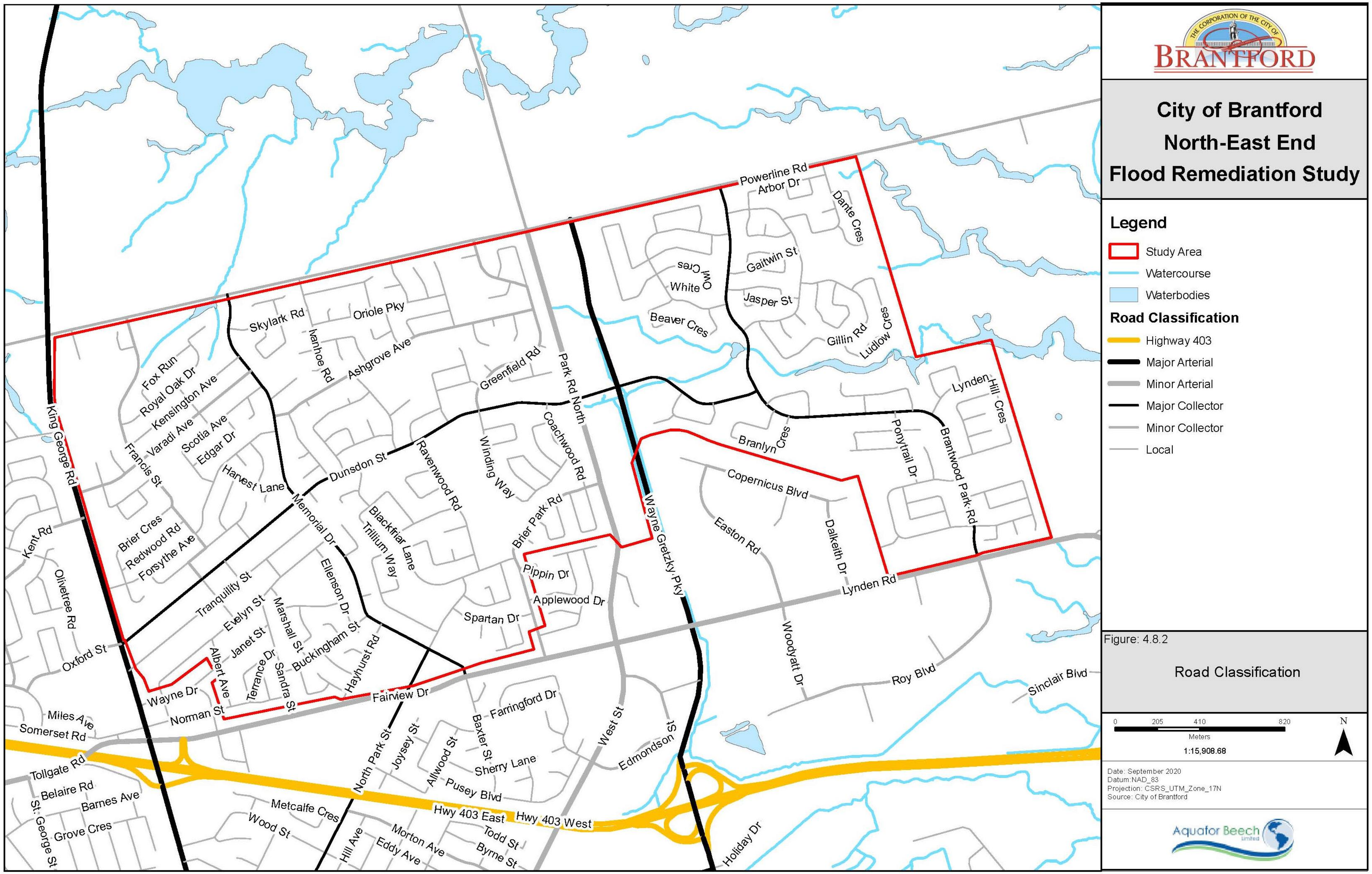


Figure 4.8.2: Study Area Road Classification

4.8.3 Ownership and Easements

Majority of the study area is privately-owned by local residents and corporates, with some City properties (e.g. parks, road right-of-way, other open space) and utility corridors (e.g. Hydro One corridor along Powerline Road). Should works to be undertaken in the privately owned properties, land acquisition or easement negotiation may be required.

The sewer system generally traverses the municipal Right-of-Way with notable exception where the sewer systems cross private property by way of an easement. Easements are generally acquired by the City for infrastructure crossing property boundaries for municipal sewer and watermain.

Aquafor requested from the City, it's easements for storm sewers within the study area in order to determine the feasibility of sewer upgrades cross private property to an outlet. The City provided the easement agreements at three (3) locations in the study area that are summarized in **Table 4.8.1**. The table defines the address and width of each easement along with a figure of each easement illustrating the location and existing site conditions as provided by the City.

Each easement is intended for twenty-four-hour access for the construction, maintenance, usage and operation of municipal storm and/or sanitary sewers where indicated.

Table 4.8.1: Study Area Easement Agreement Conditions

Area	Location	Easement Conditions
5	58 Hackney Ridge Northerly 3m (10 ft) from front to rear of lot for municipal storm sewer; and 60 Hackney Ridge Southerly 3m (10 ft) from front to rear of lot for municipal storm sewer.	

Area	Location	Easement Conditions
6	47 Fox Run Easterly 4 m easement from front to rear of lot for municipal storm sewers; 48 Fox Run Westerly 10 m easement from front to rear of lot for municipal storm sewer; and 77 Royal Oak Drive 10 m easement for municipal storm sewer.	
7	52 Kensington Avenue Easterly 10.7 m (35 ft) from front to rear of lot for municipal sanitary and storm sewer; and Oak Ridge Park Southwest edge of park as part of lot for municipal storm sewer.	

It was determined that – if required – each of these easements has sufficient width to allow for the upgrade of the storm sewer through the easement to the storm system outlet. Any constraints within the easement for constructability through the easement will be assessed at the functional design stage.

Chapter 5. Existing Storm Sewer Systems

5.1 General

The background data review, public consultation and additional data collection provided guidance to the focus of the field surveys in areas of reported flooding that were used to assess the state of the existing sewer system and assess the root causes of flooding issues within the study area. The existing storm and sanitary models and associated flow monitoring data were analysed to validate the base model in InfoWorks for the model expansion as described in **Section 5.2**.

From the field program that included: smoke testing, home visits and property survey, and a review of the existing model and associated flow monitoring and system responses, the primary issues related to basement flooding can be attributed to the following:

1. An undersized storm sewer system; and
2. The presence of a significant number of reverse-sloped driveways that impact basement flooding and overloading of the sanitary sewer system.

This section will detail the hydrologic and hydraulic model completed in InfoWorks ICM and will summarize the existing model and scenarios, model update, flow monitoring and calibration and assessment of the performance of the existing drainage system.

5.2 Model Development

InfoWorks ICM 9.5.1 was used to simulate the existing flow conditions of the minor (sewers) and major (overland) systems. Both the minor and major system was modelled using a 1-dimensional (1D) linear model network.

The InfoWorks ICM sewer existing conditions storm sewer model includes 1220 storm sewer sections totalling 77 km of storm sewer infrastructure throughout the study area.

Conversion from InfoSWMM to InfoWorks

The hydraulic model completed for the 2018 Storm Sewer Network Model and System Calibration Study using the InfoSWMM hydraulic and hydrologic modelling software was used as the base network. The sewers for the Northeast Neighborhood Study Area were clipped from the City-Wide storm sewer model and expanded where appropriate for the purposes of this project. The model network for the 2018 calibration study included all storm sewers with no defined major system or head discharge relationship representing the catchbasin inlets.

The InfoSWMM storm sewer network including all available attribute data was exported to shapefiles using the InfoSWMM GIS Gateway. All time series data (rainfall time series and flow monitoring data) was exported from the InfoSWMM model into an Excel CSV file format. The shapefiles and CSV files were then imported into InfoWorks using the Import Data Centre function.

After importing the sewer network and time series data, the model was validated for connectivity and the identifications of data gaps.

Data Gap Assessment

A data gap assessment was performed to identify inconsistencies / gaps in the data. Gaps included:

- Number and locations of catchbasins
- Missing pipe invert elevations
- Negative pipe or zero pipe gradients
- Inconsistencies between maintenance hole cover elevations and the DEM
- Subcatchment re-definition

Data gaps were addressed through the city's geodatabase, background data collection (as-built information, CCTV, etc.), supplementing the existing data sources with the field survey program and using the InfoWorks inference tool (specifically where data gaps could not be closed as well as obtaining consistent ground level at the maintenance holes). Professional judgement was also used when all other avenues were exhausted and confirmed with City staff.

Field Survey

As stated in Section 3.9, additional data collection involved a field program that included the following elements:

- Verification of sewer inverts and maintenance hole elevations;
- A survey along Powerline Road to confirm infrastructure and drainage characteristics;
- Verification of dimensions of storm outfalls and road crossings;
- General property survey of downspout connections;
- Home visits of ten (10) private properties to confirm the type and cause of flooding; and

- Smoke testing within the storm sewer system to confirm connections for catch basins, foundation drains and other infrastructure.

The data collected from the field survey was used to verify the DEM, fill in missing sewer invert information, confirm drainage characteristics (downspouts connection, drainage to ditches and sewers, catchbasins, etc) and foundation drain connections in the model.

5.2.1 Minor System

Proper network development of the model was critical to ensure that each sewer system element was representative of the current physical collection system, specifically the representation of the expanded network throughout the city-wide system.

The sewer network within the study area was extracted from the converted city-wide InfoWorks Model and expanded where appropriate. The sewer network was then updated using the City's geodatabase where applicable. The updated sewer network based on the City's GIS database contains sewer network and maintenance hole as-built information including pipe diameters, invert elevations, pipe lengths, and maintenance hole ground elevations.

To confirm the accuracy of the data once imported, extensive quality checks were completed, and data gaps were filled in through review of as-built information, field investigations, and use of best professional judgement to enhance the model accuracy. Updated and revised data were flagged and documented in the model for future reference.

All maintenance hole cover elevations were updated using the City-provided DEM. Any missing invert and ground elevations were filled in using the inference tool in InfoWorks and corrected using as-built information where there were validation errors.

Subcatchment delineation was completed on a maintenance hole to maintenance hole basis utilizing the property parcels.

5.2.2 Major System

5.2.2.1 Overland Flow Paths

The major system is the overland flow system where runoff is conveyed along the surface to the catchbasins that then inlet to the minor system. Flows attenuate in the major system when the minor system surcharges to the surface.

The major system was added in the InfoWorks model by duplicating the minor system network, re-defining the new conduits using standard road cross sections and open space cross developed in previous studies then manually defining the missing overland flow paths at low points, shorter road length or at intersections where required.

5.2.2.2 Catchbasins

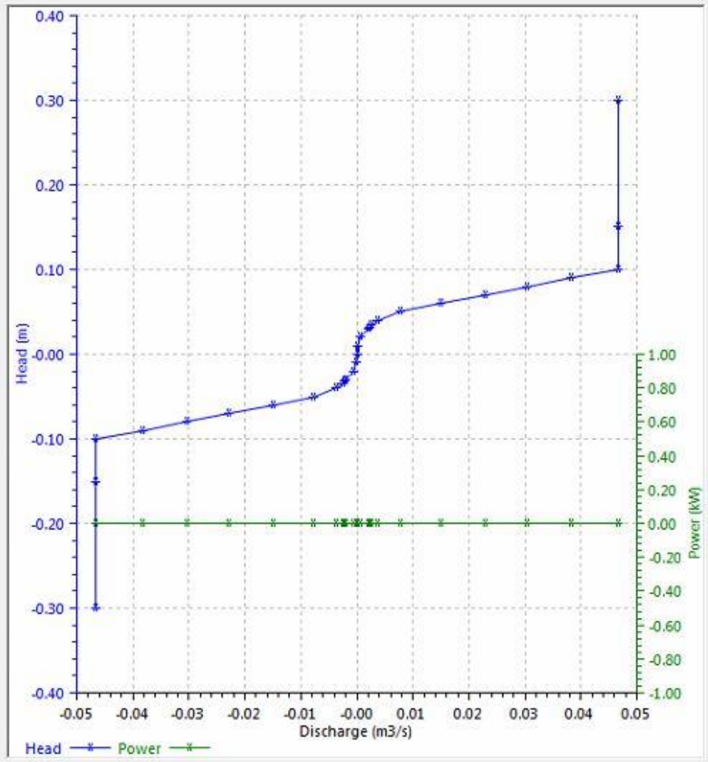
Catch basin data sets that included the location and type were provided in GIS format by the City at the beginning of the project. For modelling purposes, a typical catch basin inlet capacity curve was applied for use in the InfoWorks model.

Road drainage throughout the City consists of surface drainage and conveyance elements which are representative of pipes and ditches. The number of sewer inlets within a pipe section affects both the rate of runoff removal from the road surface and the degree of utilization of the conveyance elements. It is necessary to incorporate inlet controls for the sewer system analysis in order to characterize the existing storm sewer and surface drainage performance.

Storm sewer systems are typically designed for the 1:2 to 1:5 year storm event. During smaller storm events, under the assumption that all surface runoff enters the sewer system unimpeded, the capacity of the sewer system should be sufficient to carry flows from these events. During larger storm events, inlet flows will typically exceed the capacity of catch basin inlets. For modelling purposes, a limit is typically set to limit the capacity of the inlets to limit issues which could arise relating to associated flooding and unrealistic surcharging of the system if the inflows are not be appropriately represented.

Standard parallel slot / fishbone catchbasins provide an inflow rate of 28 L/s to 46 L/s (1.0 ft3/s to 1.5 ft3/s) depending upon many factors such as cross grade, type of inlet, depth of flow, and curb and gutter type. Volume that is not captured by the inlet of the catch basin is either stored along the road surface until the inlet rate drops below the maximum allowable capacity of the catch basin or is bypassed to the next downstream inlet. The inlet capacity curve for a standard sewer catch basin with in inflow rate of 46 L/s is shown below in **Figure 5.2.1**.

