GEI Consultants

Niagara Falls

City of Niagara Falls

Master Servicing Plan and Wet Weather Management Strategy
Volume 5: Stormwater Master Servicing Plan

Niagara Falls, Ontario

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1. Introduction

1.1. Background and Study Area

The City of Niagara Falls (herein referred to as the "City") has completed the 2025 Master Servicing Plan and Wet Weather Management Strategy (MSP-WWMS). The 2025 MSP-WWMS aims to address existing levels of service for the water distribution, wastewater collection, and stormwater collection systems as well as develop a plan to support growth to 2051 and beyond.

The City encompasses a total area of 212 km^2 bounded by the Niagara River to the east, the Town of Niagara-on-the-Lake to the north, the Town of Fort Erie to the south, and the city of Thorold to the west. The City's urban service area encompasses approximately 82.3 km^2 or 39%, with the rest of the area defined as rural. The City is unique in that it experiences an annual influx of approximately 12 million tourists in the spring and summer seasons visiting the natural attraction of Niagara Falls, which puts significant seasonal load on the City's core infrastructure. Further, the City's aging infrastructure must continue to support a rapidly growing population as directed by the Provincial Planning Statement (2024) (superseding the *Places to Grow Growth Plan for the Greater Golden Horseshoe*), the City's Official Plan, and the Niagara Region's Official Plan.

The City is one of twelve municipally serviced lower-tier municipalities within the Niagara Region ("Region") where the water, wastewater, and stormwater systems operate under a two-tier municipal service delivery model. The Region is responsible for raw water supply, water and wastewater treatment, storage facilities, major water booster pumping stations, major sewage pumping stations, transmission mains, force mains, and trunk storm and wastewater conveyance. The City is responsible for the local water distribution network, and local wastewater and stormwater collection systems' infrastructure.

The 2025 MSP-WWMS builds on the previous work undertaken as part of the 1998 Water Master Servicing Study, 2017 Pollution Prevention Control Plan, 2017 Master Drainage Plan Update, and 2021 Region Master Servicing Plan Update as well as previous long-term infrastructure planning studies.

1.2. Master Servicing Plan Objectives

Niagara Falls, like many municipalities, needs to balance addressing existing system level of service and State of Good Repair as part of a holistic and measurable management approach to infrastructure systems. The City has unique needs to balance existing servicing needs with level of service, development pressures, regulatory requirements and protection of the environment. The MSP-WWMS aims to develop a long-term management plan with short- and long-term system upgrade needs and supporting maintenance and management activities. In the development of the MSP-WWMS, each upgrade (or program) trigger, financial implications, and functional objective is identified, thereby allowing the City to manage and adjust the plan moving forward based on changing growth trends and/or management priorities.

The objective of the MSP-WWMS is to develop a long-term servicing strategy for the drinking water, wastewater, and stormwater systems for the urban areas, current and future. More specifically, the key objectives are outlined as follows:

- Address the growth projections for the City as directed by the Provincial Planning Statement (2024).
- Develop a detailed system inventory, gap assessment, and capacity assessment to clearly identify the existing condition, State of Good Repair, risk and capacity of the City's existing water, wastewater, and stormwater infrastructure to meet level of service objectives and regulatory requirements.
- Review of existing and anticipated regulatory frameworks, existing system performance, and the City's existing financial constraints/tolerability to develop:
    - Appropriate system level of service criteria (in line with O.Reg 588/17).
    - Servicing policies and principles.
    - Performance priorities.
- Update the City's existing water, wastewater, and stormwater system models to enable the assessment of the existing and projected capacity and performance of the existing systems whilst addressing existing State of Good Repair and level of service deficits.
- Build off existing studies and recommendations while revisiting and updating past recommendations with the context of revised growth projection, updated performance criteria, and the latest infrastructure priorities.
- Review of system opportunities and constraints to identify potential servicing alternatives to address existing and long-term needs.
- Develop a comprehensive capital program, along with implementation triggers, to support the existing system needs and long-term growth.
- Develop a Wet Weather Flow Management Plan that outlines the City's strategy to monitor and address wet weather flows in the wastewater system including:
    - Prioritization of reduction programs including sewer separation, maintenance and rehabilitation recommendations, and public and private programs.
- Facilitate the necessary stakeholder input to satisfy the Municipal Class Environmental Assessment Master Plan requirements, and to ensure stakeholder buy-in.
- Complete suitable documentation, outlining the methodology, results, and recommendations of the Master Servicing Plan.

All project deliverables are aligned with the City's concurrent Official Plan Review, Transportation Master Plan, Asset Management Plan for Core Assets, and Development Charges Bylaw Update. Additionally, the City's MSP-WWMS is developed under the context of the Niagara Region's Official Plan and 2021 Master Servicing Plan Update to ensure that all plans are based on the same foundational elements.

1.3. Master Servicing Plan Report Outline

The MSP-WWMS report, including all supporting volumes, is the document placed on public record for the prescribed review period. **Volume 5 – Stormwater Master Servicing Plan and Wet Weather Management Strategy** is one of five volumes that make up the complete Master Servicing Plan Wet Weather Management Strategy Class EA Study Report and should be read in conjunction with other volumes.

Volume 5 consists of the principal document summarizing the study objectives, approach, methodologies, technical analyses, and development of the preferred stormwater servicing strategy. This volume details baseline and growth stormwater system performance including detailed information regarding the capital program and additional implementation and ongoing maintenance solutions.

2. Stormwater System Policy and Criteria

Level of Service (LOS) objectives are critical elements in the evaluation of existing and future system performance and development of detailed servicing strategies, implementation of a system-wide capital program, and operations and maintenance practices. In addition to LOS objectives, policies were also laid out to provide guidelines and direction to the master planning process, in addition to ensuring that stormwater criteria are adequately representative to support the decision making for sizing and timing of future infrastructure.

This section summarizes the key Policy and LOS objectives as they relate to the stormwater management system. A detailed summary of the MSP Policies and LOS objectives review and recommendations is provided in **Appendix A** of **Volume 2 – Planning and Consultation**.

2.1. Stormwater Servicing Principles and Policies

Based on the MSP-WWMS vision statement and the identified Policy statements, the following customer service statement for the City's stormwater system was developed to guide the selection of Level of Service objectives and design criteria:

"To provide an efficient, sustainable, and reliable stormwater management system that minimizes environmental impacts and protects public health and property."

The detailed stormwater servicing policies are summarized in **Appendix A** of **Volume 2 – Planning and Consultation**.

2.2. Regional Stormwater System Level of Service Criteria

Given the inter-dependency between the Region and City infrastructure performance, the City's technical level of service was developed with consideration for the Region's criteria in order to harmonize servicing strategies and to avoid competing priorities and/or servicing philosophies.

The Region MSPU did not include recommendations for the stormwater system performance; however, Niagara Region released Region-wide Stormwater Management Guidelines in 2022 which contain level of service criteria for Regional infrastructure for use where lower-tier municipalities do not have defined technical criteria. The following is a summary of the relevant components:

- Flood Control – Post-development to pre-development for 2-year through 100-year storms.
- Water Budget – Pre-development levels maintained with a minimum of zero runoff for the first 5mm of rainfall.
- Quality Control – 80% TSS removal (MECP "Enhanced" criteria).
- Climate Change – Assessed using one of the three approved online tools or alternative method:
    - University of Western Ontario IDFCC Tool.

- Ontario Climate Change Data Portal (OCCDP) IDF Rainfall Tool.
- MTO IDF Curve Lookup.
- Alternative method – stress test scenario with increased rainfall percentages.

2.2.1. Summary of Technical Level of Service

There is no prescribed level of service in the Stormwater Management Planning and Design Manual (MECP, 2003) for minor system (storm sewer and ditch) performance. The MECP manual notes that storm sewers are generally sized to convey runoff from storms ranging from 2 year to 10-year return periods, and that during the design phase the Rational Method is typically used to calculate the required capacity of sewers.

The recommended approach to evaluate the existing stormwater system performance is as follows:

- Utilize all-pipes model with catchment characteristics calibrated to observed flow monitoring data and apply 3-hour Chicago design storm of various return periods in existing and post-development scenarios. For growth and intensification areas, subcatchment parameters typical to the type of land use will be applied.
- Recommended minor system evaluation utilizing the 5-year storm event.
- Recommend major system evaluation study to ensure that storms exceeding minor system capacity can be adequately conveyed to outlets.

New infrastructure in greenfield areas should follow the City of Niagara Falls Standards for Site Planning.

For the MSP-WWMS, detailed review of local standard IDF parameters, design storm distributions, runoff coefficients, hydraulic performance targets, water quality control targets, and flow control targets for the major and minor system are provided in **Appendix A** of **Volume 2 – Planning and Consultation** and summarized in **Table 2-1**.

Table 2-1. Summary of Stormwater Technical Criteria

Criteria		Targets
Stormwater Flows	Minimum Runoff Coefficient "R" for Rational Method	Parks and Open Spaces - 0.35 Single Family Residential - 0.6-0.65 Semi-detached Residential - 0.7 Townhouses - 0.75 Apartments - 0.85 Schools - 0.75 Industrial - 0.9 Commercial - 0.9 Churches - 0.75
	Depression Storage	Impervious areas – 1.5 mm Pervious areas – 4 mm
	Synthetic Design Storm	3-hour Chicago (minor system)
	Velocity	Minimum velocity – 0.8 m/s Maximum velocity – 6.0 m/s
Sewer System Performance	Design Return Period	Minor System – 5 Year Major System – 100 Year
	HGL Target (existing)	Below ground level
	d/D Target (new)	d/D < 1.0
Facility Assessment – Quantity Control/ Erosion Control	Coverage	100% of outfalls to sensitive watercourses have upstream control or downstream control measures. – Matching Post to Pre-development flows and duration Not required for outfalls to the Hydro Canal, Welland River, or the Niagara River provided there is sufficient capacity in the conveyance system.
Facility Assessment – Quality Control	Coverage (existing)	Minimum 50% of impervious area drains to water quality facility
	Coverage (new)	100% of impervious area drains to water quality facility
	Target	70% Total suspended solids removal into the Hydro Canal, Welland River, and the Niagara River 80% Total suspended solids removal into a quality control facility
	Thermal Mitigation	Per Subwatershed Studies or individual studies if a subwatershed study is not available
Facility Assessment – Water Balance		Per Subwatershed Studies or individual studies if a subwatershed study is not available

2.3. Costing Framework

A capital costing framework is provided for all projects proposed as part of this MSP-WWMS. For most of the stormwater management system projects, a base construction cost was first estimated using either unit rates (based on pipe diameter) or project-specific analysis. The base construction cost considered several factors specific to each project such as creek crossings, railway/ highway crossings, tunneling requirements, and area type (rural, urban, suburban).

Additional construction, design, administration, project contingency, provisional allowance, and non-recoverable HST costs were included as fixed percentages to calculate a final project cost. For a further detailed breakdown, refer to **Section 7** of **Volume 2 - Planning**.

In addition to costing, development charges splits were considered to align with the City's current Development Charges framework. These categories are outlined in **Table 2-2**.

Table 2-2. Development Charges Shares by Category

Category	DC Share %
Addresses Existing Needs and Potentially Supports Intensification Growth Needs	Variable % - Project dependent. Provides capacity for additional storm flow due to development
Supports New Growth Areas	100% - Servicing greenfield growth area (10% OB)

Note: OB – Out of Bylaw; supports post period growth .

3. Existing Stormwater Collection System

3.1. Existing Stormwater Infrastructure

Surface drainage within the City ultimately flows either to the Niagara River or Lake Ontario via numerous waterways, as illustrated by the Tertiary Watersheds in **Figure 3-1**. Within the urban areas of the City, runoff is discharged through the municipal stormwater management system which includes about 316 km of storm sewers and associated catch basins and maintenance holes. These primarily convey flow to the Hydro Canal, Sir Adam Beck Hydroelectric Station Reservoir, Welland Canal, Welland River, or Niagara River.

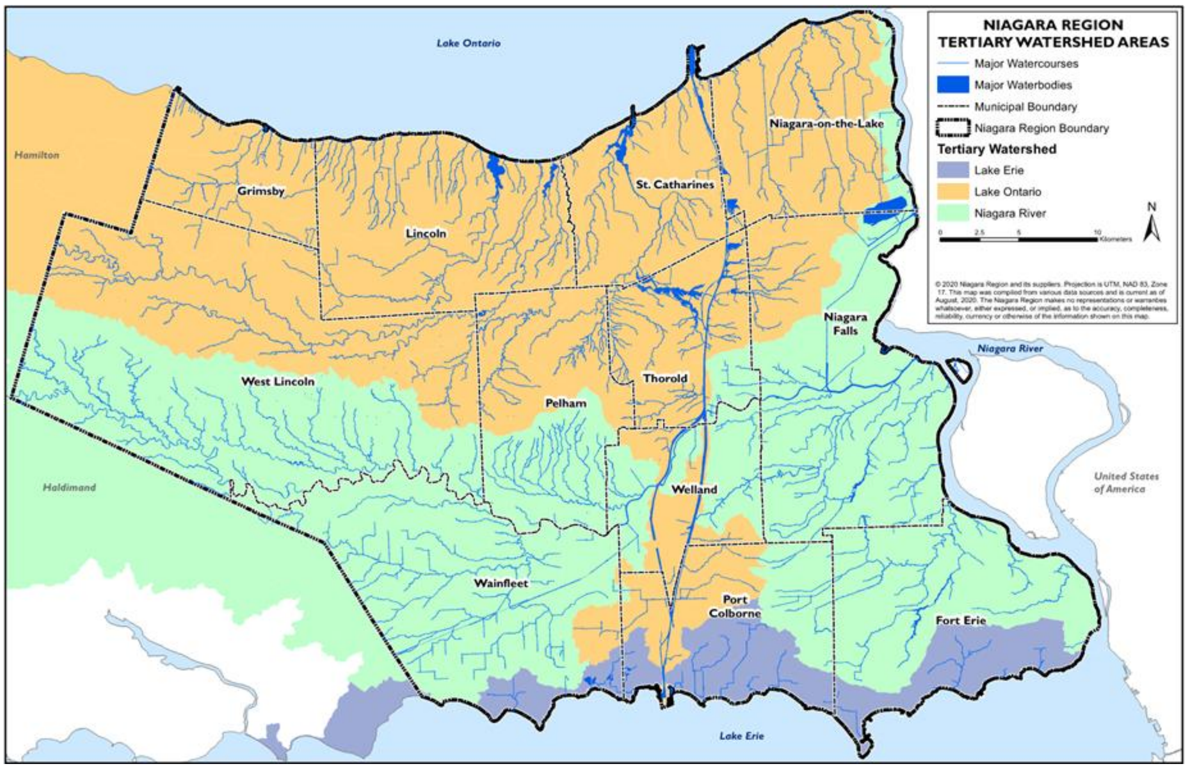


Figure 3-1. Niagara Region Tertiary Watershed Areas
(Source: Niagara Region Stormwater Management Guidelines (WSP, 2022))

In some areas, the sewer flow enters a stormwater management pond or oil and grit separator where some pollutants can settle before runoff enters a waterway. Extensive roadside ditching along both rural and semi-urban roadways and culverts help direct runoff. Collectively, the system is managed to reduce flooding and mitigate environmental impacts of pollution. The existing stormwater management system is illustrated in **Figure 3-2** and summarized in **Table 3-1**.

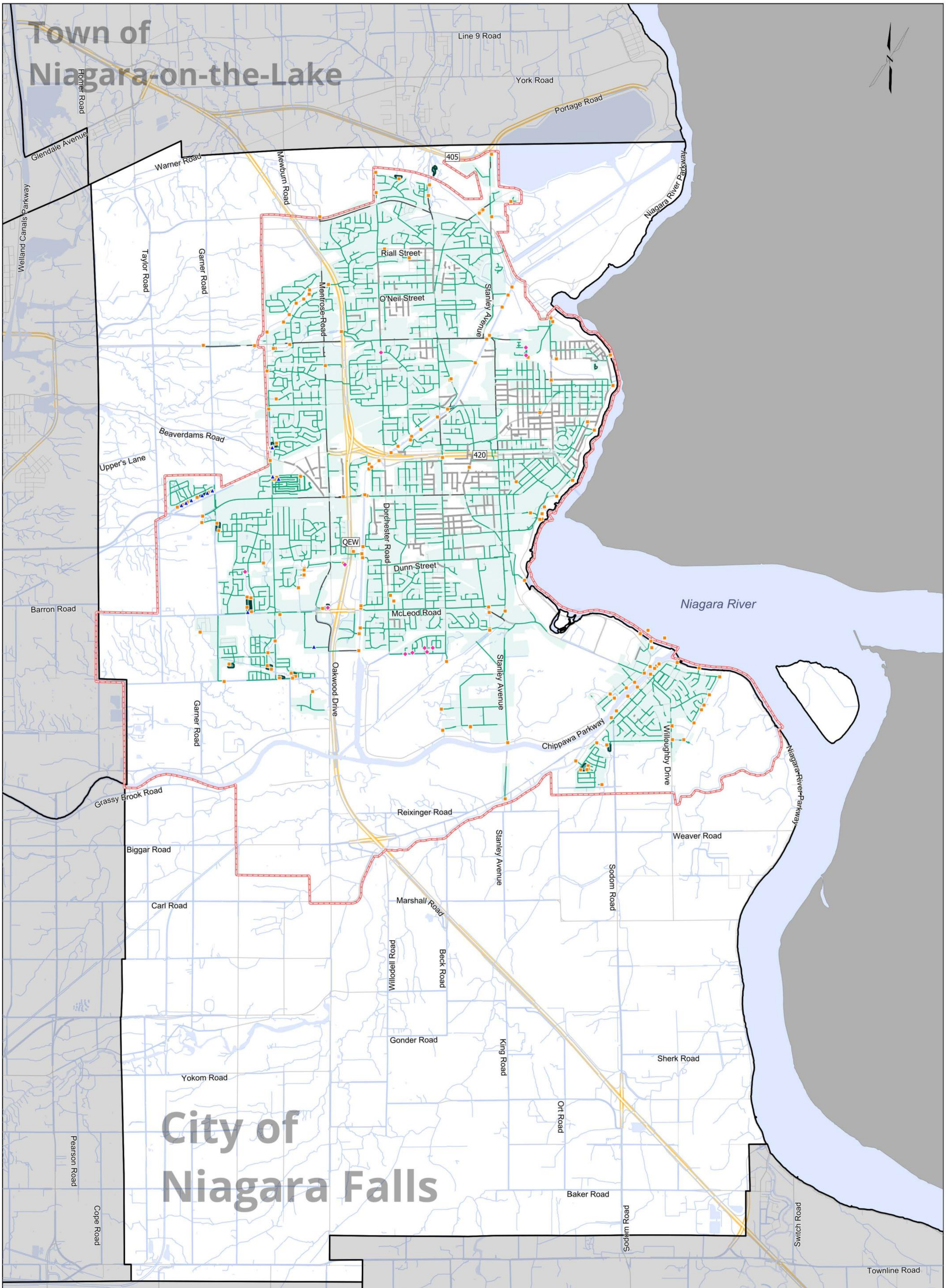
The City's stormwater management system operates under Consolidated Linear Infrastructure Environmental Compliance Approval (CLI-ECA) No. 068-S701 issued June 20, 2023.

While the stormwater system is largely separate from the sanitary sewer system, approximately 16.6% of the system remains serviced by combined sewers, in which sanitary flow and stormwater are conveyed in the same pipe. Under heavy wet weather conditions, this stormwater contributes to combined sewer overflow (CSO) risk and potential basement flooding. CSOs are evaluated under the objectives of **MECP's Procedure F-5-5: Determination of Treatment Requirements for Municipal and Private Combined and Partially Separated Sewer Systems**[1]. The City is committed to enhancing service levels, supporting future growth through both greenfield and intensification developments, and reducing CSOs to protect public health and the environment. Details on CSOs and strategies to separate the City's combined sewer network are discussed in the **Volume 4 – Wastewater Master Servicing Plan and Wet Weather Management Strategy**.

Table 3-1. City of Niagara Falls Stormwater Management System

Component	Number of Units
Storm Sewers Length (m)	316,000 m
Combined Sewers Length (m)	63,752 m
Stormwater Outfalls	136
Stormwater Management Ponds - Wet	23
Stormwater Management Ponds - Dry	4
Oil and Grit Separators	9

[1] MECP F-5-5 Website: https://www.ontario.ca/page/f-5-5-determination-treatment-requirements-municipal-and-private-combined



Stormwater Facilities
- Inlet Control Device
- Oil and Grit Separator
- Stormwater Outfalls
- Stormwater Pond

Stormwater Main
- Regional
- Municipal
- Combined Sewers

General Feature
- Urban Area Boundary
- Municipal Boundary
- Waterbody, Watercourse
- Stormwater Catchment

Reference(s)
1. Projection EPSG:26917
2. Base Data: City of Niagara Falls, 2023

1 2 km

Figure 3-2
Existing Stormwater Infrastructure

Project Name:
Master Servicing Plan and Wet Weather Management Strategy

Client Name:
City of Niagara Falls
(Ontario, Canada)

GEI Consultants Canada

Last Updated: September 2025
Document ID: 2402014-001

4. Hydraulic Stormwater Model

As part of the MSP-WWMS, a new "all-pipes" stormwater hydraulic model (PCSWMM) was developed for the City's stormwater system. The City had an existing stormwater hydraulic model (XPSWMM / InfoSWMM) which was developed as part of the City's 2017 Master Drainage Plan Study, but it was primarily a trunk sewer model, with only a small portion including all pipes. In addition, a significant number of the runoff catchments in the previous model did not have defined spatial geometry.

The model was updated to include the following City assets:

- Approximately 5,700 stormwater manhole nodes and sewer main segments.
- Culverts located within City right of ways (RoWs) and easements that support stormwater management within the City's urban boundary.
- Ditches and swales within City RoWs and easements that support stormwater management within the City's urban boundary.
- Municipally owned stormwater management facilities, where information was provided.
- Outfalls to the Niagara Peninsula Conservation Authority regulated waterbodies and Lake Ontario.
- Any streams, open channels, or additional culverts with hydraulic connection between gaps in the provided sewer network based on the Contemporary Mapping of Watercourses dataset (Niagara Peninsula Conservation Authority).

The surface drainage and hydrology were based on standard SWMM catchments. The model was calibrated to peak flow and total flow volume using data from significant rainfall events at 24 flow monitor sites. The model calibration was then used to relate to land use, network characteristics, and proximity to flow monitors to adjust any catchments that were not monitored.

Further details regarding the model update can be found in **Appendix A - Stormwater Model Methodology Technical Memo**.

5. Assessment of Existing Stormwater Infrastructure

A critical step in the master planning process is the assessment of existing infrastructure performance to establish baseline conditions for the City's stormwater system. These existing conditions form the basis for future recommendations ensuring that detailed analysis covers the full extent of the City's stormwater system. Once baseline conditions are established, the potential impacts of growth demands can be assessed to develop and recommend servicing strategies.

5.1. Existing System Performance

The existing system hydraulic performance was evaluated using the City's PCSWMM model. However, uncertainty in the accuracy of available data and the assumptions used in model development limit the reliability of results. The model development process included making the following assumptions to fill in substantial data gaps:

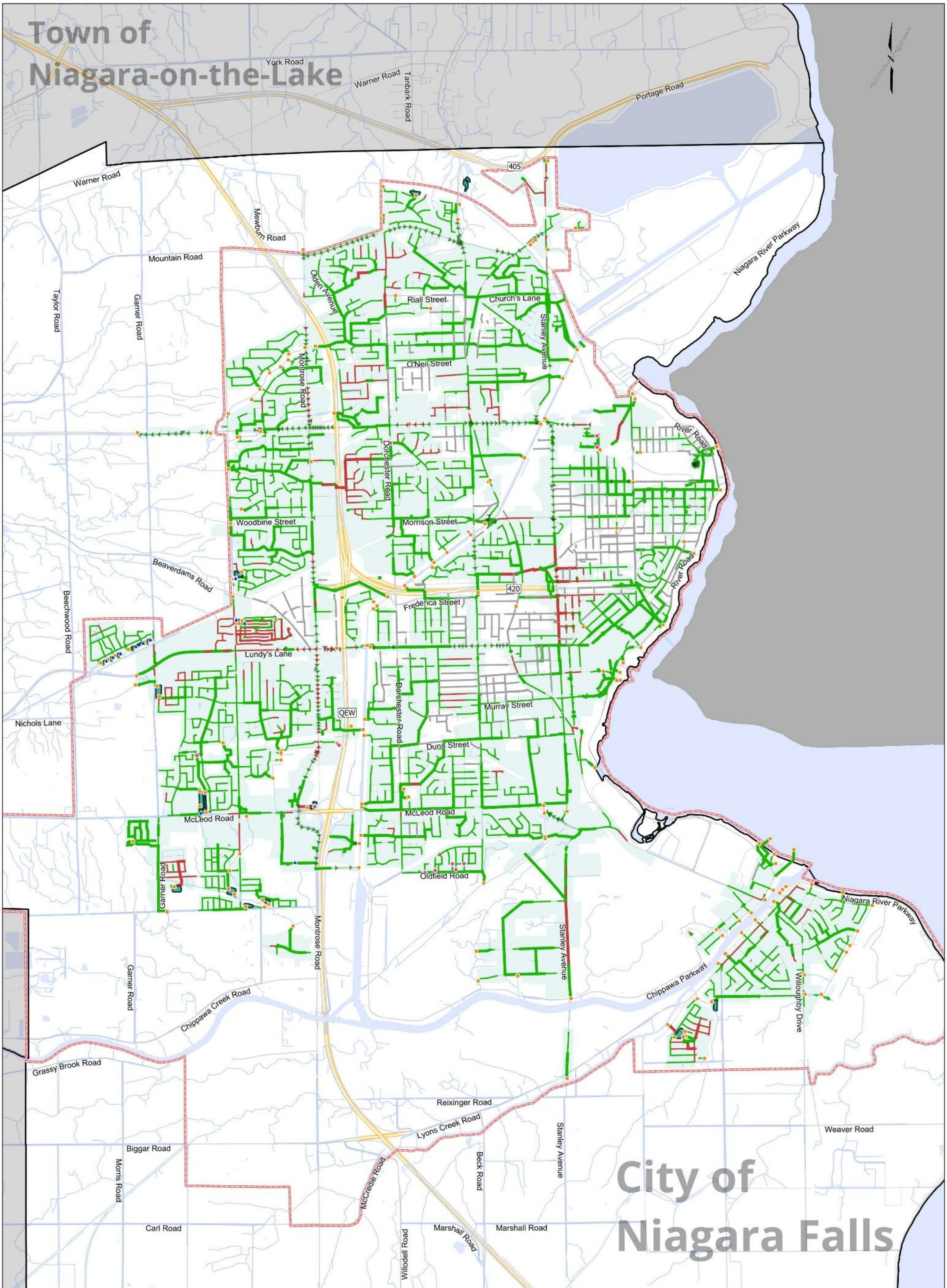
- Manhole and sewer inverts in the gravity system flow downhill
- Culverts, swales, and ditches geometry connect the stormwater system and flow downhill
- Stormwater management facility inverts adjusted to match City's GIS
- Stormwater management facility functioned as designed
- Outfalls to natural creeks, rivers, and canals modelled as free outfalls
- Applied parameters from monitored catchments to unmonitored catchments

Further details can be found in **Appendix A – Stormwater Model Methodology**.

Generally, the model shows that flooding occurs where the hydraulic grade line (HGL) exceeds rim elevation at an upstream or downstream node under the 5-year and 100-year design storms. Results are presented in **Figure 5-1** and **Figure 5-2**, and summarized in **Table 5-1**. A count of properties located along flooding storm sewer mains was also completed to estimate the proportion of properties that remain resilient to flooding under design storm conditions. Model results show that 8% of the minor system floods under the 5-year design storm and indicates that while the system generally provides adequate performance under minor storm conditions, a substantial portion of the system is vulnerable to surcharging and surface flooding under major storm conditions.

Table 5-1. Existing Stormwater System Performance

Design Storm	Flooding (Proportion to Network)	Properties Resilient to Flooding
5-Year	8%	90%
100-Year	29%	60%



Stormwater Facilities
- Inlet Control Device
- Oil and Grit Separator
- Stormwater Outfall
- Stormwater Pond

General Feature
- Urban Area Boundary
- Municipal Boundary
- Waterbody, Watercourse
- Stormwater Catchment
- Combined Sewers

Regional Sewer Performance
- Surcharging with Surface Flooding
- No Surface Flooding

Municipal Sewer Performance
- <750mm (Surcharging with Surface Flooding)
- >=750mm (Surcharging with Surface Flooding)
- <750mm (No Surface Flooding)
- >=750mm (No Surface Flooding)

Reference(s)
1. Projection EPSG:26917
2. Base Data: City of Niagara Falls, 2023

1 2 km

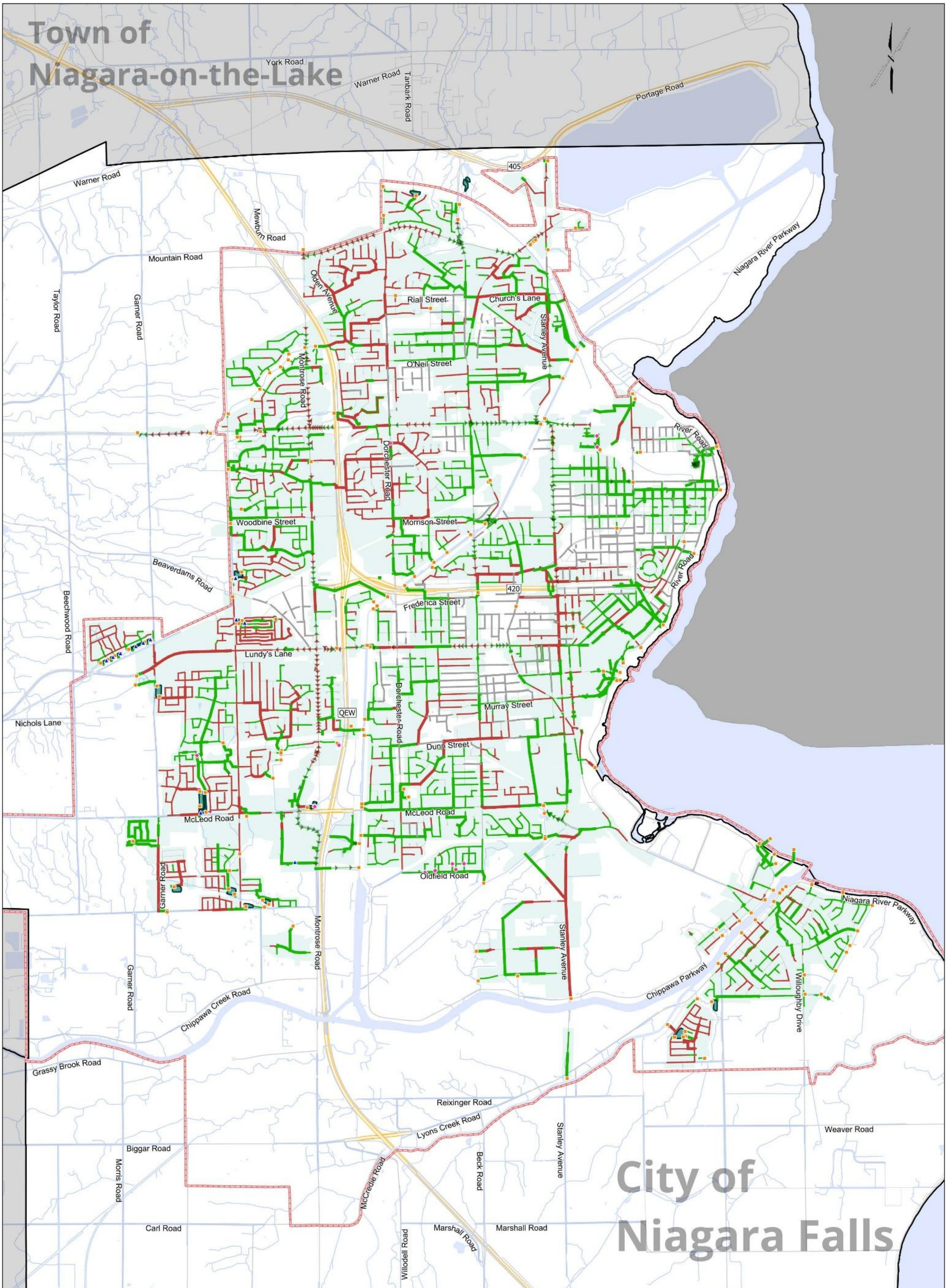
Figure 5-1
Existing System Performance under 5-Year Design Storm

Project Name:
Master Servicing Plan and Wet Weather Management Strategy

Client Name:
City of Niagara Falls
(Ontario, Canada)

GEI

Last Updated: September 2025
Document ID: 2402014-001



Stormwater Facilities
- Inlet Control Device
- Oil and Grit Separator
- Stormwater Outfall
- Stormwater Pond

General Feature
- Urban Area Boundary
- Municipal Boundary
- Waterbody, Watercourse
- Stormwater Catchment
- Combined Sewers

Regional Sewer Performance
- Surcharging with Surface Flooding
- No Surface Flooding

Municipal Sewer Performance
- <750mm (Surcharging with Surface Flooding)
- >=750mm (Surcharging with Surface Flooding)
- <750mm (No Surface Flooding)
- >=750mm (No Surface Flooding)

Reference(s)
1. Projection EPSG:26917
2. Base Data: City of Niagara Falls, 2023

1 2 km

Figure 5-2
Existing System Performance under 100-Year Design Storm

Project Name:
Master Servicing Plan and Wet Weather Management Strategy

Client Name:
City of Niagara Falls (Ontario, Canada)

GEI Consultants

Last Updated: September 2025
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6. Assessment of Future Stormwater Infrastructure

Following the evaluation of existing system performance, future growth to 2051 and ultimate buildout was assessed to understand growth impacts on the minor collection system. Together with the existing system performance results, this assessment informed the servicing strategy.