	Head (m)	Discharge (m3/s)	Power (kW)
1	-0.3000	-0.0467	
2	-0.1500	-0.0467	
3	-0.1000	-0.0467	
4	-0.0900	-0.0383	
5	-0.0800	-0.0304	
6	-0.0700	-0.0229	
7	-0.0600	-0.0149	
8	-0.0500	-0.0077	
9	-0.0400	-0.0038	
10	-0.0350	-0.0026	
11	-0.0320	-0.0023	
12	-0.0300	-0.0020	
13	-0.0200	-0.0007	
14	-0.0100	-0.0001	
15	0.0000	0.0000	
16	0.0100	0.0001	
17	0.0200	0.0007	
18	0.0300	0.0020	
19	0.0320	0.0023	
20	0.0350	0.0026	
21	0.0400	0.0038	
22	0.0500	0.0077	
23	0.0600	0.0149	
24	0.0700	0.0229	
25	0.0800	0.0304	
26	0.0900	0.0383	
27	0.1000	0.0467	
28	0.1500	0.0467	
29	0.3000	0.0467	
*			



Reference: City of Windsor Sewer and Coastal Flooding Master Plan (2020)

Figure 5.2.1: Standard Catch Basin Inlet Capacity Curve for Parallel Slot / Fishbone

Subcatchments

Subcatchment areas that were initially defined in the InfoSWMM model were re-defined in GIS pipe-by-pipe using the parcel fabric. Newly delineated subcatchments were based on the sewer segment, closest land parcel and were assigned to the upstream node of the sewer segment. Subcatchments were parametrized based on similar land use classifications in the original model. To simplify subcatchment parametrization, the previously assigned land use classification was generally applied to the newer, smaller subcatchments if they had the same land use. In some cases, new subcatchments were assigned another land use classification as appropriate. Land use types include residential, commercial, industrial and open space, among others as discussed in **Section 4**. Once the delineations were completed, the subcatchments were imported back into InfoWorks and validated.

5.2.2.3 Runoff Surfaces

When rain falls it is important to understand where the runoff goes, as this flow pattern will define the amount of water in each of the sewer systems. Given that the City of Brantford has a separated sewer system runoff will ultimately make its way to the storm sewer in a manner shown in the figure below. It is however, still important to understand the flow path for water which originally falls on the roofs of buildings. For example, if the roof downspout is directly connected to the storm sewer then virtually all of the water will make its way to the storm sewer system. Alternatively, if the downspout discharges to the ground then some of the flow will infiltrate into the ground, thereby reducing the amount of flow which makes its way to the storm sewer system.

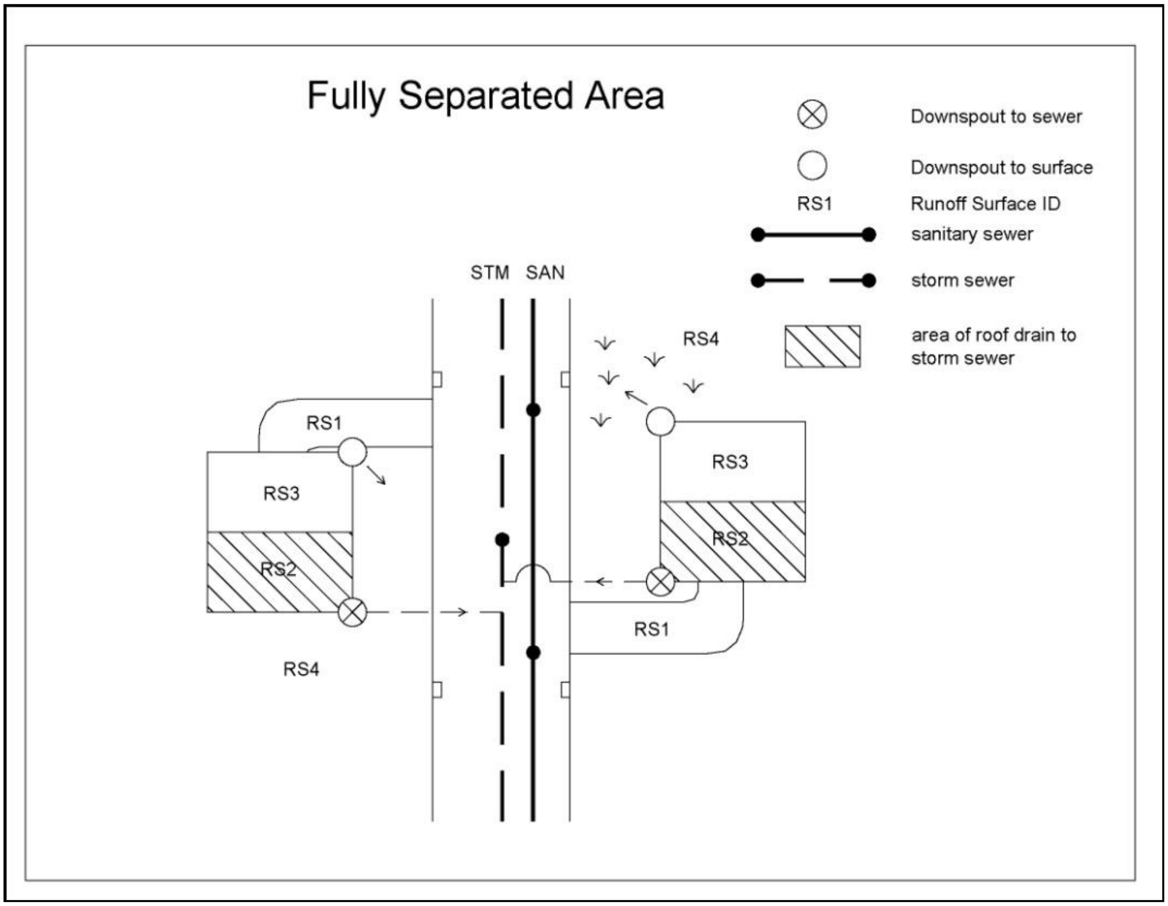


Figure 5.2.2: Runoff Flow Path in Fully Separated Area

Runoff within fully separated areas makes its way to the storm sewer by overland drainage to inlet structures. It is important to define flow path lengths for rainfall that falls on hard surfaces but may be conveyed across pervious areas before reaching the sewer inlet (also referred to as impervious to pervious surface runoff). These areas include roof downspouts that discharge to the grassed surface instead of directly into the storm sewer system. Portions of flow will infiltrate into the ground, thereby reducing the amount of surface flow that make its way into the storm sewer system.

5.3 Model Calibration

After converting the model from InfoSWMM to InfoWorks the original City-Wide model was revalidated and checked for consistency with the original minor system model. Overall, the calibration was found to be consistent. The model was then isolated to the study area and expanded and calibrated.

Model re-validation is achieved by changing model parameters to produce results matching the measurements within a reasonable accuracy in terms of peak flows, runoff volumes and water levels. Model validation involves testing the calibrated model performance using a different set of measurements than the calibration period to ensure the repeatability of the model results.

For the Northeast Neighborhood Study Area, two (2) flow monitors were located within the study area boundary. Of these two flow monitors, only FM20 at Dunsdon Street at Edinburgh Crescent had flow monitoring data for three (3) events: May 1, 2017, May 21, 2017 and July 13, 2017. FM19 was not used as this flow monitor recorded flow depth only and not flow rate as required for adequate calibration and validation. Given the limited information available to calibrate the model, the primary focus was the calibrate the model to the August 11, 2017 event.

For the August 11,2017 event, calibration was achieved by matching the system response to the rainfall event to flooding records within the study area, and adjusting key parameters that included runoff surfaces (downspout disconnection) and Manning's roughness. An additional event was not available to validate the system response to the August event for the study area.

5.4 Assessment of Existing Conditions

Recent wet weather events have resulted in flooding of properties and buildings within the study area. There are several potential causes of the flooding that has occurred. This study addresses flooding that occurs as a result of water entering the basement through the floor drain or foundation (i.e. basement flooding) or water entering the house through uncovered window wells, doors, etc. (surface / overland flooding).

The August 11, 2017 flooding event, similar to a 5-year design storm event in magnitude, extended across the City and was known to have created a number of flooding issues. In turn, it was used in-place of the 1:5-year design storm to evaluate the minor system performance as shown in **Figure 5.4.1**. Additionally, the 25-year and 100-year 4-hour Chicago storms were used to assess the major/minor system performance under existing conditions.

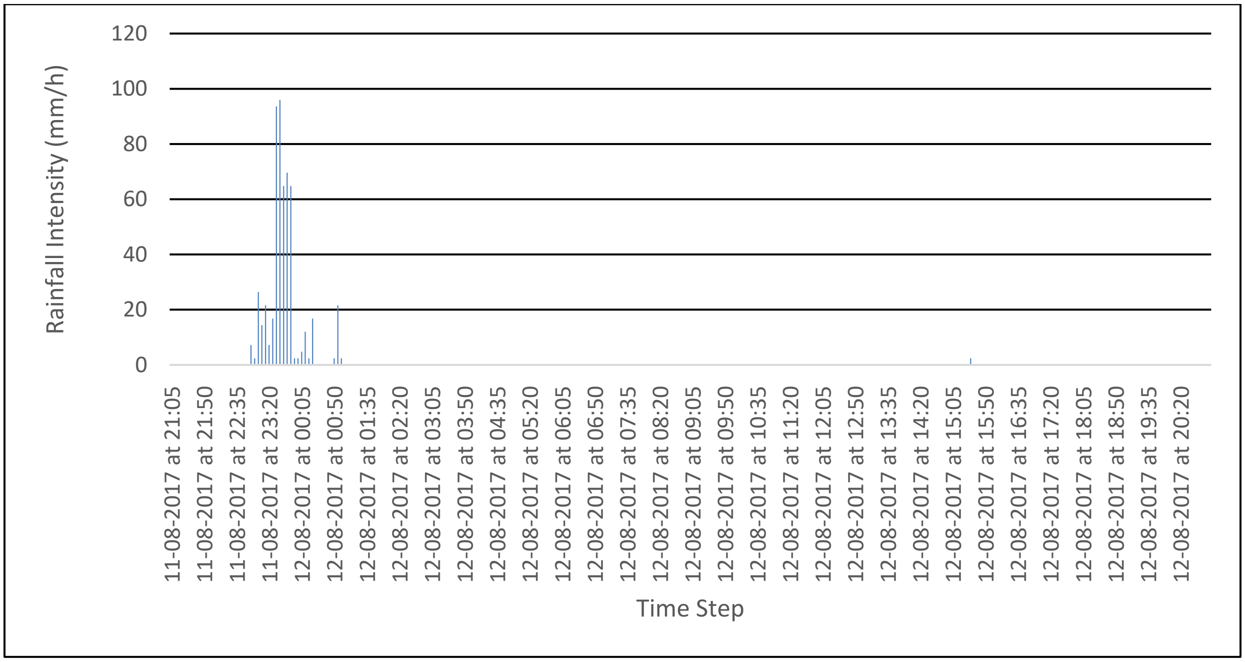


Figure 5.4.1: August 11, 2017 Event

Figure 5.4.2 shows the one of the model outputs in plan and profile form of a section of storm sewer in the study area within one of the flood vulnerable areas resulting from the August 2017 event. The hydraulic grade line (HGL) – represented by the blue line in the figure – is above the pipe crown indicating that the system is in exceedance of the capacity of the storm sewer. In this case, the HGL rises above a typical basement level of 1.8 m below ground. The modelled profile indicates that homes with foundation drains connected to the storm sewers along this sewer are at risk of water backing up into the basement. Proceeding upstream, the HGL rises above ground within a low point indicating a high-risk of both basement flooding and flooding onto the road surface.

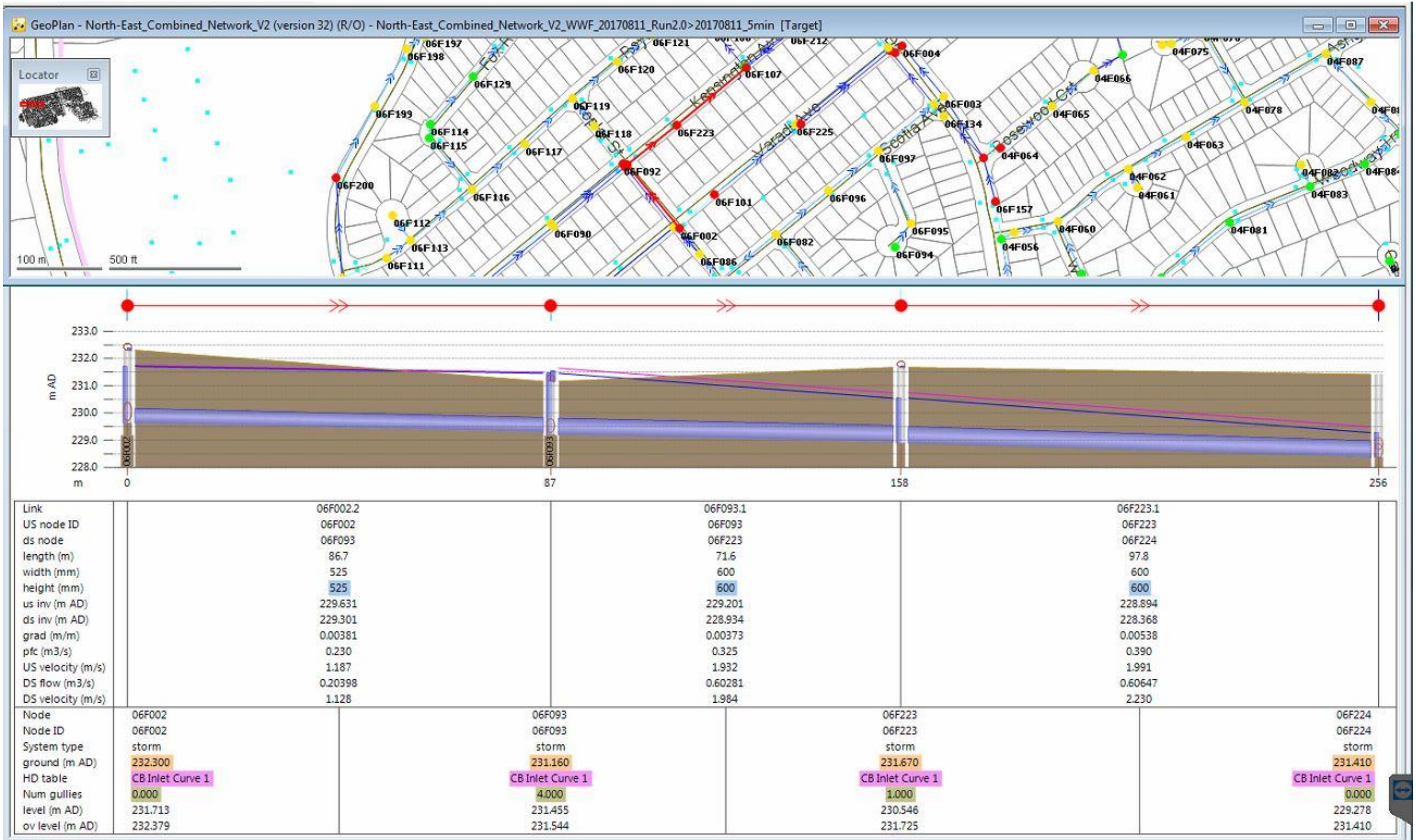


Figure 5.4.2: Sample Model Output of Under the August 11, 2017 Event (Kensington Ave. and Poplar Street)

5.4.1 Level of Service

The current City of Brantford's Design and Construction Manual for Storm Sewers (December 2018) states that the minor (sewer) system shall convey the frequent runoff events up to the 5-year design storm while the major (overland) system shall convey the runoff from infrequent storm events, typically greater than 5-year design storm and up to a 100-year design storm, that exceeds the minor system capacity. The Level of Service is graphically illustrated in **Figure 5.4.3**.