6.1. Growth Projections

To confirm appropriate projections, the growth forecast was established through planning data review and workshops with City Staff as presented in **Section 4.2** of **Volume 2** of this MSP-WWMS.

Table 6-1 summarizes the 2051 and buildout stormwater servicing area projections with growth areas shown in **Figure 6-1**. Additional details regarding growth can be found in **Volume 2**.

Table 6-1. Stormwater Catchment Area Growth Projections

Growth Horizon	Stormwater Servicing Area (ha)
Existing	3,900
2051 and Buildout	5,710

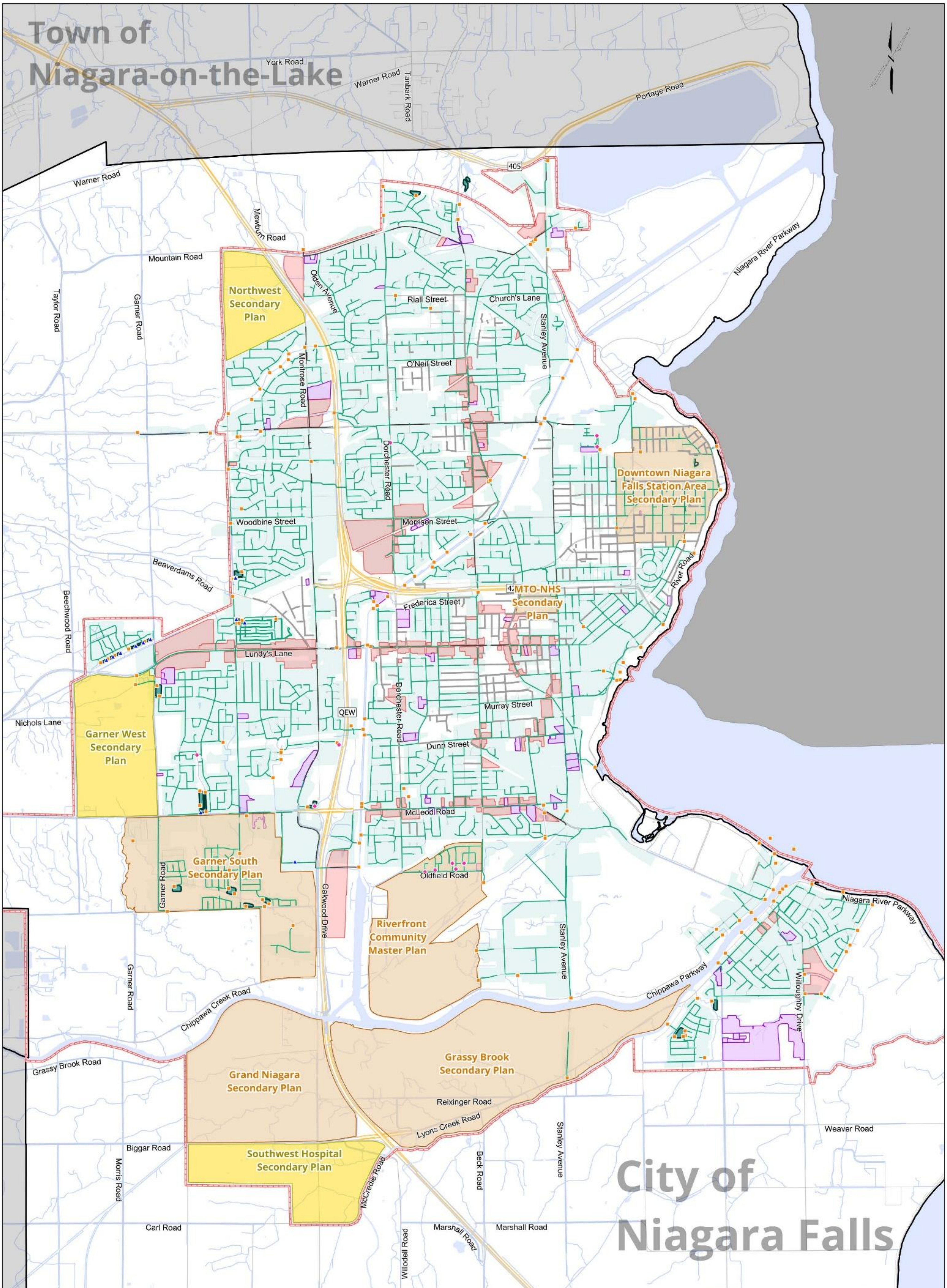
6.2. Future System Flows

6.2.1. Intensification

Within intensification areas, stormwater peak flow matching will be required, with post-development peak flows controlled to pre-development levels. Intensification areas are unique to the site development plans and may involve maintaining pre-development impervious coverage levels in post-development conditions. Alternatively, developments may utilize underground storage or Low Impact Development to manage increases in impervious coverage as required. Accordingly, in the model development, no adjustments were applied to the subcatchments to reflect growth in intensification areas.

6.2.2. Greenfield Growth

Greenfield growth areas, due to the size, scale of works, and initial conditions, are generally predominantly pervious (near 100%). Due to the naturalized pre-development conditions these lands will often require end-of-pipe stormwater management facilities. These end-of-pipe facilities will be sized to control post-development peak runoff to pre-development levels, based on planned land uses and assumed imperviousness.



Stormwater Facilities
- Inlet Control Device
- Oil and Grit Separator
- Stormwater Outfall
- Stormwater Pond

Stormwater Main
- Regional
- Municipal
- Combined Sewers

Growth Plans
- Corridor Intensification
- Existing and Active Secondary Plans
- Pending and Future Secondary Plans
- Passed Residential Development Applications

General Feature
- Urban Area Boundary
- Municipal Boundary
- Waterbody, Watercourse
- Stormwater Catchment

Reference(s)
1. Projection EPSG:26917
2. Base Data: City of Niagara Falls, 2023

1 2 km

Figure 6-1
Growth Areas

Project Name:
Master Servicing Plan and Wet Weather Management Strategy

Client Name:
City of Niagara Falls (Ontario, Canada)

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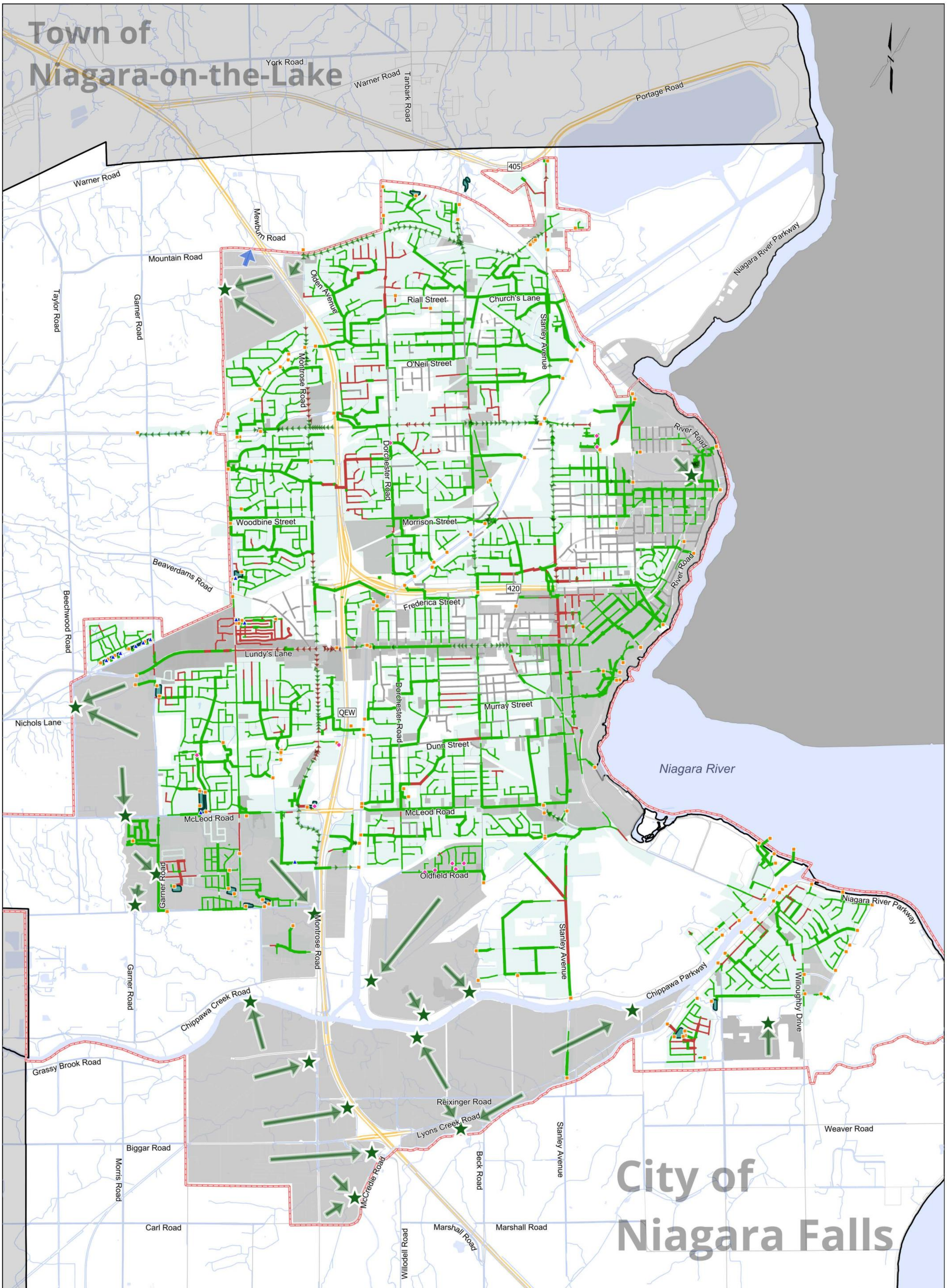
6.3. Future System Performance

The future system under climate change is expected to perform similarly to the existing system. Future IDF projections beyond 2050 may introduce greater uncertainty requiring adaptive management. Modelled system impacts under climate change scenarios based on the 2050 MTO IDF Curve (as detailed in **Appendix B – Stormwater Level of Service Technical Memo**) did not differ significantly from the existing system performance, as shown in **Figure 6-2**.

Increased flows from intensification are anticipated to be managed on-site in accordance with City stormwater policies, typically through measures such as underground storage, or LIDs. Greenfield growth will be serviced by new storm sewer mains that are independent of the existing network and therefore will not impact current system performance.



Stormwater Facilities
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General Feature
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- Waterbody, Watercourse
- Stormwater Catchment
- Growth Plans
- Combined Sewers

Regional Sewer Performance
- Surcharging with Surface Flooding
- No Surface Flooding

Municipal Sewer Performance
- <750mm (Surcharging with Surface Flooding)
- >=750mm (Surcharging with Surface Flooding)
- <750mm (No Surface Flooding)
- >=750mm (No Surface Flooding)

Future Infrastructure
- Greenfield Flow to Watercourse
- Greenfield Flow to Future Stormwater Pond
- Future Stormwater Pond

Reference(s)
1. Projection EPSG:26917
2. Base Data: City of Niagara Falls, 2023

1 2 km

Figure 6-2
Buildout System Performance under Future 5-Year Design Storm

Project Name:
Master Servicing Plan and Wet Weather Management Strategy

Client Name:
City of Niagara Falls
(Ontario, Canada)

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Last Updated: September 2025
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7. Stormwater Servicing Strategy

The Stormwater Servicing Strategy was developed under the context of identifying servicing solutions to address both system-wide and local opportunities and constraints. These solutions focus on supporting growth and identifying existing system deficiencies to form a comprehensive stormwater servicing strategy for the City.

As part of the MSP-WWMS, stormwater servicing strategies were guided by the following principles:

- Optimization of existing infrastructure to minimize the need for new assets.
- Minimization of capital cost for new infrastructure;
- Integration of long-term operations and maintenance considerations to ensure financial sustainability.
- Long-term reliability and security of the stormwater system.
- Minimization of environmental and cultural heritage impacts and disruptions,
- Planning new infrastructure within existing road rights-of-way where feasible.

The servicing plan establishes a proactive and targeted approach for managing existing and future stormwater flows in the City.

7.1. Collection System Upgrades

Existing system deficiencies resulting in a risk of surface flooding were identified and linear upgrade projects have been recommended. Intensification growth is not anticipated to increase flows to the existing system, as developers are required to match post- to pre-development flows on-site in accordance with City stormwater policies. However, recommended projects addressing existing deficiencies along intensification corridors may also provide growth-related benefits and may be eligible for Development Charges (DC) funding.

To service greenfield growth areas, new storm sewer mains and outlets are necessary. These projects will exclusively service growth and are expected to be 100% developer led.

7.2. Growth-related studies

Limitations in the quality of data used for model development constrain the level of confidence in recommendations. A key recommendation is to continue ongoing model updates as new data become available, and to update the Master Servicing Plan periodically with improved certainty.

7.3. Prioritization Strategy

Areas are prioritized based on growth needs, existing deficiencies, and the established DC timeline. This system aims to ensure that the storm system provides servicing for planned growth and addresses existing deficiencies. This prioritization strategy is outlined as follows:

1. Existing Needs and Potentially Growth Needs – Short-Term
    a. Addresses existing needs
    b. Has DC timeline assigned
    c. May be located along an intensification corridor
2. Existing Needs and Potentially Growth Needs – Medium-Term
    a. Addresses existing needs
    b. May be located along an intensification corridor
    c. Does not have DC timeline assigned
3. Existing Needs – DC
    a. Addresses existing needs
    b. Has DC timeline assigned
4. Existing Needs – Exceeds Level of Service
    a. Addresses existing needs – Freeboard ≤ 0m (Flooding to Surface)
    b. Does not have DC timeline assigned
5. Supports New Growth Areas
    a. Triggered by growth
    b. Remaining projects

In general, this prioritization can be overlayed with works proposed within each right-of-way to further optimize overall replacements and system improvements.

8. Recommended Stormwater Servicing Strategy

This section outlines the preferred capital program that addresses current and future hydraulic deficiencies, supporting forecasted growth demands, and improving overall system performance using the criteria detailed in **Section 2.2**. The recommended strategy mainly consists of linear upgrades to address existing undersized pipes based on the City's calibrated stormwater model, and to service greenfield growth. These upgrades are designed to meet the LOS objectives through to 2051 and buildout. All recommended projects are located within existing road rights-of-way or within greenfield growth areas and are therefore Schedule A or A+ Environmental Assessment type projects.

8.1. Capital Program

The Stormwater Capital Program was developed through a detailed process of infrastructure sizing and cost estimation to support long-term servicing needs. **Figure 8-1** summarizes the capital program by need. The full Stormwater Capital Program was provided to the City as an Excel file detailed by asset, road, and type. A summary of the program, by road, is provided in **Appendix C**.

The recommended projects were sized to meet growth to full buildout requirements, ensuring adequate future system capacity. Cost estimates were based on unit rates that accounted for factors such as location, construction complexity, materials handling, and whether the work involves new infrastructure or rehabilitation. Costing also incorporated development charges and OB servicing needs as outlined in **Section 2.3**.

The timelines presented in this capital program were developed with City Staff and with the consideration of the City's development charges program. The majority of the Stormwater Capital Program projects are sewer upgrades to address existing needs. The sewer projects for servicing growth are triggered by developer timelines. Unless driven by growth needs, timelines for existing system upgrades are flexible and can be adjusted to meet funding and staffing capacity availability. The Capital Program totals 27,799 m of linear sewer projects with a total of $140M. The City should continue with their SOGR program to address ongoing sewer deterioration and improve the City's overall LOS.

Table 8-1 presents the summary of the stormwater capital program timeline with the total length and costs.

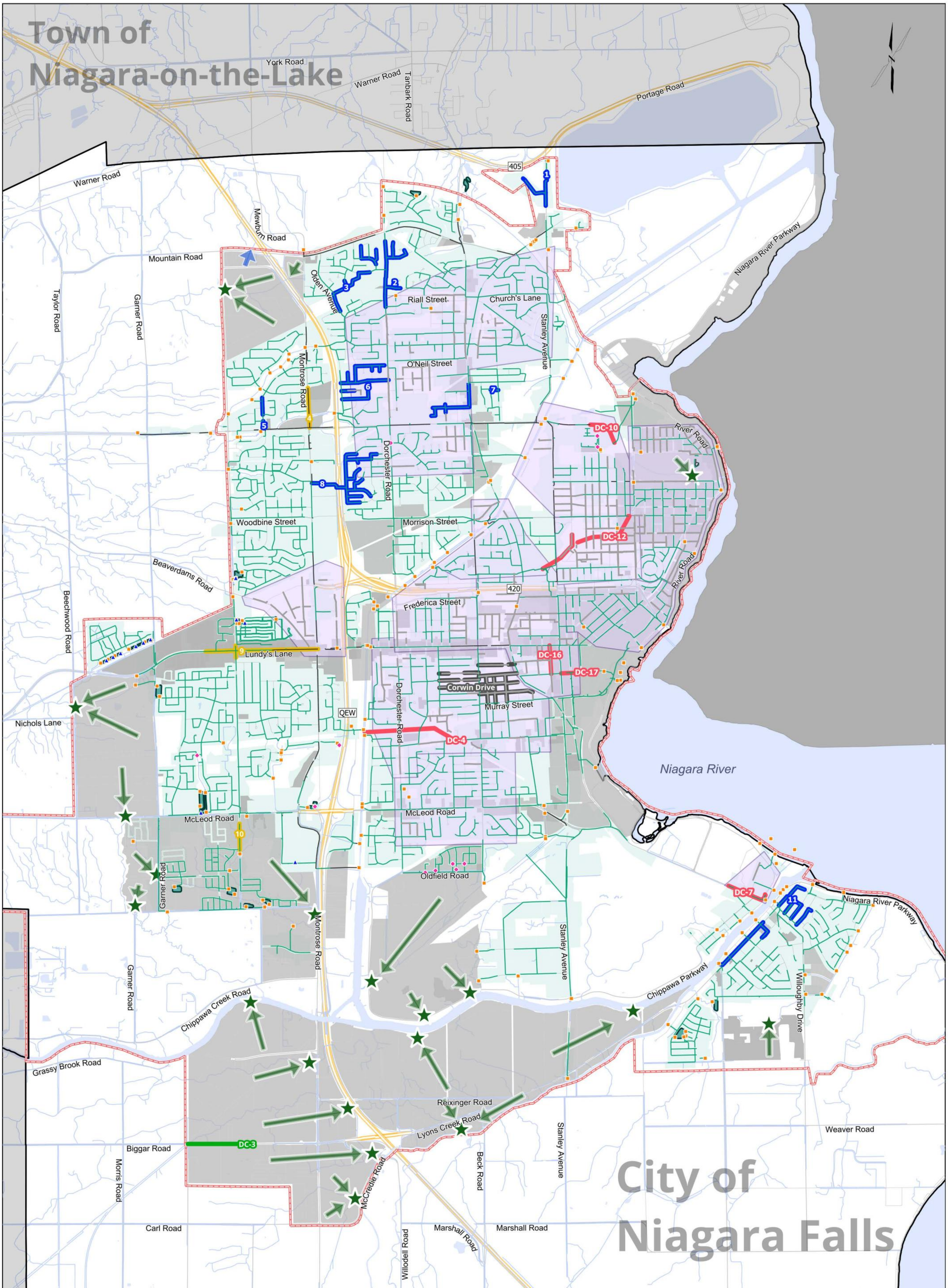
Table 8-1. Stormwater Capital Program Summary

Project Timeline	Length (m)	Total Cost	DC Cost	OB Cost	City Cost
0 - 2 years	2,290	$17,299,650	$3,981,600	-	$13,318,050
3 - 5 years	0	-	-	-	-
5 - 10 years	7,360	$61,810,950	$5,572,350	$80,000	$56,158,600
>10 years	15,649	$65,318,000	$1,156,700	-	$64,161,300
TOTAL	**25,299**	**$144,428,600**	**$10,710,650**	**$80,000**	**$133,637,950**

The Stormwater Capital Program has been categorized by the type of upgrade to maintain consistency with the City's development charges program. The categories start with addressing existing needs, followed by supporting intensification or new growth areas. Further detailed prioritization was completed for each project which ultimately split into the categories summarized in **Section 7.3. Table 8-2** presents the summary of the Stormwater Capital Program prioritization categories with the total length and costs.

Table 8-2. Stormwater Capital Program Prioritization

Prioritization Category	DC Share	Length (m)	Total Cost	DC Cost	OB Cost	City Cost
Addresses Existing Needs	0%	13,075	$54,101,000	-	-	$54,101,000
Addresses Existing Needs and Supports Growth Needs	10%	2,574	$11,567,000	$1,156,700	-	$10,410,300
Addresses Existing Needs and Supports Growth Needs	20%	3,140	$28,553,500	$5,710,700	-	$22,842,800
Addresses Existing Needs and Supports Growth Needs	50%	810	$1,738,900	$869,450	-	$869,450
Addresses Existing Needs and Supports Growth Needs	100%	700	$1,000,000	$1,000,000	-	$0
Triggered by Growth	20%	0	$2,868,000	$573,600	-	$2,294,400
Triggered by Growth	100%	850	$1,480,200	$1,400,200	$80,000	$0
Completed EA	0%	4,150	$43,120,000	-	-	$43,120,000
TOTAL		**25,299**	**$144,428,600**	**$10,710,650**	**$80,000**	**$133,637,950**



Stormwater Facilities
- Inlet Control Device
- Oil and Grit Separator
- Stormwater Outfall
- Stormwater Pond

Future Infrastructure
- Greenfield Flow to Watercourse
- Greenfield Flow to Future Stormwater Pond
- Future Stormwater Pond

CP - Linear Projects
- Existing and Short-Term Growth Needs
- Existing and Medium-Term Growth Needs
- Existing Risk: Exceeds Level of Service
- Supports/Triggered By Growth
- Completed EA
- Sewer Separation Area

Stormwater Main
- Regional
- Municipal
- Combined Sewers

General Feature
- Urban Area Boundary
- Municipal Boundary
- Waterbody, Watercourse
- Stormwater Catchment
- Growth Plans

Reference(s)
1. Projection EPSG:26917
2. Base Data: City of Niagara Falls, 2023

1 2 km

Figure 8-1
Stormwater Capital Program Infrastructure Projects

Project Name:
Master Servicing Plan and Wet Weather Management Strategy

Client Name:
City of Niagara Falls (Ontario, Canada)

GEI Consultants Canada

Last Updated: March 2026
Document ID: 2402014-001

9. Implementation and Lifecycle

The City's preferred stormwater management strategy to maintain reliable service delivery to 2051 will be achieved through a detailed implementation plan. This plan translates the recommended stormwater servicing strategy into an actionable, phased capital program with associated timelines and implementation considerations. It also provides a framework for ongoing monitoring and refinement to ensure that infrastructure delivery keeps pace with growth priorities, system conditions, and regulatory requirements.

9.1. Capital Program Implementation Plan

The stormwater infrastructure phasing and implementation strategy was developed to align the delivery of capital projects with projected growth, wet weather management, system performance requirements, and overall program coordination with road, water, and wastewater management infrastructure projects. Project timelines and design capacities may require adjustments if planning projections or other major conditions change.

The timing for each project is provided at the following planning horizons:

- 0-2 years
- 3-5 years
- 5-10 years
- 10+ years

Servicing needs were assessed to determine when infrastructure is required based on potential capacity constraints and risk factors such as overflows and basement flooding. Key factors considered in developing future phasing plans should include:

- **Servicing Dependencies**: Downstream impacts such as constraints or other servicing strategies that must be in place before a project can begin.
- **Construction Coordination**: Coordination with other City infrastructure programs such as roads, water, and wastewater.
- **Project Bundling**: Opportunities to group projects geographically or functionally to improve efficiency and minimize disruption. Not bundled with other assets – just storm?
- **Lead Time Requirements**: Recognition of regulatory approvals, property acquisition, Environmental Assessment processes, and other factors influencing project readiness. How was this incorporated in the 3 programs / project lists

This program provides a high-level baseline estimate for the City's capital budget. These costs will be further developed and refined during implementation as detailed information becomes available. During project implementation, primarily during detailed design, the following requirements should be considered:

- Refinement of infrastructure locations and alignments.
- Review and confirmation of property requirements.
- Identification of preferred construction methodologies, including review and mitigation of potential construction-related impacts (e.g., traffic, noise and vibration, dust, dewatering requirements, service disruptions, etc.).
- Assessment of installation methods (e.g., trenchless vs. open cut) for infrastructure near or crossing watercourses and valley lands.
- Completion of additional site-specific supporting investigations as required (e.g., source water protection, geotechnical, hydrogeological, topographic surveys, flood plain analysis, etc.).
- Fulfillment of all provincial, municipal and conservation authority permits and approval requirements.
- Additional engagement with First Nations communities where treaty rights may be impacted by projects.

9.2. Monitoring and Adaptive Management

The MSP WWMS provides a long-range framework for infrastructure delivery that reflects the current understanding of existing and future servicing needs. Servicing priorities are expected to evolve over time as new information becomes available, thus it is essential that assumptions supporting the plan be periodically re-evaluated.

A monitoring approach towards key technical, regulatory, and planning considerations will ensure the successful delivery of the recommended projects and alignment with evolving conditions and priorities. This monitoring approach may result in plan refinements and should consider the following:

- Technical thresholds, such as facility and system capacity through flow monitoring data and refined calibration of the sewer model. Certain facilities and areas may require more frequent monitoring based on their sensitivity to system capacity constraints or growth pressures.
- Updated growth forecasts or changes in development timing.
- Completion of detailed design, which may alter scope and/or timing of projects.
- Permitting and approvals timelines, particularly for projects with longer lead times. Monitoring will consider the status and duration of permitting processes required under applicable legislation, such as approvals from the MECP, Conservation Authorities (e.g., under Ontario Regulation 41/24), and other regulatory bodies.
- Delays or acceleration of upstream/downstream or dependent projects.
- Status of funding sources, including development charges, capital reserves, and other funding programs, to assess financial readiness for project implementation.
- Changes to regulatory requirements. The City will continue to monitor updates to federal, provincial and local policies, legislation, and technical guidelines that may influence the planning, design, or delivery of stormwater infrastructure. Where applicable, the City should

adapt implementation strategies to maintain compliance and minimize delays associated with new or evolving regulatory requirements.

9.3. Operation and Maintenance Practices

Effective operation and maintenance (O&M) practices are essential to ensure the long-term reliability, safety, and performance of the municipal stormwater management system. These strategies focus on preserving existing infrastructure, maintaining regulatory compliance, and minimizing service disruptions and risks to public health, safety, and the environment. The City's Stormwater Collection System Operations Manual describes the various practices and procedures to support these goals. For Example, the City's stormwater management pond inspection program inspects ponds annually and reports on the need for maintenance. The information from the reports can be used to develop a SWM Pond maintenance and cleanout schedule to forecast capital need.

9.4. On-going Studies

In addition to the core O&M practices, there are several studies such as the development review process, sewer model updates, and master plan studies, that may be eligible for potential development charges contribution due to their role in supporting growth and system expansion. These initiatives are instrumental to capacity management, long-term planning, and the integration of new development into the existing stormwater system.

9.4.1. Development Review Process

The development review process ensures that servicing capacity and infrastructure requirements are evaluated during the planning and approval of new developments. This process helps align growth with available system capacity and identifies where upgrades may be needed.

The City currently undertakes confirmation of system capacity needs through modelling analysis on an as needed basis. This process should be continued and further refined as required.

9.4.2. Sewer Model Updates

Regular maintenance and updates to the City's hydraulic stormwater model are essential to reflect changes in the system due to growth, infrastructure upgrades, and advances in climate change projections. Updated flow monitoring data can provide refined calibration for portions of the system. Minor updates should be undertaken every couple of years with major updates and calibration at least every five years. To support the data quality of the model, regular update and maintenance of the City's GIS database of stormwater infrastructure with as-built drawings and field surveys is essential. Basic information should be populated or confirmed for storm sewer inverts, pipe diameters, outlet inverts and configuration, and SWM pond sizing and function.

9.4.3. Master Plan Studies

The MSP WWMS provides a strategic framework for long-term infrastructure investment and policy development. This study should be updated every five years, in accordance with provincial best practices.

Appendix A Stormwater Model Methodology

Master Servicing Plan Update and Wet Weather Management Strategy

Model Methodology – Stormwater

City of Niagara Falls

Submitted to:
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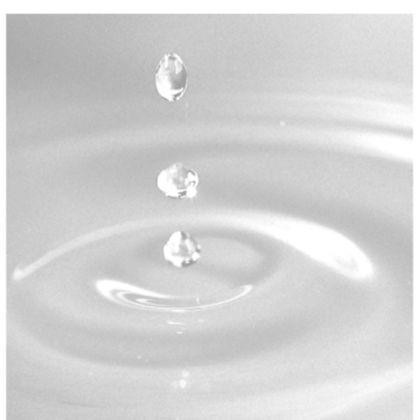
Niagara Falls, ON L2E 6X5

Submitted by:
GEI Consultants Canada Ltd.
1266 South Service Road, Unit C31
Stoney Creek, ON L8E 5R9
905-643-6688

March 11, 2026
Project No. 2402014



Mark Zamojc, P.Eng.
Vice President, Infrastructure Planning Practice Lead

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Appendices

1. Existing Stormwater System Model

The City of Niagara Falls (City) has an existing stormwater hydraulic model which was developed as part of the City's previous Master Drainage Plan Study (2017). Within the previously developed model, the majority of the City's trunk stormwater sewer network was modelled, with a few localized areas being modelled as "all-pipes". The previously developed model has approximately 2200 sewer elements with approximately 17% being smaller than 600 mm in diameter. The model was created with SWMM based runoff catchments; however, a significant number of the runoff catchments did not have a defined spatial geometry based on contours and network geometry (only area, length, and width were provided). As part of the City's ongoing Master Servicing Plan and Wet Weather Management Strategy (MSP-WWMS), a new all-pipes model was developed for the City's urban stormwater system.

1.1. Model Update Objectives

The City's project Terms of Reference (ToR) identified the following as the minimum criteria for consideration in the development/upgrade of the City's hydraulic models:

- Maintain compatibility with the Region's water and wastewater models, such that the information can be easily integrated and shared.
- Incorporate all Region owned pipes and facilities.
- Incorporate any system changes since the last updates to the models including network improvements (through replacement and rehabilitation) and additions.
- Incorporate any refinements to the model data utilizing updated network information provided by the City as a result of recent infrastructure investigation and condition assessments.
- Certain planned and committed future projects and system enhancements are known and should be incorporated into a future conditions model for evaluation in the various growth projection scenarios. While the specific timing of these projects is not fixed, the subsequent scenario analyses will provide some guidance on prioritization based on modelled impacts. These include:
    - Committed City and Region capital projects.
    - Recommended tanks and storage facilities removal and / or optimization (where appropriate).
    - South Niagara Falls Wastewater Solutions recommendations (new 30 MLD Wastewater Treatment Plant, Montrose Trunk Sewer, South Thorold, decommissioning of SPS) per Niagara Region's ongoing capital project.
    - Proposed Chippawa Trunk Sewer from the new WWTP along Lyons Creek to drain the Chippawa catchment as recommended in the most recent Region MSPU.

Further, the project ToR anticipated scope of work for all model updates includes the following key tasks:

- Utilize existing hydraulic models as a basis for the model updates to leverage effort previously undertaken to establish topology, include facilities and provide validation.
- Incorporate new system elements as provided by the City.
- Synchronize updated network attribute data as provided by the City.
- Confirm facility data including pump attributes and storage capacity.
- Confirm a wastewater flow loading procedure for the model and update all manhole flows.
- Confirm a stormwater flow loading procedure for the model and update all manhole/ catch basin flows.
- Confirm a water demand loading procedure for the model and update all node/junction demands.
- Utilize City contour data sets to attempt to determine overland flow/drainage patterns.
- Utilize orthophotography of the City to establish sub-catchment parameters such as impervious area.
- Assumptions for the hydraulic parameters are to be presented, reviewed and documented.
- Orthophotography should also be utilized to provide information on drainage features including ponds.
- Establish baseline stormwater model runs.
- Calibration of all 3 models using flow data gathered historically and throughout the study.
- Validate the results of the new existing condition models with the current model and with available system flow monitoring results.
- Confirm operational parameters for the water, wastewater, and stormwater systems and update any control settings in the model.
- Identify a future workplan to be completed as part of a separate project to enhance and calibrate the stormwater model, including an implementation plan and design for storm sewer flow monitoring, including location, software, hardware and schedule. Some recent, localized monitoring will be made available from the City following award.

1.2. Model Update Scope

Based on the City's stated modelling objectives and taking into consideration the existing state of the City's model, it was recommended the City develop a new all pipes model of the City's urban stormwater system. The previously developed storm sewer model was leverage to supplement data gaps; however, the model will be primarily built using the City's available infrastructure data.

To achieve the desired objectives, the scope of the City's stormwater model consists of:

- An all-pipes storm sewer model, which includes:
  - All City owned storm sewer mains
  - All culverts located within City right of ways (RoW) and easements that support stormwater management within the City's urban boundary
  - All City ditches within City RoW and easements, that support stormwater management within the City's urban boundary
- All City stormwater owned management facilities with provided data, including quantity control Low Impact Development (LID) systems and best management practices (BMPs) where information was provided and excluding quality control LIDs and BMPs
- All outfalls to the NPCA regulated water creeks and rivers, and Lake Ontario
- Any streams, open channels, or additional culverts that indicate hydraulic connection between gaps in the provided sewer network based on the Contemporary Mapping of Watercourses dataset

Further, the surface drainage and hydrology were based on standard SWMM catchments.

1.3. Model Limitations

It is understood that the previously developed stormwater model was built using the best available information at the time of development and completed to a scope sufficient to satisfy the City's objectives for the Master Drainage Plan Study (2017).

In developing the new PCSWMM model, the following limitations and observations are placed on the model:

- Based on the gaps identified through the development of the model and assumptions required to fill the gaps, as outlined in **Section 3**, in the following instances, the model is not recommended for use in making planning decisions without verification that the infrastructure in the subject catchment is accurate.
  - Areas where significant system upgrades are proposed,
  - Areas where the system performance is marginally (10%) above/below system capacity triggers
  - Uncalibrated areas of the system where the system is 25% above/below system capacity triggers
- Infrastructure within the model will require future verification through either up to date as-constructed drawings or field verification of inverts and infrastructure geometry.
- Private site controls may have a significant impact on the stormwater model as all private developments are currently assumed to directly connect to the municipal conveyance system.

1.4. Software Selection

Innovyze InfoSWMM was initially considered for the model development to maintain interoperability with the Region's wastewater system modelling; however, InfoSWMM does not currently have the capability to integrate a 2D surface model, with their InfoSWMM 2D option having been discontinued. As such, should the City wish to develop a 2D surface model in the future, an alternate modelling software would be required.

PCSWMM was ultimately recommended as the modelling software for the development of the City's 1D model due to the low cost of entry and industry-wide usage, based on available EPA-SWMM compatible software packages. PCSWMM is fully EPA-SWMM compatible, provided 1D and 2D functionality, and can incorporate InfoSWMM model conversions with minimal modifications.

2. Data Sources

The following outlines the data sources that were used to develop the PCSWMM stormwater model.

2.1. Sewer Network

The City's storm GIS, including storm gravity pipes and storm manholes, will be used as the basis of the network development and will be the primary sources of infrastructure geometry including diameters and inverts.

The City's existing GIS data had substantial data gaps in the manhole and sewer inverts. Data from the City's CCTV investigation was consulted to fill in data gaps in the GIS but yielded no additional information for missing invert data.

2.2. Ditch Stream Network

The City's ditch network was modelled based on the provided GIS shapefile. Further, the open license Contemporary Mapping of Watercourses developed by the Niagara Region and Niagara Peninsula Conservation Authority was used to connect the network between ditches and storm sewers where there were connectivity gaps in the City provided data.

2.3. Stormwater Management Facilities

Based on the City's 2022 Asset Management Plan, it is our understanding that the City has 26 stormwater ponds, as outlined in **Table 2-1**. The stormwater pond geometry was gathered from available facility drawings provided by the City including:

- Provided facility as constructed drawings
- Provided bathometric surveys

Table 2-1. Stormwater Management Ponds

	ID	Street	Watershed	Subdivision
1	DSP_00002	DOMENIC CR	NIAGARA-ON-THE-LAKE	Calaguiro Estates Subdivision
2	DSP_00003	FORESTVIEW BV	BEAVERDAMS AND SHRINERS CREEKS	Edgewood Estates Subdivision
3	DSP_00007	FOURTH AV	NIAGARA FALLS URBAN	
4	DSP_00008	GARNER RD	BEAVERDAMS AND SHRINERS CREEKS	Fernwood Estates Subdivision Phase Two
5	DSP_00009	GARNER RD	BEAVERDAMS AND SHRINERS CREEKS	Fernwood Estates Subdivision Phase Two
6	DSP_00010	GARNER RD	BEAVERDAMS AND SHRINERS CREEKS	Fernwood Estates Subdivision Phase Two
7	DSP_00011	GARNER RD	BEAVERDAMS AND SHRINERS CREEKS	Fernwood Estates Subdivision Phase One
8	DSP_00012	GARNER RD	BEAVERDAMS AND SHRINERS CREEKS	Fernwood Estates Subdivision Phase One
9	DSP_00026	HACKBERRY TL	NIAGARA FALLS URBAN	Warren Woods Phase Four Stage One
10	DSP_00004	KALAR RD	NIAGARA FALLS URBAN	
11	DSP_00023	KALAR RD	NIAGARA FALLS URBAN	Warren Woods Phase Three Stages One and Two
12	DSP_00006	MAGNOLIA DR	BEAVERDAMS AND SHRINERS CREEKS	Orchard Grove Subdivision Extension
13	DSP_00027	MARPIN CT		Southgate Estates
14	DSP_00016	MCLEOD RD	NIAGARA FALLS URBAN	
15	DSP_00017	MCLEOD RD	NIAGARA FALLS URBAN	
16	DSP_00018	MCLEOD RD	NIAGARA FALLS URBAN	
17	DSP_00019	MONTROSE RD	NIAGARA FALLS URBAN	
18	DSP_00030	ODELL CR		Warren Woods Phase Five
19	DSP_00013	ORCHARD GROVE PY	BEAVERDAMS AND SHRINERS CREEKS	Orchard Grove Estates Subdivision
20	DSP_00014	ORCHARD GROVE PY	BEAVERDAMS AND SHRINERS CREEKS	Orchard Grove Estates Subdivision
21	DSP_00015	ORCHARD GROVE PY	BEAVERDAMS AND SHRINERS CREEKS	Orchard Grove Estates Subdivision
22	DSP_00031	SEABISCUIT DR	BEAVERDAMS AND SHRINERS CREEKS	
23	DSP_00005	SODOM RD	SOUTH NIAGARA FALLS	
24	DSP_00020	ST PAUL AV	NIAGARA-ON-THE-LAKE	
25	DSP_00021	ST PAUL AV	NIAGARA-ON-THE-LAKE	
26	DSP_00029	TALLGRASS AVE	SOUTH NIAGARA FALLS	Chippawa West Phase Two

2.4. Flow Data

There were 24 flow monitors were installed as part of the data collection process. The collected flow monitoring data was used to calibrate the hydraulic model. Further discussion and a figure showing the placement of the 24 flow monitors as well as upstream flow monitor catchments are available in **Section 4.1.3**.

It was not possible for the flow monitoring program to provide a full spatial coverage of the City's stormwater system. Accordingly, the flow monitoring program was established with the goal of maximizing total coverage and land use types. For un-monitored catchments, parameters from equivalent monitored catchments were applied.

3. Hydraulic Model Build

3.1. Sewer Network

The sewer network was constructed by using the GIS sewer diameters and inverts. Following network construction, the stormwater network was cleaned based on the following assumptions:

- Private infrastructure or unconnected infrastructure was not modelled
- All gravity sewers flow downhill
- There are no steps (incoming inverts that are lower than outgoing inverts) in the system
- Where pipe inverts are missing, the inverts were estimated using the following process:
    - Taken from the attached node chamber floor level, or
    - Interpolated between two known invert levels
- Likewise, where node inverts are missing, the inverts were estimated using the following process:
    - Taken from the lowest attached pipe, or
    - Interpolated between two known invert levels
- If not invert information was available:
    - Sewer depth was estimated using minimum coverage depth at the upstream manhole
    - Minimum sewer depth and/slope requirements were maintained based on available topography
    - The above approach was used until inverts could appropriately tie-into know inverts at downstream/upstream locations
- Negative gradients and steps were corrected
- Conduit geometry is:
    - Circular if a single with value was provided
    - Rectangular if a width and depth values were provided
- Manning's roughness of 0.013

Table 3-1 provides a summary of previously developed model vs. the City's latest GIS noting that only 35% of the City's sewer network are included in the previously developed model.

A list of pipe inverts where data was missing and estimated or where data was adjusted due to the model assumptions is summarized in **Appendix A**.

.

Table 3-1. Stormwater Model and GIS Data Comparison

Stormwater Asset Type	Comparison Details	Existing Model	Updated GIS
Stormwater Manholes	Total number of objects	2141	5698
	Consistent objects	1978 (92% of existing model) (35% of Updated GIS)	
	Different inverts (%)	0%	
	Different rim (%)	2.6%	
Stormwater Pipes	Total number of objects	2185	5962
	Consistent objects	2038 (93%)	
	Different diameter (%)	52%	
	Different US invert (%) >=10cm	51%	
	Different DS invert (%) >=10cm	52%	

3.2. Culverts

Culverts were added to the collection using the GIS culvert diameters and inverts. The Contemporary Mapping of Watercourses also provided supplemental information of where there may be culverts that may be missing in the City dataset. The culvert data was cleaned based on the following assumptions:

- Where inverts were missing, the inverts were:
  - Interpolated between two known invert levels (if upstream and downstream culvert inverts were available), or
  - Existing ground elevation minus culvert diameter and 0.3 m cover allowance
- Geometry was:
  - Circular if a single with value was provided
  - Rectangular if a width and depth values were provided
- Manning's roughness of
  - Smooth walled pipes 0.013
  - Corrugated Steel pipes 0.024
  - All other material (including unknown) 0.025
- Exit and entrance loss coefficient of 1.0

3.3. Swales and Ditches

Ditch and swale geometry was created through a combination of:

- City provided ditches in GIS
- Utilization of the NPCA Contemporary Mapping of Watercourses dataset
- System topology gaps filled through interpolating ditch alignments between known culvert, sewer, and outfall locations

Ditch and swale geometry was interpolated based on culvert geometry and windscreen survey. Generally, the conveyance capacity of ditches and swales are limited by the culverts. As such, the following conservative methodology was used to estimate channel geometry:

- Shape = Trapezoid
- Upstream & Downstream Inverts = matching culvert inverts
- Base Width = 2m
- Side Slopes = 2H:1V
- Depth = 1m
- Manning's roughness of 0.035

The above methodology does not account for the potential storage volume present within larger ditches.

3.4. Stormwater Facilities

Stormwater management facilities were modelled as storage objects in the model based on existing facility drawings and reports provided by the City.

3.5. Stormwater Outfalls

All outfalls to natural creeks, the Welland River, Niagara River, and the Hydro Canal were modelled as free outfalls.

3.6. Hydrology

3.6.1. Catchment Delineation

The City's parcel fabric was provided which includes land use and property size for properties. A combination of topographic contour and the Parcel fabric was utilized to support the delineation of individual sewer catchments. Catchments outside of the City boundaries which may contribute to the City's system were developed with general catchment boundaries delineated using topographic contours.

3.6.2. Impervious Coverage

Impervious coverage was estimated using orthophotography and the infrared band, as shown in **Figure** 3-1.

Figure 3-1. Impervious Coverage Results - Example

3.7. Incorporation of Growth Areas

3.7.1. Intensification

Within intensification areas, stormwater peak flowrates matching will be required, controlling peak flows from post development to pre-development conditions. Intensification areas are unique to the site development plans and may consist of matching post-development impervious coverage to pre-development impervious coverage. Alternatively, developments may utilize underground storage or Low Impact Development to manage increases in impervious coverage as required. Accordingly, in the model build and development, no adjustments have been made to the subcatchments to account for growth in intensification areas.

3.7.2. Greenfield Growth

Greenfield growth areas, due to the size, scale of works, and initial conditions, are generally 100% or near 100% pervious coverage. Due to the more naturalized pre-development conditions generally seen in greenfield growth areas, these lands will often require end-of-pipe stormwater management facilities. These end-of-pipe facilities will be sized to manage peak runoff to pre-development conditions based on the anticipated land uses and assumed impervious coverage in-line with the planned land use.

4. Model Calibration Criteria

4.1. Calibration Criteria

The goal of model calibration is to adjust various attributes within the model, allowing modeled flow to resemble observed flow more closely at each monitor. A total of 24 flow monitors were installed to collect flow data at various points of the Niagara Falls stormwater network. The calibration process was completed for both wastewater and stormwater models. The stormwater model calibration methodology is documented below.

4.1.1. Calibration Philosophy

For each flow monitor site, observed flow data were compared to modelled results for all three calibration events using the following criteria from the CIWEM Urban Drainage Group Code of Practice (2017):

- Timing of peaks and troughs for flow, depth, and velocity should be within ± 0.5 hour (between modelled and observed hydrographs) with respect to the duration of the event and timing of rainfall.
- Peak flow rates at each significant peak should be between the range +25% to -15%.
- Total volume of flow should be within the range +20% to -10%.

Following selection of the rainfall events, rain gauges were assigned to each flow monitor based on proximity of the specific catchment centroid to the nearest rain gauge. Upon initial review of the modeled rainfall against the observed flows, the timing of the peaks between the theoretical and observed data was aligned; however, the peak flowrates observed were higher than the modeled peak flowrates.

Initial baseline catchment parameters were determined through orthophotography and the infrared bad as noted in **Section 3.6.2**. **Table 4-1** provides a summary of the catchment parameters developed through the calibration process and the upper and lower limits for calibration parameters. The model calibration process focused on adjusting these hydrologic parameters and routing rules.

Table 4-1. Parameter Values

Parameter	Lower Limit	Upper Limit
Ratio of Flow Length to Width (L:W)	3.34 : 1	6:26 : 1
Slope (%)	0.33 %	0.57 %
Impervious %	0 -100 % Based on Orthophotography	
N Impervious Area	0.15	
N Pervious Area	0.25	
DStore Impervious (mm)	1.5 mm	
DStore Pervious (mm)	4 mm	
Zero Imperv (%)	25 %	
Subarea Routing %	25 %	100 %
Horton's Max Infiltration Rate (mm/hr)	16.5 mm/hr	
Horton's Min Infiltration Rate (mm/hr)	12.7 mm/hr	
Horton's Decay Constant (1/hr)	3	

4.1.2. Calibration Rainfall Event Selection

Real life rainfall events with sufficient intensity and volume were identified as a point of reference for model calibration. These events generated enough rainfall-derived flow response in the stormwater system to allow their corresponding rainfall data to be used within the model. Within the scope of the rainfall event selection, GEI defined a significant event as an event with enough precipitation and intensity that result in a stressed response to the sewer system providing sufficient information to be used to evaluate capacity and performance of the systems as well as extrapolate design storm level responses. For the City of Niagara Falls, based on the collected flow monitoring data, these significant events were selected as events with a total depth of at least 15mm and a peak 1-hour intensity of 5mm/hr. **Table 4-2** provides a summary of the two selected "significant" rainfall events based on the above criteria which were used in the model calibration. The two events were selected based on relative rainfall across the rain gauges during these events and meeting the above depth and intensity criteria.

Table 4-2. Significant Event Summary

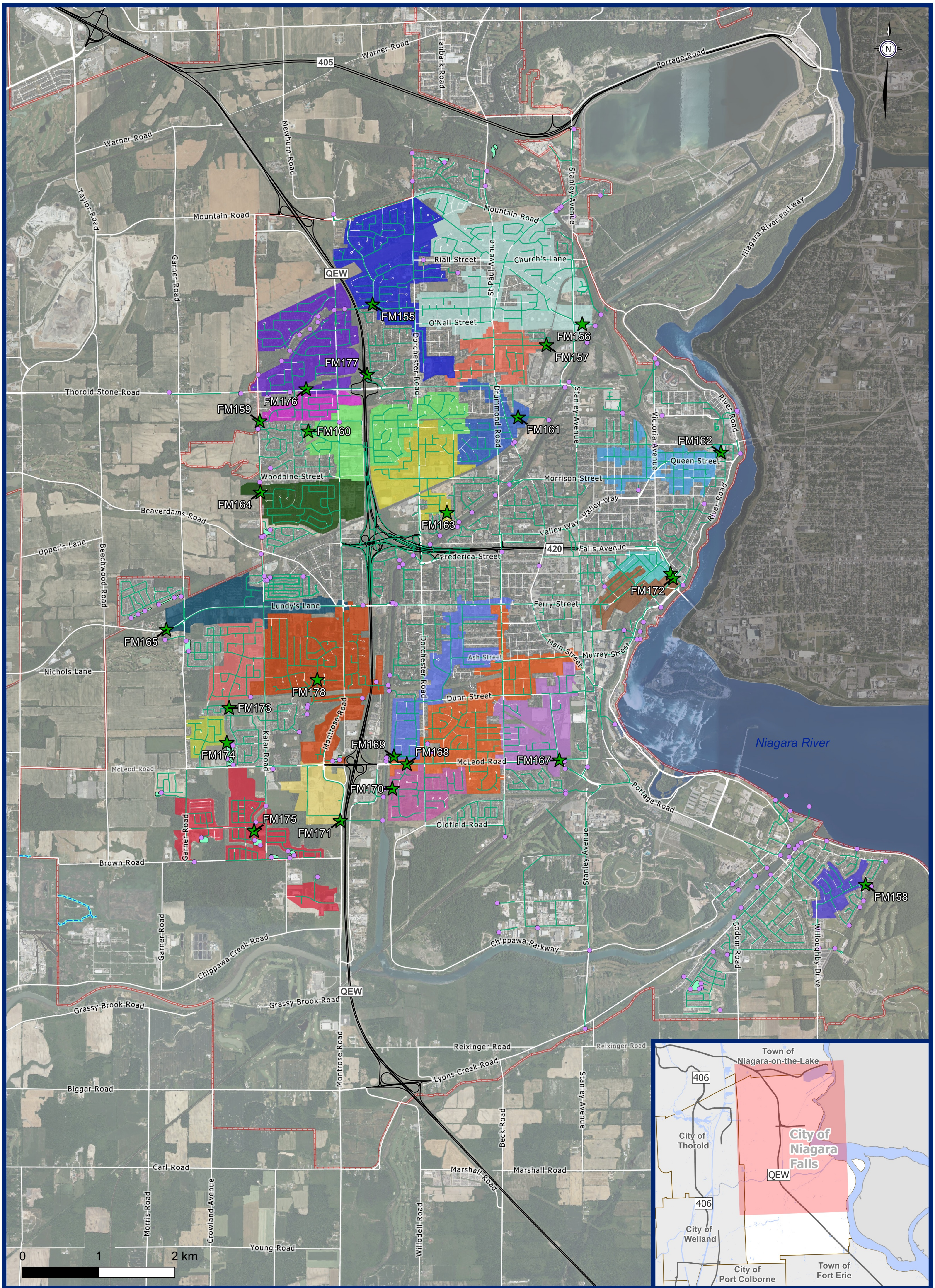
Start of Rain	End of Rain	Total Depth (mm)	Peak 1-hr (mm/hr)
2023/07/20 17:45	2023/07/29 13:20	113	25
2023/09/06 21:30	2023/09/07 5:40	31	20

4.1.3. Flow Monitor Selection

Through consultation with the City, 24 flow monitor locations were selected in order to adequately characterize the system and calibrate the model. **Table 4-3** provides a summary of the flow monitor IDs and associated characteristics of the installation location (MH and flow direction). Flow monitors were collecting data roughly between 2023/05/13 and 2023/11/21 with a slightly staggered installation timeline and brief data gaps for specific flow monitors based on maintenance requirements. **Figure 4-1** visually depicts the flow monitor locations within the storm sewer network along with the colour-coded upstream catchments associated with each flow monitor.

Table 4-3. Summary of Flow Monitor Locations

FM ID	Name	Catchment Area (ha)	GIS Diameter (mm)	Pipe ID	Land Use
FM155	Harte	171	2100	DGM_02029	Residential
FM156	Stanley E	254	2100	DGM_03313	50% Residential, 50% Industrial
FM157	Keith	59	1200	DGM_03312	50% Residential, 50% Commercial
FM158	Cattell	31	1200	DGM_02901	Residential
FM159	Kalar	32	1500	DGM_00371	75% Residential, 25% Industrial
FM160	Alpine	122	1800	DGM_03615	50% Residential, 50% Commercial
FM161	Portage E	56	1350	DGM_04273	50% Residential, 50% Commercial
FM162	Park	69	2100	DGM_03142	50% Residential, 50% Commercial
FM163	Dawson	89	1650	DGM_01768	50% Residential, 50% Commercial
FM164	Lexington	79	1800	DGM_03539	Residential
FM165	Lundy	79	1350	DGM_02441	50% Residential, 50% Commercial
FM166	Bender (formerly rainbow)	21	1200	DGM_00557	50% Residential, 50% Commercial
FM167	McLeod	96	2100	DGM_04694	Residential
FM168	McLeod	165	1500	DGM_01542	Residential
FM169	Ann	92	1500	DGM_02597	50% Residential, 50% Commercial
FM170	Redhaven	58	1500	DGM_02556	Residential
FM171	Montrose	47	1650	DGM_02015	Commercial
FM172	Falls	37	1500	DGM_05543	Commercial
FM173	Parkside	58	1500	DGM_04773	Residential
FM174	McGarry	20	1050	DGM_00254	Residential
FM175	Warren	118	1350	DGM_04899	Residential
FM176	Don Murie	132	1500	DGM_02058	Residential
FM177	Greenwood	-	1200	DGM_02892	Residential
FM178	Charnwood	191	1500	DGM_04708	Residential



Existing Infrastrucutre
- Stormwater Outfalls
- Stormwater Main
- Stormwater Flow Monitor (FM)

General Features
- Urban Area Boundary
- Waterbody

Stormwater FM Subcatchment
FM155, FM156, FM157, FM158, FM159, FM160, FM161, FM162, FM163, FM164, FM165, FM166, FM167, FM168, FM169, FM170, FM171, FM172, FM173, FM174, FM175, FM176, FM178

Niagara Falls Master Servicing Plan and Wet Weather Management Strategy

Figure 4-1
Summary of Rain Gauge Locations and Associated Catchments

GEI Consultants

June, 2024
622071-SW-003
Projection EPSG:2958

4.1.4. Calibration Results

As noted in **Section 4.1.1**, the CIWEM Urban Drainage Group Code of Practice (2017) criteria was used to calibrate the model. The overall calibration results and error percentages between observed and modeled data for the July 20, 2023 to July 29, 2023 storm event is compiled in **Table 4-4**. The July 20, 2023 to July 29, 2023 storm event has been split into two separate storm events for discussion, as there are two separate peaks which occur on July 24, 2023 and July 27, 2023.

The green highlighted cells in **Table 4-4** indicate that the flow monitor was able to be calibrated to meet the CIWEM Urban Drainage Group Code of Practice (2017) per **Section 4.1.1** for the specified storm event. It was not possible for all flow monitors and catchments to meet the CIWEM criteria, which may be due to multiple factors including:

- Discrepancies in rainfall based on the proximity of the catchment centroid from the assigned rain gauge.
- Assumptions and discrepancies in the modelled pipe network development due to missing or assumed data and the assumptions used to build the model from **Section 3**.
- Potential unknown on-site controls for private developments.

Table 4-4. Flow Monitor Calibration Results Peak Flow Error

Flow Monitor	July 24, 2023			July 27, 2023		
	Modeled Flowrate (Calibrated) (m3/s)	Observed Flowrate (m3/s)	Percent Error (%)	Modeled Flowrate (Calibrated) (m3/s)	Observed Flowrate (m3/s)	Percent Error (%)
FM155	3.41	5.35	-36%	6.87	3.62	90%
FM156	3.50	4.61	-24%	6.88	4.04	70%
FM157	1.10	1.20	-9%	2.05	1.14	80%
FM158	0.23	0.21	8%	0.23	0.24	-4%
FM159	0.49	0.51	-4%	0.94	0.80	17%
FM160	1.71	2.10	-19%	3.96	2.12	87%
FM161	0.62	0.70	-12%	1.27	0.67	89%
FM162	1.52	1.16	31%	2.32	2.38	-2%
FM163	2.00	2.43	-18%	3.36	2.21	52%
FM164	0.78	1.27	-38%	2.23	1.21	84%
FM165	1.45	2.46	-41%	3.50	1.92	82%
FM166	1.05	1.23	-15%	1.57	1.37	14%
FM167	3.45	4.06	-15%	3.41	3.30	3%
FM168	3.08	2.82	9%	3.31	3.35	-1%
FM169	1.57	1.49	5%	1.72	1.59	8%
FM170	1.47	1.16	27%	1.41	1.45	-3%
FM171	2.43	2.98	-18%	2.83	3.10	-9%
FM172	1.47	1.17	26%	2.23	2.35	-5%
FM173	1.19	0.81	46%	1.12	0.76	48%
FM174	0.95	0.97	-2%	0.91	0.83	9%
FM175	0.77	0.13	484%	0.72	0.68	6%
FM176	0.30	0.07	317%	0.44	0.19	136%
FM177[1]	0.34	-	-	0.31	-	-
FM178	1.82	1.59	14%	1.60	1.82	-12%

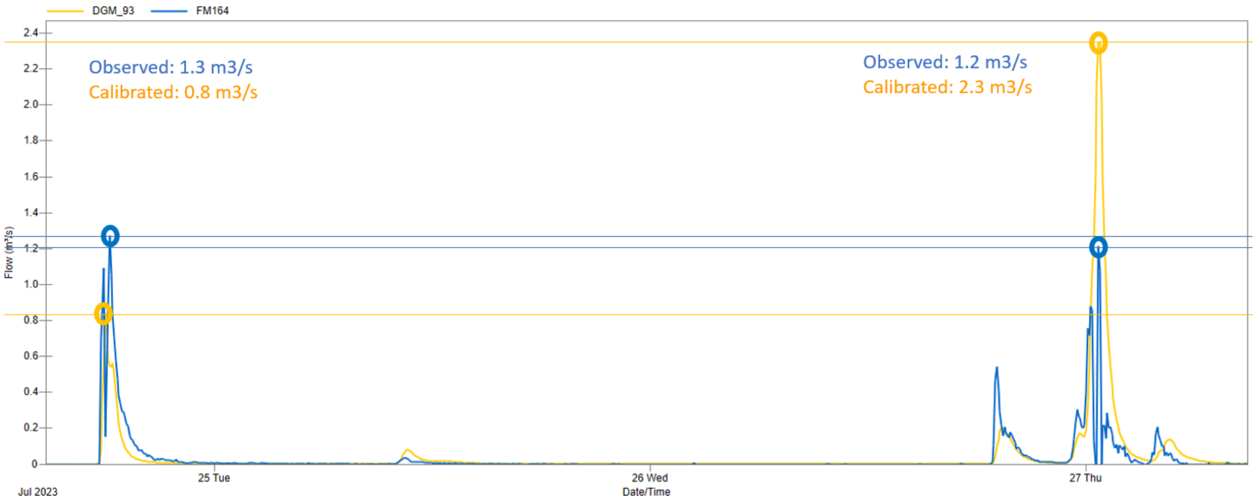
Notes:
1. FM177 had inadequate observed data to perform calibration process

The following is a listing of the scenarios in which catchment and flow monitors could not be calibrated within the CIWEM criteria.

Scenario 1: Opposite Peaks

In the July 20, 2023 to July 27, 2023 scenario, which captures multiple peaks across one storm event (July 24 & July 27), there are some instances where the observed data (blue) has a higher July 24 peak than the modeled data (yellow); however, the similarly sized July 27 peak is for the observed (blue) data is less than the modeled (yellow) data. An example of this is outlined in **Figure 4-2** for flow monitor FM164. It is not possible to adequately calibrate flow monitors under these conditions as the calibration parameters applied to the modeled data either raise or lower both event peaks.