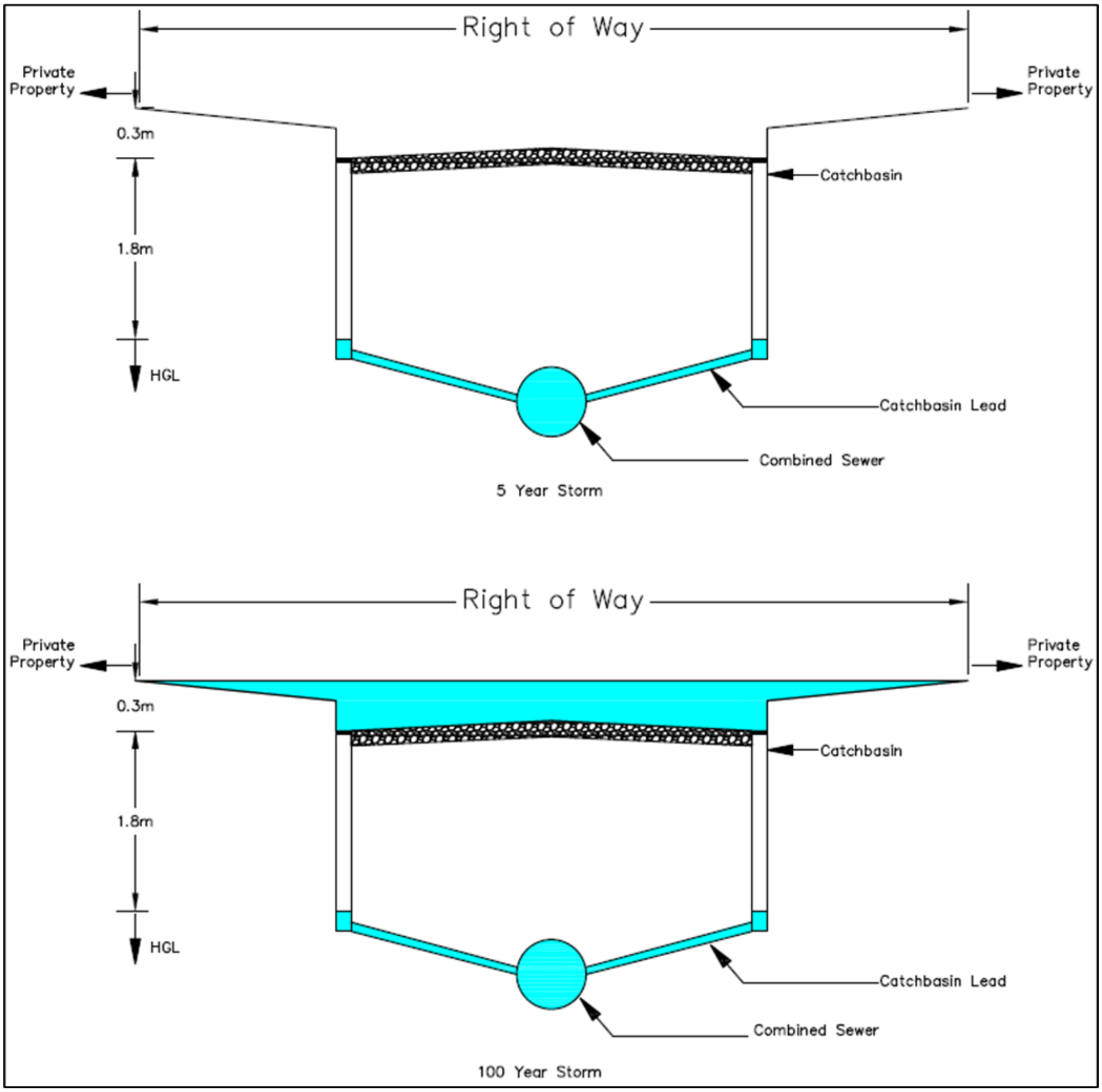


Figure 5.4.3: Level of Service Criteria (City of Brantford Design and Construction Manual, 2018)

5.4.2 Existing Conditions: Minor System

Figure 5.4.4 through **Figure 5.4.6** show the model simulation results of the August 2017 event, the 25-year design event and the 100-year design event respectively. The figure indicates the state of the hydraulic grade line (HGL) at each maintenance hole based on the level of service criteria through the following colour coding:

- **Green** – HGL is greater than 1.8 m below ground surface indicating the level of service is met;
- **Yellow** – HGL is between 1.8 m below ground and the ground surface indicating increasing basement flooding risk; and
- Red – HGL is above the ground surface indicating surface flooding risk and a high potential for basement flooding.

The results indicate that under the August 11, 2017 storm nearly one third of the minor system is in a state of surcharge (HGL above 1.8 m below ground), which is similar to the 5-year design storm simulation. Under the 25-year event, over two thirds of the storm system are surcharged beyond the conveyance capacity with nearly 75% of the system surcharged under the 100-year event. The results are summarized in **Table 5.4.1**.

Table 5.4.1 Percentage of Storm System Meeting Targeted Level of Service

Conditions	Percentage of System Surcharged			
	August 11, 2017	5-Year Design Storm	25-Year Design Storm	100-Year Design Storm
No Basement Flooding	56%	56%	35%	26%
Potential for Basement Flooding	37%	36%	47%	48%
Surface Flooding	7%	8%	18%	26%
Total	100%	100%	100%	100%

In summary, modelling of the major/minor system shows that storm sewers are generally undersized with a lack of sufficient outlet capacity as a main bottleneck throughout the system. In total, eight (8) areas of the storm sewer system were identified and will be discussed in **Section 5.5**.