Figure 4-2. FM164 Observed Flow (Blue) and Modeled Flow (Yellow) Comparison



This scenario is true for the following flow monitor locations:

- FM155
  - Model underestimates July 24 event
  - Model overestimates July 27 event (higher modeled peak of two events)
- FM156
  - Model underestimates July 24 event
  - Model overestimates July 27 event (higher modeled peak of two events)
- FM157
  - Calibration for July 24 event is within acceptable range
  - Model overestimates July 27 event
- FM160
  - Calibration for July 24 event is within 4% error of acceptable range
  - Model overestimates July 27 event
- FM161
  - Calibration for July 24 event is within acceptable range
  - Model overestimates July 27 event
- FM163
  - Calibration for July 24 event is within 3% error of acceptable range
  - Model overestimates July 27 event

- FM164
  - Model underestimates July 24 event
  - Model overestimates July 27 event (higher modeled peak of two events)
- FM165
  - Model underestimates July 24 event
  - Model overestimates July 27 event (higher modeled peak of two events)

Scenario 2: July 27 Event Adequately Calibrated

There are multiple instances where the July 27, 2023 event was calibrated within the CIWEM criteria requirements; however, the smaller peak July 24, 2023 event was outside of the CIWEM criteria. As these catchments could only be adequately calibrated to one of the two events, these were specifically calibrated to the July 27 event as it had the higher peak observed data. An example of this is outlined in **Figure 4-3** for flow monitor FM162.

Figure 4-3. FM162 Observed Flow (Blue) and Modeled Flow (Yellow) Comparison

This scenario is true for the following flow monitor locations:

- FM162
  - Calibration for July 24 event is within 6% error of acceptable range
- FM170
  - Calibration for July 24 event is within 2% error of acceptable range
- FM171
  - Calibration for July 24 event is within 3% error of acceptable range
- FM172
  - Calibration for July 24 event is within 1% error of acceptable range

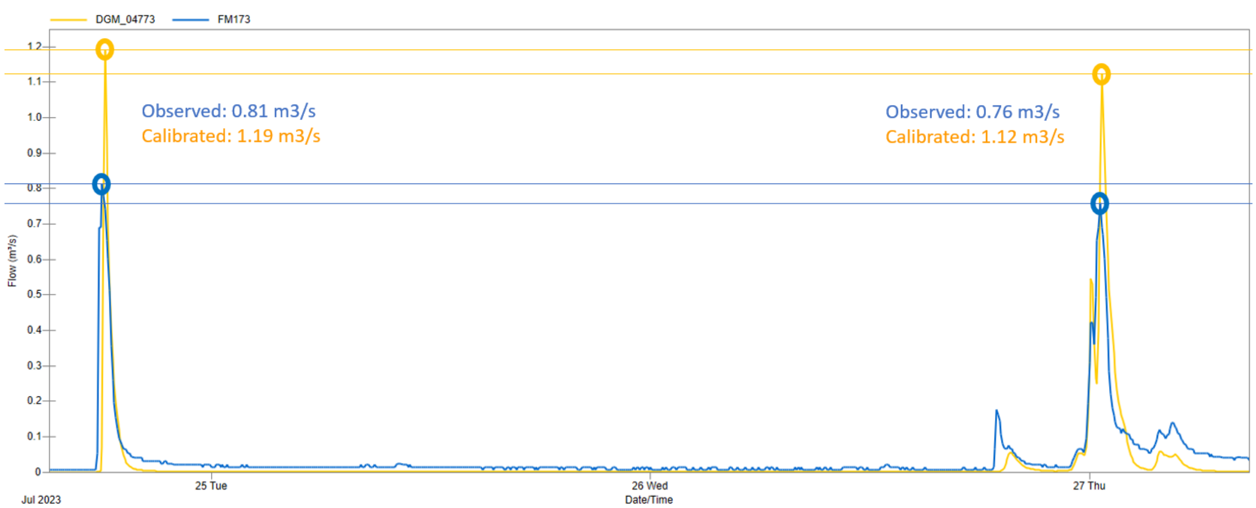
Scenario 3: Observed Lower Than Calibrated – FM173 & FM 176

The calibrated values for FM173 for both the July 24 and July 27 events have approximately 50% error in peak flowrate when compared against the observed peak flowrate as seen in **Figure 4-4**. During the calibration, the parameters were adjusted to the upper/lower limits within reason and peak flow matching was not possible. This indicates an issue with the model build, most likely in either inaccurate underground infrastructure/connectivity or inaccurate catchment delineation. FM176 exhibited similar issues with the ability to match observed and calibrated flows; however, the observed flows were between 1/3 to 1/2 the peak flowrates of the calibrated flows indicating more significant error thresholds.

The following is a brief list of potential error sources which may lead to the lower observed peak flowrates:

- Upstream flow splits – there are multiple flow splits within the upstream catchment which may have inaccurate initial/input data which may lead to an increased modeled peak flow estimate.
- Contributing subcatchments – As subcatchments were developed based on a combination of parcel mapping and elevation data, there is a possibility that some subcatchments may be overcontributing to the collection system based on conservative model build assumptions.
- Unknown private-side controls – The observed data has lower peak flowrates with a slightly elongated release which is indicative of private-side flow controls managing peak flowrates.

Figure 4-4. FM173 Observed Flow (Blue) and Modeled Flow (Yellow) Comparison



Scenario 4: July 24, 2023 Event Minimal Observed Flow – FM175

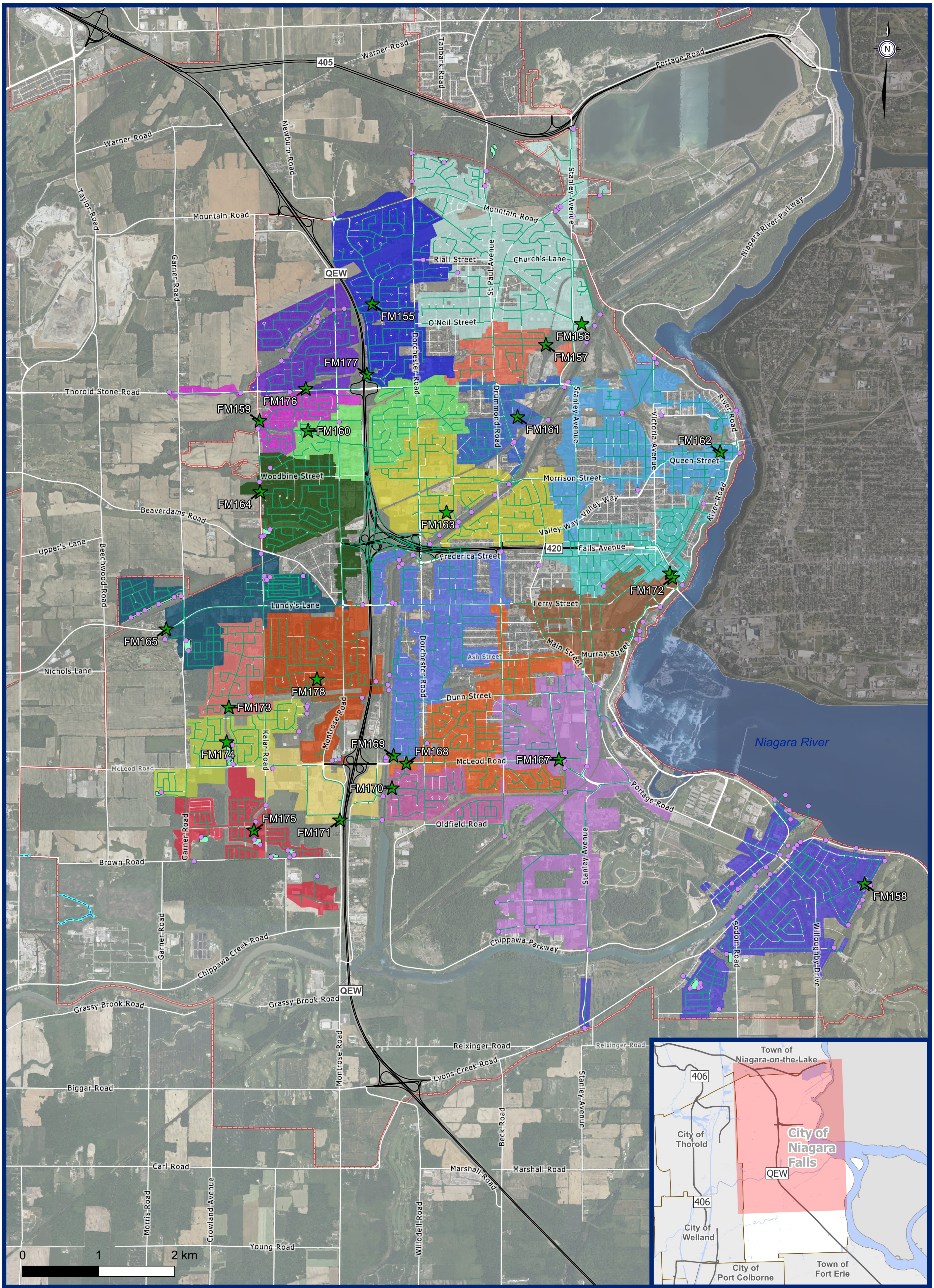
The calibrated value for the July 27, 2023 event falls within the acceptable CIWEM criteria; however, the observed peak flowrate for the July 24, 2023 is significantly smaller than the modeled peak flow rate, as seen in **Figure 4-5**. FM175 was installed upstream of the Warren Woods stormwater management facility which discharges to Warren Creek. During the flow monitoring period there were active land development construction activities between McLeod Road and Elderberry Drive, which are upstream of FM175. Based on aerial imagery, there appears to be an on-site storm facility within the active development which accounts for almost 50% of the tributary land area to FM175. There are a few possible reasons why the observed peak flow rate at FM175 for the July 24 are much lower than the July 27 observed peak flowrate while the modeled peak flowrates approximately match up, including:

- Flow monitor error – there is a possibility that the flow monitor experienced an obstruction or error during recording of the initial July 24 storm event.
- Development storage – there is a possibility that the on-site stormwater management facility at the active development held back stormwater during the first July 24 storm event but was at capacity during the July 27 storm event at which time overflows would have been directed to the flow monitor.

Figure 4-5. FM175 Observed Flow (Blue) and Modeled Flow (Yellow) Comparison

4.1.5. Calibrated Parameter Translation to Unmonitored Catchments

Overall, this process resulted in 24 catchments and associated flow monitors with calibration parameters applied across contributing subcatchments. All catchments that were not a part of the flow monitored catchments were then adjusted following calibration to match percent changes to these values based on the catchment make-up (land use), network make up, and proximity to nearby flow monitors. **Figure 4-6** provides a visual depiction of all subcatchments and the associated flow monitor in which parameters were aligned.



Existing Infrastrucutre

- Stormwater Outfalls
- Stormwater Main
- Stormwater Flow Monitor (FM)

General Features

- Urban Area Boundary
- Waterbody

Stormwater FM Subcatchment

FM155, FM156, FM157, FM158, FM159, FM160, FM161, FM162, FM163, FM164, FM165, FM166, FM167, FM168, FM169, FM170, FM171, FM172, FM173, FM174, FM175, FM176, FM178

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Figure 4-6

Stormwater Catchments Including Associated Flow Monitor Parameter Mapping

GEI Consultants

June, 2024
622071-SW-003
Projection EPSG:2958

Appendix A Sewer Network Model Assumptions

	CITY GIS			PCSWMM MODEL		
PIPE ID	**SIZE (mm)**	**US INV ELE**	**DS INV ELE**	**SIZE (m)**	**US INV ELE**	**DS INV ELE**
C1				2.4	183.428	183.394
C10				2.4	178.317	178.288
C11				2.4	183.626	183.625
C12				2.4	176.122	176.095
C13				2.4	176.095	176.08
C14				2.4	183.492	183.49
C15				2.4	181.871	180.495
C16				2.4	183.522	183.492
C17				2.4	176.507	176.4
C18				2.4	176.4	176.385
C19				1.8	180.32	180.303
C2				2.4	184.354	184.348
C20				0.6	173.44	173.427
C21				2.4	182.58	182.577
C22				2.4	183.604	182.577
C23				2.4	182.577	182.572
C24				0.525	181.08	180.267
C25				2.4	184.418	184.4
C26				2.4	184.4	184.395
C27				2.4	180.524	180.52
C28				2.4	178.288	178.276
C29				2.4	183.585	183.539
C3				0.675	184.692	184.69
C30				2.4	183.611	183.594
C31				2.4	183.534	183.531
C32				2.4	183.531	183.522
C33				2.4	183.539	183.534
C34				2.4	183.625	183.611
C35				2.4	183.594	183.585
C36				2.4	183.634	183.626
C37				1	183.49	183.488
C38				2.4	183.712	183.604
C39				2.4	183.607	183.604
C4				0.15	173	173.5
C40				0.2	187.55	187.5
C41				1	179.644	177.91
C42				1.65	180.586	180.569
C43				1	171.45	171.439
C44				0.525	173.99	173.735
C45				1.35	176.123	176.122
C46				0.375	189.425	189.402
C47				0.45	171.749	171.72
C48				0.3	174.401	174.239
C49				0.6	173.72	173.52
C5				1.4	175.982	175.981
C50				0.9	169.917	169.912
C51				0.25	184.45	185.25
C52				1	184.7	184.75
C53				0.8	180.55	180.9
C54				0.25	189.84	189.81
C55				0.2	189.71	0
C56				0.2	0	189.863
C57				0.125	183.93	183.78
C58				0.1	184.02	183.86
C59				0.125	184.14	183.77
C6				2.4	179.356	179.319
C60				0.125	184.3	183.87
C61				0.125	184.08	183.92
C62				9	184.874	184.8
C63				0.6	173	172.8
C64				0.125	184.14	183.77
C7				2.4	179.319	179.316
C8				2.4	179.337	179.336
C9				2.4	179.369	179.451
CMH_00205				1.2	173.52	173.517
DGM_00001	0	0	0	0.7	169.182	169.175
DGM_00003	300	0	0	0.3	192.558	192.545
DGM_00005	375	0	0	0.375	190.294	190.237
DGM_00008	300	0	0	0.3	190.345	190.183
DGM_00010	0	0	0	1	158.12	142.289
DGM_00033	600	187.909	0	0.6	187.909	188.214
DGM_00051	0	0	0	0.3	172.426	173.538
DGM_00069	355	0	0	0.355	183.02	182.951
DGM_00075	300	184.67	0	0.3	184.67	184.643
DGM_00076	300	0	185.13	0.3	185.307	185.13
DGM_00077	675	188.13	0	0.675	188.13	187.183
DGM_00078	675	0	0	0.675	187.129	187.125
DGM_00079	675	0	0	0.675	187.125	187.121
DGM_00086	1050	0	0	1.05	180.924	180.916
DGM_00115	NOT	189.198	188.214	1.2	189.198	188.214
DGM_00118	825	0	0	0.825	189.603	189.564
DGM_00143	450	0	184.04	0.45	184.043	184.04
DGM_00151	0	0	0	0.2	174.282	173.991
DGM_00152	300	0	0	0.3	174.661	174.5

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_00154	300	0	0	0.3	175.518	175.29
DGM_00155	0	0	0	2.4	171.198	171.161
DGM_00158	525	0	0	0.525	173.759	173.751
DGM_00183	1050	0	0	1.05	178.656	178.64
DGM_00188	0	0	0	0.75	181.024	181.004
DGM_00209	300	0	0	0.3	189.915	189.805
DGM_00212	300	0	0	0.3	189.507	188.973
DGM_00214	0	0	0	1	192.8	192.797
DGM_00215	250	0	0	0.25	192.764	192.51
DGM_00224	300	0	0	0.3	191.397	191.083
DGM_00228	1050	0	0	2.4	175.084	175.079
DGM_00243	600	606.5	0	0.6	184.861	183.263
DGM_00248	525	0	0	0.525	184.68	183.42
DGM_00249	300	0	0	0.3	190.934	190.763
DGM_00258	900	0	0	0.9	190.078	190.076
DGM_00269	0	0	0	2.4	175.079	175.074
DGM_00274	0	0	0	1	193.8	193.796
DGM_00275	250	0	0	0.25	191.701	191.446
DGM_00277	1050	0	0	1.05	189.762	189.75
DGM_00278	250	0	0	0.25	191.977	191.732
DGM_00279	300	0	0	0.3	191.083	190.479
DGM_00280	0	0	0	1	193.8	193.796
DGM_00282	375	188.36	187.74	0.375	188.36	188.34
DGM_00283	200	0	0	0.2	192.992	192.764
DGM_00285	300	0	0	0.3	191.545	191.347
DGM_00295	375	0	0	0.375	182.761	182.59
DGM_00302	200	0	0	0.2	191.797	190.6
DGM_00327	NOT	171.05	170.99	1.5	171.05	170.98
DGM_00328	NOT	171.22	171.19	1.5	171.22	171.19
DGM_00329	1050	0	175.84	1.05	175.84	175.84
DGM_00334	300	0	0	0.3	190.672	190.499
DGM_00335	250	0	0	0.25	191.605	191.38
DGM_00337	375	0	0	0.375	188.752	188.641
DGM_00338	300	0	0	0.3	189.859	189.725
DGM_00340	200	0	0	0.2	192.6	192.4
DGM_00342	1650	175.074	174.504	2.4	175.074	174.504
DGM_00345	300	0	0	0.3	190.701	190.503
DGM_00350	300	0	0	0.3	190.638	190.474
DGM_00355	450	0	0	0.45	189.216	189.198
DGM_00359	525	0	0	0.525	189.037	188.999
DGM_00376	600	0	0	0.6	183.868	183.798
DGM_00379	1350	0	0	1.35	183.465	183.45
DGM_00384	600	187.95	187.93	0.6	188.01	187.93
DGM_00398	300	0	0	0.3	188.79	188.773
DGM_00400	900	186.59	185.81	2.4	186.59	185.81
DGM_00411	300	0	0	0.3	190.629	190.4
DGM_00431	250	0	0	0.25	191.821	191.625
DGM_00454	150	0	0	0.15	189.261	189.037
DGM_00459	300	0	0	0.3	190.122	190.011
DGM_00462	525	0	0	0.525	184.019	183.95
DGM_00468	300	0	0	0.3	191.625	191.397
DGM_00482	375	0	0	0.375	186.488	186.414
DGM_00483	375	0	0	0.375	186.249	186.145
DGM_00484	600	0	0	0.6	185.208	185.144
DGM_00485	600	0	0	0.6	183.829	183.775
DGM_00486	450	0	0	0.45	183.843	183.775
DGM_00499	750	0	0	0.75	180.96	180.91
DGM_00500	975	0	0	0.975	180.86	180.7
DGM_00501	NOT	180.503	180.331	1.2	180.503	180.331
DGM_00502	900	0	0	0.9	181.195	180.91
DGM_00507	750	0	0	0.75	182.233	181.695
DGM_00508	750	0	0	0.75	185.046	184.975
DGM_00509	750	0	0	0.75	182.775	182.708
DGM_00518	450	175.429	174.83	0.45	175.47	174.75
DGM_00519	600	175.46	173.35	0.6	172.94	170.66
DGM_00520	900	171.8	171.1	0.9	171.44	171.36
DGM_00521	900	0	0	0.9	171.45	171.44
DGM_00534	0	0	0	0.3	185.802	185.7
DGM_00542	NOT	180.535	180.503	1.2	180.535	180.503
DGM_00545	0	0	0	0.3	173.746	173.726
DGM_00562	300	0	0	0.3	140.443	140.432
DGM_00563	300	0	0	0.3	140.506	140.443
DGM_00564	300	0	0	0.3	153.195	153.179
DGM_00565	300	0	0	0.3	155.614	155.59
DGM_00568	600	0	0	0.6	158.193	158.093
DGM_00570	900	0	0	0.9	157.533	157.528
DGM_00571	0	0	0	0.9	156.141	156.137
DGM_00572	450	0	0	0.45	160.207	160.178
DGM_00573	0	0	0	1.5	158.945	158.921
DGM_00574	0	0	0	0.3	165.332	165.24
DGM_00575	0	0	0	1.5	160.85	160.806
DGM_00578	1200	0	0	1.2	174.66	173.906
DGM_00579	1200	0	0	1.2	166.374	166.355
DGM_00584	600	193.63	192.17	0.6	192.887	191.511

	CITY GIS			PCSWMM MODEL		
PIPE ID	**SIZE (mm)**	**US INV ELE**	**DS INV ELE**	**SIZE (m)**	**US INV ELE**	**DS INV ELE**
DGM_00597	675	189.831	0	0.675	189.831	188.91
DGM_00639	750	0	0	0.75	182.72	182.7
DGM_00642	525	0	0	0.525	182.81	182.797
DGM_00643	0	0	0	1	178.53	178.528
DGM_00644	0	0	0	0.3	176.429	176.417
DGM_00653	0	0	0	0.4	161.264	162.87
DGM_00654	200	0	0	0.2	163.138	163.005
DGM_00655	300	0	0	0.3	162.498	162.473
DGM_00657	0	0	0	1.05	158.55	158.54
DGM_00662	0	0	0	1.05	159.085	159.08
DGM_00663	600	0	0	0.6	158.991	158.95
DGM_00668	0	0	0	0.4	161.957	161.888
DGM_00670	0	0	0	0.7	155.873	155.87
DGM_00675	450	0	0	0.45	156.54	156.483
DGM_00676	0	0	0	0.7	156.352	156.348
DGM_00677	0	0	0	1	158.859	158.815
DGM_00682	0	0	0	0.975	157.212	157.178
DGM_00685	0	0	0	1	158.22	158.208
DGM_00692	350	0	0	0.35	157.934	157.91
DGM_00693	NOT	157.47	157.47	0.375	157.47	157.47
DGM_00694	0	0	0	0.3	190.381	190.37
DGM_00705	1350	0	180.16	1.35	180.17	180.16
DGM_00707	2400	0	0	2.4	179.37	179.331
DGM_00708	2400	0	0	2.4	179.331	179.293
DGM_00709	0	0	0	0.675	184.425	184.39
DGM_00710	UNKNOWN	174.66	174.66	0.75	174.66	174.66
DGM_00711	UNKNOWN	0	0	0.75	174.362	174.356
DGM_00718	0	0	0	0.3	180.433	180.411
DGM_00722	0	0	0	0.9	166.358	166.329
DGM_00723	0	0	0	0.9	158.707	158.7
DGM_00724	0	0	0	0.9	167.947	167.921
DGM_00725	0	0	0	0.9	167.973	167.947
DGM_00726	0	0	0	0.9	173.697	173.668
DGM_00727	0	0	0	0.9	178.739	178.731
DGM_00728	0	0	0	0.9	176.307	176.288
DGM_00729	0	0	0	0.9	177.525	177.499
DGM_00730	0	0	0	0.9	164.588	164.575
DGM_00731	UNKNOWN	0	0	2.4	162.588	162.583
DGM_00732	UNKNOWN	0	0	2.4	169.31	169.303
DGM_00733	UNKNOWN	0	0	2.4	176.79	176.778
DGM_00734	UNKNOWN	0	0	2.4	185.4	185.392
DGM_00735	600	0	0	2.4	185.42	185.4
DGM_00736	600	0	0	2.4	184.732	184.704
DGM_00737	UNKNOWN	0	0	2.4	185.723	185.688
DGM_00738	UNKNOWN	0	0	2.4	184.754	184.732
DGM_00739	300	0	0	2.4	185.517	185.504
DGM_00740	0	0	0	0.9	162.583	162.578
DGM_00741	0	0	0	1	182.65	182.641
DGM_00742	825	0	0	0.825	180.33	180.323
DGM_00743	300	0	0	0.3	187.096	187.057
DGM_00744	600	0	0	0.6	187.157	187.096
DGM_00745	600	0	0	0.6	187.195	187.157
DGM_00779	1200	0	0	1.2	201.192	201.168
DGM_00780	1050	0	0	1.05	201.397	201.376
DGM_00806	375	187.306	186.261	2.4	187.306	186.261
DGM_00820	900	0	0	0.9	185.479	185.46
DGM_00826	375	0	187.74	0.375	187.805	187.74
DGM_00830	375	0	0	0.375	186.71	186.69
DGM_00842	300	0	0	0.3	187.221	187.03
DGM_00849	900	0	0	0.9	186.49	186.472
DGM_00851	NOT	172.537	172.479	0.9	172.537	172.479
DGM_00902	0	0	0	0.9	171.366	171.36
DGM_00904	0	0	0	0.825	187.255	187.177
DGM_00915	525	186.34	187.5	0.525	187.5	186.34
DGM_00920	1350	0	0	1.35	179.35	179.348
DGM_00965	300	0	0	0.3	188.66	185.152
DGM_00966	375	0	0	0.375	183.205	183.088
DGM_00967	375	0	0	0.375	182.138	182.07
DGM_00968	375	0	0	0.375	182.143	182.07
DGM_00969	375	0	0	0.375	184.104	184.002
DGM_00970	375	0	0	0.375	185.411	185.319
DGM_00971	400	182.07	0	0.4	182.07	160.411
DGM_00972	600	0	0	0.6	159.077	159.026
DGM_01002	250	0	0	0.25	197.327	197.31
DGM_01029	1050	0	0	1.05	187.66	186.83
DGM_01042	1050	0	0	1.05	190.141	190.106
DGM_01043	900	0	0	0.9	190.9	190.861
DGM_01044	375	0	0	0.375	190.919	190.9
DGM_01045	900	0	0	0.9	190.939	190.9
DGM_01046	750	0	0	0.75	190.9	190.84
DGM_01047	1050	0	0	1.05	188.881	188.85
DGM_01048	1500	0	0	1.5	188.404	188.4
DGM_01051	1050	0	0	1.05	188.821	188.777
DGM_01052	NOT	182.06	182.115	2.1	182.115	182.06

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_01054	UNKNOWN	0	0	0.6	183.2	183.164
DGM_01055	UNKNOWN	0	0	0.6	183.2	183.179
DGM_01059	0	0	0	1.65	186.284	185.118
DGM_01061	375	0	0	0.375	187.476	187.461
DGM_01063	600	0	0	0.6	184.2	184.191
DGM_01064	1050	0	0	1.05	183.362	183.332
DGM_01065	750	0	0	0.75	184.05	183.384
DGM_01066	1050	0	0	1.05	183.384	183.362
DGM_01067	1200	0	0	1.2	183.332	183.306
DGM_01113	1050	0	0	1.05	190.75	190.44
DGM_01147	0	0	0	0.3	173.846	173.5
DGM_01151	450	0	0	0.45	173.82	173.796
DGM_01169	1050	177.36	0	1.05	177.36	177.264
DGM_01170	750	0	0	0.75	175.728	175.692
DGM_01183	0	0	0	0.3	174.239	174.117
DGM_01186	250	0	0	0.25	171.72	171.574
DGM_01189	975	0	0	0.975	172.398	172.35
DGM_01196	675	0	0	0.675	173.167	173.101
DGM_01197	750	0	0	0.75	173.163	173.106
DGM_01198	975	0	0	0.975	173.106	173.058
DGM_01199	0	0	0	2.4	169.688	169.526
DGM_01204	675	0	0	0.675	173.243	173.167
DGM_01207	525	0	0	0.525	173.58	173.275
DGM_01227	250	0	172.948	0.25	173.104	172.948
DGM_01228	0	0	0	0.9	172.766	172.688
DGM_01232	500	175.948	176.295	0.5	176.295	175.948
DGM_01238	750	0	0	0.75	192.62	190.35
DGM_01239	900	0	0	0.9	189.32	189.289
DGM_01240	900	0	0	0.9	189.289	189.262
DGM_01241	1050	0	0	1.05	189.787	189.75
DGM_01242	1200	0	0	1.2	189.637	189.6
DGM_01243	1200	0	0	1.2	189.6	189.563
DGM_01244	375	0	0	0.375	187.738	187.589
DGM_01245	750	187.45	186.52	0.75	186.52	186.15
DGM_01269	200	0	0	0.2	192.333	191.955
DGM_01276	450	0	0	0.45	182.448	182.42
DGM_01286	375	0	0	0.375	190.268	189.875
DGM_01291	300	0	0	0.3	191.254	191.05
DGM_01292	2100	0	0	2.1	186.78	186.66
DGM_01293	300	0	0	0.3	189.861	189.725
DGM_01294	600	0	0	0.6	181.98	181.61
DGM_01305	600	0	0	0.6	182.096	182.016
DGM_01313	200	0	0	0.2	188.398	188.357
DGM_01318	300	0	0	0.3	196.293	196.108
DGM_01320	300	0	0	0.3	189.758	189.725
DGM_01322	675	0	0	0.675	181.408	181.33
DGM_01328	250	0	0	0.25	191.855	191.55
DGM_01337	200	0	0	0.2	190.737	190.574
DGM_01338	300	0	0	0.3	190.465	190.312
DGM_01340	675	0	0	0.675	184.55	184.513
DGM_01362	1050	0	0	1.05	185.16	185.116
DGM_01363	1050	0	0	1.05	183.349	183.32
DGM_01377	750	0	0	0.75	182.77	182.51
DGM_01380	525	0	0	0.525	178.129	178.03
DGM_01381	1500	0	0	1.5	177.207	177.17
DGM_01397	0	0	0	0.3	192.595	192.58
DGM_01399	0	0	0	0.3	193.906	193.749
DGM_01400	0	0	0	0.375	193.342	193.203
DGM_01401	0	0	0	0.375	192.554	192.415
DGM_01402	0	0	0	0.45	190.652	190.535
DGM_01403	0	0	0	0.45	190.481	190.435
DGM_01404	0	0	0	0.6	190.24	190.2
DGM_01405	0	0	0	0.6	190.377	190.36
DGM_01414	0	0	0	0.3	191.789	191.64
DGM_01415	600	0	0	0.6	186.296	186.2
DGM_01416	600	0	0	0.6	186.2	186.103
DGM_01417	600	0	0	0.6	185.407	185.314
DGM_01426	375	0	0	0.375	184.444	184.338
DGM_01435	750	0	0	0.75	183.39	183.345
DGM_01449	300	0	182.786	0.3	182.895	182.786
DGM_01450	750	0	0	0.75	182.818	182.786
DGM_01451	750	0	0	0.75	182.85	182.818
DGM_01453	375	183.84	183.87	0.375	183.87	183.84
DGM_01464	1200	0	0	1.2	183.328	183.31
DGM_01472	600	0	0	0.6	183.834	183.77
DGM_01473	525	0	0	0.525	186.125	186.042
DGM_01474	300	0	0	0.3	186.5	186.406
DGM_01476	600	0	0	0.6	184.65	183.77
DGM_01477	1200	0	0	1.2	185.17	183.77
DGM_01479	825	0	0	0.825	186.13	185.36
DGM_01480	675	0	0	0.675	186.13	186.077
DGM_01481	300	0	0	0.3	186.077	185.99
DGM_01482	450	0	0	0.45	186.5	186.278
DGM_01483	825	0	0	0.825	186.82	186.525

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_01484	1050	0	0	1.05	185.897	185.86
DGM_01514	0	0	0	1.35	176.232	176.17
DGM_01525	675	0	179.266	0.675	179.516	179.266
DGM_01532	0	0	0	0.375	181.98	181.948
DGM_01537	1800	0	0	1.8	170.84	170.796
DGM_01539	1500	0	174.257	1.5	174.264	174.257
DGM_01556	0	0	0	0.675	184.16	184.132
DGM_01557	600	0	0	0.6	191.619	191.61
DGM_01587	900	0	0	0.9	175.72	175.656
DGM_01629	1050	0	0	1.05	191.98	191.4
DGM_01654	1800	187.36	187.248	2.4	187.36	187.248
DGM_01656	200	0	0	0.2	174.253	173.69
DGM_01657	0	0	0	0.9	172.636	172.618
DGM_01659	375	0	0	0.375	188.183	188.17
DGM_01688	0	0	0	1.2	142.289	142.285
DGM_01689	1200	0	0	1.2	188.094	188.074
DGM_01690	1050	190.463	190.089	0.975	190.463	190.089
DGM_01691	1200	0	0	1.2	188.074	188.056
DGM_01693	0	0	0	0.3	187.247	187.24
DGM_01698	0	0	0	0.75	158.048	158.002
DGM_01700	0	0	0	0.25	176.255	176.16
DGM_01702	1200	0	0	1.2	170.36	170.3
DGM_01704	600	176.457	175.701	0.6	176.46	175.701
DGM_01714	450	589.8	583.4	0.45	179.771	177.82
DGM_01727	0	0	0	0.45	186.987	186.974
DGM_01807	600	0	0	0.6	197.5	195.65
DGM_01828	300	0	0	0.3	196.5	196.403
DGM_01829	300	0	0	0.3	196.403	196.331
DGM_01830	300	0	0	0.3	196.51	196.482
DGM_01831	300	0	0	0.3	196.331	196.293
DGM_01832	300	0	0	0.3	197.627	197.509
DGM_01833	250	0	0	0.25	198.468	198.273
DGM_01834	300	0	0	0.3	203.069	198.303
DGM_01835	375	0	0	0.375	198.303	198.22
DGM_01836	375	0	0	0.375	198.22	198.12
DGM_01837	1200	0	0	1.2	200.346	200.327
DGM_01839	1200	0	0	1.2	199.014	199
DGM_01840	1200	0	0	1.2	200.363	200.346
DGM_01841	1200	0	0	1.2	200.619	200.609
DGM_01842	1200	0	0	1.2	200.6	200.577
DGM_01843	1200	0	0	1.2	200.624	200.6
DGM_01844	1200	0	0	1.2	200.778	200.761
DGM_01845	1050	0	0	1.05	204.172	204.15
DGM_01846	1050	0	0	1.05	202.412	202.389
DGM_01847	1050	0	0	1.05	202.082	202.063
DGM_01848	1050	0	0	1.05	201.938	201.918
DGM_01849	1050	0	0	1.05	203.111	203.089
DGM_01850	1050	0	0	1.05	203.45	203.438
DGM_01851	1050	0	0	1.05	203.438	203.417
DGM_01852	1050	0	0	1.05	203.52	203.494
DGM_01853	825	0	0	0.825	204.96	204.15
DGM_01854	825	0	0	0.825	205.254	205.22
DGM_01855	600	0	0	0.6	205.685	205.638
DGM_01856	375	0	0	0.375	208.549	208.43
DGM_01857	600	0	0	0.6	206.185	206.131
DGM_01858	300	0	0	0.3	211.216	210.98
DGM_01859	250	0	0	0.25	207.203	206.986
DGM_01860	600	0	0	0.6	206.969	206.956
DGM_01861	600	0	0	0.6	207.239	207.181
DGM_01862	375	0	0	0.375	209.578	209.466
DGM_01863	450	0	0	0.45	204.107	204.034
DGM_01868	300	0	0	0.3	195.08	194.951
DGM_01869	300	0	0	0.3	197.268	197.143
DGM_01870	300	0	0	0.3	193.405	193.318
DGM_01871	300	0	0	0.3	192.228	192.17
DGM_01874	600	0	0	0.6	190.1	190.035
DGM_01879	0	0	0	1.05	178.848	178.75
DGM_01881	0	0	0	1	181.83	181.01
DGM_01894	900	0	0	0.9	177.649	177.59
DGM_01901	UNKNOWN	0	0	0.3	172.658	172.481
DGM_01903	0	0	0	0.3	202.201	202.19
DGM_01907	375	0	0	0.375	191.334	191.236
DGM_01909	UNKNOWN	0	0	0.4	160.566	160.507
DGM_01912	300	173.57	173.46	0.3	174.804	174.687
DGM_01914	0	0	0	0.3	173.587	173.423
DGM_01919	825	0	0	0.825	180.08	179.187
DGM_01930	300	0	172.98	0.3	173.005	172.98
DGM_01949	1200	0	0	1.2	173.07	173.046
DGM_01961	1200	0	0	1.2	181.86	181.13
DGM_01981	0	0	0	2.4	171.161	171.054
DGM_01983	UNKNOWN	0	0	2.4	186.639	186.636
DGM_01984	UNKNOWN	0	0	2.4	186.646	186.639
DGM_01985	UNKNOWN	0	0	0.525	187.384	187.367
DGM_01986	UNKNOWN	0	0	2.4	186.661	186.646

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_01987	UNKNOWN	0	0	0.525	187.466	187.384
DGM_01988	UNKNOWN	0	0	0.525	187.535	187.466
DGM_01989	UNKNOWN	0	0	0.525	187.589	187.535
DGM_01990	900	0	0	0.9	175.87	175.26
DGM_01991	0	0	0	0.45	192.585	192.533
DGM_01994	0	0	0	0.45	192.61	192.585
DGM_02000	0	0	0	0.3	174.078	173.999
DGM_02002	1050	0	0	1.05	177.842	177.83
DGM_02005	UNKNOWN	0	0	0.75	180.518	180.468
DGM_02006	UNKNOWN	0	0	0.75	181.078	181.047
DGM_02007	UNKNOWN	0	0	0.825	180.757	180.711
DGM_02008	UNKNOWN	0	0	0.825	180.018	179.975
DGM_02009	UNKNOWN	0	0	0.825	177.036	177.007
DGM_02018	900	0	0	0.9	178.38	178.335
DGM_02035	0	0	187.99	0.3	188.088	187.99
DGM_02110	750	0	0	0.75	178.32	176.89
DGM_02112	975	0	0	0.975	176.896	176.89
DGM_02136	250	0	0	0.25	192.13	191.87
DGM_02140	450	189.95	189.71	0.45	189.9	189.71
DGM_02141	250	0	0	0.25	192.23	191.983
DGM_02146	250	0	0	0.25	192.487	192.23
DGM_02148	250	0	0	0.25	192.112	191.86
DGM_02149	250	0	0	0.25	192.232	192.112
DGM_02150	250	0	0	0.25	192.711	192.487
DGM_02151	300	0	0	0.3	189.719	189.717
DGM_02152	UNKNOWN	0	0	0.3	190.665	190.5
DGM_02153	UNKNOWN	0	0	0.3	191.674	191.51
DGM_02154	UNKNOWN	0	0	0.3	192.493	192.328
DGM_02155	UNKNOWN	0	0	0.3	192.5	192.384
DGM_02156	UNKNOWN	0	0	0.3	190.183	190.052
DGM_02157	UNKNOWN	0	0	0.3	190.5	190.345
DGM_02158	UNKNOWN	0	0	0.3	190.102	190.035
DGM_02159	600	0	0	0.6	189.907	189.88
DGM_02177	1500	188.427	187.726	2.4	188.427	187.726
DGM_02181	1800	187.034	186.29	2.4	187.034	186.29
DGM_02182	1800	186.077	185.834	2.4	186.077	185.834
DGM_02183	600	0	0	0.6	199.99	198.65
DGM_02204	375	0	0	0.375	173.519	173.425
DGM_02218	450	0	0	0.45	179.67	179.567
DGM_02237	300	0	0	0.3	190.369	190.229
DGM_02242	NOT	189.205	189.205	0.9	189.205	189.205
DGM_02244	300	0	0	0.3	189.488	189.332
DGM_02249	375	0	0	0.375	182.73	182.33
DGM_02253	675	0	0	0.675	182.295	182.266
DGM_02254	300	0	0	0.3	191.033	190.808
DGM_02255	825	0	0	0.825	181.257	181.23
DGM_02260	100	0	0	0.1	190.089	190.076
DGM_02276	200	0	0	0.2	191.807	191.545
DGM_02278	450	0	0	0.45	190.496	190.486
DGM_02300	450	0	0	0.45	189.379	189.332
DGM_02304	600	0	0	0.6	183.798	183.74
DGM_02305	750	0	0	0.75	182.03	181.61
DGM_02306	300	0	0	0.3	183.74	183.73
DGM_02314	450	0	0	0.45	188.697	188.65
DGM_02326	450	188.297	188.65	0.45	188.65	188.297
DGM_02328	250	0	0	0.25	191.231	191.003
DGM_02333	450	0	0	0.45	191.35	191.34
DGM_02334	200	0	0	0.2	192.472	192.158
DGM_02343	1050	0	0	1.05	189.75	189.695
DGM_02344	675	0	0	0.675	182.581	182.518
DGM_02354	200	0	0	0.2	190.613	190.517
DGM_02357	675	0	0	0.675	184.089	184.05
DGM_02359	375	0	0	0.375	190.479	190.268
DGM_02360	200	0	0	0.2	190.515	190.407
DGM_02361	250	0	0	0.25	192.092	191.923
DGM_02362	1050	0	0	1.05	180.98	180.72
DGM_02365	250	0	0	0.25	191.315	191.065
DGM_02366	250	0	0	0.25	191.983	191.821
DGM_02367	375	0	0	0.375	189.875	189.861
DGM_02368	525	0	0	0.525	181.817	181.775
DGM_02373	1200	0	0	1.2	172.15	172.02
DGM_02376	1050	0	0	1.05	189.482	189.472
DGM_02377	600	0	0	0.6	182.67	182.581
DGM_02386	150	0	0	0.15	190.103	189.875
DGM_02388	375	0	0	0.375	184.25	184.163
DGM_02390	200	0	0	0.2	192.6	192.416
DGM_02402	900	188.58	185.05	0.9	185.83	185.05
DGM_02405	0	0	0	0.3	188.617	188.58
DGM_02415	600	0	0	0.6	200.538	200.47
DGM_02421	600	0	0	0.6	189.218	189.2
DGM_02424	UNKNOWN	0	0	0.825	189.028	188.975
DGM_02425	UNKNOWN	0	0	0.825	186.904	186.864
DGM_02426	825	0	0	0.825	190.174	190.13
DGM_02427	450	0	0	0.45	187.858	187.738

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_02428	UNKNOWN	0	0	0.3	189.527	189.468
DGM_02429	1050	0	0	1.05	186.875	186.864
DGM_02432	600	191.23	0	0.6	191.23	190.813
DGM_02433	675	0	0	0.675	190.159	190.125
DGM_02437	1200	0	0	1.2	186.322	186.305
DGM_02438	1350	0	0	1.35	185.45	185.423
DGM_02439	1350	0	0	1.35	184.723	184.696
DGM_02440	1350	0	0	1.35	184.473	184.45
DGM_02441	1350	0	0	1.35	183.691	183.657
DGM_02442	1350	0	0	1.35	184.068	184.041
DGM_02443	1350	0	0	1.35	184.229	184.207
DGM_02444	750	0	0	0.75	189.183	189.13
DGM_02445	750	0	0	0.75	188.174	188.135
DGM_02446	1350	0	0	1.35	183.45	183.421
DGM_02447	1350	0	0	1.35	185.45	185.42
DGM_02448	1350	0	0	1.35	185.471	185.45
DGM_02449	1200	0	0	1.2	185.62	185.599
DGM_02450	1200	0	0	1.2	186.592	186.56
DGM_02451	1050	0	0	1.05	186.696	186.664
DGM_02452	1050	0	0	1.05	186.729	186.696
DGM_02453	0	0	0	0.75	188.052	188.01
DGM_02454	900	0	0	0.9	187.806	187.764
DGM_02455	750	0	0	0.75	190.236	190.185
DGM_02456	750	0	0	0.75	191.086	191.033
DGM_02457	750	0	0	0.75	191.982	191.93
DGM_02458	750	0	0	0.75	192.152	192.099
DGM_02459	675	0	0	0.675	192.962	192.9
DGM_02460	675	0	0	0.675	193.241	193.184
DGM_02462	675	0	0	0.675	193.941	193.884
DGM_02463	600	0	0	0.6	194.559	194.498
DGM_02464	450	0	0	0.45	195.425	195.336
DGM_02465	UNKNOWN	0	0	0.3	192.291	192.153
DGM_02466	UNKNOWN	0	0	0.3	193.726	193.599
DGM_02467	UNKNOWN	0	0	0.3	192.77	192.632
DGM_02480	600	0	0	0.6	186.334	186.274
DGM_02498	900	0	0	0.9	181.08	180.38
DGM_02501	750	0	0	0.75	183.113	183.09
DGM_02502	450	0	183.9	0.45	183.917	183.9
DGM_02511	1350	0	0	1.35	188.973	188.972
DGM_02515	0	0	0	0.3	182.487	182.423
DGM_02519	1200	181.504	181.088	1.2	180.06	179.644
DGM_02530	900	0	0	0.9	179	181.02
DGM_02546	450	0	0	0.45	178.966	170.95
DGM_02597	1500	0	0	1.5	175.98	177.17
DGM_02603	1650	0	0	1.65	187.85	187.829
DGM_02616	600	0	0	0.6	185.858	185.846
DGM_02620	0	0	0	0.6	185.865	185.858
DGM_02628	900	0	0	0.9	185.95	185.944
DGM_02632	0	0	0	0.525	189.282	189.235
DGM_02640	300	0	0	0.3	192.866	192.752
DGM_02641	300	0	0	0.3	193.5	193.369
DGM_02642	375	0	0	0.375	193.836	193.767
DGM_02669	1200	0	0	1.2	182.544	182.51
DGM_02670	1200	0	0	1.2	179.52	179.475
DGM_02671	1200	0	0	1.2	177.31	177.279
DGM_02673	1500	0	0	1.5	177.236	177.207
DGM_02697	300	0	0	0.3	185.967	185.892
DGM_02700	375	0	0	0.375	171.486	171.463
DGM_02704	0	0	0	1	171.33	171.314
DGM_02705	0	0	0	1	170.859	170.842
DGM_02706	0	0	0	1	171.885	171.8
DGM_02707	0	0	0	1	164.329	164.321
DGM_02708	0	0	0	1	164.299	164.298
DGM_02709	0	0	0	1	164.311	164.309
DGM_02710	0	0	0	1	162.6	162.561
DGM_02711	250	0	0	0.25	166.421	166.282
DGM_02713	2100	0	0	2.1	157.831	157.823
DGM_02714	1350	0	0	1.35	158.35	158.344
DGM_02715	300	0	0	0.3	165.794	165.754
DGM_02716	0	0	0	1	164.108	164.105
DGM_02717	0	0	0	1	164.311	164.309
DGM_02718	0	0	0	1	164.311	164.309
DGM_02719	0	0	0	1	161.067	161.041
DGM_02721	0	0	0	1	160.184	159.402
DGM_02726	375	0	0	0.375	172.198	172.04
DGM_02735	1200	0	0	1.2	173.176	173.136
DGM_02739	0	0	0	0.2	175.073	174.488
DGM_02741	250	0	0	0.25	173.661	173.457
DGM_02746	1800	0	0	1.8	172.489	172.45
DGM_02749	1050	187.4	185.65	2.4	187.4	185.65
DGM_02750	1050	185.6	185.1	2.4	185.6	185.1
DGM_02756	375	0	0	0.375	188.425	188.346
DGM_02757	675	0	0	0.675	189.451	189.4
DGM_02765	450	0	0	0.45	186.532	185.47

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_02774	750	0	184.48	0.75	184.95	184.48
DGM_02796	0	0	0	0.3	189.257	189.177
DGM_02812	450	0	189.932	0.45	189.946	189.932
DGM_02817	375	0	0	0.375	190.132	190.047
DGM_02819	600	0	0	0.6	190.931	190.047
DGM_02849	1050	190	189.973	1.05	190.14	189.58
DGM_02851	600	0	0	0.6	188.379	188.373
DGM_02855	1350	0	0	1.35	188.984	188.973
DGM_02856	1350	0	0	1.35	188.972	188.954
DGM_02857	1350	0	0	1.35	188.319	188.31
DGM_02867	1350	0	0	1.35	188.023	188
DGM_02868	1200	0	0	1.2	188.052	188.023
DGM_02869	600	0	0	0.6	190.159	190.153
DGM_02870	600	0	0	0.6	190.153	190.152
DGM_02871	600	0	0	0.6	190.152	190.14
DGM_02875	0	0	0	1	179.8	179.79
DGM_02876	0	0	0	0.9	181.185	181.176
DGM_02895	525	173.898	174.022	0.525	174.022	173.898
DGM_02898	1200	0	0	1.2	173.281	173.26
DGM_02902	0	0	0	0.3	174.5	174.407
DGM_02908	900	0	0	0.9	173.44	173.402
DGM_02911	300	0	0	0.3	172.95	172.426
DGM_02916	375	0	0	0.375	171.631	171.48
DGM_02917	0	0	0	0.6	184.17	184.16
DGM_02920	300	0	0	0.3	199.196	199.11
DGM_02923	300	184.728	0	0.3	184.728	184.703
DGM_02932	0	0	0	1.5	142.285	155.532
DGM_02937	200	0	0	0.2	188.186	188.155
DGM_02938	0	0	0	0.3	186.505	186.469
DGM_02940	0	0	0	0.3	179.789	179.77
DGM_02942	525	176.69	176.527	0.525	176.69	176.53
DGM_02943	0	0	0	1	175.32	174.79
DGM_02944	0	0	0	0.3	173.58	173.542
DGM_02945	375	0	0	0.375	174.707	174.694
DGM_02946	0	0	0	0.375	172.942	172.761
DGM_02964	600	0	0	0.6	172.345	172.31
DGM_02966	0	0	0	0.3	176.5	176.486
DGM_02978	525	196.139	196.094	0.525	186.139	186.094
DGM_02988	250	0	0	0.25	173.293	172.974
DGM_02993	UNKNOWN	0	0	0.375	171.253	171.24
DGM_02995	600	0	0	0.6	181.83	180.99
DGM_02996	1350	0	0	1.35	183.45	183.429
DGM_02999	525	0	0	0.525	192.5	191.8
DGM_03008	0	0	0	0.825	178.8	177.81
DGM_03011	0	0	0	0.6	178.615	178.522
DGM_03034	600	0	0	0.6	158.568	158.519
DGM_03038	750	0	0	0.75	192.942	192.911
DGM_03040	UNKNOWN	0	0	2.4	182.025	182.01
DGM_03041	UNKNOWN	0	0	0.7	182.032	182.025
DGM_03044	750	182.01	0	0.75	182.01	181.971
DGM_03045	2400	0	0	2.4	177.95	177.924
DGM_03046	0	0	0	0.75	176.124	176.05
DGM_03048	825	0	0	0.825	181.785	181.78
DGM_03049	825	0	0	0.825	181.82	181.785
DGM_03050	825	0	0	0.825	181.866	181.82
DGM_03051	750	0	0	0.75	181.92	181.866
DGM_03053	600	0	0	0.6	184.144	184.073
DGM_03054	600	0	0	0.6	186.271	186.2
DGM_03055	525	0	0	0.525	186.62	186.532
DGM_03061	825	0	0	0.825	180.877	180.87
DGM_03062	900	0	0	0.9	180.882	180.877
DGM_03063	900	0	0	0.9	181.544	180.882
DGM_03064	900	0	0	0.9	181.583	181.544
DGM_03065	825	0	0	0.825	181.628	181.583
DGM_03066	750	0	0	0.75	181.68	181.628
DGM_03068	600	0	0	0.6	182.09	182.02
DGM_03071	600	0	0	0.6	184.961	184.915
DGM_03072	600	0	0	0.6	186.24	186.176
DGM_03073	450	177.65	177.428	0.45	173.35	173.13
DGM_03074	0	0	0	0.3	186.5	186.468
DGM_03075	0	0	0	1	184.466	184.425
DGM_03076	0	0	0	0.45	189.716	189.649
DGM_03077	0	0	0	0.675	179.108	179.086
DGM_03078	0	0	0	0.45	187.076	186.956
DGM_03079	0	0	0	0.45	188.673	188.582
DGM_03081	975	0	0	0.975	179.07	179.057
DGM_03082	975	0	0	0.975	179.057	179.035
DGM_03102	525	173.05	173.521	0.525	173.521	173.05
DGM_03103	0	0	0	0.3	171.757	171.686
DGM_03107	750	177.124	176.289	0.75	172.83	171.53
DGM_03111	375	177.88	174.91	0.375	173.96	171.9
DGM_03113	UNKNOWN	0	0	0.525	176.126	176.097
DGM_03114	900	174.559	173.818	0.9	171.38	170.64
DGM_03116	1050	173.518	172.959	1.05	170.64	170.08

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_03117	450	0	175.72	0.45	175.74	175.72
DGM_03121	0	0	0	0.825	170.718	170.697
DGM_03127	750	0	0	0.75	176.89	176.877
DGM_03128	450	0	0	0.45	177.36	177.13
DGM_03129	750	0	0	0.75	176.03	175.818
DGM_03130	600	0	0	0.9	170.64	170.45
DGM_03131	NOT	170.317	170.29	1.5	170.37	170.36
DGM_03138	NOT	0	0	1.5	170.36	170.19
DGM_03139	2100	0	0	1.5	169.63	169.743
DGM_03140	1050	170.16	169.79	1.05	170.08	170
DGM_03142	2100	0	0	2.1	169.743	168.806
DGM_03147	1050	0	0	1.05	186.745	186.729
DGM_03148	1050	0	0	1.05	187.477	187.468
DGM_03149	375	0	0	0.375	191.15	191.087
DGM_03151	450	0	0	0.45	190.814	189.364
DGM_03161	0	0	0	0.45	159.095	158.898
DGM_03162	1200	0	0	1.2	188.131	188.094
DGM_03165	900	171.34	0	0.9	171.34	171.308
DGM_03166	675	0	0	0.675	190.104	190.061
DGM_03169	250	0	0	0.25	191.387	191.361
DGM_03170	NOT	178.492	178.412	1.2	178.492	178.412
DGM_03177	0	0	0	0.75	180.539	180.473
DGM_03182	NOT	172.479	172.421	0.9	172.479	172.421
DGM_03185	0	0	0	0.3	177.5	177.42
DGM_03188	600	177.03	176.93	0.6	177.03	177.03
DGM_03190	1800	0	0	1.8	171.5	171.43
DGM_03191	1050	175.8	175.731	1.05	175.84	175.8
DGM_03200	250	0	0	0.25	176.33	176.255
DGM_03202	NOT	170.54	170.317	1.5	170.55	170.37
DGM_03203	NOT	170.99	170.74	1.5	170.98	170.74
DGM_03207	2100	0	0	2.1	178.45	178.404
DGM_03214	825	0	0	0.825	179.017	178.975
DGM_03216	900	0	0	0.9	178.975	178.94
DGM_03233	1350	0	0	1.35	181.015	180.99
DGM_03237	0	0	0	1	182.595	182.55
DGM_03239	900	0	0	0.9	179.26	179.24
DGM_03243	1350	0	0	1.35	183.495	183.45
DGM_03251	300	200.24	199.313	0.3	195.75	194.823
DGM_03273	375	0	0	0.375	171.615	171.486
DGM_03274	200	0	0	0.2	174.477	174.305
DGM_03276	250	0	0	0.25	174.334	174.186
DGM_03279	300	0	0	0.3	175.005	174.94
DGM_03287	0	0	0	0.4	175.717	175.7
DGM_03290	975	0	0	0.975	177.03	176.93
DGM_03291	900	0	0	0.9	171.22	171.1
DGM_03294	450	0	0	0.45	173.59	173.55
DGM_03315	2100	0	0	2.1	178.095	178.07
DGM_03316	0	0	0	1	182.592	182.591
DGM_03322	450	173.444	0	0.45	173.444	173.276
DGM_03324	250	0	0	0.25	175.112	175.056
DGM_03325	250	0	0	0.25	173.853	173.17
DGM_03326	250	0	0	0.25	172.482	172.054
DGM_03328	250	0	0	0.25	172.054	171.978
DGM_03330	250	0	0	0.25	173.69	173.409
DGM_03333	375	173.151	0	0.375	173.151	173.016
DGM_03340	300	173.75	173.46	0.3	174.687	174.401
DGM_03344	1200	0	0	1.2	188.056	188.052
DGM_03346	0	0	0	0.3	202.202	202.19
DGM_03348	450	0	0	0.45	190.239	190.104
DGM_03356	450	158.898	0	0.45	158.898	156.14
DGM_03374	0	0	0	0.525	182.731	182.64
DGM_03380	0	0	0	1	163.602	163.55
DGM_03384	NOT	161.532	161.284	1	161.532	161.284
DGM_03385	0	0	0	1.5	172.27	171.91
DGM_03393	0	0	0	0.2	174.488	174.192
DGM_03396	NOT	172.282	172.12	0.9	172.282	172.12
DGM_03404	300	0	0	0.3	176.867	176.688
DGM_03405	0	0	0	2.4	171.22	171.202
DGM_03406	0	0	0	2.4	171.202	171.188
DGM_03411	375	0	0	0.375	174.791	174.78
DGM_03417	0	0	0	0.9	173.402	173.397
DGM_03421	0	0	0	0.3	173.186	173.091
DGM_03422	250	0	0	0.25	173.538	173.293
DGM_03423	900	0	0	2.4	186.626	186.59
DGM_03424	900	0	0	2.4	186.636	186.626
DGM_03425	375	0	0	0.375	195.558	195.425
DGM_03426	250	0	0	0.25	192.562	192.265
DGM_03427	600	0	0	0.6	190.42	190.35
DGM_03454	750	0	0	0.75	190.05	190.044
DGM_03455	1350	188.358	188.63	1.35	188.63	188.358
DGM_03462	1500	0	0	1.5	187.312	187.294
DGM_03463	1500	0	0	1.5	186.121	186.098
DGM_03469	750	0	0	0.75	186.861	186.85
DGM_03470	300	0	0	0.3	187.459	187.394

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_03471	300	0	0	0.3	187.51	187.459
DGM_03473	750	0	0	0.75	186.93	186.889
DGM_03474	450	0	0	0.45	187.033	186.93
DGM_03478	750	0	0	0.75	186.982	186.93
DGM_03479	750	0	0	0.75	187.035	186.982
DGM_03480	675	0	0	0.675	187.051	187.035
DGM_03481	675	0	0	0.675	187.072	187.051
DGM_03482	675	0	0	0.675	187.122	187.072
DGM_03483	300	0	0	0.3	188.818	188.723
DGM_03484	675	0	0	0.675	187.146	187.122
DGM_03485	600	0	0	0.6	187.159	187.146
DGM_03486	600	0	0	0.6	189.649	189.63
DGM_03487	600	0	0	0.6	189.711	189.649
DGM_03525	750	0	0	0.75	185.78	185.574
DGM_03526	525	185.75	0	0.525	185.75	185.698
DGM_03538	675	0	0	0.675	185.43	182.439
DGM_03539	1800	0	0	1.8	181.314	181.289
DGM_03541	1200	0	0	1.2	184.14	184.107
DGM_03556	750	0	0	0.75	184.64	184.05
DGM_03562	825	0	0	0.825	186.014	185.57
DGM_03568	300	0	0	0.3	189.57	188.605
DGM_03575	300	0	0	0.3	186.8	186.75
DGM_03577	375	0	0	0.375	185.727	185.57
DGM_03592	300	0	0	0.3	185.726	185.66
DGM_03597	375	0	0	0.375	188.425	188.259
DGM_03598	375	0	0	0.375	188.343	188.285
DGM_03608	375	0	0	0.375	189.635	189.452
DGM_03615	1800	0	0	1.8	184.908	184.384
DGM_03620	750	0	0	0.75	184.104	184.811
DGM_03624	300	0	0	0.3	186.366	186.323
DGM_03625	300	0	0	0.3	185.724	185.519
DGM_03626	300	0	0	0.3	185.765	185.656
DGM_03630	300	186.504	186.51	0.3	186.51	186.504
DGM_03653	300	188.104	184.6	0.3	185.104	184.6
DGM_03660	600	0	0	0.6	185.885	185.869
DGM_03661	600	0	0	0.6	186.077	186.019
DGM_03663	UNKNOWN	0	0	0.6	183.164	183.149
DGM_03712	1050	0	0	1.05	184.217	184.209
DGM_03713	1050	0	0	1.05	185.153	184.668
DGM_03714	1050	0	0	1.05	184.628	184.617
DGM_03716	300	0	0	0.3	186.5	186.391
DGM_03719	975	0	0	0.975	186.156	186.141
DGM_03720	1050	0	0	1.05	185.768	185.75
DGM_03721	1050	0	0	1.05	185.75	185.734
DGM_03722	1050	0	0	1.05	185.456	185.421
DGM_03734	375	185.36	185.9	0.375	185.9	185.36
DGM_03736	300	0	0	0.3	190.619	190.5
DGM_03737	300	0	0	0.3	191.372	191.284
DGM_03738	300	0	0	0.3	190.555	190.5
DGM_03739	375	0	0	0.375	190.5	190.423
DGM_03740	450	0	0	0.45	190.38	190.35
DGM_03741	450	0	0	0.45	190.35	190.289
DGM_03742	300	0	0	0.3	190.5	190.469
DGM_03743	525	0	0	0.525	188.49	188.43
DGM_03747	600	0	0	0.6	187.996	186.2
DGM_03754	975	0	0	0.975	186.615	186.572
DGM_03755	300	0	0	0.3	186.5	186.291
DGM_03756	825	0	0	0.825	186.688	186.645
DGM_03757	300	0	0	0.3	188.5	188.365
DGM_03758	300	0	0	0.3	187.757	187.603
DGM_03762	300	0	0	0.3	188.18	188.03
DGM_03768	300	0	0	0.3	191.111	191.07
DGM_03769	300	0	0	0.3	191.07	191.042
DGM_03774	525	0	0	0.525	189.632	189.601
DGM_03775	600	0	0	0.6	189.022	188.997
DGM_03776	600	0	0	0.6	188.997	188.973
DGM_03777	600	0	0	0.6	188.973	188.94
DGM_03788	300	0	0	0.3	188.5	188.306
DGM_03789	375	0	0	0.375	189.852	189.754
DGM_03790	375	0	0	0.375	189.513	189.425
DGM_03791	450	0	0	0.45	189.284	189.18
DGM_03792	750	0	0	0.75	187.53	187.496
DGM_03793	750	0	0	0.75	187.496	187.483
DGM_03795	525	0	0	0.525	188.335	188.241
DGM_03796	600	0	0	0.6	188.241	187.613
DGM_03805	750	186.896	186.7565	0.75	186.896	186.756
DGM_03810	750	0	0	0.75	188.147	187.955
DGM_03815	1050	0	0	1.05	186.031	185.739
DGM_03817	1200	0	0	1.2	185.564	185.556
DGM_03825	300	0	0	0.3	192.425	192.226
DGM_03826	375	0	0	0.375	188.661	188.527
DGM_03827	675	0	0	0.675	188.661	188.368
DGM_03828	750	0	0	0.75	188.368	188.147
DGM_03829	300	0	0	0.3	192.5	192.308