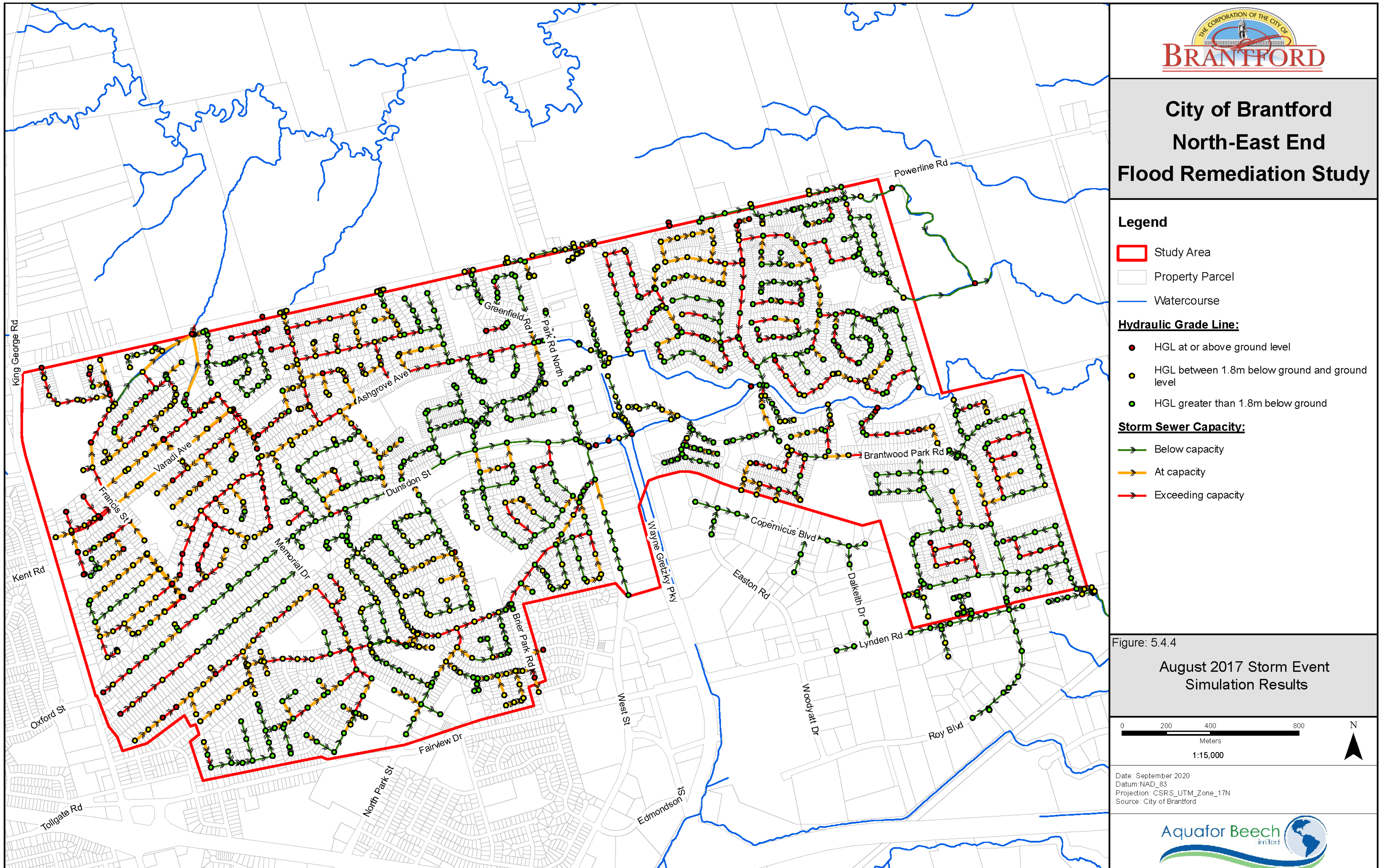


Figure 5.4.4: August 2017 Storm Event Simulation Results

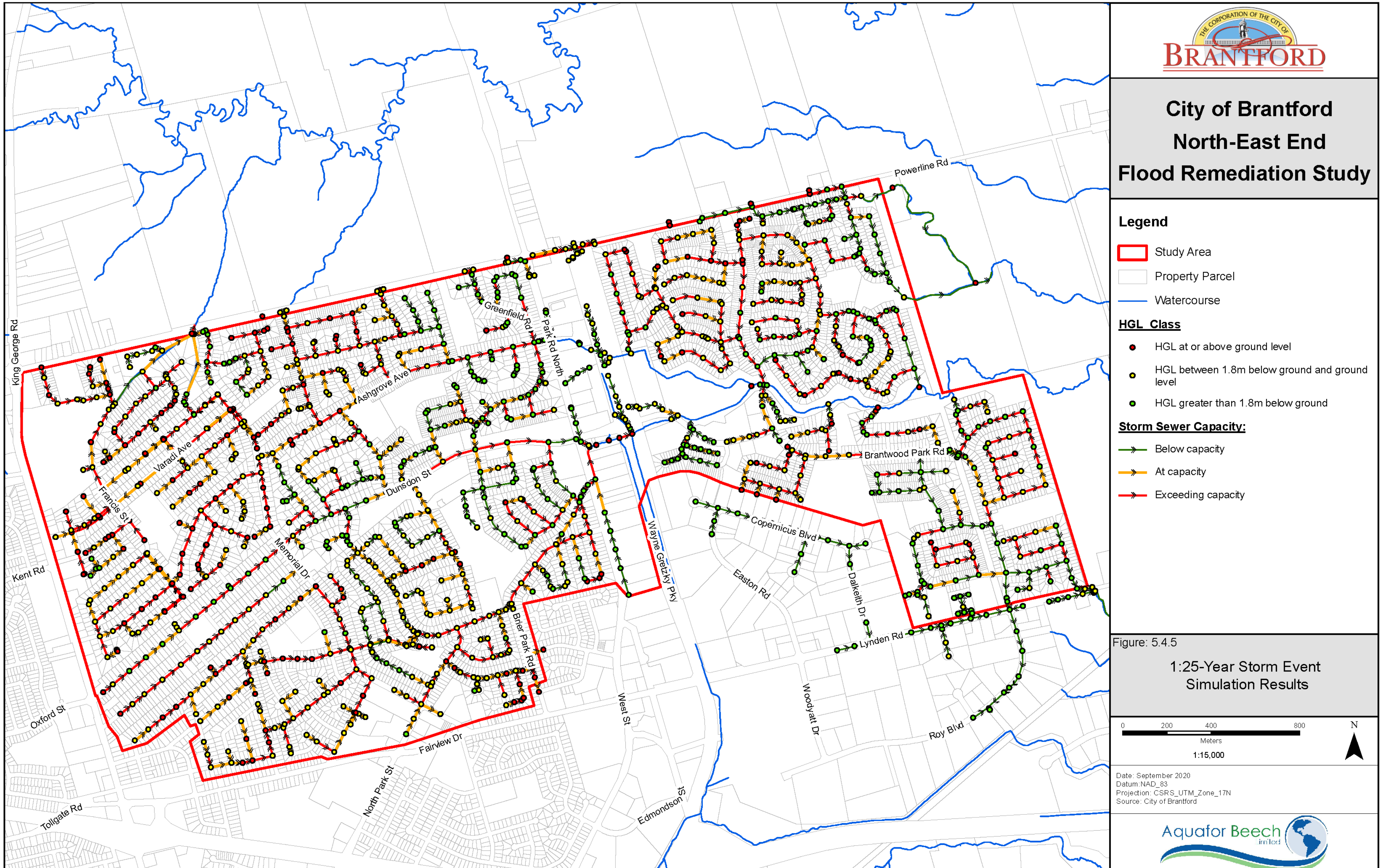


Figure 5.4.5: 1:25-Year Event Simulation Results

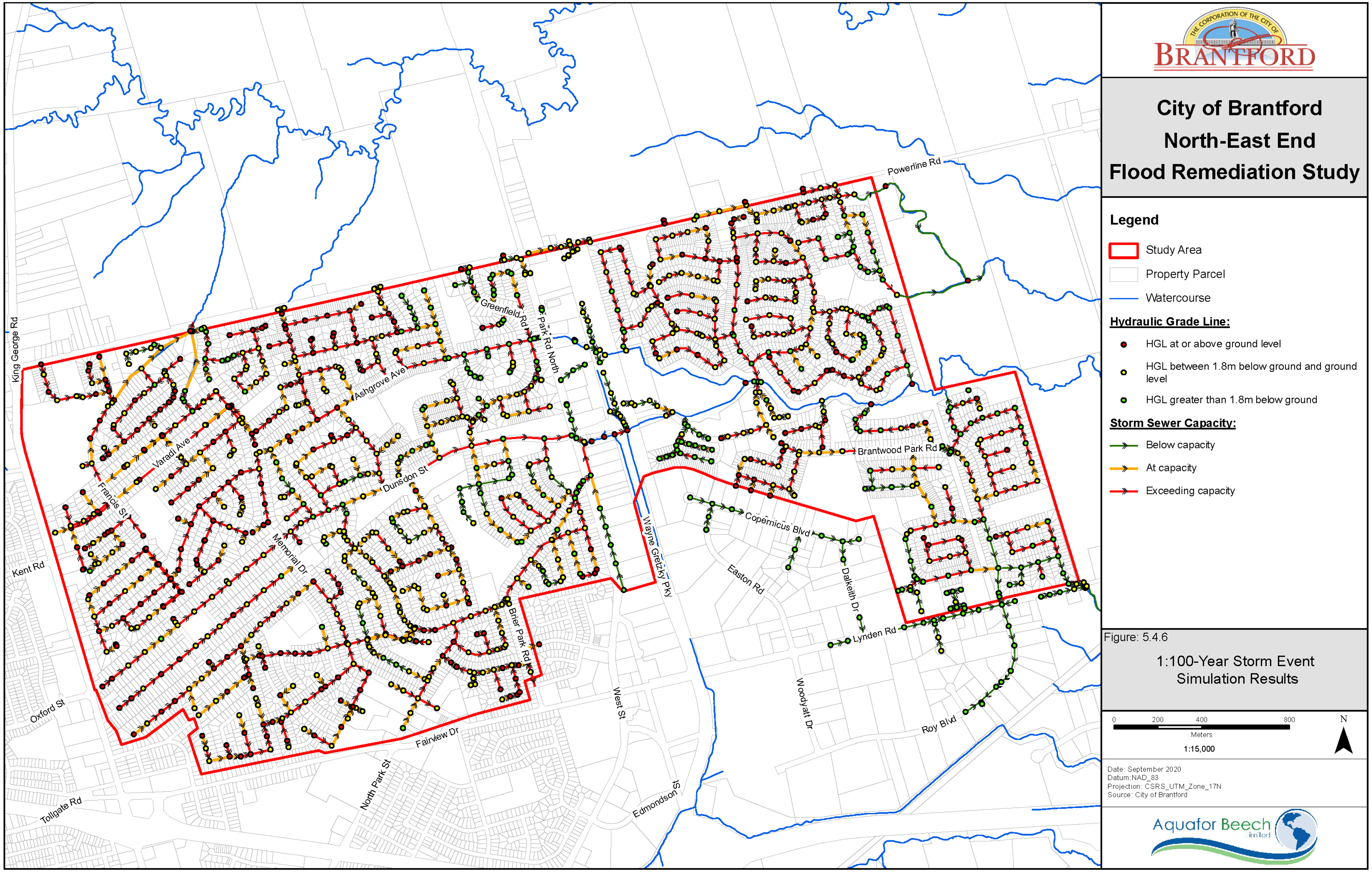


Figure 5.4.6: 1:100-Year Event Simulation Results

5.5 Identification of Problem Areas

Based on the reported flooding records which were received from residents as well as the model simulation results using the existing level of service, the study team then identified eight (8) flood-vulnerable areas together with the approximate extent where infrastructure replacement may be required as shown in **Figure 5.5.1**.

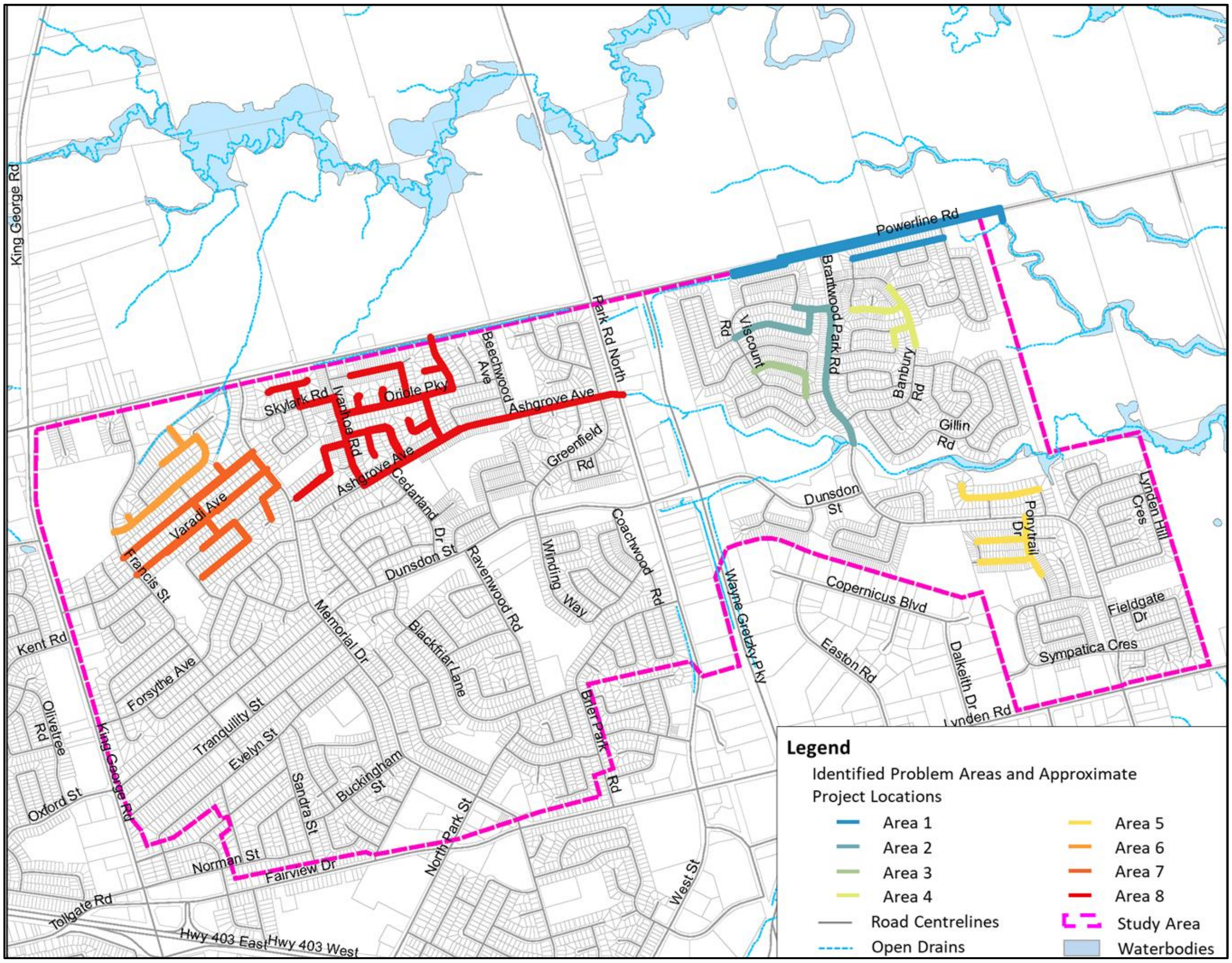


Figure 5.5.1: Approximate Extent of Infrastructure Replacement

In general, the storm sewers are undersized for the 5-yr event and do not meet the targeted Level of Service criteria. Flooding issues along Powerline Road area somewhat different from the rest of the system in that the area is primarily serviced by road-side ditches. The general, infrastructure deficiencies for each are summarized below:

Table 5.5.1: Primary Deficiencies in Each Flood-Vulnerable Area

Area	Location	Deficiency Summary
1	Powerline Road	Insufficient ditch conveyance capacity and improper flow direction were observed along Powerline Road. A local low point was observed west of the catchbasin inlet, which creates ponding during large storm events. The ditch outlet / catchbasin inlet structure is controlled by a 350 mm diameter orifice, which worsens the water ponding issue during extreme storm events.
2	Coxwell Crescent / Viscount Road	Sewers are generally undersized with the HGL above the pipe crown and in some areas above the ground surface under the August 11, 2017 storm. All of these streets have a few homes with reverse-sloped driveways which could be susceptible to stormwater runoff from the road and / or storm sewer surcharge at the driveway catchbasin / drain trench.
3	White Owl Crescent	
4	Enfield Crescent / Banbury Road	
5	Hackney Ridge	Sewers in this are generally undersized with the HGL near or above the ground surface under the August 11, 2017 storm event. Flows are restricted by a 375 mm outlet sewer though the easement at 52 Hackney Ridge Dr.
6	Royal Oak Drive	Sewers in this are generally surcharged under the August 11, 2017 storm with the HGL near or above ground surface. The model shows that this area as a high risk for basement and surface flooding with downstream flows restricted by the outlet sewers at the downstream easement on Fox Run.
7	Kensington Avenue / Varadi Avenue	Sewers in this are generally surcharged under the August 11, 2017 storm event with the HGL near or above ground surface. This area as a high risk for basement and surface flooding with downstream flows restricted by the outlet sewers at the downstream easement at 72 Kensington Avenue.
8	Ashgrove Avenue Area	Sewers in this are generally surcharged under the August 11, 2017 storm event with the HGL near or above ground surface. This area as a high risk for basement and surface flooding with downstream flows restricted by the outlet sewer downstream on Ashgrove Ave. There are also a large cluster of homes with reverse sloped driveways that would increase the risk of basement flooding resulting from road surface flooding entering though the garage.

Chapter 6. Evaluation of Alternative Solutions

6.1 General

This chapter provides a description of the types of alternative solutions that were considered in order to mitigate the problems and assess the opportunities. Four basic alternatives are presented and includes "Do Nothing" as the first alternatives followed by alternatives involving sewer size upgrades, inline storage, offline storage or a combination off all three solution types. In some areas, only one alternative was considered as the sites were relatively straightforward (pipe upgrades only) while others required more complex alternatives. The preferred Alternative for each area is summarized in the following sections. Evaluation of the effectiveness of the alternative solutions will also be briefly discussed in the following sections.

6.2 Level of Service for the Problem Areas

Following the City's Design and Construction Standards as well as a discussion with City Staff on December 2019, the proposed solutions will provide the City a standard of a 100-year level of service (major and minor) for the eight identified problem areas which were flooded during the August 2017 event. This will enhance the current level of service within the eight problem areas.

6.3 Description of Alternatives Solutions

Four general alternatives were considered for each of the problem areas. These include:

1. <u>Alternative 1: Do Nothing:</u>
   No mitigation measures would be taken for this alternative, with the exception of ongoing operation and maintenance activities together with emergency measures.

2. <u>Alternative 2: Pipe Upsizing within the Existing Storm System</u>
   Existing sewers where the rate of inflow is greater than the current sewer capacity would be upsized to accommodate more inflow in order to alleviate existing flooding problems.
3. <u>Alternative 3: System Storage (In-line / Off-line) within the Existing Storm System</u>
   This alternative involves restricting the rate of inflow to certain existing sewers to the existing capacity. Flows in excess of the capacity of the existing sewers are directed to localized storage tanks or are temporarily stored within the road right of way.

4. Alternative 4: Pipe Upsizing and System Storage (In-line / Off-line) within the Existing Storm System
   This alternative will include pipe upsizing and local storage measures at strategic locations to improve the system performance and mitigate existing flooding problems.

The above alternatives were considered for all areas with the exception of Area 1 (Powerline Road) and evaluated based on the evaluation criteria in **Section 6.4**.

6.3.1 Powerline Road Alternatives

Powerline Road is unique in that the road has a rural cross-section (ditches to either side) and currently forms a border between developed lands to the south and rural lands to the north (to be developed). Three (3) alternatives considered for Area 1 include:

1. Alternative A – Do Nothing;
2. Alternative B – A combination of new sewers or in-line storage along Powerline Road; and
3. Alternative C – Ditching within public road right-of-way along Powerline Road, from approximately 155m west of Brantwood Park Road to the adjacent creek east of Coulbeck Road.

These alternatives were also evaluated based on the criteria in **Section 6.4**.

6.4 Evaluation Criteria

In order to evaluate the alternative solutions identified in the previous sections, four general categories of criteria were considered. The four (4) categories are natural environment, social / cultural environment, economical / financial, and technical, and the detailed list of criteria for each category is summarized in **Table 6.4.1**. The evaluation of the alternatives based on these criteria would form the basis and justification for the selection of the preferred alternative(s).

Table 6.4.1: Summary of Evaluation Criteria

Category	Criteria	Description of Criterial
Natural Environment	Impact of existing vegetation	Potential to impact existing vegetation.
	Impact on surface flooding	Potential to decrease surface flooding.
	Impact on erosion	Potential to mitigate existing erosion issues.
Social / Cultural Environment	Potential disruption to community	Potential for the proposed alternative to impact residents as a result of construction practices, rerouting of traffic or items associated with proposed construction (e.g. noise, dust, mud, etc.).
	Potential benefit to community	Potential for the proposed alternative to provide positive impact to residents.
Economical / Financial	Estimated construction cost	The relative capital cost as compared to the other alternatives.
	Estimated operation & maintenance cost	The relative cost of maintaining the works in short-term and long-term based on factors such as access/ egress, ownership implications, future risks due to failures or flooding, overall operation frequency and intensity.
	Potential requirements for property acquisition / easements	Potential cost to acquire any lands that may be necessary in order to construct or maintain proposed infrastructure.
Technical	Feasibility of alternative	The relative ease with which the alternative can be implemented taking into consideration of approvals, community landowner acceptance, and length of time to implement.

6.5 Public Consultation

6.5.1 Public Notification

A Notice of Project was published in November 2018 on the City's website (https://www.brantford.ca/en/your-government/north-east-flood-remediation-study.aspx). The notice introduced the study, illustrated the study area boundary identifies means of providing public input, and invited the public to attend the Public Information Centre.