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_03832	300	0	0	0.3	189.06	188.939
DGM_03833	300	0	0	0.3	191.786	191.745
DGM_03834	300	0	0	0.3	192.5	192.462
DGM_03842	600	0	0	0.6	187.944	187
DGM_03856	900	0	0	0.9	188.127	188.099
DGM_03857	900	0	0	0.9	188.099	188.092
DGM_03872	300	0	0	0.3	191.532	191.515
DGM_03873	UNKNOWN	0	0	0.3	190.731	190.5
DGM_03874	300	0	0	0.3	191.872	191.814
DGM_03875	300	0	0	0.3	191.532	191.5
DGM_03876	375	0	0	0.375	191.254	191.14
DGM_03877	450	0	0	0.45	190.439	190.35
DGM_03878	450	0	0	0.45	190.35	190.33
DGM_03879	525	0	0	0.525	190.294	190.275
DGM_03880	525	0	0	0.525	189.869	189.82
DGM_03881	825	0	0	0.825	187.313	187.28
DGM_03884	900	0	0	0.9	187.28	187.269
DGM_03885	825	0	0	0.825	189.975	189.944
DGM_03886	825	0	0	0.825	189.997	189.975
DGM_03887	825	0	0	0.825	190.288	190.259
DGM_03888	825	0	0	0.825	190.332	190.288
DGM_03889	825	0	0	0.825	190.356	190.332
DGM_03890	825	0	0	0.825	190.398	190.356
DGM_03891	450	0	0	0.45	191.412	191.35
DGM_03892	825	0	0	0.825	190.45	190.398
DGM_03893	1350	0	0	1.35	190.408	190.404
DGM_03903	300	0	0	0.3	191.006	190.888
DGM_03904	525	0	0	0.525	190.744	190.663
DGM_03905	600	0	0	0.6	190.244	190.2
DGM_03906	600	0	0	0.6	190.2	190.159
DGM_03907	600	0	0	0.6	189.75	189.714
DGM_03908	600	0	186.48	0.6	186.495	186.48
DGM_03910	375	0	0	0.375	189.429	189.409
DGM_03911	300	190.19	0	0.3	190.19	187.8
DGM_03990	450	0	0	0.45	194.49	193.76
DGM_04005	375	191.62	0	0.375	191.62	191.605
DGM_04011	1200	0	0	1.2	188.97	188.95
DGM_04014	450	191.41	0	0.45	191.41	191.1
DGM_04018	750	192.051	190.58	0.75	190.451	190.111
DGM_04021	750	190.58	189.733	0.75	190.111	189.733
DGM_04024	900	0	0	0.9	190.159	188.906
DGM_04029	750	0	0	0.75	189.1	188.91
DGM_04030	1200	188.909	188.91	1.2	188.91	188.909
DGM_04032	NOT	0	0	1.2	188.887	188.6
DGM_04033	NOT	0	0	1.4	188.6	188.581
DGM_04034	900	0	0	0.9	188.9	188.9
DGM_04036	900	0	0	0.9	190.082	190.076
DGM_04042	750	0	0	0.75	191.05	190.32
DGM_04058	750	0	0	0.75	173.646	173.634
DGM_04059	675	0	0	0.675	173.863	173.646
DGM_04069	900	0	0	0.9	174.343	174.343
DGM_04073	900	0	0	0.9	174.926	174.9
DGM_04074	900	0	0	0.9	177.639	177.631
DGM_04075	900	0	0	0.9	177.954	177.927
DGM_04085	900	0	0	0.9	181.69	181.664
DGM_04086	900	0	0	0.9	181.323	181.316
DGM_04087	600	0	0	0.6	184.135	184.091
DGM_04088	600	0	0	0.6	187.234	187.2
DGM_04093	600	0	0	0.6	189.859	189.849
DGM_04094	600	0	0	0.6	190.651	190.601
DGM_04095	600	0	0	0.6	194.885	194.838
DGM_04108	600	0	0	0.6	197	196.92
DGM_04115	675	0	0	0.675	179.18	179.111
DGM_04125	750	0	0	0.75	177.501	177.486
DGM_04126	825	0	0	0.825	176.03	176.004
DGM_04127	825	0	0	0.825	173.197	173.146
DGM_04128	825	0	0	0.825	171.92	171.899
DGM_04129	450	0	0	0.45	173.35	173.345
DGM_04132	750	0	0	0.75	194.007	193.98
DGM_04134	750	0	0	0.75	194.757	194.748
DGM_04135	600	0	0	0.6	195.006	194.939
DGM_04136	600	0	0	0.6	194.03	193.98
DGM_04137	300	0	0	0.3	195.5	195.447
DGM_04138	1050	0	0	1.05	193.59	193.57
DGM_04139	1050	0	0	1.05	192.89	192.22
DGM_04147	600	0	0	0.6	191.27	189.66
DGM_04156	825	0	0	0.825	188.37	188.328
DGM_04157	825	0	0	0.825	188.328	188.293
DGM_04159	300	0	0	0.3	192.19	192.171
DGM_04171	0	0	0	0.375	187.98	187.962
DGM_04172	300	0	0	0.3	187.982	187.962
DGM_04183	300	0	0	0.3	193.038	192.933
DGM_04191	300	0	0	0.3	193.063	192.922
DGM_04192	300	0	0	0.3	192.893	192.855

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_04193	0	0	0	0.3	189.168	189.098
DGM_04203	300	0	0	0.3	190.274	190.24
DGM_04204	300	0	0	0.3	191.385	191.363
DGM_04223	0	0	0	0.3	181.857	181.82
DGM_04229	1350	0	0	1.35	185.219	185.193
DGM_04230	1350	0	0	1.35	184.481	184.45
DGM_04260	450	0	0	0.45	186.29	186.25
DGM_04261	450	0	0	0.45	186.35	186.254
DGM_04262	300	0	0	0.3	186.315	186.25
DGM_04267	600	-185.661	-185.76	0.6	185.76	185.661
DGM_04270	0	0	0	1	164.779	164.76
DGM_04272	0	0	0	1	164.466	164.321
DGM_04287	1375	189.983	189.607	1.2	189.983	189.607
DGM_04305	375	0	0	0.375	192.987	192.858
DGM_04306	450	0	0	0.45	192.566	192.55
DGM_04307	450	0	0	0.45	192.366	192.35
DGM_04308	750	0	0	0.75	191.682	191.667
DGM_04309	750	0	0	0.75	189.216	189.157
DGM_04310	750	0	0	0.75	188.706	188.67
DGM_04311	900	0	0	0.9	187.506	187.488
DGM_04323	0	0	0	0.6	188.749	188.741
DGM_04343	250	197.72	196.51	0.25	196.51	195.82
DGM_04360	300	0	0	0.3	194.429	194.28
DGM_04375	300	0	0	0.3	194.5	194.496
DGM_04376	0	0	0	0.4	194.5	194.441
DGM_04435	1350	0	0	1.35	190.465	190.45
DGM_04459	1350	0	0	1.35	189.65	189.609
DGM_04460	1350	0	0	1.35	189.379	189.37
DGM_04461	1350	0	0	1.35	188.465	188.45
DGM_04462	1350	0	0	1.35	189.48	189.466
DGM_04464	1350	0	0	1.35	189.03	188.993
DGM_04469	300	0	0	0.3	191.723	191.647
DGM_04470	0	0	0	1.8	184.9	183.982
DGM_04471	300	0	0	0.3	190.093	190
DGM_04475	600	0	0	0.6	190.14	190.124
DGM_04478	UNKNOWN	0	0	0.675	187.05	187.049
DGM_04481	200	0	0	0.2	190.399	190.366
DGM_04486	1050	0	0	1.05	178.74	178.736
DGM_04488	1200	0	0	1.2	176.078	170.36
DGM_04491	900	0	0	0.9	171.44	171.3
DGM_04498	450	177.72	177.39	0.2	177.05	177.36
DGM_04499	750	0	0	0.75	177.45	177.35
DGM_04500	450	0	0	0.45	187.926	187.91
DGM_04504	1050	185.45	185.64	1.05	185.64	185.45
DGM_04505	1050	0	0	1.05	185.87	185.64
DGM_04536	450	0	0	0.45	177.734	177.72
DGM_04537	450	0	0	0.45	177.735	177.72
DGM_04538	600	0	0	0.6	183.27	183.216
DGM_04539	600	0	0	0.6	183.327	183.27
DGM_04540	600	0	0	0.6	184.2	184.111
DGM_04541	600	0	0	0.6	184.2	184.179
DGM_04542	600	0	0	0.6	184.2	184.15
DGM_04543	600	0	0	0.6	184.18	184.117
DGM_04545	450	0	0	0.45	185.384	185.38
DGM_04546	375	0	0	0.375	185.5	185.384
DGM_04547	300	0	0	0.3	185.698	185.5
DGM_04549	1200	0	0	1.2	182.908	182.901
DGM_04550	1200	0	0	1.2	183.226	183.219
DGM_04551	1200	0	0	1.2	191.491	191.47
DGM_04552	1200	0	0	1.2	192.47	192.444
DGM_04554	1050	0	0	1.05	193.741	193.734
DGM_04560	0	0	0	0.3	205.643	205.62
DGM_04561	1050	0	0	1.05	189.149	186.77
DGM_04562	750	0	0	0.75	189.206	189.149
DGM_04563	375	0	0	0.375	191.536	191.428
DGM_04564	300	0	0	0.3	192.647	192.491
DGM_04565	0	0	0	0.3	190.624	190.576
DGM_04566	750	0	0	0.75	189.22	189.206
DGM_04567	0	0	0	0.3	177.461	177.35
DGM_04568	450	0	174.124	0.45	174.144	174.124
DGM_04570	600	0	195.23	0.6	199.86	195.23
DGM_04580	750	0	0	0.75	183.9	183.863
DGM_04583	1050	0	0	1.05	178.835	178.825
DGM_04584	1050	0	0	1.05	177.15	176.077
DGM_04585	1050	0	0	1.05	176.077	176.05
DGM_04590	525	0	0	0.525	177.661	177.649
DGM_04591	1650	0	0	1.65	118.125	118.123
DGM_04593	450	0	0	0.45	203.144	203.126
DGM_04594	375	0	0	0.375	173	172.896
DGM_04595	375	0	0	0.375	175.48	175.38
DGM_04597	750	0	0	0.75	172.757	172.42
DGM_04616	0	0	0	0.3	188.014	187.99
DGM_04637	250	0	0	0.25	188.211	188.169
DGM_04638	300	0	0	2.4	185.528	185.517

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_04639	250	0	0	0.25	187.896	187.838
DGM_04641	0	0	0	0.25	188.299	188.255
DGM_04647	1500	0	0	1.5	188.801	186.32
DGM_04650	1650	0	0	1.65	184.54	184.529
DGM_04651	450	0	0	0.45	190.401	190.256
DGM_04652	525	0	0	0.525	187.784	187.683
DGM_04653	375	0	0	0.375	189.174	189.078
DGM_04657	1350	0	0	1.35	188.993	188.945
DGM_04660	1050	0	0	1.05	182.95	182.919
DGM_04661	750	0	0	0.75	183.159	183.14
DGM_04662	900	0	0	0.9	188.906	188.839
DGM_04663	900	0	0	0.9	188.9	188.888
DGM_04664	900	0	0	0.9	189.024	189.021
DGM_04665	NOT	0	0	0.3	189.5	189.413
DGM_04666	750	0	0	0.75	189.011	189.001
DGM_04669	0	0	0	1.05	182.088	182.057
DGM_04680	1200	0	186.995	1.2	187.068	186.995
DGM_04681	1350	0	0	1.35	181.41	180.17
DGM_04689	1200	0	0	1.2	177.279	177.236
DGM_04690	1500	0	0	1.5	176.01	176.005
DGM_04692	0	0	0	1.35	179.149	179.09
DGM_04696	1350	175.651	0	1.35	175.651	175.617
DGM_04697	NOT	181.275	181.256	1.35	181.275	181.256
DGM_04702	1650	0	0	1.65	185.909	185.861
DGM_04704	1800	0	0	1.8	181.289	181.259
DGM_04705	0	0	0	1.35	177.07	177.044
DGM_04708	1500	0	0	1.5	183.16	183.065
DGM_04709	1525	0	0	1.525	183.1	183.073
DGM_04712	1200	0	0	1.2	191.13	190.771
DGM_04714	1375	0	0	1.375	190.45	190.38
DGM_04715	1375	0	0	1.375	172.139	172.127
DGM_04717	1200	0	0	1.2	172.603	172.6
DGM_04718	900	0	0	0.9	173.06	173.034
DGM_04719	900	0	0	0.9	174.867	174.785
DGM_04720	900	0	0	0.9	174.222	174.102
DGM_04721	900	0	0	0.9	174.252	174.222
DGM_04722	1500	0	0	1.5	190.451	190.41
DGM_04723	1350	0	0	1.35	172.127	172.097
DGM_04724	1200	0	0	1.2	172.763	172.734
DGM_04725	1200	0	0	1.2	175.064	175.014
DGM_04726	1200	0	0	1.2	175.125	175.101
DGM_04727	1200	0	0	1.2	175.17	175.125
DGM_04728	1200	0	0	1.2	175.626	175.6
DGM_04729	1200	0	0	1.2	176.6	176.574
DGM_04737	675	0	0	0.675	181.051	181.029
DGM_04738	675	0	0	0.675	182.206	182.125
DGM_04739	600	0	0	0.6	182.448	182.39
DGM_04744	0	0	0	0.3	177.647	177.59
DGM_04747	355	0	0	0.355	182.054	181.98
DGM_04754	1200	0	0	1.2	188.634	188.6
DGM_04755	1200	0	0	1.2	188.95	188.925
DGM_04762	NOT	180.452	180.367	1.5	180.452	180.367
DGM_04763	1500	0	0	1.5	180.367	179.629
DGM_04765	2400	0	0	2.4	177.847	177.844
DGM_04766	2400	0	0	2.4	177.924	177.847
DGM_04767	1200	182.017	181.6	1.2	182.017	181.366
DGM_04768	1200	0	0	1.2	180.575	180.574
DGM_04770	600	0	0	0.6	182.677	182.538
DGM_04772	2400	0	0	2.4	179.293	179.287
DGM_04776	600	0	0	0.6	182.68	182.75
DGM_04778	675	0	0	0.675	184.286	184.149
DGM_04781	1800	172.74	172.52	1.8	172.939	172.719
DGM_04782	750	175.7	174.79	0.75	173.58	172.92
DGM_04783	0	0	0	1.5	170.74	170.55
DGM_04784	900	0	0	0.9	180.87	179.74
DGM_04785	975	0	0	0.975	179.08	179.07
DGM_04786	1800	172.45	172.22	1.8	172.719	172.489
DGM_04788	2400	0	0	2.4	179.287	179.26
DGM_04790	2100	167.986	165.199	2.1	164.919	162.132
DGM_04791	900	0	0	0.9	190.016	189.991
DGM_04792	1050	0	0	1.05	182.88	182.84
DGM_04793	1200	0	0	1.2	182.84	182.795
DGM_04809	525	0	0	0.525	184.38	184.345
DGM_04810	600	0	0	0.6	184.345	184.34
DGM_04812	600	0	0	0.6	158.519	158.504
DGM_04813	750	0	0	0.75	172.77	172.758
DGM_04814	675	0	0	0.675	173.524	172.77
DGM_04815	675	0	0	0.675	173.58	173.524
DGM_04816	675	0	0	0.675	173.663	173.58
DGM_04817	675	0	0	0.675	173.8	173.744
DGM_04818	1050	0	0	1.05	173.351	173.33
DGM_04819	900	0	0	0.9	173.49	173.451
DGM_04820	825	0	0	0.825	173.92	173.876
DGM_04821	600	0	0	0.6	174.19	174.121

	CITY GIS			PCSWMM MODEL		
PIPE ID	**SIZE (mm)**	**US INV ELE**	**DS INV ELE**	**SIZE (m)**	**US INV ELE**	**DS INV ELE**
DGM_04822	1050	0	0	1.05	174.133	174.1
DGM_04824	600	0	0	0.6	190.694	190.625
DGM_04826	600	0	0	0.6	199.696	199.6
DGM_04827	600	0	0	0.6	198.112	198.05
DGM_04828	750	0	0	0.75	197.933	197.88
DGM_04829	600	0	0	0.6	199.728	199.717
DGM_04832	900	0	0	0.9	191.379	191.33
DGM_04833	750	0	0	0.75	195.814	195.76
DGM_04841	750	0	0	0.75	200.47	198.832
DGM_04842	750	0	0	0.75	197.08	197.046
DGM_04843	750	0	0	0.75	193.935	193.848
DGM_04844	825	0	0	0.825	192.079	192.044
DGM_04845	1050	0	0	1.05	189.948	189.912
DGM_04846	1050	0	0	1.05	187.125	187.095
DGM_04847	675	0	0	0.675	186.265	186.22
DGM_04848	675	0	0	0.675	189.115	189.052
DGM_04849	675	184.153	184.12	0.675	184.14	184.12
DGM_04850	675	184.811	184.733	0.675	184.811	184.16
DGM_04856	825	184.32	184.27	0.825	184.13	184.25
DGM_04882	300	188.56	188.001	0.3	188.56	188.01
DGM_04888	375	0	0	0.375	192.514	192.391
DGM_04889	375	0	0	0.375	192.172	192.024
DGM_04890	375	0	0	0.375	191.336	191.278
DGM_04891	375	0	0	0.375	189.508	189.425
DGM_04892	375	0	0	0.375	189.546	189.425
DGM_04893	375	0	0	0.375	191.14	191.064
DGM_04894	375	0	0	0.375	191.474	191.425
DGM_04895	300	0	0	0.3	191.5	191.401
DGM_04900	525	0	0	0.525	181.87	181.817
DGM_04937	0	0	0	0.45	188.077	188.04
DGM_04945	0	0	0	0.3	182.33	182.3
DGM_04946	0	0	0	0.3	181.983	181.95
DGM_04951	0	0	0	0.3	181.903	181.87
DGM_04952	0	0	0	0.3	182.501	182.47
DGM_04984	750	0	0	0.75	194.326	194.291
DGM_04985	300	0	0	0.3	195.328	195.063
DGM_04986	675	0	0	0.675	194.693	194.688
DGM_04990	1525	0	0	1.525	183.24	183.183
DGM_04991	1050	0	0	1.05	183.485	183.483
DGM_04998	NOT	170.88	170.92	1.2	170.92	170.88
DGM_05001	825	176.01	176.001	0.825	175	176
DGM_05002	NOT	172.421	172.335	0.9	172.421	172.335
DGM_05003	NOT	172.335	172.282	0.9	172.335	172.282
DGM_05004	0	0	0	1.35	179.2	179.197
DGM_05008	750	0	179	0.75	179.003	179
DGM_05017	375	0	0	0.375	192.425	192.351
DGM_05018	525	191.118	0	0.525	191.118	191.048
DGM_05019	525	0	190.51	0.525	190.529	190.51
DGM_05036	825	0	0	0.825	188.17	188.128
DGM_05039	0	0	0	0.2	177.631	177.219
DGM_05040	0	0	0	0.2	177.219	176.78
DGM_05041	0	0	0	0.25	176.78	176.458
DGM_05042	0	0	0	0.2	177.912	177.631
DGM_05043	0	0	0	0.2	178.492	178.164
DGM_05046	300	0	0	0.3	192.047	191.96
DGM_05047	300	0	0	0.3	191.95	191.894
DGM_05048	300	0	0	0.3	192.175	192.09
DGM_05049	375	0	0	0.375	192.496	192.378
DGM_05050	375	0	0	0.375	192.211	192.101
DGM_05051	375	0	0	0.375	188.106	187.962
DGM_05081	0	0	0	1	180.588	180.583
DGM_05082	0	0	0	1	180.642	180.637
DGM_05085	1200	0	0	1.2	182.448	182.439
DGM_05086	1200	185.81	185.41	1.2	182.848	182.448
DGM_05088	600	0	0	0.6	186.355	186.34
DGM_05089	900	0	0	0.9	182.86	182.848
DGM_05090	900	0	0	0.9	182.88	182.86
DGM_05091	250	0	0	0.25	178.502	178.466
DGM_05092	1200	185.27	185.16	1.2	182.439	182.333
DGM_05093	1650	185.16	184.18	1.65	181.572	180.586
DGM_05094	1350	0	0	1.35	181.58	181.572
DGM_05095	1650	184.91	181.44	1.65	180.569	177.1
DGM_05101_Pond5				0.6	184.986	184.104
DGM_05118	NOT	99.5	97.76	1	99.5	97.76
DGM_05119	NOT	97.76	97.674	1	97.76	97.674
DGM_05120	NOT	97.674	92.93	1	97.674	92.93
DGM_05130	675	184.69	184.6533	0.675	184.69	184.653
DGM_05136	600	186.8204	186.795	0.6	186.82	186.795
DGM_05143	400	185.922	185.957	0.4	185.957	185.922
DGM_05149	600	187.74	187.57	0.6	188.4	187.83
DGM_05150	450	0	0	0.45	189.443	189.4
DGM_05151	525	0	0	0.525	195.994	195.985
DGM_05152	250	0	0	0.25	192.725	192.232
DGM_05179	375	0	0	0.375	174.363	174.216

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_05185	300	0	0	0.3	174.015	173.98
DGM_05206	1200	171.91	171.23	1.2	171.91	171.75
DGM_05207	1200	171.23	171.82	1.2	171.75	170.99
DGM_05208	1200	170.82	170.723	1.2	170.99	170.723
DGM_05226	1050	176.01	176	1.05	176	175.95
DGM_05253	0	0	0	1	164.978	164.953
DGM_05254	1050	0	0	1.05	175.758	175.728
DGM_05257	NOT	174.346	170.688	1.2	174.346	170.688
DGM_05258	750	0	0	0.75	175.962	175.934
DGM_05259	750	0	0	0.75	176.014	175.962
DGM_05260	1350	179.233	178.971	1.35	176.385	176.123
DGM_05261	NOT	180.48	180.48	1.4	176.08	176.081
DGM_05262	NOT	175.981	174.769	1.5	175.981	174.769
DGM_05263	NOT	174.769	174.444	1.5	174.769	174.444
DGM_05264	NOT	174.444	170.775	1.5	174.444	170.775
DGM_05265	NOT	179.222	175.268	1.2	179.222	175.268
DGM_05266	NOT	175.268	170	1.2	175.268	170
DGM_05281	NOT	185.834	175.077	2.4	185.834	175.077
DGM_05286	1950	173.373	172.845	2.4	173.373	172.845
DGM_05287	1950	173.955	173.373	2.4	173.955	173.373
DGM_05288	NOT	188.214	187.068	1.2	188.214	187.068
DGM_05293	NOT	190.6	186.24	0.9	190.6	186.24
DGM_05295	NOT	189.387	188.025	0.375	189.387	188.025
DGM_05301	NOT	175.02	170.554	1.5	175.02	170.554
DGM_05302	NOT	175.09	175.02	1.5	175.09	175.02
DGM_05312	200	0	0	0.2	191.87	191.69
DGM_05321	1500	162.618	158.35	1.5	162.099	157.831
DGM_05341	0	0	0	0.3	189.213	189.168
DGM_05344	1050	0	0	1.05	189.49	189.482
DGM_05347	600	0	0	0.6	187	186.988
DGM_05351	900	0	0	0.9	185.539	185.537
DGM_05352	900	0	0	0.9	185.351	185.322
DGM_05353	900	0	0	0.9	186.224	186.208
DGM_05354	900	0	0	0.9	186.773	186.738
DGM_05360	1650	0	0	1.65	188.162	188.15
DGM_05366	600	0	0	0.6	184.2	184.191
DGM_05370	525	0	0	0.525	184.365	184.306
DGM_05382	900	0	0	0.9	184.149	184.11
DGM_05394	0	0	0	0.9	178.543	178.54
DGM_05412	0	0	0	1.525	182.76	182.746
DGM_05413	NOT	181.37	181.184	1.525	181.37	181.184
DGM_05414	NOT	183.998	183.998	1.5	183.998	183.998
DGM_05415	1650	174.504	174.26	2.4	174.504	174.26
DGM_05418	375	178.76	178.95	0.375	178.95	178.76
DGM_05428	250	178.34	179.42	0.25	179.42	178.34
DGM_05436	250	179.06	179.48	0.25	179.48	179.06
DGM_05443	450	0	177.12	0.45	177.188	177.12
DGM_05454	1200	0	0	1.2	175.76	175.757
DGM_05484	0	0	0	1.05	175.86	175.8
DGM_05489	525	175.5	0	0.525	175.75	175.65
DGM_05500	NOT	176.35	176.28	1.65	176.35	176.28
DGM_05519	375	0	0	0.375	197.983	197.97
DGM_05540	0	0	0	0.3	193.897	193.83
DGM_05556	375	0	0	0.375	173.134	173.132
DGM_05578	0	0	0	1	164.329	164.321
DGM_05605	0	0	0	1.05	176.781	176.651
DGM_05607	375	202.23	0	0.375	202.23	201.955
DGM_05608	250	0	0	0.25	186.657	186.492
DGM_05609	0	0	0	0.25	185.524	185.42
DGM_05611	NOT	180.552	180.503	0.975	180.552	180.503
DGM_05618	300	0	0	0.3	189.539	189.429
DGM_05621	450	177.44	0	0.45	177.44	178.707
DGM_05623	1200	0	0	1.2	171.585	171.577
DGM_05624	1200	0	170.88	1.2	170.9	170.88
DGM_05636	375	178.871	178.72	0.375	178.871	173.96
DGM_05637	0	0	0	0.375	190.09	190.057
DGM_05638	700	0	0	0.7	190.09	190.085
DGM_05639	450	0	0	0.45	186.35	186.294
DGM_05640	525	0	0	0.525	186.677	186.585
DGM_05641	525	0	0	0.525	182.7	182.631
DGM_05642	600	0	0	0.6	182.631	182.616
DGM_05644	350	0	190.582	0.35	190.7	190.582
DGM_05672	375	173.181	0	0.375	173.181	172.19
DGM_05674	900	0	0	0.9	159.026	158.983
DGM_05679	750	171.04	0	0.75	171.04	171.009
DGM_05680	900	172.26	0	0.9	172.26	171.25
DGM_05681	0	0	0	0.3	171.289	171.25
DGM_05682	900	171.25	0	0.9	171.25	171.233
DGM_05683	250	0	0	0.25	191.138	191.094
DGM_05684	300	0	0	0.3	195.149	195.1
DGM_05685	300	0	0	0.3	176.579	176.56
DGM_05686	300	177.56	0	0.3	177.56	177.554
DGM_05687	200	192.6	0	0.2	192.6	192.554
DGM_05688	300	0	195.59	0.3	192.554	192.388

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_05689	600	0	0	0.6	179.32	179.285
DGM_05690	600	0	177.29	0.6	177.296	177.29
DGM_05691	300	193.73	0	0.3	193.73	193.73
DGM_05692	300	193.73	0	0.3	193.73	193.7
DGM_05693	250	190.78	0	0.25	190.78	189.35
DGM_05694	150	190.78	0	0.15	189.436	189.433
DGM_05698	NOT	170.74	170.72	1.5	170.74	170.74
DGM_05699	NOT	170.72	170.54	1.5	170.74	170.55
DGM_05710	825	0	0	0.825	193.789	193.779
DGM_05711	900	0	0	0.9	191.656	191.605
DGM_05712	900	0	0	0.9	190.027	189.976
DGM_05713	900	0	187.65	0.9	187.662	187.65
DGM_05714	900	187.65	0	0.9	187.65	187.628
DGM_05715	375	0	0	0.375	173.781	173.756
DGM_05716	375	173.87	0	0.375	173.87	173.781
DGM_05723	0	172.8	172.71	0.525	172.8	172.71
DGM_05728	825	172.51	172.84	0.825	172.84	172.51
DGM_05729	825	172.85	172.9	0.825	172.9	172.85
DGM_05730	825	172.16	172.4	0.825	173.25	172.9
DGM_05731	825	0	0	0.825	172.51	172.499
DGM_05732	1200	0	0	1.2	174.66	174.646
DGM_05733	1200	0	0	1.2	174.646	174.641
DGM_05734	450	0	0	0.45	173.732	173.71
DGM_05735	525	0	0	0.525	173.455	173.43
DGM_05736	450	0	0	0.45	173.82	173.8
DGM_05737	525	0	0	0.525	173.82	173.8
DGM_05738	450	0	0	0.45	174.349	174.327
DGM_05739	1050	0	0	1.05	173.33	173.283
DGM_05740	600	0	0	0.6	189.524	189.397
DGM_05741	600	0	0	0.6	189.376	189.37
DGM_05754	0	0	0	1.05	175.86	175.816
DGM_05755	0	0	0	1.05	175.816	175.758
DGM_05765	900	179.46	178.79	2.4	179.46	178.79
DGM_05766	300	0	187.72	0.3	187.737	187.72
DGM_05768	1200	0	0	1.2	178.6	178.559
DGM_05769	1200	0	0	1.2	176.922	176.808
DGM_05770	1200	0	0	1.2	176.216	176.105
DGM_05785	0	0	0	0.3	185.354	185.34
DGM_05787	600	178.46	178.37	0.6	179.81	179.72
DGM_05788	600	178.57	178.46	0.6	179.72	179.61
DGM_05789	525	178.86	178.67	0.525	179.61	179.42
DGM_05792	250	179.59	179.52	0.25	179.42	179.35
DGM_05793	300	0	192.92	0.3	192.71	192.92
DGM_05850	1200	0	0	1.2	177.35	176.905
DGM_05851	1200	0	0	1.2	176.807	176.75
DGM_05852	1350	0	0	1.35	176.75	176.683
DGM_05853	1350	0	0	1.35	180.15	180.133
DGM_05854	200	0	0	0.2	179.977	179.947
DGM_05855	200	0	0	0.2	179.955	179.925
DGM_05856	1050	0	0	1.05	180.228	180.15
DGM_05858	600	0	0	0.6	189.351	189.343
DGM_05859	600	0	0	0.6	188.434	188.422
DGM_05963	450	174.39	175.95	0.45	175.95	174.39
DGM_05967	450	0	0	0.45	174.25	173.71
DGM_05968	300	0	0	0.3	175.66	175.373
DGM_05969	375	0	0	0.375	175.55	175.199
DGM_05970	450	0	0	0.45	175.168	174.9
DGM_05971	450	0	0	0.45	174.269	174
DGM_05972	0	0	0	0.3	174.543	174.517
DGM_05973	0	0	0	0.3	175.129	174.85
DGM_05974	0	0	0	0.3	174.85	174.823
DGM_05977	300	0	0	0.3	188.755	188.72
DGM_05989	1200	175.38	175.4	1.2	175.4	175.38
DGM_05991	300	175.48	1755.39	0.3	175.48	175.39
DGM_05994	600	175.86	178.94	0.6	178.94	175.86
DGM_05995	600	0	0	0.6	178.974	178.94
DGM_05996	600	0	179.15	0.6	179.3	179.15
DGM_05997	0	0	0	0.45	179.038	178.974
DGM_05998	0	0	0	0.45	179.048	179.038
DGM_06003	0	0	0	0.3	179.761	179.638
DGM_06004	0	0	0	0.3	179.68	179.153
DGM_06005	0	0	0	0.6	179.153	176.754
DGM_06006	0	0	0	0.3	179.965	179.878
DGM_06007	0	0	0	0.3	180.063	180.018
DGM_06008	0	0	0	0.45	179.62	179.528
DGM_06009	0	0	0	0.6	176.754	176.474
DGM_06010	0	0	0	0.3	179.79	179.757
DGM_06011	450	0	0	0.45	179.208	179.048
DGM_06012	0	0	0	0.45	180.547	179.208
DGM_06018	525	178.54	0	0.525	178.54	178.253
DGM_06023	375	0	0	0.375	177.677	177.67
DGM_06024	375	0	0	0.375	176.89	176.87
DGM_06077	300	172.76	0	0.3	172.76	172.507
DGM_06078	300	181.994102	181.46	0.3	181.994	181.46

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_06079	750	0	0	0.75	185.43	185.38
DGM_06080	975	0	0	0.975	184.81	184.81
DGM_06082	0	0	0	0.3	184.73	184.694
DGM_06083	0	0	0	0.3	184.471	184.453
DGM_06084	0	0	0	0.3	184.483	184.461
DGM_06085	0	0	0	0.2	184.885	184.507
DGM_06086	200	0	0	0.2	184.8	184.8
DGM_06088	750	0	0	0.75	171.36	171.43
DGM_06089	900	0	0	0.9	171.36	171.34
DGM_06090	900	0	0	0.9	171.36	172.33
DGM_06091	450	0	0	0.45	173.21	172.91
DGM_06092	450	0	0	0.45	172.91	172.694
DGM_06093	450	0	172.01	0.45	172.121	172.01
DGM_06098	450	0	0	0.45	172.207	172.201
DGM_06099	375	0	0	0.375	172.497	172.489
DGM_06100	300	0	0	0.3	193.369	193.249
DGM_06101	375	0	192.62	0.375	192.725	192.62
DGM_06105	375	0	0	0.375	192.472	190.21
DGM_06106	600	0	190.73	0.6	190.838	190.73
DGM_06110	375	0	0	0.375	190.523	190.5
DGM_06111	525	190.99	0	0.525	190.99	190.942
DGM_06114	600	173.54	173.6	0.6	173.6	173.54
DGM_06118	450	0	173.75	0.45	173.76	173.75
DGM_06119	375	0	0	0.375	173.425	173.375
DGM_06122	0	0	0	1	196.807	196.8
DGM_06123	600	0	0	0.6	186	182.244
DGM_06126	450	187.62	197.92	0.45	187.66	187.62
DGM_06129	525	186.19	186.86	0.525	186.86	186.19
DGM_06135	375	185.95	185.98	0.375	185.98	185.95
DGM_06139	0	0	0	1.2	175.214	175.09
DGM_06140	975	176.06	176.15	0.975	176.15	176.06
DGM_06152	900	177.89	178.31	0.9	178.31	177.89
DGM_06154	600	170.83	180.48	0.6	180.48	170.83
DGM_06414	600	190.95	0	0.6	190.95	190.936
DGM_06415	300	0	0	0.3	193.35	192.82
DGM_06419	375	180.2275	180.1895	0.375	180.228	180.19
DGM_06421	525	178.7725	178.6825	0.525	178.772	178.682
DGM_06422	250	179.025	179.0164232	0.25	179.025	179.016
DGM_06424	525	180.5625	180.4575	0.525	180.562	180.458
DGM_06425	675	180.6375	180.5495	0.675	180.638	180.55
DGM_06426	525	180.0485	179.9684401	0.525	180.048	179.968
DGM_06427	525	180.2725	180.0825	0.525	180.272	180.082
DGM_06428	525	180.3425	180.3055	0.525	180.342	180.306
DGM_06429	675	180.5175	180.4495	0.675	180.518	180.45
DGM_06430	600	180.97	180.9021837	0.6	180.97	180.902
DGM_06431	375	180.7315	180.6875	0.375	180.732	180.688
DGM_06432	375	181.3736516	181.2727414	0.375	181.374	181.273
DGM_06433	525	181.3525	181.2605089	0.525	181.352	181.261
DGM_06434	675	181.3375	181.2203419	0.675	181.338	181.22
DGM_06435	525	181.4725	181.3552163	0.525	181.472	181.355
DGM_06436	375	181.4520546	181.2955496	0.375	181.452	181.296
DGM_06437	600	181.39	181.2834	0.6	181.39	181.283
DGM_06438	450	181.4644809	181.364631	0.45	181.464	181.365
DGM_06439	525	181.327131	181.1214636	0.525	181.327	181.121
DGM_06440	750	181.355	181.2901168	0.75	181.355	181.29
DGM_06441	750	181.295	181.1630547	0.75	181.295	181.163
DGM_06442	375	181.4475	181.3008651	0.375	181.448	181.301
DGM_06443	525	181.3725	181.2539815	0.525	181.372	181.254
DGM_06444	525	181.2525	181.0831386	0.525	181.252	181.083
DGM_06445	600	181.12	180.9969015	0.6	181.12	180.997
DGM_06446	900	181.15	181.0995981	0.9	181.15	181.1
DGM_06447	375	180.9359305	180.8575	0.375	180.936	180.858
DGM_06448	825	181.0125	180.9275	0.825	181.012	180.928
DGM_06449	975	180.8965	180.8375	0.975	180.896	180.838
DGM_06450	1050	180.865	180.8251049	1.05	180.865	180.825
DGM_06455	200	178.9015932	179.4	0.2	179.4	178.902
DGM_1				1.5	175.102	175.09
DGM_10				1.8	182.508	182.477
DGM_100				0.375	179.757	179.718
DGM_101				0.525	178.652	178.514
DGM_102				0.525	178.514	178.482
DGM_104				1.5	170	169.63
DGM_11				0.9	179.688	179.68
DGM_12				0.525	183.394	183.389
DGM_13				1.65	185.33	185.33
DGM_14				1.65	182.802	185.33
DGM_15				1.8	183.103	182.508
DGM_16				1.2	172.09	169.584
DGM_17				1.8	182.477	182.459
DGM_18				1.8	182.428	182.422
DGM_19				1.8	182.459	182.428
DGM_2				1.05	179.828	179.809
DGM_20				1.2	171.455	171.437
DGM_21				1.35	190.627	190.593

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_22				1.35	190.593	190.59
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DGM_24				1.8	181.746	181.649
DGM_25				0.6	192.89	192.887
DGM_26				1.35	179.768	179.72
DGM_27				1.35	177.225	177.222
DGM_28				1.5	188.49	185.695
DGM_29				1.5	188.336	188.296
DGM_3				0.3	189.547	189.52
DGM_30				1.05	187.424	187.4
DGM_31				1.05	189.12	189.092
DGM_32				0.6	200.767	199.728
DGM_33				0.6	201.62	199.728
DGM_34				1.2	183.332	183.308
DGM_35				1.2	183.389	183.332
DGM_36				0.9	181.252	180.5
DGM_37				2.1	162.132	162.125
DGM_38				1.2	178.854	178.409
DGM_39				2.1	162.125	162.124
DGM_4				0.3	189.9	188.257
DGM_40				2.1	162.124	162.099
DGM_41				1.2	178.499	178.492
DGM_42				2.1	168.806	164.965
DGM_43				0.75	175.987	175.967
DGM_44				1.5	158.12	153.111
DGM_45				1.5	155.545	155.537
DGM_46				0.375	177.578	176.98
DGM_47				0.375	179.623	176.98
DGM_48				1.95	182.116	182.115
DGM_49				1.8	179.452	179.449
DGM_5				1.8	181.651	181.314
DGM_50				2.4	178	177.95
DGM_51				2.4	179.26	179.259
DGM_52				0.375	189.07	187.431
DGM_53				0.375	188.906	188.77
DGM_54				0.675	193.725	193.724
DGM_55				0.675	193.783	193.725
DGM_56				0.825	176.35	176.348
DGM_57				0.825	176.267	176.23
DGM_58				1.2	175.111	175.102
DGM_59				0.3	173.65	173.625
DGM_6				1.8	181.323	181.314
DGM_60				1.05	180.101	180.094
DGM_61				1.2	183.27	183.219
DGM_62				1.2	181.096	181.08
DGM_63				0.375	191.642	191.63
DGM_64				0.375	192.509	192.388
DGM_65				0.675	189.992	189.949
DGM_66				0.675	191.085	191.085
DGM_67				0.525	180.24	178.191
DGM_68				0.525	179.814	179.78
DGM_69				2.1	164.945	164.943
DGM_7				1.8	185.698	185.66
DGM_70				2.1	164.943	164.919
DGM_71				0.75	175.032	175.02
DGM_72				1.5	170.19	170.18
DGM_73				1.5	170.18	170
DGM_74				1.8	182.153	182.151
DGM_75				1.95	182.151	182.116
DGM_76				1.8	179.455	179.452
DGM_77				0.675	179.79	177.54
DGM_78				0.675	178.899	178.85
DGM_79				0.375	180.414	180.336
DGM_8				0.6	193.89	192.98
DGM_80				0.375	177.83	177.797
DGM_81				1.35	190.68	190.658
DGM_82				1.35	190.658	190.627
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DGM_84				1.05	192.572	192.545
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DGM_89				1.2	170.92	170.914
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DGM_90				1.2	170.92	170.919
DGM_91				1.8	183.953	183.492
DGM_92				1.8	183.492	183.103
DGM_93				1.8	181.259	181.21
DGM_94				1.8	181.21	181.207
DGM_95				0.75	192.078	192.059
DGM_96				0.75	192.059	192.05
DGM_97				1	160.189	160.185
DGM_98				1	160.185	160.184

	CITY GIS			PCSWMM MODEL		
PIPE ID	SIZE (mm)	US INV ELE	DS INV ELE	SIZE (m)	US INV ELE	DS INV ELE
DGM_99				0.375	180.199	180.164
GMBP_SWM_DSP00014Outlet2				0.6	187	186.8
SGM_06475				0.25	177.904	176.33

Appendix B Principles, Policies, and Level of Service

Master Servicing Plan Update and Wet Weather Management Strategy

Appendix B – Principles, Policies, and Level of Service

City of Niagara Falls

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June 6, 2024
Project No. 2402014

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1. Introduction

The City of Niagara Falls retained GEI Consultants Canada to complete a Master Servicing Plan and Wet Weather Management Strategy (MSP-WWMS). The intent of this study is to complete an evaluation of the City's existing water, wastewater, and stormwater infrastructure and to establish short-term and long-term vision, strategy, and policies to support the management and enhancement of water, wastewater, and stormwater infrastructure.

The MSP-WWMS will determine and optimize future water, wastewater, and stormwater infrastructure needs, including operation and maintenance improvements, within the City of Niagara Falls through to 2051 and beyond.

The purpose of this report is to summarize the recommended water, wastewater, and stormwater Policies, Hydraulic Level of Service (HLOS) Objectives, and Design Criteria that will be used to effectively evaluate the existing and future performance of the water, wastewater, and stormwater systems and further, as rationale in the development of a long-term servicing strategy which meets infrastructure capacity needs and details necessary upgrades.

1.1. Background Objectives

Execution of reasonable Policies and Hydraulic Level of Service (HLOS) objectives are essential in ensuring that the proper planning and design principles are followed in the development of detailed servicing strategies, implementation of system capital programs, and operations and maintenance practices.

Through the MSP-WWMS; draft Policies and HLOS objectives will be established and used to guide future investment in the water, wastewater, and stormwater systems.

The development of water, wastewater, and stormwater Policies and HLOS objectives have been based on existing documentation and related sources, and an assessment of the City's existing infrastructure condition and performance, including the following:

- City of Niagara Falls Official Plan (currently being updated)
- City of Niagara Falls Asset Management Plan (2022)
    - Niagara Falls Climate Change Adaptation Plan (2021)
- Federal and Provincial Policies and Legislation

- Existing design criteria
  - Niagara Region 2021 Master Servicing Plan Update (MSPU)
  - City of Niagara Falls 2020 Water System Model Update Calibration Report
  - City of Niagara Falls Engineering Design Guidelines Manual, updated in 2017
  - City of Niagara Falls Master Drainage Plan Update (2017)
  - City of Niagara Falls Pollution Prevention & Control Plan Study Update (2017)
  - Criteria required by the Ministry of Environment, Conservation, and Parks (MECP)
  - Other local municipal design criteria
- Existing system performance
  - Historic and existing system operations and performance
  - Resiliency to climate change
- Stakeholder feedback
  - City of Niagara Falls staff
- Financially feasible objectives

The objectives of the Principles, Policies, and Level of Service Document include, but are not limited to, the following:

- Providing direction for planning and identifying water, wastewater, and stormwater servicing issues that may impact growth options
- Providing direction for normal operation and maintenance of the water and wastewater systems (the policies do not replace normal operation and maintenance procedures or best practices)
- Providing direction for development and evaluation of servicing strategies for the Master Servicing Plan Update and Wet Weather Management Strategy
- Ensuring appropriate design and costing criteria are utilized for developing and evaluating servicing strategies for the Master Servicing Plan Update and Wet Weather Management Strategy
- Setting policies and Level of Service Objectives that are reasonably implemented
- Setting policies and Level of Service Objectives that are robust, sustainable, and measurable

Although best management practices, criteria, and key performance indicators are updated over time, the context, intent and validity of the Policies and HLOS objectives should remain intact as policies form the overall guiding principles while criteria is the tactical implementation of policy.

1.2. Approach

The Policies and HLOS discussion are split into four main categories and aim to link the analysis of system needs and replacement triggers with the customer experience.

- Policy Statements: communicate the overall guiding principles and objectives of the infrastructure systems.
- Customer Level of Service objectives: communicate and translate technical Levels of Service into terminology relevant to customers.
- Technical Level of Service objectives (Criteria): quantitatively measure the system performance that are used to compare potential strategies and solutions.
- Key performance indicator: measures the relative system performance against the Technical and Customer Level of Service objectives and validate the beneficial impact of any given investment.

The system performance goals are intended to be used in the medium to long-term and will form the basis of a continuous improvement program by which each system investment is measured.

This approach is in line with the Ontario Regulation 588/17 made under the Infrastructure for Jobs and Prosperity Act, 2015, S.O. 2015,

Through the MSP-WWMS, initial development of the HLOS framework will be completed; however, the focus of MSP-WWMS will be on achieving the Technical Level of Service Objectives (Criteria). Refinement and final development of the HLOS framework will be completed under future Asset Management Plans and will require further discussion with Senior Staff and Council to finalize.

2. MSP-WWMS Vision Statement

Through the Municipal Class EA process, Phase 1 requires the identification of the problem and opportunity statement that guides the process of establishing preferred strategies to address the deficiencies observed in the water, wastewater, and stormwater systems. The following vision statement is a driver for the MSP-WWMS where problems and opportunities are clearly identified through the desire to provide an adequate level of service to users and improve system performance under both current and future conditions.

The Vision Statement is as follows:

Supporting a Strong and Growing Niagara Falls

To establish a preferred servicing plan for the City's water, wastewater, and stormwater systems that:

- Meets current needs,
- Supports projected growth to 2051 and beyond,
- Maintains or improves service levels, and
- Considers priority areas of climate change, infrastructure optimization and renewal, and system resiliency.

3. Policy Statements

Niagara Region has established water and wastewater servicing policies, developed through the Region's Master Servicing Plan Updated (2023). The Region's servicing policies have been reviewed, updated and adapted to align with the City's 2023 – 2027 Strategic Plan. The servicing principles and policies were developed to specifically to support key Pillars of the Strategic Plan, specifically Pillar #1 Sustainability (Financial, Environmental, Social), and Pillar #2 Economic Diversity and Growth. The policy statements will guide and provide direction for the development and evaluation of servicing strategies.

In general, the City of Niagara Falls is looking to build and maintain efficient, effective, and well managed water, wastewater, and stormwater systems that provide a high level of service to the end users. The servicing principles have been categorized into four categories – general, water, wastewater, and stormwater.

Table 3-1 presents the general servicing policies which impact water, wastewater, and stormwater servicing. While **Table 3-2** to **Table 3-4** present the servicing policies for the water, wastewater, and stormwater systems.

Table 3-1. General Servicing Principles

No.	Area of Interest	Principle Statement	Servicing Implications
G.01	Municipal Servicing	*"The City of Niagara Falls shall provide adequate municipal servicing for water, wastewater, stormwater in accordance with the population and employment projections in the time horizon of the Official Plan. This includes consideration for land available for re-development and full buildout of developable greenfield identified within the Official Plan."*	• Planning and design of servicing strategies will optimize use of existing infrastructure where possible • Infrastructure will be planned and designed in accordance with growth projections in the City's Official Plan • Infrastructure strategies and sizing will make consideration for all of developable lands identified within the City's Official Plan • Timing of growth will be reviewed with consideration to a reasonable implementation schedule for infrastructure required to meet the projected growth • Municipal servicing will be implemented using typical standards (MECP Guidelines, City Design Criteria and Standards)
G.02	Environmental Protection	*" The City of Niagara Falls shall consider, protect and endeavour to minimize impact to the natural, built and cultural environment and heritage of the community"*	• Servicing studies shall consider the City's Official Plan Environmental Management Policies • Services will be planned through the appropriate Environmental Assessment process to ensure full regard for the natural and cultural heritage
G.03	Planning Horizon	*"The City of Niagara Falls shall ensure that the design of water, wastewater, and stormwater infrastructure recognizes the potential for growth beyond the time horizon of the Official Plan and/or changes in the density and/or rate of growth"*	• Recognize that the service life of infrastructure may be 60 years or more • Consider, where appropriate, potential for growth beyond the time horizon of the Official Plan for the planning and sizing of infrastructure • Consider, where appropriate, the potential for growth to occur at increased density and/or rate of growth for the planning and sizing of infrastructure
G.04	Reserve Capacity	*"The City of Niagara Falls will endeavor to maintain sufficient reserve capacity in its water, wastewater, and stormwater infrastructure and facilities to provide operational flexibility and meet potential changes in servicing conditions."*	• Recognize that infrastructure and facility expansions require sufficient lead time with consideration to the in-service date for planning, the Environmental Assessment process, design, and construction • Day to day operation and maintenance of infrastructure and facilities requires flexibility for operating conditions, fluctuating flows, equipment shutdowns, maintenance, emergency operations and other unforeseen conditions • Water, wastewater, and stormwater assets will be designed with consideration to the potential extreme weather impacts due to climate change
G.05	System Reliability and Security	*"The City of Niagara Falls shall endeavor to provide reliability, redundancy and security in its water, wastewater, and stormwater systems with attention to high risk and critical areas."*	• Recognize that all systems are susceptible to some level of failure or breakdown or need to be taken out of service for regular maintenance. • Provide a reasonable level of reliability to ensure an acceptable level of service is maintained
G.06	Location of Municipal Services and Facilities	*"The City of Niagara Falls shall locate all of its services and facilities on public property or on municipally-owned easements."*	• Ensure that any new and existing infrastructure be located within road right-of-ways, or on City-owned property (including designated lots and easements) • Adequate property size will be maintained to facilitate all day-to-day activities and emergency response • Adequate property will be acquired to meet future infrastructure requirements
G.07	Climate Change	*"The City of Niagara Falls shall be aware of and consider the potential impact of climate change on planning and sizing of infrastructure."*	• Water, wastewater, and stormwater facilities will be designed with consideration to the potential impacts of climate change as set out by the City's Climate Change Adaptation Plan • Support green infrastructure and low impact development as part of building resilience to the impacts of a changing climate
G.08	Integrated Infrastructure Program	*"The City of Niagara Falls shall coordinate and integrate the MSP-WWMS program with Region and City planning, programs and policies where appropriate."*	• Coordination and integration will ensure servicing principles and strategies are aligned between the City and Region • Consideration for integration of sustainability upgrades necessary to maintain existing system performance • Coordination and integration ensures servicing principles and strategies align between key City initiatives including Official Plan, Master Servicing Plan, Council's Strategic Plan, Transportation Master Plan, Asset Management Plan, and other strategic City and Regional Plans
G.09	Level of Service	*"The City of Niagara Falls shall outline the Level of Service Objectives through the Master Servicing Plan and endeavor to meet/exceed the minimum requirements as outlined in the objectives."*	• The City will review and evaluate strategies developed through the Master Servicing Plan based on their ability to meet requirements outlined in the Level of Service Objectives • The City will continuously track the Level of Service of their water, wastewater, and stormwater assets through setting, tracking, and reporting as mandated by O.Reg. 588/17.
G.10	Region and Local Municipality Consistency	*"The City of Niagara Falls shall maintain consistent criteria, standards and policy with respect to approach and level of service for planning and design the water, wastewater, and stormwater systems to meet growth"*	• The City has responsibility to plan, build, operate and maintain the local water and wastewater systems while the Region has the responsibility to plan, build, operate and maintain the trunk water and wastewater systems including major facilities • The City has responsibility to plan, build, operate and maintain the local and trunk stormwater infrastructure • It is critical that consistent criteria be utilized when analyzing the long-term servicing needs for both trunk and local system capacity • The trunk and local systems are integrated and should be planned accordingly
G.11	Sustainability	*" The City of Niagara Falls shall endeavour to undertake sustainable planning, operation and maintenance of the water, wastewater, and stormwater Systems."*	• The City will strive to plan, operate, and maintain water, wastewater, and stormwater systems that are environmentally, financially, operationally, legislatively, and socially sustainable • Financial sustainability shall consider and utilize appropriate funding mechanisms including but not limited to Development Charges, local cost to development, rates, and reserves to provide a long term balanced and equitable plan to fund the delivery of servicing

Table 3-2. Water Servicing Principles

No.	Area of Interest	Principle Statement	Servicing Implications
W.01	Health & Safety	"The City of Niagara Falls will promote health, productivity and safety of the community through design, construction and maintenance of the City's potable water infrastructure"	• The City will prepare a comprehensive strategy to manage existing and future water servicing needs • Ensure that planning and implementation of the potable water systems are consistent with legislative policies and guidelines • Municipal servicing will be implemented under typical standards (MECP Guidelines, Region/City criteria and standards)
W.02	Distribution & Water Quality	"The City of Niagara Falls shall meet or exceed legislated drinking water quality criteria"	• Water quality will meet, at a minimum, all legislated criteria • Ensure regular testing and monitoring for chlorine residual in the system • Implement industry best practices to ensure water quality is maintained • Review the economics, reliability, and water quality impacts of implementing new technology
W.03	Water Demand Projections	"The City of Niagara Falls shall utilize a water demand projection methodology that recognizes recent water supply data and current consumption trends; with consideration for the Regional water conservation initiatives and available water supply capacity"	• Forward-looking water demand projections in the Master Servicing Plan must appropriately identify future water needs to ensure the best estimate for infrastructure capacity and timing • The City will consider the Regional criteria used to project water supply, pumping, and storage requirements • The City will utilize a starting point methodology based on recent water supply conditions • The City will establish current water design criteria and standards for new growth
W.04	Distribution Requirements	"The City of Niagara Falls shall provide potable water at adequate pressure and flow to its customers"	• Provide pressures which meet current design criteria and standards while considering MECP and Regional guidelines • Review and optimize pressure zone boundaries throughout the City • Consider the available Regional storage capacity, pumping capacity to meet the desired level of service
W.05	Fire Flow Requirements	"The City of Niagara Falls shall consider the Ministry of the Environment Guidelines and the Fire Underwriters Guidelines for establishing the acceptable level of fire flow."	• Provide pressures and flows which meet current design criteria and standards while considering MECP, Regional, and other industry guidelines
W.06	Water Efficiency and Consumption Trends	"The City of Niagara Falls shall be aware of the impacts water efficiency and conservation has on the water network."	• Continue to assess water demand conditions and determine reasonableness of trends (potential lower water use and consumption) • Utilize water efficiency studies where available • Apply where appropriate demand trends (efficiency) into future design criteria and growth forecasts • Apply awareness to how it will impact strategies and scheduling of future infrastructure
W.07	Water Supply and Distribution Security	"The City of Niagara Falls shall plan, design, construct, operate and maintain the water system to balance level of service and security of supply to the customers"	• The City shall continue to implement standards, criteria, and standard operating procedures for the water system • There is an awareness and integration between the Region water system, local distribution system and water services on private property • The City will maintain appropriate design, operations, and maintenance standards for the City water system to protect the public and private infrastructure including backflow prevention

Table 3-3. Wastewater Servicing Principles

No.	Area of Interest	Principle Statement	Servicing Implications
WW.01	Health & Safety	*"The City of Niagara Falls will promote health, productivity and safety of the community through design, construction and maintenance of the City's wastewater infrastructure"*	• The City will prepare a comprehensive strategy to manage existing and future wastewater servicing needs • Ensure that planning and implementation of the wastewater systems are consistent with legislative policies and guidelines • Municipal servicing will be implemented under typical standards (MECP guidelines, Region criteria and standards)
WW.02	Sustainability	*"The City of Niagara Falls will endeavour to undertake sustainable planning, operation and maintenance of the Wastewater System."*	• The City will strive to plan, operate and maintain a wastewater system that is environmentally, financially, operationally, legislatively, and socially sustainable • Financial sustainability shall consider and utilize appropriate funding mechanisms including but not limited to Development Charges, local cost to development and rate reserves to provide a long term balanced and equitable plan to fund the delivery of servicing
WW.03	Wastewater Treatment and Collection Requirements	*"The City of Niagara Falls shall meet at a minimum the requirements of the Environmental Compliance Approvals set out by governing bodies and the appropriate legislated treatment and collection criteria."*	• Wastewater quality (air and effluent) will meet at a minimum all legislated criteria • Manage wet weather conditions (inflow/infiltration) through asset management programs to minimize extraneous flows and maximize efficient use of available wastewater infrastructure • Implement industry best practices to ensure influent quality is within the City and Regional requirements and is supportive of the Region Treatment Plant maintaining their effluent quality objectives • Review the economics, reliability, and effluent quality impacts of implementing new technology
WW.04	Wastewater Flow Projections	*"The City of Niagara Falls shall utilize a wastewater flow projection methodology that recognizes recent wastewater flow and treatment data and current consumption trends*; with consideration for the Regional wet weather flow management initiatives and available wastewater treatment capacity""	• Forward-looking wastewater flow projections in the Master Servicing Plan must appropriately identify future wastewater needs to ensure the best estimate for infrastructure capacity and timing • The City will consider the Regional criteria used to project wastewater treatment and pumping requirements • The City will consider the potential impacts of wet weather flow management initiatives on the management of existing system flows and requirements to support new growth • The City will utilize a starting point methodology based on recent wastewater flow conditions • The City will establish current wastewater design criteria and standards for new growth
WW.05	Sewer Use Criteria	*"The City of Niagara Falls shall maintain a sewer use program that sets the appropriate limits and procedures to control discharge"*	• Review and maintain a sewer use by-law, which is supported by Council • Maintain a monitoring program to ensure the discharges meet the limits set out in the by-law • The City shall consider over-strength discharge and surcharge agreements
WW.06	Separated Wastewater and Stormwater Systems	*"The City of Niagara Falls shall plan and endeavour to maintain separate wastewater and stormwater systems where it is technically and financially feasible to do so"*	• The City will continue to build, maintain, and operate separated wastewater and stormwater systems • The City will endeavor to ensure that new wastewater systems are constructed in a manner that minimizes new wet weather flow (inflow/infiltration) contributions • The City will endeavor, as part of wet weather flow management initiatives, to identify and remediate existing sanitary sewer cross connections and implement strategy to prevent future cross connections and stormwater impact on the wastewater system • The City will endeavor, where technically and financially feasible, to eliminate existing combined sewer systems and replace them with separated wastewater and stormwater systems
WW.07	Wastewater Collection and Pumping Systems	*"The City of Niagara Falls shall work with the Region to support reliability, security, and appropriate levels of redundancy in the wastewater pumping systems"*	• The Region is responsible for the operation and maintenance of wastewater pumping system; however, the performance of the pump stations are impacted by condition and performance of the local collection system • Adequate retention capacity should be provided in the sewer system • The Region and the City shall consider the joint management of the wastewater system to endeavor to provide adequate level of facility storage, system storage, and standby power to manage emergency conditions
WW.08	Wet Weather Flow Criteria	*"The City of Niagara Falls shall utilize current wet weather flow criteria to determine peak wet weather flows and size wastewater infrastructure"*	• Existing systems across the City have a range of existing performance and levels of flow under wet weather flow conditions • The level of service under wet weather conditions will be established through the Master Servicing Plan design criteria • Consideration to environmental, social, and financial factors as well as the feasibility for implementation should be given when determining the wet weather criteria

No.	Area of Interest	Principle Statement	Servicing Implications
WW.09	Wet Weather Strategies	*“The City of Niagara Falls shall review a combination of servicing strategies including infrastructure and non-infrastructure (i.e., I/I reduction) solutions to meet wet weather level of service and provide sufficient wastewater capacity.”*	• Providing wastewater system capacity in the City collection system requires a wide review of potential servicing strategies with consideration of Regional level infrastructure • The City Master Servicing Plan will develop and evaluate a comprehensive list of alternatives against multiple-bottom-line criteria including lifecycle costs • The most cost-effective and beneficial strategy may include not providing additional infrastructure but creating additional capacity through flow reduction methods such as inflow/infiltration control • Development of the servicing strategies to address high wet weather flows should consider the joint City and Regional capacity needs and implementation costs • As additional flows from growth are added to the system, the City should look for opportunities to not make overflow conditions worse than the current baseline conditions
WW.10	Capacity Allocation	*“The City of Niagara Falls shall review opportunities to allocate capacity gained through the implementation of wet weather strategies and system optimization for growth and non-growth benefit”*	• Provision of additional capacity within the wastewater system will need to consider the desired benefit • Additional capacity may be required to meet regulatory requirements or to improve level of service in the system
WW.11	Wet Weather Guidelines	*“The City of Niagara Falls shall approach Guidelines F-5-5 and F-5-1 such that new development will not put the City out of compliance with the regulations and the City shall consider opportunities to not increase wet weather overflows beyond current conditions”*	• The City will continue to manage system performance under wet weather conditions • As required under F-5-5, baseline performance of the system has been established • New growth should not negatively impact the system and should not put the City out of compliance with existing regulations • As additional flows from growth are added to the system, the City should look for opportunities to not make overflow conditions worse than the current baseline conditions

Table 3-4. Stormwater Servicing Principles

Policy No.	Policy Area	Policy Statement	Servicing Implications
SW.01	Health and Safety	*"The City of Niagara Falls will prioritize the health and safety of the public and property by implementing a strategy to provide sufficient conveyance and control infrastructure to safely manage stormwater runoff."*	• Prepare a comprehensive strategy to manage existing and future stormwater related impacts • Ensure that planning and implementation of stormwater management systems are consistent with legislative policies and guidelines • Stormwater Management (SWM) strategies will need to be coordinated with flood plain management strategies and the Niagara Peninsula Conservation Authority • Municipal servicing will be implemented under typical standards (MECP guidelines, design standards and criteria)
SW.02	Sustainability	*"The City of Niagara Falls will endeavour to undertake sustainable planning, operation and maintenance of the Stormwater System."*	• Strive to plan, operate and maintain a stormwater system that is financially, environmentally, and socially sustainable • Financial sustainability shall consider and utilize appropriate funding mechanisms including but not limited to Development Charges, local cost to development and tax reserves to provide a long term balanced and equitable plan to fund the delivery of servicing • All existing storm drainage systems shall be maintained and improved in order to ensure their efficient operation and to minimize the potential for flooding
SW.03	Receiving Water Bodies	*"The City of Niagara Falls shall endeavor to enhance, protect, and maintain quality, quantity, and safety of its receiving water bodies"*	• Act in accordance with the Official Plan Source Water Protection Plan developed under the Source Protection Plan for the Niagara Peninsula Source Protection Area
SW.04	Natural Environment and Hydrologic Cycle	*"The City of Niagara Falls, through stormwater servicing strategy and policy implementation, will endeavour to preserve and/or re-establish a more natural hydrologic cycle."*	• Promote the utilization of facilities and low impact development techniques that mimic the existing hydrologic cycle • Stormwater management plans shall incorporate the use and creation of naturalized overland systems • Promote and facilitate strategies within existing service areas that implement retrofit programs and no net increase in runoff for infill and redevelopment sites • Strive to develop sustainable stormwater management practices
SW.05	Natural Environment and Erosion Control	*"The City of Niagara Falls will endeavour to reduce impacts to the natural environment and protect against erosion."*	• Require the implementation of stormwater management measures to mitigate the impacts of urban runoff on existing streams' stability and to minimize erosion • Not permit any new development or redevelopment where it would interfere with, or reduce, the drainage capacity of any natural watercourse or agricultural field drainage system, result in any erosion, pollution or drainage problems along watercourses and their tributaries or where it would adversely affect the quality/quantity of groundwater or a water recharge/discharge area
SW.06	Water Quality	*"The City of Niagara Falls, through its stormwater servicing strategy and implementation, endeavours to improve runoff water quality."*	• Require the implementation of stormwater management measures to improve storm water runoff quality • Conduct regular operation and maintenance for stormwater facilities, in particular sediment removal, to ensure long-term effectiveness • Implement sewer rehabilitation programs, including ongoing storm sewer and sanitary sewer separation, detention ponds, inline storage and other improvement works
SW.07	Management Responsibility	*"The City of Niagara Falls will develop and implement a stormwater management strategy and program that promotes and implements shared responsibility between the City and property owners."*	• Stormwater Management is a shared responsibility • The City's Official Plan set land use restrictions and specify minimum levels of onsite measures and controls • The City shall continue to maintain city-owned assets on private property • The City shall continue to prohibit through by-law the discharge of collected water on private property to adjacent properties • The City's Official Plan supports private property owners to improve stormwater water quality through programs and guidelines (e.g. weeping tile disconnection) • Development and sharing of of public education materials and resources clearly communicating delineation of responsibilities
SW.08	Integrated Planning Approach	*"The City of Niagara Falls will improve Management of the Stormwater System through Integrated Stormwater Management Planning."*	• The City will agree to a comprehensive stepped approach to developing a robust understanding and delivery plan for stormwater management including: development and continuous update of master drainage plans, subwatershed studies, area specific stormwater management plan, and storm water management reports • The City will strive to develop sustainable stormwater management practices
SW.09	Separated Wastewater and Stormwater Systems	*"The City of Niagara Falls shall plan and maintain separate wastewater and stormwater systems."*	• The City will continue to build, maintain and operate separated wastewater and stormwater systems • The City will endeavor, as part of Inflow and Infiltration reduction measures, to identify and remediate existing sanitary sewer cross connections and implement strategies to prevent future Inflow and Infiltration

4. Water System

4.1. Water Level of Service Framework

Based on the MSP-WWMS vision statement and the identified Policy statements, the following customer service statement for the City's water system was developed to guide the selection of Level of Service objectives and design criteria:

"To provide an efficient, sustainable, and safe water system that meets regulatory requirements, minimizes service disruptions, and is capable of accommodating growth."