6.5.2 Public Information Centres

Two Public Information Centres (PICs) were held on December 6, 2018 and October 17, 2019 respectively at the Branlyn Community Centre in Brantford. The purpose of the first PIC was to introduce the project to the community, learn about the nature and types of flooding, present information on existing conditions, study progress and timelines as well as seek community input on existing conditions information and identification of opportunities. The second PIC was held in order to provide an overview of the study including key tasks completed, present findings of investigations, recommend proposed remediation solutions, and provide opportunities for community input.

A total of 66 people participated in the first PIC and 71 people attended the second PIC. During the PICs, participants were able to review display boards that focused on various aspects of the study. Members of the project team and City staff were available at the PIC to answer questions informally and respond to feedback. Feedback forms were also provided to the participants to collect public input. There were 6 comment sheets and 11 comment sheets collected during the two PICs respectively.

A summary of the PIC boards and public comments can be found in **Appendix D**.

6.6 Selection and Description of the Preferred Alternative

Based on the results of the alternative evaluations and consultation and input from the public and City staff, the preferred alternative for each problem was selected and presented in **Table 6.6.1**. The EA Schedule for all proposed undertakings associated with the preferred alternatives is also shown in the table below.

Table 6.6.1: Summary of Preferred Alternatives

Problem Area	Preferred Alternative	Municipal Class EA Schedule
Area 1 – Powerline Road	Alternative C – Ditching within Public Right-of-Way Along Powerline Road	Schedule A
Area 2 – Coxwell Crescent / Viscount Road	Alternative 2 – Pipe Upsizing within the Existing Storm System	Schedule A+
Area 3 – White Owl Crescent	Alternative 3 – System Storage (In-line / Off-line) within the Existing Storm System	Schedule A+
Area 4 – Enfield Crescent / Banbury Road	Alternative 4 – Pipe Upsizing and System Storage (In-line / Off-line) within the Existing Storm System	Schedule A+
Area 5 – Hackney Ridge	Alternative 2 – Pipe Upsizing within the Existing Storm System (Utilizing the Easement and Outlet Sewer)	Schedule A+
Area 6 – Royal Oak Drive	Alternative 2 – Pipe Upsizing within the Existing Storm System (Utilizing the Easement and Outlet Sewer)	Schedule A+
Area 7 – Kensington Avenue / Varadi Avenue	Alternative 2 – Pipe Upsizing within the Existing Storm System (Utilizing the Easement and Outlet Sewer)	Schedule A+
Area 8 – Ashgrove Avenue Area	Alternative 2 – Pipe Upsizing within the Existing Storm System	Schedule A+

A detailed description of each Preferred Alternative is provided in the following sections. The estimated cost associated with each alternative is presented in **Section 6.7**. A plan view of the proposed works for each area is illustrated in **Figure 6.6.1** through **Figure 6.6.8**.

6.6.1 Area 1 – Powerline Road

Alternative C – Ditching within Public Right-of-Way Along Powerline Road

The recommended ditching works, a total length of ~950m, will start from the storm sewer inlet within the existing ditch (adjacent to 75 Anastasia Crescent) to approximately 260m east of Coulbeck Road, within the road right-of-way along both sides of Powerline Road with proper grading. A culvert across Powerline Road upstream of the catchbasin inlet structure will intercept the flows from the existing ditch, and re-direct a portion of the flows to the proposed ditches on both sides of Powerline Road. The re-directed flows will then outlet into an adjacent creek east of Coulbeck Road (see **Figure 6.6.1**).

The selection of this alternative takes into consideration of the proposed development of lands to the north of Powerline Road as part of the City of Brantford's Master Servicing Plan Update. It is expected that the runoff from the existing agricultural lands north of Powerline Road could be re-directed to the tributaries of Fairchild Creek north of the fields as part of the development process. The volume of stormwater into the existing ditch system along Powerline Road would also be reduced.

The other alternatives, including increasing the storage volume upstream of the existing control structure (orifice plate within the storm sewer inlet at end of the existing ditch), increasing the downstream storm sewer capacity along Arbor Street, or a combination of the two measures were considered. These alternatives were found to be relatively expensive, especially in light of potential reduction in runoff volume as noted above. The existing orifice should remain in place.

6.6.2 Area 2 – Coxwell Crescent / Viscount Road

Alternative 2 – Pipe Upsizing within the Existing Storm System

This alternative includes replacement of existing 675mm to 975mm storm sewers with 900mm to 1350mm pipes on Viscount Road, Coxwell Crescent, Brantwood Park Road to the outfall. Sewer upsizing on Brantwood Park Road also benefits the adjacent storm sewer system south of this area as the proposed sewers now have more capacity to convey flows. The proposed works are illustrated on **Figure 6.6.2**.

This sewer upgrade alternative was the only alternative considered for Area 2 as the solution is the least complex and effectively addresses flood risk.

6.6.3 Area 3 – White Owl Crescent

Alternative 3 – System Storage (In-line / Off-line) within the Existing Storm System

The proposed works for this area include increasing storm sewer capacity in the Coxwell Crescent / Viscount Road area. The existing 300mm storm sewers would be replaced by 600mm sewers which would store excess storm runoff and release flows to downstream sewers at a controlled rate. The proposed works are illustrated on **Figure 6.6.3**.

This sewer upgrade alternative was the only alternative considered for Area 3 as the solution is the least complex and effectively addresses flood risk.

6.6.4 Area 4 – Enfield Crescent / Banbury Road

Alternative 4 – Pipe Upsizing and System Storage (In-line / Off-line) within the Existing Storm System

This alternative involves storm sewer upsizing from 450mm to 675mm on Hallmark Street, and local storage on Gaitwin Street and Banbury Road between Coulbeck Road and Gaitwin Street. The proposed system will be constrained with a 525mm orifice plate at the downstream limit, which improves the performance of the downstream system as a portion of the existing sewer capacity is freed up. The proposed works are illustrated on **Figure 6.6.4**.

Other alternatives considered included upsizing the storm sewer all the way to the Gillian Road outlet but was deemed not cost effective as the upgrade would take place in an area with no flood risk.

6.6.5 Area 5 – Hackney Ridge

Given the proximity of the easement at #58 and #60 Hackney Ridge as the key constraint in the development of storm solutions, two alternatives were considered to mitigate flooding in Area 5 as summarized below.

Alternative 2 – Pipe Upsizing within the Existing Storm System (utilizing the easement and outlet sewer)

The existing 375mm dimeter sewers on Hackney Ridge would be replaced with 450mm to 825 mm diameter pipes to the end of the cul-de-sac and an 825 mm diameter outlet pipe utilizing the easement between #58 and #60 Hackney Ridge, which discharge to the nearby creek. The proposed works will be constructed within the public road right-of-way and via the existing the easement on two private properties that was deemed feasible based on the existing easement agreement and easement width. It is anticipated that the recommendation will follow a Schedule A+ process.

Alternative 4 – Pipe Upsizing and System Storage (In-line / Off-line) within the Existing Storm System

This alternative considered the replacement of the existing 375mm dimeter sewers on Hackney Ridge with 450mm and 750mm diameter pipes and storage tanks to the end of the cul-de-sac. Outflows of this system would be limited by a 375mm orifice plate. The proposed works would be constructed within the public road right-of-way, thus, the existing outfall pipe that traverses the easement on two private properties would be left in place. This recommendation would follow a Schedule A/A+ process.

Preferred Alternative

Alternative 2 was found to be more cost-effective and hence was selected as the preferred alternative for Area 5; the proposed configuration is shown in **Figure 6.6.5**.

6.6.6 Area 6 – Royal Oak Drive

Given the proximity of the easement between #48 and #50 Fox Run as the key constraint in the development of storm solutions, two alternatives were considered to mitigate flooding in Area 5 as summarized below.

Alternative 2 – Pipe Upsizing within the Existing Storm System (utilizing the easement and outlet sewer)

This alternative involves replacement of existing 375mm to 600mm storm sewers with 675mm to 1050 mm diameter pipes. The storm sewer system in this area outlets to an open channel through an easement on two private properties at 48 and 50 Fox Run and along the rear of 77 Royal Oak Drive to the creek outlet.

Alternative 4 – Pipe Upsizing and System Storage (In-line / Off-line) within the Existing Storm System

This alternative involves replacement of existing 375mm to 600mm storm sewers with 675mm and 900mm diameter pipes. The storm sewer system in this area outlets to an open channel through an easement on two private properties. Therefore, storage tanks with a 525mm orifice are proposed on Fox Run to store excess inflows and limit potential impacts on private properties.

Preferred Alternative

Alternative 2 was found to be more cost-effective and hence was selected as the preferred alternative for Area 5; the proposed configuration is shown on **Figure 6.6.6**. At the functional design stage, the assessment of this alternative should address the technical feasibility of constructing a new storm sewer between the two properties, determine the status of the outlet and assess the capacity of the receiving stream.

6.6.7 Area 7 – Kensington Avenue / Varadi Avenue

Given the proximity of the easement at #72 Kensington Avenue as the key constraint in the development of storm solutions, two alternatives were considered to mitigate flooding in Area 7 as summarized below.

Alternative 2 – Pipe Upsizing within the Existing Storm System (utilizing the easement and outlet sewer)

Existing storm sewers ranging from 300mm to 600 mm diameter will be upsized to sewers ranging from 375mm to 1350 mm diameter in order to increase conveyance capacity through the easement at 52 Kensington Avenue to the outlet in Oak Ridges Park.

Alternative 4 – Pipe Upsizing and System Storage (In-line / Off-line) within the Existing Storm System

Existing storm sewers ranging from 300mm to 600mm diameter will be upsized to sewers ranging from 375mm to 825mm diameter in order to increase conveyance capacity. In addition, a storage tank along Kensington Avenue to reduce flows to sewers downstream which have limited capacity is required.

Preferred Alternative

Alternative 2 was found to be more cost-effective and hence was selected as the preferred alternative for Area 7; the proposed configuration is shown in **Figure 6.6.7**. At the functional design stage, the assessment of this alternative should address the technical feasibility of constructing a new storm sewer between the two properties, determine the status of the outlet and assess the capacity of the receiving stream.

6.6.8 Area 8 – Ashgrove Avenue Area

Ashgrove Avenue is a minor collector road the drains an area with a high concentration of homes with reverse-sloped driveways. Along with considering upgrading of storm sewers, consideration was also given to providing off-line storage into Cedarland Park. The considered alternatives are summarized below:

Alternative 2 – Pipe Upsizing within the Existing Storm System

This alternative includes upsizing existing storm sewers, ranging from 300mm to 1650mm diameter, to 375mm to 2400mm diameter to the outlet at Park Road. The proposed works will increase flow conveyance within this drainage system and mitigate flooding issues throughout the system.

Alternative 3 – System Storage (In-line / Off-line) within the Existing Storm System

This alternative provides off-line storage of approximately 9,800 cubic meters within Cedarland Park that outlets from Ashgrove Avenue at Beechwood Avenue. This alternative also includes upsizing existing storm sewers, ranging from 300mm to 1650mm diameter upstream of the intersection at Ashgrove Avenue and Beechwood Avenue. The proposed works will increase flow conveyance within this drainage system and mitigate flooding issues throughout the system.

Preferred Alternative – Area 7

Alternative 2 was found to be more cost-effective and hence was selected as the preferred alternative for Area 7. The construction of an offline storage facility within Cedarwood Park was found to be more costly compared to upgrading the sewers within the right-of-way.

The proposed configuration is shown in **Figure 6.6.8**.

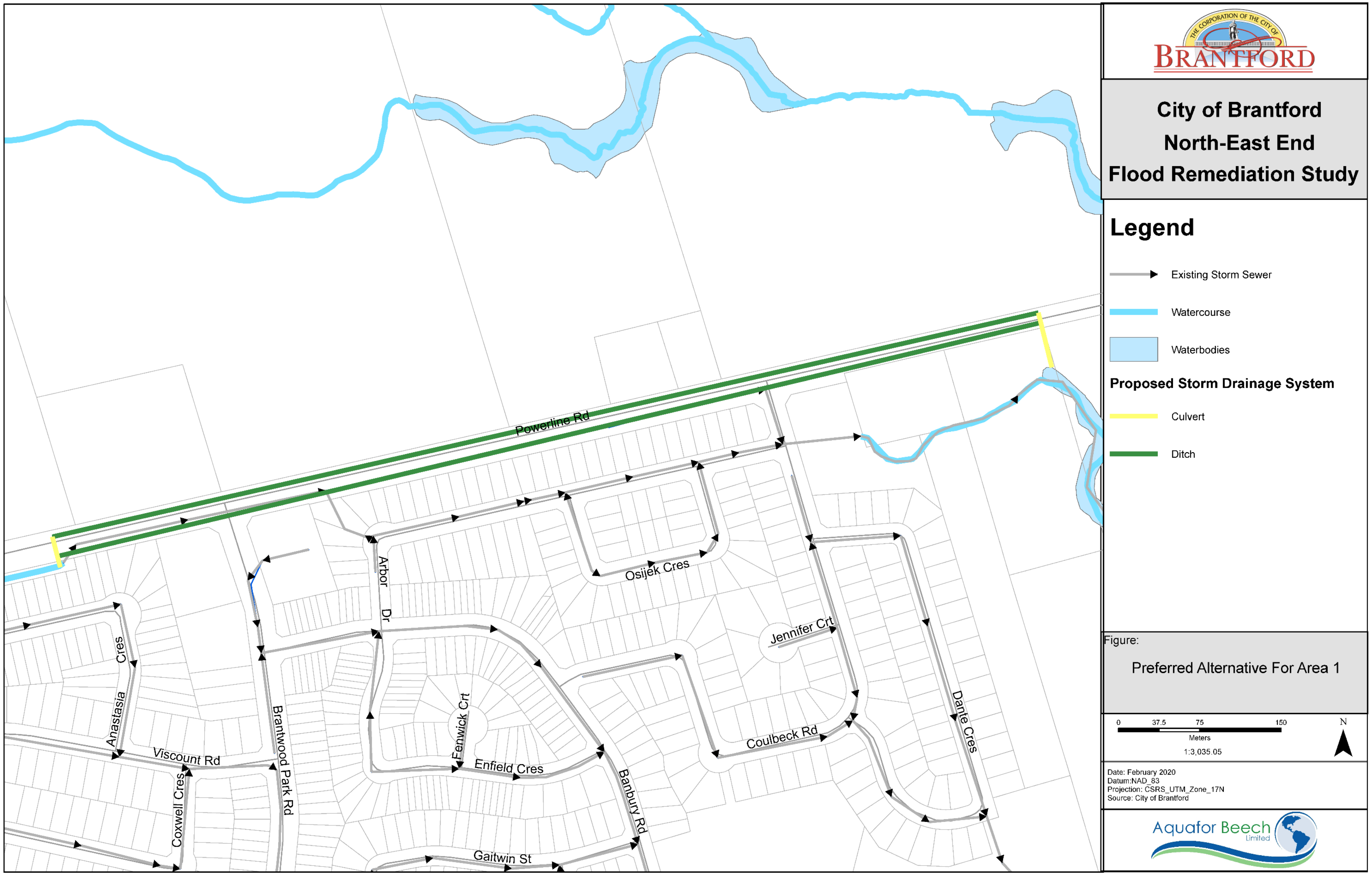


Figure 6.6.1: Proposed Storm Sewer Works for Area 1 – Powerline Road

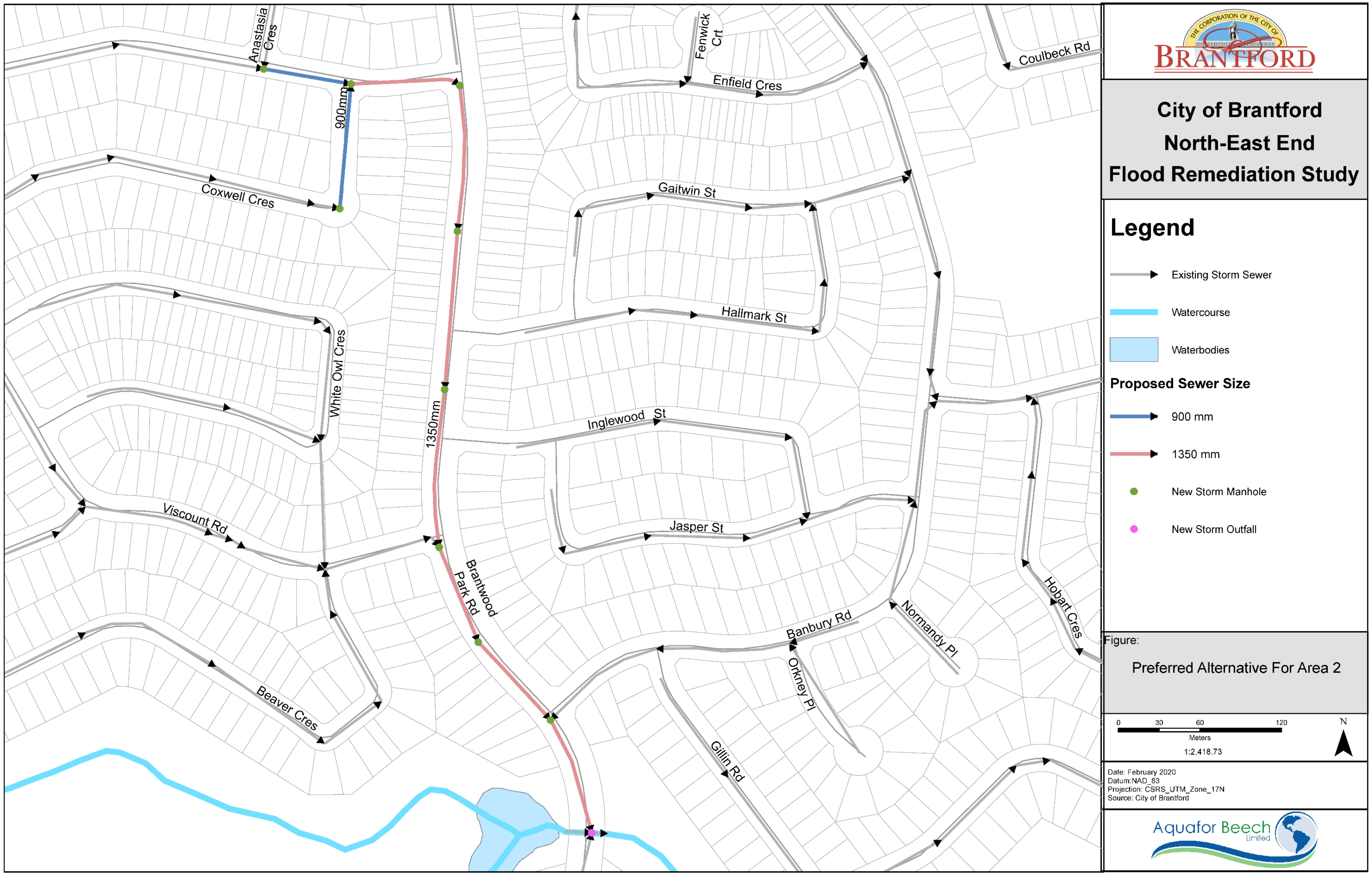


Figure 6.6.2: Proposed Storm Sewer Works for Area 2 – Coxwell Crescent / Viscount Road

Figure 6.6.3: Proposed Storm Sewer Works for Area 3 – White Owl Crescent

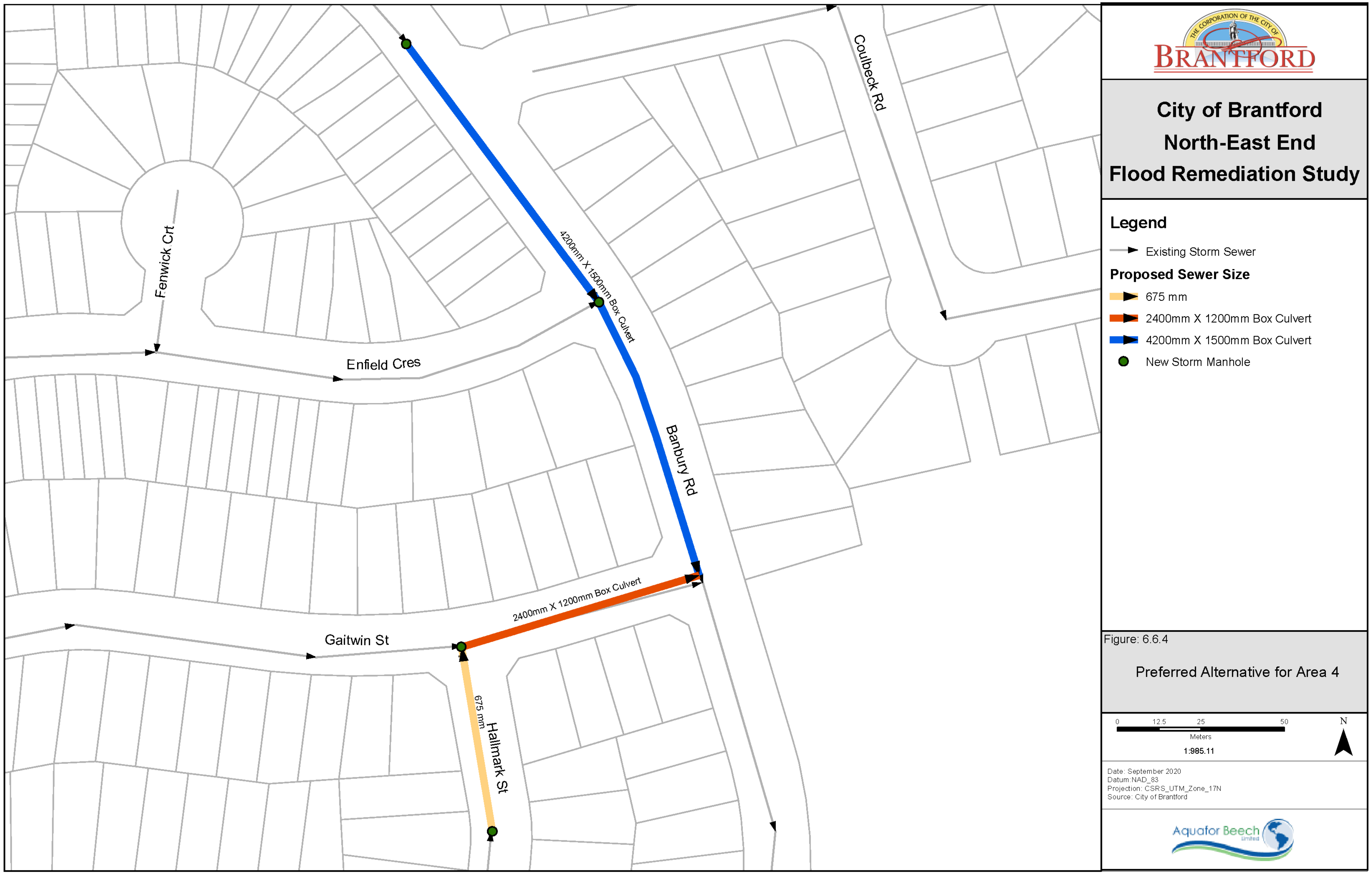


Figure 6.6.4: Proposed Storm Sewer Works for Area 4 – Enfield Crescent / Banbury Road

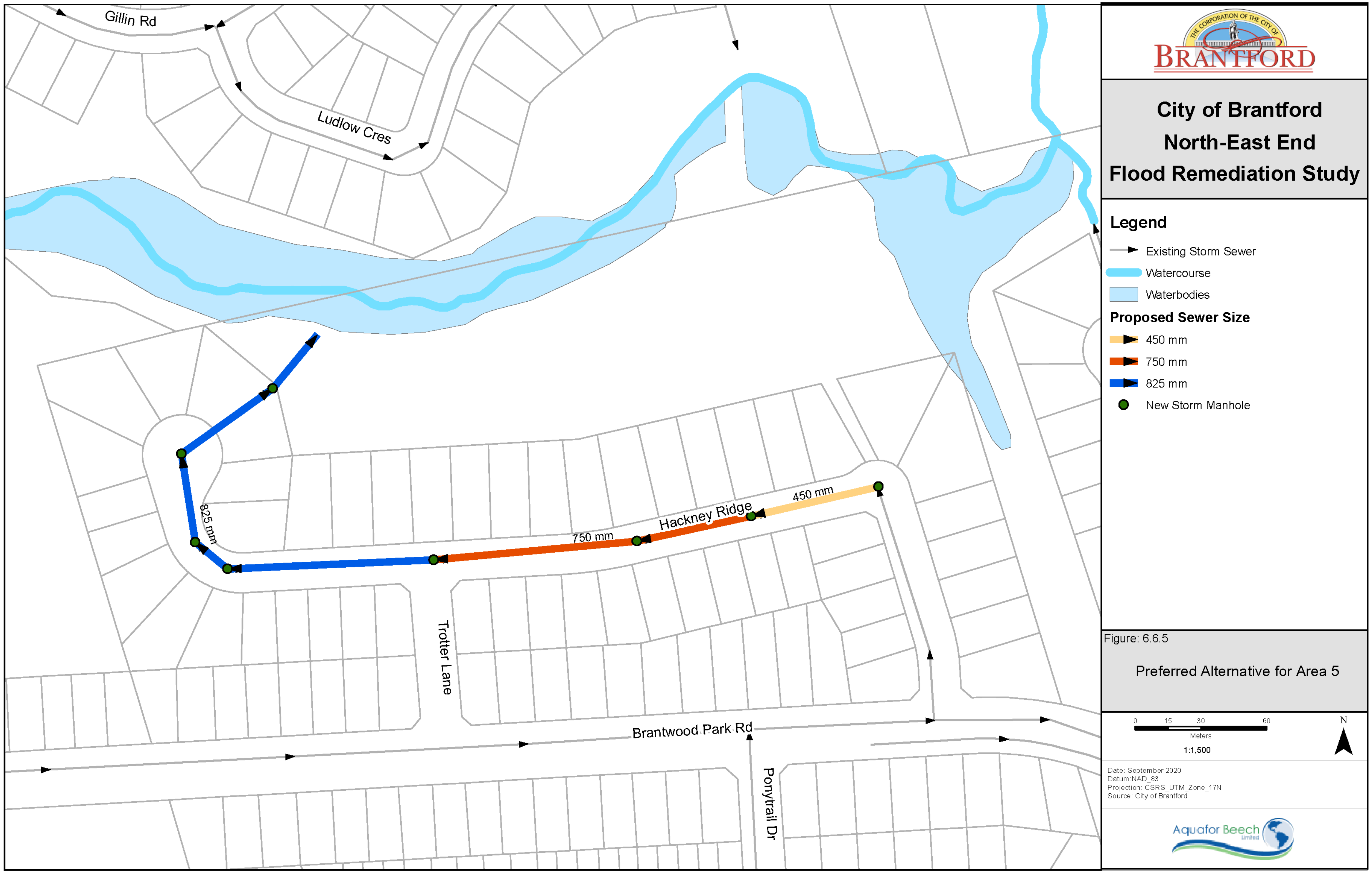


Figure 6.6.5: Proposed Storm Sewer Works for Area 5 – Hackney Ridge

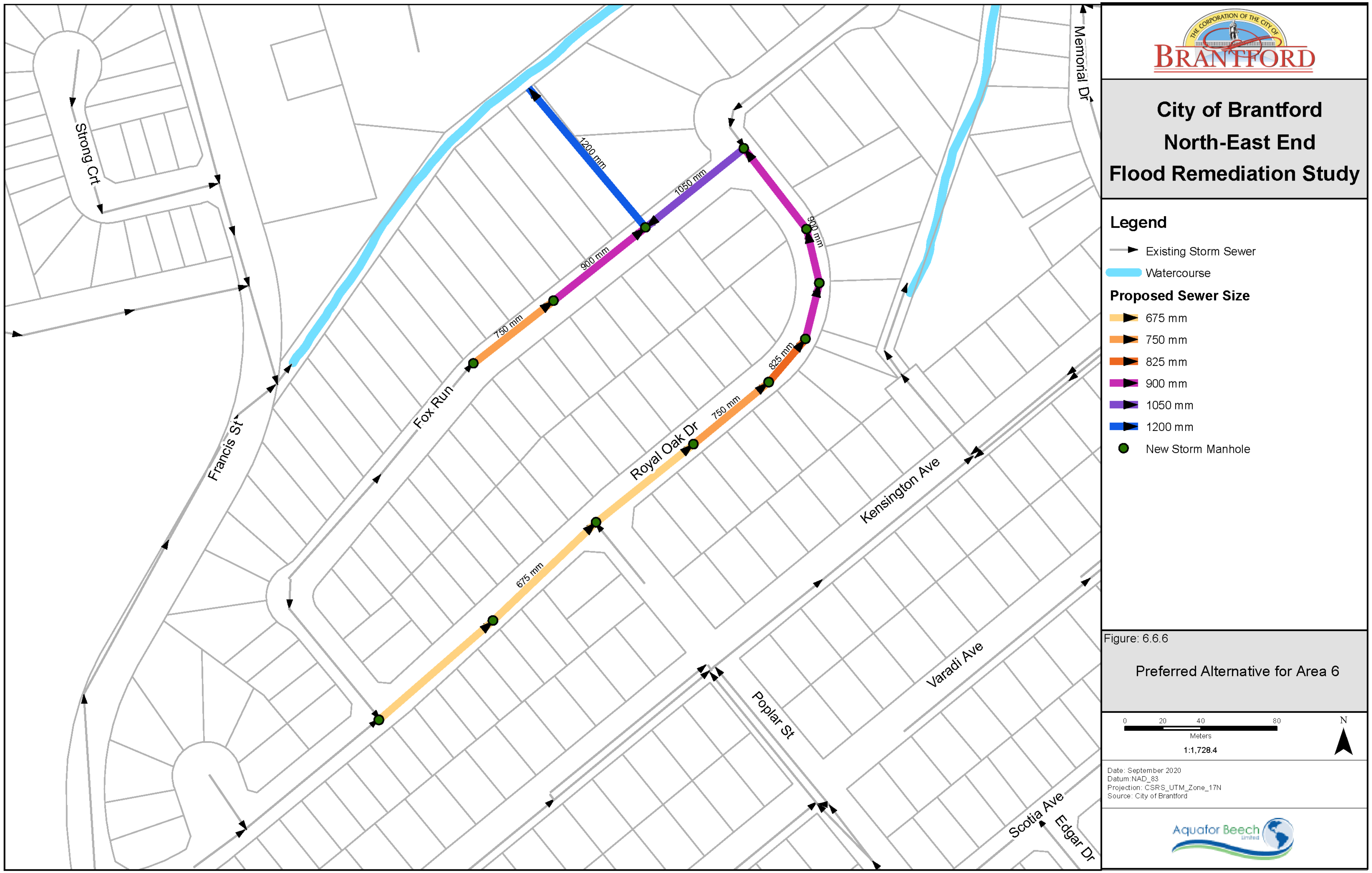


Figure 6.6.6: Proposed Storm Sewer Works for Area 6 – Royal Oak Drive

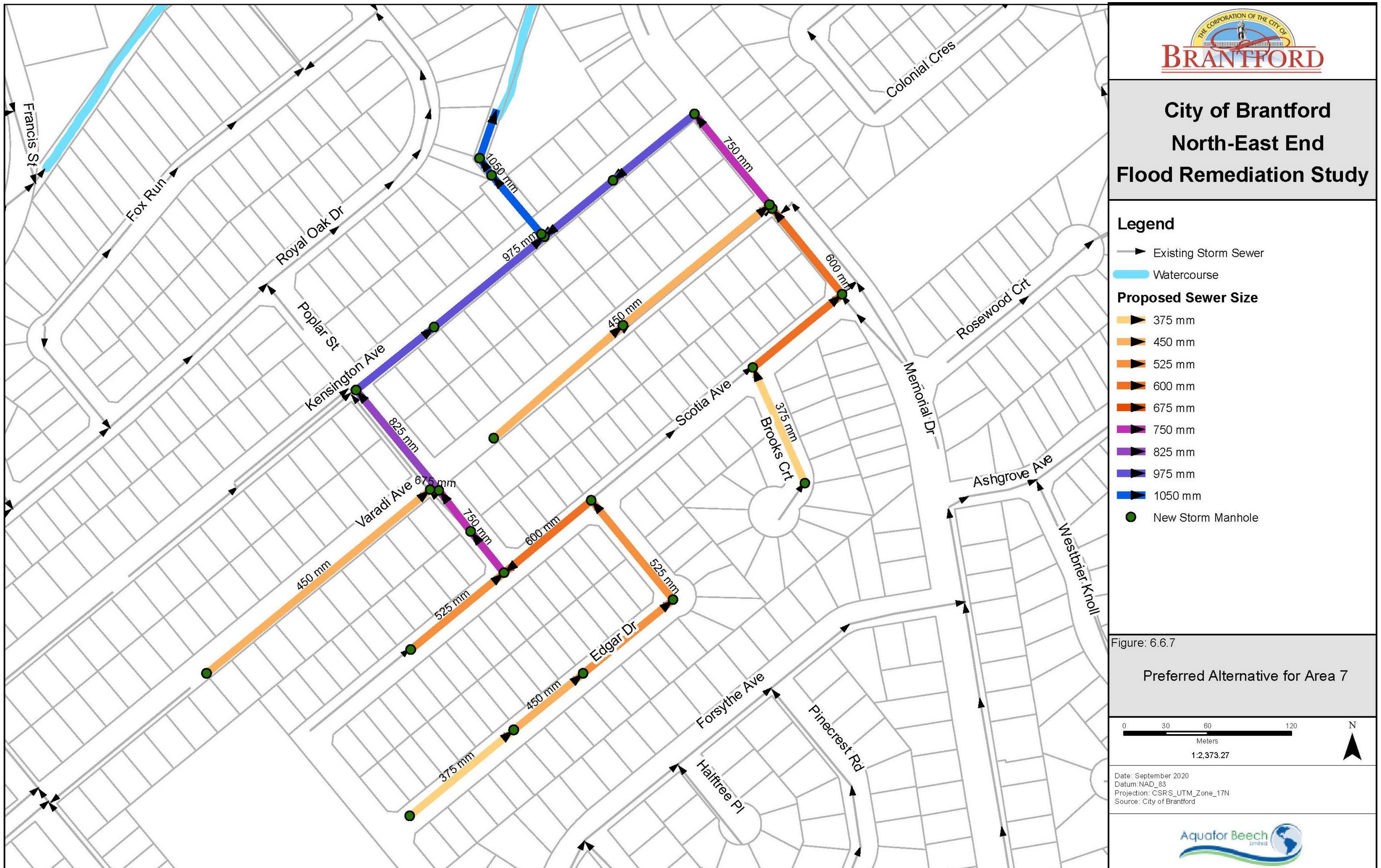


Figure 6.6.7: Proposed Storm Sewer Works for Area 7 – Kensington Avenue / Varadi Avenue

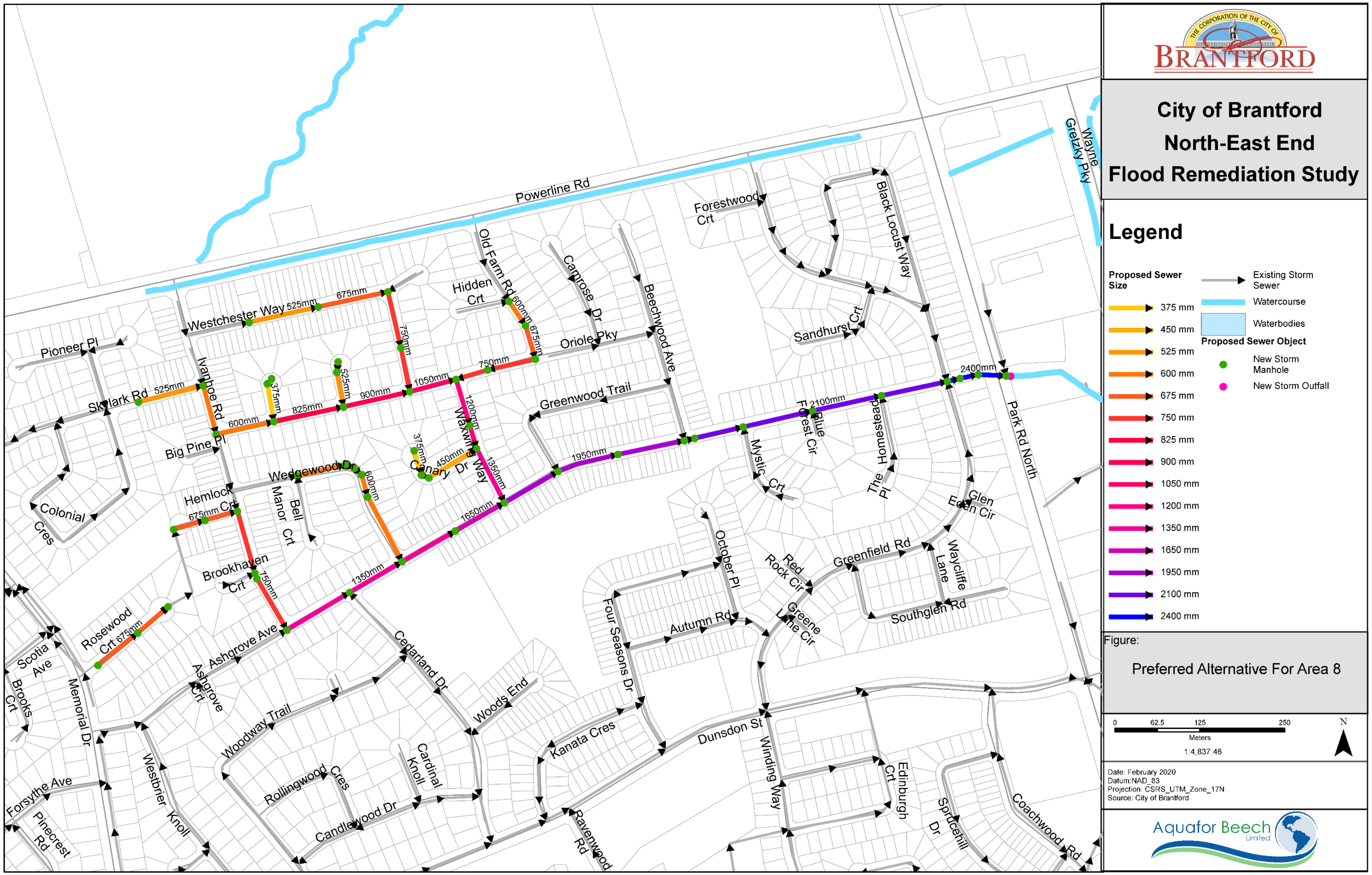


Figure 6.6.8: Proposed Storm Sewer Works for Area 8 – Ashgrove Avenue Area

6.7 Cost Estimation of Preferred Alternative

The estimated cost associated with each preferred alternative is summarized in **Table 6.7.1**.

Table 6.7.1: Estimated Costs for Preferred Alternatives

Problem Area	Preferred Alternative	Estimated Costs
Area 1 – Powerline Road	Alternative C – Ditching within Public Right-of-Way Along Powerline Road	$ 530,000
Area 2 – Coxwell Crescent / Viscount Road	Alternative 2 – Pipe Upsizing within the Existing Storm System	$ 2,800,000
Area 3 – White Owl Crescent	Alternative 3 – System Storage (In-line / Off-line) within the Existing Storm System	$ 400,000
Area 4 – Enfield Crescent / Banbury Road	Alternative 4 – Pipe Upsizing and System Storage (In-line / Off-line) within the Existing Storm System	$ 2,500,000
Area 5 – Hackney Ridge	Alternative 2 – Pipe Upsizing within the Existing Storm System (Utilizing the Easement and Outlet Sewer)	$ 1,200,000
Area 6 – Royal Oak Drive	Alternative 2 – Pipe Upsizing within the Existing Storm System (Utilizing the Easement and Outlet Sewer)	$ 1,800,000
Area 7 – Kensington Avenue / Varadi Avenue	Alternative 2 – Pipe Upsizing within the Existing Storm System (Utilizing the Easement and Outlet Sewer)	$ 4,200,000
Area 8 – Ashgrove Avenue Area	Alternative 2 – Pipe Upsizing within the Existing Storm System	$ 10,800,000
Subtotal		**$ 24,230,000**
Contingency (15%)		$ 3,640,000
Engineering Costs (10%)		$ 2,430,000
Total		**$ 30,300,000**

The estimated costs include supply and installation of the proposed sewer works and associated maintenance holes, excavation and earth works, sheathing and shoring, bedding, backfilling and compacting of trench material. The prices provided exclude atypical costs such as cost for disposal of contaminated materials (e.g. asbestos). A 15% contingency and 10% engineering costs are included within the total price.

The estimated costs as assumed above may be reduced if the works are done as part of an overall road reconstruction project.

At this stage, all Preferred Alternatives have been limited to the works which are in the municipal right-of-way and in City easements with one potential acquisition of property.

It should also be noted that the Preferred Alternatives are subject to minor revisions during the functional design stage based on City comments and other factors. As such, the proposed pipe sizes and associated costing may be adjusted once functional design is completed.

Chapter 7. Community Education and Public Awareness Program

One of the key components of this study is promote community education and enhance public awareness regarding basement flooding, in-house flood prevention and mitigation measures to protect their homes from flooding risks. In turn, a community education and public awareness brochure was developed, covering the following topics:

- Cause of basement flooding;
- City’s and residents’ roles;
- How to reduce the risk of basement flooding at your property;
- What the City is doing to prevent basement flooding; and
- What to do if your basement is flooded.

The brochure can be found in **Appendix E**. The section below presents flood mitigation measures which could be implemented across the study area in addition to the recommended solutions for the eight problem areas.

7.1 Other Flood Mitigation Measures

In addition to the proposed localized solutions, it is recommended that a few measures to help reduce flooding and improve the performance of the overall sewer network within the study area be considered. The recommended measures are described below:

Operation and Maintenance Measures

CCTV inspections provide a visual of the inside of a pipe and assist in defining the structural and hydraulic capacity of the sewers. The results from previous CCTV records show that some streets have issues such as calcite build-up, cracks along the sewer, etc., which can reduce flows within the pipe and ability to convey flows.

It is recommended that the existing CCTV program that identifies structural / hydraulic limitations within the system be continued to include the remaining streets within the study area.

Private Property Measures

Homeowners can help mitigate flood threats by managing stormwater on private property that can assist in reducing the stormwater amounts before it enters the City's sewers. Private property measures include but not limited to:

- Downspout disconnection;
- Install rain barrels to collect stormwater;
- Install a sump pump and discharge flows to pervious ground surface; and
- Build rain gardens to increase infiltration.

The City currently has grant, loan and incentive programs that are available to the residents within the study area to implement measures on private properties to lower the risk of basement flooding. The programs include the Private Sewer Lateral Replacement Grant Program, Rain Barrels Program, as well as grants for Basement Flooding Prevention Program. More information can be found through the links below:

- Grant, loan and incentive programs (https://www.brantford.ca/en/living-here/grant-loan-and-incentive-programs.aspx)
- Rain barrel program (https://www.brantford.ca/en/living-here/rain-barrels.aspx)

Protect Homes with Reverse Slope Driveways

As noted in **Section 6.2**, many homes within the study area have reverse slope driveways with a single catchbasin drain in front of the garage. Many of the catchbasins are in need of maintenance, repair or replacement.


Elevated catchbasin which is not able to capture low overland flows


Grate in front of reverse slope driveway

During large rainfall events, stormwater on the road spills over the curb and flows down the driveway. In turn, these homes are more subject to garage and / or basement flooding, and may also contribute to flooding of adjacent homes.

It is recommended to implement driveway grates at driveway approaches with reverse slope driveways in order to improve the capture of storm runoff during rainfall events.

Chapter 8. Implementation Measures

The previous chapters reviewed the alternatives that were considered and provided a summary of the Preferred Solution selection process. This chapter will further discuss the following elements associated with respect to implementing the Preferred Solutions:

- Mitigation of potential impact considerations;
- Considerations at detailed design;
- Environmental approvals and permitting;
- Construction documents preparation and tender; and
- Construction.

8.1 Mitigation Measures

The potential environmental and social impacts associated with the Preferred Solution are typically related to the construction, implementation and long-term usage of the remedial measures. The impacts, their potential sources and methods of mitigation are identified and discussed in the following sections.

Vegetation

Since a majority of the proposed remedial measures will occur within the municipal right-of-way, minimal impacts on vegetation are expected within the proposed project areas. Nevertheless, should any construction activities to be undertaken adjacent to existing trees where tree removal may be required, the following mitigation measures shall be implemented:

- Protective fencing around trees designated to remain;
- Mature trees to be avoided where possible so as to eliminate the need for their removal;
- Small trees, if removed, will be replaced or replanted. The replaced trees will be in accordance with City's requirements; and
- Root pruning, if required, will be done in accordance with City Standards.

Noise and Vibration

Truck traffic and construction equipment operation and general construction activities are potential noise and vibration sources. Mitigation measures include:

- Enforcement of the City's anti-noise by-law for all construction activities;

- Hours of operation during construction activities will be restricted to the hours between 7:00 am and 7:00 pm;
- Pre-construction survey will be undertaken for houses which may be affected by soil vibration during construction activities; and
- Should rock excavation is required, blasting will not be permitted.

Fuel Spills

Fuel spills are likely to occur during the onsite refueling of construction equipment with the potential to contaminate surface and groundwater. Mitigation measures include:

- Refueling in designated areas at a minimum distance of 15 m from a watercourse;
- Spill containment for on-site storage tanks; and
- Preparation of a spill clean-up contingency plan.

Traffic

Potential concern includes local traffic disruption during construction due to closed roads or blockage of driveways. The following mitigating measures are proposed:

- Consultation will be held with the City's Transportation Department to determine which lane(s) of traffic will be maintained or detours utilized to ensure a constant flow of traffic during construction; and
- Homeowners will be notified if temporary blockage to their driveway during construction has to be considered, which will be kept to a minimum. Where possible, alternative short-term parking will be provided.

Private Property

Temporary disruptions to private property include access/egress to driveways and potential interruption of water and sanitary services to residences. Due to the maturity of the existing neighborhoods, these impacts can only be managed through a well-managed construction program that will require consultation with the City and the various agencies and liaising between property owners and construction crews.

Restoration

All sites/areas disturbed by construction activities shall be restored as per the following recommendations:

- Disturbed sidewalks, roads and parking areas will be restored to their existing conditions after construction;
- Removed small trees will be replanted or replaced;
- Disturbed park areas will be restored to their existing conditions; and,
- Disturbance to private properties is to be restored to original conditions or better.

8.2 Functional Design

The functional design for this project will be undertaken after submission and approval of the main report. The functional design is expected to be 30% design and shall include identification of conflicts with the sanitary sewer and relocation requirements, confirmation of sewer invert elevations and necessary hydraulic free board in the sewer systems. This will also include meeting the minimum requirements per the City's Linear Municipal Infrastructure Standards with respect to separation between the storm and sanitary systems, depth of cover, spacing between maintenance holes, easement works and cost estimates.

8.3 Considerations at Detailed Design

Should the City move forward with the preferred alternatives, then detailed design shall be initiated. The detailed design package should include the preparation of 60%, 90%, and final design drawings for review by the City and relevant stakeholders. The detailed design drawing package should include, but not be limited to, the following components:

- General plan (detailing structure, property lines and services);
- Site plan (including site access, staging and stockpile area delineation);
- Plan and profile drawings (detailing location of proposed utility bridge, existing utilities and existing bridge);
- Subsurface utility investigation (SUE) for field confirmation of all existing sewers, watermain and utilities;
- Erosion and sediment control plan (as per the Erosion and Sediment Guidelines for Urban Construction, GGHACA);
- Traffic management plan;
- Landscape restoration plan (including tree removal, preservation and planting plan);
- Associated design brief.

Additional investigations are also recommended at some of the sites during detailed design stage. These include:

- Geotechnical investigations to characterize subsurface conditions and requirements for groundwater monitoring, dewatering, pipe bedding and pavement structure;
- Species-at-Risk and other Species of Conservation Concern;
- Tree Inventories to be carried out by a certified arborist;
- Easement Acquisitions where appropriate; and
- Stage 2 Archaeological Assessment at east end of Area 1 (Powerline Road).

8.4 Environmental Approvals and Permitting

Ministry of Environment, Conservation and Parks (MECP)

Each element of the recommended infrastructure will require an MECP Environmental Compliance Approval (formerly a Certificate of Approval) for Sewage Works since these projects fall under Section 53 of the Ontario Water Resources Act (amended 2011).

Considerations for each project may include:

- A pre-application consultation with the City's Public Works Commission;
- Application fees for Environmental Compliance Approval;
- Filing of applications at least 6-8 weeks in advance of construction activities;
- Development of a monitoring program for tracking short-term and long-term system performance; and
- Early and ongoing dialogue with the MECP during planning stages.

City of Brantford Departments

The following departments must be circulated and consulted in the design and construction phases:

- Community Development
    - Planning
- Public Works
    - Engineering Services
    - Operational Services;
    - Environmental Services;
    - Parks Services; and

  - Fleet and Transit Services.

Projects must comply with City of Brantford's Bylaws, Policies, and Permitting requirements, including an arborist inventory, Ecological Land Classification (ELC) assessment of the potential areas of impact and adjacent vegetation communities, and mitigation and compensation (e.g. tree replacements, restoration, and/or enhancements).

Grand River Conservation Authority (GRCA)

The Memorandum of Understanding between GRCA and the City of Brantford (https://www.grandriver.ca/en/Planning-Development/resources/MOU-signed-final_2017_Brantford.pdf) indicates that the GRCA will provide plan review and/or technical clearance services to the City per the following Schedules:

- Circulation Status by Application Type and Definitions
- Review Function Responsibilities; and
- Screening Protocols

Schedule 3 is a pre-screening schedule for proposed works that guides the level of review by the GRCA – plan review or technical review – and the designated lead agency – GRCA or City.

It is anticipated that planning and/or technical approval will be required for the preferred alternative for Areas 1, 5, 6, 7 and 8 as these alternatives require increasing the size of the outlet to a watercourse. The lead review agency will be determined by Schedule 2.

The preferred alternatives for Areas 2 through 4 do not involve watercourse outlet construction works and it is anticipated that a review by the GRCA will not be required.

Hydro One Corridor

The Provincial Secondary Land Use Program (PSLUP) is administered jointly by Infrastructure Ontario (IO) and Hydro One and operates on the basis of a series of public use principles, which give priority to public uses over private ones

The hierarchy of secondary uses is as follows:

- New linear public uses have top priority;
- New provincial/inter-regional linear public uses have priority over local uses;
- New non-linear public infrastructure uses have priority over private uses;

- Non-linear public recreational uses have priority over private uses;
- Multi-use corridors are preferred.

It is our understanding that the proposed works for Area 1 may traverse the hydro corridor along the south side of Powerline Road (to be confirmed at the functional design stage) and therefore, the City may need to apply to use hydro corridor lands for a secondary use through the PSLUP. Hydro One is responsible for completing a technical review of the proposal and, if Hydro One gives its technical clearance, IO is responsible for executing the appropriate agreement to facilitate the proposed secondary use (e.g., easement/licence).

Consultation with Hydro One on the approval process will be undertaken upon the completion of the functional design and the consultation correspondence will be included in the final report.

8.5 Contract Documents and Construction

A tender document package shall be prepared for the detailed design project with the intent that the proposed works be publicly tendered. The tender will be consistent with the requirements of the City of Brantford standards. The package shall include several sections common to most tenders, as well as sections on:

- Special specifications;
- Schedule of quantities;
- Detailed cost estimates based on tender schedule of quantities; and
- Final detailed design drawings.

The proposed construction timing will be based on subsequent discussions within the City and will be integrated with the proposed timing for the proposed road construction in order to minimize the level of inconvenience to residents, businesses and commuters and maximize cost-savings.

Chapter 9. Conclusions and Recommendations

This study was completed following the Municipal Class Environmental Assessment per Phase 1 and 2 of the EA process for any Schedule 'A' and 'A+' projects. Subsequent phases will also include completion of functional design followed by detail design, construction and monitoring, as required, for the preferred alternative solution.

Basement and surface flooding has occurred in various locations within the study area over the past few years, therefore, the primary purpose of the Study is to review the drainage area, undertake minor (sewer) and major (overland) system capacity analysis, investigate the causes of flooding, identify any deficiencies in the infrastructure, and recommend solutions to reduce the risk of future flooding in the area.

A program involving background data review, field verifications, home visits, smoke testing, field inspection, property surveys and hydrologic and hydraulic modelling was undertaken to better define the causes and extent of flooding. The analysis also showed that flooding would occur relatively frequently (flooding in low lying areas and properties with reverse-sloped driveways) for the 5-year storm or greater.

Based on background data review, field investigations, and model simulations, a total of eight (8) flood vulnerable areas were identified across the study area where the primary cause of flooding include:

1. Undersized storm sewer system; and
2. The presence of a significant number of reverse-sloped driveways that impact basement flooding and overloading of the sanitary sewer system.

A variety of alternatives which included the following were considered for the problem areas:

- Alternative 1 - Do Nothing
- Alternative 2 - Pipe Upsizing within the Existing Storm System
- Alternative 3 - System Storage (In-line / Off-line) within the Existing Storm System
- Alternative 4 - Pipe Upsizing and System Storage (In-line / Off-line) within the Existing Storm System

For Areas where an outlet sewer traversed private properties through an easement, consideration was also given to the utilization of pipe upsizing opportunity through the easement to reduce or eliminate the need for a large upstream inline/offline storage.

For Powerline Road, separate alternatives were considered that included:

- Alternative A – Do Nothing;
- Alternative B – A combination of new sewers or in-line storage along Powerline Road; and
- Alternative C – Ditching within public road right-of-way along Powerline Road, from approximately 155m west of Brantwood Park Road to the adjacent creek east of Coulbeck Road.

The Preferred Alternative, which was selected based on the evaluation approach as outlined in **Section Chapter 6**, meets the objective of mitigating flooding issues associated with the storm sewer system and addresses the potential of stormwater as an additional source of inflow into the sanitary sewer system. The components of the Preferred alternative area summarized below:

Problem Area	Preferred Alternative	Municipal Class EA Schedule
Area 1 – Powerline Road	Alternative C – Ditching within Public Right-of-Way Along Powerline Road	Schedule A
Area 2 – Coxwell Crescent / Viscount Road	Alternative 2 – Pipe Upsizing within the Existing Storm System	Schedule A+
Area 3 – White Owl Crescent	Alternative 3 – System Storage (In-line / Off-line) within the Existing Storm System	Schedule A+
Area 4 – Enfield Crescent / Banbury Road	Alternative 4 – Pipe Upsizing and System Storage (In-line / Off-line) within the Existing Storm System	Schedule A+
Area 5 – Hackney Ridge	Alternative 2 – Pipe Upsizing within the Existing Storm System (Utilizing the Easement and Outlet Sewer)	Schedule A+
Area 6 – Royal Oak Drive	Alternative 2 – Pipe Upsizing within the Existing Storm System (Utilizing the Easement and Outlet Sewer)	Schedule A+

Problem Area	Preferred Alternative	Municipal Class EA Schedule
Area 7 – Kensington Avenue / Varadi Avenue	Alternative 2 – Pipe Upsizing within the Existing Storm System (Utilizing the Easement and Outlet Sewer)	Schedule A+
Area 8 – Ashgrove Avenue Area	Alternative 2 – Pipe Upsizing within the Existing Storm System	Schedule A+

Recommendations for the implementation of the Preferred Alternative are summarized below:

1. Implementation of the Preferred Alternative that includes:
    a. Construction of the proposed storm sewer upgrades within the road right-of-way;
    b. Construction of the proposed storm outfall upgrades through the easements on private properties; and / or
    c. Construction of the proposed ditch system upgrades along Powerline Road.
2. A Stage 2 Archeological Survey be conducted prior to construction in the area of Powerline Road east of Coulbeck Street;
3. Stage construction such that construction proceeds upstream from the proposed outfall, prioritizes high flood risk areas first and be coordinated with on-going road reconstruction projects; and
4. Obtain the required agency approvals from:
    a. Ministry of Environment Conservation and Parks (MECP) for the construction of the recommended storm sewer and outfall works;
    b. Grand River Conservation Authority (GRCA) for ecological impacts (if any) during construction
    c. City Divisions including:
        i. Municipal Works – Infrastructure and Asset Management;
        ii. Environmental Services
        iii. Transportation, and
        iv. Parks, Recreation and Culture

In addition to the proposed localized solutions, it is recommended that a few measures to help reduce flooding and improve the performance of the overall sewer network within the study area be considered. The recommended measures are described below:

- Operation and maintenance measures include the following:
    - The City will continue the CCTV program to define any structural / hydraulic limitations and deficiencies within the system, and undertake measures to reinstate, repair and cleaning of sewers and catchbasins.
- Preventive solutions within private property that can help the property owners to protect their properties and mitigate flood threats by managing stormwater on the private side of the right-of-way. Also, this can reduce the stormwater amounts before it enters the City's sewers. These solutions on private property include the following:
    - Downspout disconnection;
    - Install rain barrels to collect stormwater;
    - Install a sump pump and discharge flows to pervious ground surface; and
    - Build rain gardens on their property to enhance infiltration.