Table 4-1 outlines the water system level of service framework, outlining the water system in terms of technical and customer key performance indicators and relating to each relevant policy statement. Both technical objectives and key performance indicators which are relevant to only Regional infrastructure are included; however, noted as such in italics.

4.2. Region Water System Technical Level of Service Criteria

Table 4-2 summarizes the water system technical level of service criteria utilized in the Region's MSPU. Given the inter-dependency between the Region and City infrastructure Performance it is critical that the City's technical level of service be developed with consideration for the Region's criteria in order to harmonize servicing strategies and to avoid competing priorities and/or servicing philosophies.

It is noted that the City MSP-WWMS review will be limited to Demand and System Performance Criteria, while the Regional Facility Triggers will not be revisited.

Table 4-1. Water Level of Service Objectives

<table>
<tr><th>Service Objective</th><th colspan="2">Supporting Policy Statements</th><th>Technical Objective</th><th>Key Performance Indicators - Technical</th><th>Key Performance Indicators - Customer</th></tr>
<tr><td>Efficient</td><td></td><td>W.02
W.06</td><td>• Full life-cycle costing
• Renewal of aging infrastructure
• Optimization of system operations (Applicable Regional Infrastructure)
• Increased water conservation
• Non-revenue water is at a reasonable rate</td><td>• Water use including non-revenue water rate, per capita rate, peaking factor estimated through water production and billing records
• SOGR program
• Watermain head losses and velocities
• Facility needs (supply, storage, and pumping) (Applicable Regional Infrastructure)</td><td rowspan="7">• Number of complaints (water bills, cost, pressure, quality etc.)
• Default rates
• Service interruptions
• Compliance with MECP Standards</td></tr>
<tr><td>Sustainable</td><td>G.07
G.10</td><td>W.06</td><td>• Full life-cycle costing
• Renewal of aging infrastructure
• Resiliency to climate change
• Costs associated with water servicing rates</td><td>• State of Good Repair (SOGR) program
• Age of infrastructure
• Number of watermain breaks
• Replacement/ rehab costs
• O&M costs</td></tr>
<tr><td>Safe</td><td>G.10</td><td>W.01
W.04
W.05</td><td>• Reliability of the distribution system
• Safe Drinking Water Act legislated requirements
• Maintain chlorine residual in distribution system at acceptable levels
• Provide adequate fire protection</td><td>• Water quality including water age, chlorine residuals, flushing rates, and watermain velocities
• Water turnover rate in storage facilities (Applicable Regional Infrastructure)
• Available fire flow
• Emergency storage (Applicable Regional Infrastructure)</td></tr>
<tr><td>Reliable</td><td>G.04
G.05
G.09</td><td>W.03
W.04
W.05
W.07</td><td>• Ability to supply adequate pressures and flows, uninterrupted to the distribution system
• Ability to meet daily demands
• Minimal service interruptions
• Facilities have backup power available (Applicable Regional Infrastructure)</td><td>• Water system performance including pressures and fire flows
• Facility needs (supply, storage, and pumping) (Applicable Regional Infrastructure)
• Backup power at facilities (Applicable Regional Infrastructure)
• System redundancies</td></tr>
<tr><td>Capacity</td><td>G.04</td><td>W.04
W.05</td><td>• Provide adequate, uninterrupted pressures and flows, to the existing and future distribution system
• Ability to meet daily demands
• Minimal service interruptions</td><td>• Water system performance including pressures and fire flows
• Facility needs (supply, storage, and pumping (Applicable Regional Infrastructure)</td></tr>
<tr><td>Regulatory</td><td></td><td>W.02
W.04
W.05
W.07</td><td>• Safe Drinking Water Act
• MECP
• Ontario Water Resources Act</td><td>• Pressure and emergency pressure
• Chlorine residuals
• Supply capacity (Applicable Regional Infrastructure)</td></tr>
<tr><td>Growth</td><td>G.03</td><td>W.03
W.04
W.05
W.06</td><td>• Rated capacity of facility can support growth (Applicable Regional Infrastructure)
• Pressures, fire flow, and water quality are maintained at or above current performance
• Projected demands are applied to areas of planned growth</td><td>• Water system performance including pressures and fire flows
• Facility needs (supply, storage, and pumping) (Applicable Regional Infrastructure)
• Water use including rate, per capita rate, peaking factor</td></tr>
</table>

Table 4-2. Summary of Niagara Region 2021 MSPU Water Design Criteria

<table>
<tr><th colspan="3">Description</th><th>Criteria</th></tr>
<tr><td rowspan="5">Demand Criteria</td><td rowspan="2">Water Demand</td><td>Residential</td><td>240 L/c/d</td></tr>
<tr><td>Employment</td><td>270 L/e/d</td></tr>
<tr><td rowspan="2">Peaking Factor</td><td>Maximum Day</td><td>1.60 (Based on historic average of maximum day peaking factors from 2011 – 2020)</td></tr>
<tr><td>Peak Hour Factor</td><td>Based on system mass balance using hourly SCADA data from 2018 – 2020</td></tr>
<tr><td colspan="2">Existing System Demands</td><td>Starting Point Methodology
• Based on local billing meter records and production records to establish existing system demands
• Growth demands are added to the existing system baseline using design criteria</td></tr>
<tr><td rowspan="4">System Performance Criteria</td><td colspan="2">System Pressures</td><td>Acceptable pressure range of 40 – 100 psi
• Regional objective of maximizing areas within the preferred range of 50 – 80 psi on Regional watermains</td></tr>
<tr><td colspan="2">Fire Flow</td><td>250 L/s on Regional watermains at residual pressure of 30 psi</td></tr>
<tr><td rowspan="2">Velocity</td><td>Average Day</td><td>Flag areas less than 0.6 m/s minimum velocity</td></tr>
<tr><td>MDD+FF or PHD</td><td>Flag areas greater than 1.5 m/s
Trigger upgrades greater than 2 m/s</td></tr>
<tr><td rowspan="5">Sizing and Triggers</td><td colspan="2">Plant and Facility Upgrade Triggers</td><td>• 80% trigger for plant and facility planning process (time based trigger on a case-by-base basis)
• Complete plant and facility expansions before 90% capacity is reached</td></tr>
<tr><td colspan="2">Treatment Plant Sizing</td><td>Maximum day demand</td></tr>
<tr><td colspan="2">Pumping Station Sizing</td><td>Various potential demand scenarios:
• Maximum day demand (MDD)
• MDD + fire flow (250 L/s or MECP)
• Peak Hour Demand (PHD)
Appropriate design sizing scenario depends on the configuration of the service area for the pumping station. Refer to the Niagara Region 2021 MSPU Volume 3 - Introduction for further discussion.</td></tr>
<tr><td colspan="2">Watermain Sizing</td><td>Regional transmission main system for PHD and MDD + fire flow demands</td></tr>
<tr><td colspan="2">Storage Sizing</td><td>MECP methodology (A + B + C)
• Refer to the Niagara Region 2021 MSPU Volume 3 - for discussion regarding contact time (CT) volume requirement at WTP reservoirs</td></tr>
</table>

4.3. City of Niagara Falls Water Technical Level of Service Criteria Context

4.3.1. Water Use Design Criteria

The basis of the growth water system evaluation relies heavily on water per capita consumption and maximum day demand peaking factors as these design criteria will be used to estimate growth demands. **Table 4-4** summarizes the analysis of historic water treatment plant production and water billing records (2011-2022).

4.3.1.1. Non-Revenue Water

Non-Review Water (NRW) demand consists of the difference between water billing records are subtracted from water production records. The NRW is inclusive of:

- Water system losses: such as leakage, data errors, and unauthorized consumption
- Authorized unbilled demands; such as fire fighting, watermain flushing, etc.

The City currently has an average NRW 30% which is above the Region 2021 MSPU target of 25% Through more detailed analysis utilizing the American Water Works Association (AWWA) approach, the City has indicated that the previous average is further reduced to approximately 18%.

4.3.1.2. Residential Per Capita Demand

The average residential demand criteria from 2018 to 2022 , including NRW, was estimated to be 235 L/cap/day inline with the Niagara Region 2021 MSPU of 240 L/cap/day. On this basis it is recommended that the City MSP-WWMS utilize the Niagara Region 2021 MSPU criteria of 240 L/cap/day.

4.3.1.3. Employment Per Capita Demand

The City's employment based water demands are heavily influenced by the City's Tourism industry, which experiences approximately 15M tourist day visits per year – excluding COVID-19 affected years.

Table 4-4 outlines the average employment demand, including NRW, of 530 L/job/day during non COVID-19 influenced years and 410 L/job/day during COVD-19 influenced years. Both of employment values are substantially higher than the Niagara Region 2021 MSPU of 270 L/emp/day.

Table 4-3 summarizes the estimated Tourist based impacts on the observed employment demands. Utilizing the 15M tourist day visits per year and the City's 240 L/cap/day demand, the average daily tourist demand is estimated at 9.8 million litres per day (MLD), which is marginally lower than 10.5 MLD of tourist based demands assuming employment based demand using the Niagara Region 2021 MSPU of 270 L/emp/day. This would suggest that tourist independent employment criteria is generally in line with the Region's MSPU criteria.

Table 4-3. Employment per Capita Demands

Year	Commercial incl. NRW (MLD)	Employment Population	Employment Demand without tourist demand (assuming 270 L/cap/d) (MLD)	Demand attributed to tourists (MLD)
2018	21.4	40,495	10.9	10.5
2019	21.2	39,655	10.7	10.5
2020	16.2	38,815	10.5	5.7
2021	15.2	37,975	10.3	4.9
2022	19.1	No pop data	No pop data	10.5
5-Year Average	18.6	39,235	10.6	8.4
5-Year Peak	21.4	40,495	10.9	10.5

On this basis it is recommended that the City MSP-WWMS:

- Utilize the Niagara Region 2021 MSPU criteria of 270 L/job/day for employment growth
- That the tourist based increase in water demands be applied separately from the employment based growth as follows:
  - Utilize a starting point tourism based demand of 10.5 MLD
  - Increase in tourist be applied as a percentage increased relative to the increase in tourist day visits.

Table 4-4. Historic Water Use

Year	Niagara Falls WTP	Billing		Non-revenue water		Niagara Falls WTP	Average Per Capita Rate (L/c/d) (with NRW)	
	Average Day Demand (MLD)	Residential (MLD)	Employment (MLD)	MLD	%	Average Per Capita Rate (with NRW) (L/c/d)	Residential	Employment
2011	52.2	-	-	-	-	446	-	-
2012	53.1	17.7	18.1	17.2	32%	449	272	706
2013	46.7	16.5	15.5	14.7	31%	392	258	618
2014	43.8	16.1	14.0	13.7	31%	364	253	560
2015	46.2	-	-	-	-	379	-	-
2016	47.4	17.0	15.8	14.7	31%	360	252	497
2017	45.2	15.9	15.5	13.8	31%	342	234	505
2018	44.8	17.8	16.3	10.8	24%	337	253	529
2019	43.4	15.7	15.8	11.9	28%	325	224	534
2020	40.1	16.3	11.7	12.2	30%	299	237	418
2021	41.1	15.5	10.8	14.8	36%	305	226	400
2022	43.1	15.2	13.9	14.0	32%	312	210	490
5-Year Average (2018-2022)	**42.5**	**16.1**	**13.7**	**12.7**	30%	**316**	**230**	**474**
5-Year Peak	*44.8*	*17.8*	*16.3*	*14.8*	*36%*	*337*	*253*	*534*
12-Year Average	45.6	**16.4**	**14.7**	**13.8**	**31%**	**359**	**242**	**526**
12-Year Peak	*53.1*	*17.8*	*18.1*	*17.2*	*36%*	*449*	*272*	*706*
Historic Criteria								
City of Niagara Falls Design Standards (MECP Drinking Water Systems General Design Consideration)							**270 – 450**	**General: 28 m^3/ha/d**
Niagara Region 2021 MSPU Average Per Capita Rate (L/c/d) (with NRW)							**240**	**270**

4.3.1.4. Peaking Factor

Table 4-5 summarizes the water system peaking factors for 2018-2022 as compared to prior peaking factor criteria. The 5 year average peaking factor of 1.59 is in line with the Region MSPU peaking factor of 1.6. As such, it is recommended that the system analysis be completed using the 1.6 peaking factor. Further, due to the high tourist population within the City, growth demands will apply a 2.0 peaking factor to these areas.

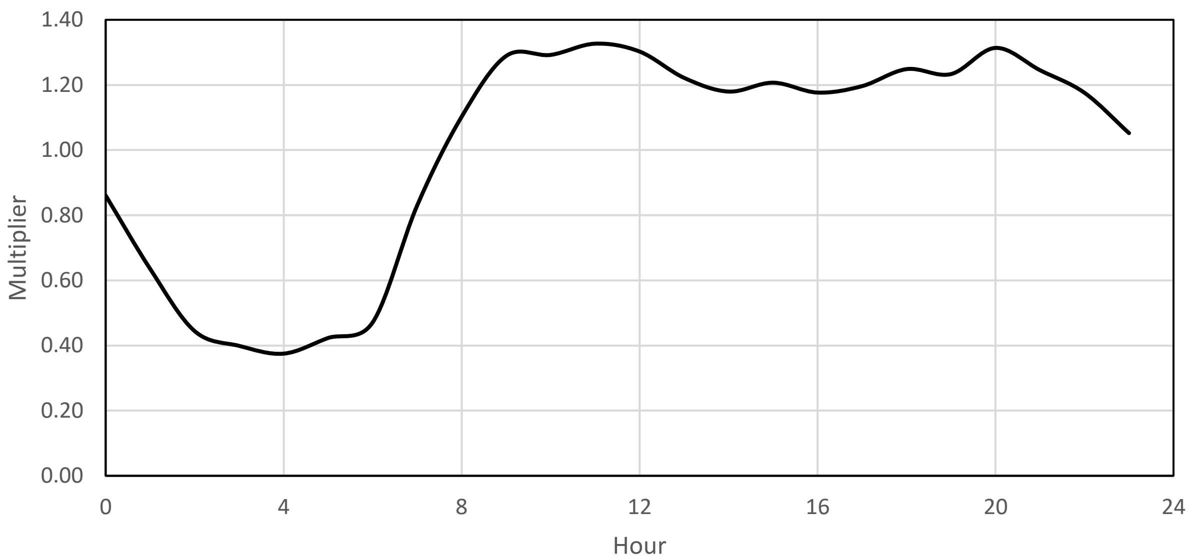
Table 4-5. Max Day Peaking Factors

Year	Average Day Demand (MLD)	Maximum Day Demand (MLD)	Maximum Day Demand Peaking Factor
2018	44.8	74.5	1.66
2019	43.4	71.8	1.65
2020	40.1	65.6	1.63
2021	41.1	63.7	1.55
2022	43.1	62.7	1.45
5-Year Average	42.5	**67.6**	**1.59**
5-Year Peak	44.8	74.5	1.66
Niagara Region MSPU			**1.6**
City of Niagara Falls 2021 Model Update			**1.65 (Max Peaking Factor from Previous 7 years (2018))**
MECP Methodology (Population 75,001 – 150,000)			**1.65**

4.3.1.5. Diurnal Curve

Water use typically follows a diurnal pattern dependent on water consumption rates throughout the day. A typical diurnal pattern peaks during the morning and evening hours which coincide with conventional work day hours, and drops to a minimum during the overnight hours. Hourly flows were assessed to determine a diurnal curve based on the historic SCADA records and used to develop hourly diurnal curve factors. A representative average demand day was identified for developing a diurnal curve, as illustrated in **Figure 4-1**. The diurnal curve factors were used for modelling the both average day demand and maximum day demand ensuring that peak conditions are captured.

Figure 4-1. Average Demand Day Diurnal Curve



4.3.2. Starting Point Methodology

The five-year rolling average of average day demands will be used to establish baseline system average day demands. Baseline system max day demand will be calculated using a peaking factor of 1.6.

4.3.3. Growth Demand Projections

Future system demands were developed using a starting point methodology, the standard approach within Southern Ontario for projecting future growth demands. Expected demand due to growth was added to the starting point demand to establish future demands. Example is provided below.

2051 ADD = Baseline ADD + (2051 total equivalent pop[1]. – 2021 total equivalent population) × 270 L/c/d

[1] Equi. Pop – Total of the combined people and employment population

4.3.4. Hydraulic Performance Criteria

An updated and calibrated hydraulic water model, as part of both this Niagara Falls MSP-WWMS and the 2021 Region MSPU, was used to evaluate the existing water system performance without the application of growth. Through this process, the water system technical level of service criteria were developed with the consideration of existing system performance.

4.3.4.1. Pressures

Pressures within the existing system, detailed as a percent of the system in **Table 4-6**, are typically between 40-100 psi under both average day demand (ADD) and maximum day demand (MDD) scenarios. Noting that due to local topography, there are a number of areas near the Niagara River which experience pressures >100 psi; as such, minimization and mitigation of these areas should be prioritized. Further reducing the pressure bounds to 50-80 psi is not feasible without major adjustments to pressure zone boundaries; as such, was not carried forward.

Recommended design criteria to be utilized for pressure are as follows:

- Maintain pressure design criteria between 40-100 psi, consistent with the MECP Criteria and the City's existing design standard
  - Minimize and mitigate areas of exceeding 100 psi while maximizing areas between 50-80 psi
- Watermains shall be designed to withstand the maximum operating pressure plus transient pressure, at a minimum of 150 psi regardless of working pressure
- Reduction of the pressure boundaries would require system operations modifications and water system upgrades with minimal to moderate benefit

Table 4-6. Existing System Pressures

Pressure (psi)	ADD (Percentage of Nodes in the System)	MDD (Percentage of Nodes in the System)
<40	0%	0.3%
40-50	0%	0.4%
50-60	0%	2.7%
60-80	5%	47.5%
80-90	22%	29.2%
90-100	31%	16.8%
>100	41%	3.2%

4.3.4.2. Fire Flow – Network Capacity

The local watermain sizing within the distribution system is typically driven by fire flow targets which are commonly evaluated using the "Water Supply for Public Fire Protection Guidelines" by the Fire Underwriters Survey[2] (FUS) or Ontario Building Code. Land-use based fire flow targets can be developed can be defined while considering the following:

- Commits a certain level of service for a typical property of a specific land use,
- Provides guidance in the prioritization of the City's State of Good Repair (SOGR) program and clearly identifies upsizing needs, and
- Requires developers to meet City's fire flow targets should they require a higher fire flow based on FUS evaluation

Through the City's 2019 review of the water system, land use based FUS derived fire flow targets were developed. In consultation with the City, the land used based was carried forward; however, a review of the multi-family residential targets was revisited to account for the increase in residential densities of new developments.

A FUS review was completed of sample multi-family residential properties within the City to determine appropriate fire flow targets for the majority of proposed growth property types. These FUS calculations, outlined in **Table 4-7**, demonstrate a range of fire flow targets such that the City's target can balance between these values.

Table 4-7. FUS Fire Flow Examples

Building	3757 St Peter Avenue		6118 Kelsey Crescent		6420 Delta Drive	
Land Use	Residential (Multi)		Residential (Muli)		Residential (Multi)	
Total Floor Area (m^2)	1,250		1,050		970	
Estimate	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Type of Construction	Ordinary	Wood	Ordinary	Wood	Ordinary	Wood
Fire Hazard	Limited Combustibility		Limited Combustibility		Limited Combustibility	
Sprinklers	No	No	No	No	No	No
Proximity Adjustment	0.55		0.50		0.60	
FUS Target (L/s)	171	256	151	227	155	233

Based on the results of the multi-family review, the prior multi-family criteria was modified from a single 150 L/s category to 150 L/s for Semi Family Residential and Row Houses and 200 L/s for Residential Multi (Apartments and Stacked Townhouses). **Table 4-8** summarizes the recommended fire flow targets to be used when assessing system capacity.

[2] Fire Under Writers Survey: https://www.fireunderwriters.ca/

Table 4-8. Range of Recommended Fire Flow Targets

Land Use	Fire Flow Target
Single Family Dead End	50 L/s
Single Family Residential	75 L/s
Semi Family Residential and Row Houses	150 L/s
Residential Multi (Apartments and Stacked Townhouses)	200 L/s
Commercial	175 L/s
Institutional	175 L/s
Industrial	250 L/s
Tourist Area	300 L/s

The recommended process of defining fire flow targets is as follows:

- FUS and land use-based approach
- Fire flow at a hydrant is governed by land use with the highest fire flow target

4.3.4.3. Water Quality

Based on MECP requirements, the City must maintain total chlorine residuals at 0.25 mg/L in the distribution network. The recommended approach to water quality is:

- Water age, as evaluated by the hydraulic water model, is correlated to chlorine residuals as shown in **Table 4-9** as percentage of the City's existing system
- Areas with high water ages (greater than 98 percentile) will be flagged and reviewed with City staff to confirm any water quality issues
- Dead ends with minimal demands will result in high water age as water is consumed a slow rate; as such, the City should continue to monitor dead end chlorine residuals

Table 4-9. Existing Average Day Water Age

Water Age	Distribution (<400 mm)
0-7 days	98.6%
>7 days	1.4%

4.3.4.4. Peak Velocities

The Region's MSPU criteria require watermains to maintain peak velocities, under peak hour conditions, less than 1.5 m/s with peak velocities exceeding 2.0 m/s to be triggered for replacement. This methodology is to be used to evaluate the existing system for the MSP-WWMS as well. The majority of the local existing system is currently within these bounds, as detailed in **Table 4-10**.

Table 4-10. Existing System Peak Velocities

Peak Velocity (m/s)	Distribution (<400 mm)
<0.5	98.4%
0.5-1.0	1.4%
1.0-1.5	0.2%
1.5-2.0	0.0%
≥2.0	0.0%

4.4. Water System Technical Level of Service Criteria - Recommendations

Table 4-11 summarizes the draft water system technical level of service criteria that will be utilized as the decision-making rationale related to the City's water system capacity needs and triggers for upgrades.

Table 4-11. Summary of Water Technical Criteria

Criteria			Performance Target
Water Use	Per Capital Rate	Residential	240 L/c/d
		Employment	270 L/c/d
	Peaking Factor	Tourist Area	2.0
		Remainder of City	1.6
System Performance	Peak Velocity		Flag >1.5 m/s Trigger upgrades > 2 m/s
	Water Age		Flag >7 days
	Pressure	Pressure under daily demand	40 – 100 psi
		Pressure under fire flow	20 psi
	Fire Flow	Single Family Dead End	50 L/s
		Single Family Residential	75 L/s
		Semi Family Residential and Row Houses	150 L/s
		Residential Multi (Apartments and Stacked Townhouses)	200 L/s
		Commercial	175 L/s
		Institutional	175 L/s
		Industrial	250 L/s
		Tourist Area	300 L/s

5. Wastewater System

5.1. Wastewater Level of Service Framework

Based on the MSP-WWMS vision statement and the identified Policy statements, the following customer service statement for the City's wastewater system was developed to guide the selection of Level of Service objectives and design criteria:

"To provide an efficient, sustainable, and reliable wastewater system that minimizes environmental impacts and is capable of accommodating growth"

Table 5-1 details objectives intended to evaluate the existing and future performance of the wastewater system in terms of technical and customer key performance indicators.

5.2. Region Wastewater System Technical Level of Service Criteria

Table 5-2 summarizes the wastewater system technical level of service criteria utilized in the Region's MSPU. Given the inter-dependency between the Region and City infrastructure Performance it is critical that the City's technical level of service be developed with consideration for the Region's criteria in order to harmonize servicing strategies and to avoid competing priorities and/or servicing philosophies.

It is noted that the City MSP-WWMS review will be limited to Flow and System Performance Criteria, while the Regional Facility Triggers will not be revisited.

Table 5-1. Wastewater Level of Service Objectives

<table>
<tr><th>Service Objective</th><th colspan="2">Supporting Policy Statements</th><th>Technical Objective</th><th>Key Performance Indicators - Technical</th><th>Key Performance Indicators - Customer</th></tr>
<tr><td>Efficient</td><td>G.08</td><td>WW.05
WW.08
WW.10</td><td>• Full life-cycle costing
• Renewal of aging infrastructure
• Optimization of system operations (Applicable Regional Infrastructure)
• Reduction of inflow and infiltration</td><td>• SOGR program
• Pumping Station Capacity (Applicable Regional Infrastructure)
• I/I flows
• Percent of sewage treated with conformance to MECP F-5-5 requirements
• Sewer surcharging during wet weather events</td><td rowspan="7">• Number of complaints (water bills, cost, odour, etc.)
• Basement flooding (due to extraneous flows)
• Default rates
• Service interruptions
• Compliance with MECP Standards</td></tr>
<tr><td>Sustainable</td><td>G.07
G.11</td><td>WW.02</td><td>• Full life-cycle costing
• Renewal of aging infrastructure
• Resiliency to climate change
• Costs associated with Wastewater servicing rates</td><td>• SOGR program
• Age of infrastructure
• Replacement/rehab costs
• O&M costs</td></tr>
<tr><td>Safe</td><td>G.10</td><td>WW.01
WW.04</td><td>• Compliance with Provincial Water Quality Objectives
• CCME Wastewater Effluent Regulations
• MECP Guideline F-5-5 & F-5-1 (compliance with Effluent Criteria)
• Sewer system meeting capacity targets</td><td>• I/I flows
• Treatment Plant Capacity (Applicable Regional Infrastructure)
• System CSO Volumes</td></tr>
<tr><td>Reliable</td><td>G.04
G.05
G.10</td><td>WW.05</td><td>• Condition of sewer system (CCTV)
• Capacity to meet wastewater treatment (Applicable Regional Infrastructure)
• Minimal service interruptions
• Facilities have backup power available (Applicable Regional Infrastructure)</td><td>• System capacity is compliant with Pipeline Assessment Certification Program scores
• Percent of system meeting capacity needs
• Sewer surcharging during wet weather event</td></tr>
<tr><td>Capacity</td><td>G.04</td><td>WW.05
WW.06
WW.09
WW.11</td><td>• Availability to service Urban Boundaries
• Minimal service interruptions
• Ability to convey growth wastewater production</td><td>• Treatment Plant Capacity (Applicable Regional Infrastructure)
• Pump Station Capacity (Applicable Regional Infrastructure)
• Percent of system meeting capacity needs
• Sewer surcharging during wet weather event</td></tr>
<tr><td>Regulatory</td><td></td><td>WW.03
WW.04
WW.07</td><td>• Compliance with Provincial Water Quality Objectives
• CCME Wastewater Effluent Regulations
• MECP Guideline F-5-5 & F-5-1 (compliance with Effluent Criteria)</td><td>• System CSO Volumes
• Sewer and forcemain (Applicable Regional Infrastructure) velocities
• Pump Station Capacity (Applicable Regional Infrastructure)
• Treatment Plant Capacity (Applicable Regional Infrastructure)
• Sewer surcharging during wet weather event</td></tr>
<tr><td>Growth</td><td>G.03</td><td>WW.06
WW.09</td><td>• Rated capacity of facility can support growth (treatment, pumping) (Applicable Regional Infrastructure)
• Sewers system can support growth (gravity sewers)
• Projected demands are applied to areas of planned growth</td><td>• Pump Station Capacity (Applicable Regional Infrastructure)
• Treatment Plant Capacity (Applicable Regional Infrastructure)
• I/I allowance
• Per capita rate
• Percent of system meeting capacity needs
• Sewer surcharging during wet weather event</td></tr>
</table>

Table 5-2. Summary of Niagara Region 2021 MSPU Wastewater Design Criteria

Component		Criteria	
Flow Criteria	Existing System Flows	Starting Point Methodology • Based on local billing meter records and flow monitoring data to establish existing dry and wet weather flows • Growth flows are added to the existing system baseline using design criteria	
	Flow Generation	Residential	255 L/c/d
		Employment	310 L/e/d
	Peaking Factor	Peak Dry Weather Flow	Harmon's Peaking Factor
	Extraneous Flow Design Criteria	• 0.4 L/s/ha for existing areas • 0.286 L/s/ha for new developments	
WWTP	System Performance and Triggers	• MECP Procedure F-5-1 • Trigger upgrade study at 80% capacity • Trigger upgrade construction at 90% capacity	
	Upgrade Sizing	• Average daily flow plus growth based on population design flows	

Pump Station	System Performance and Triggers Sizing	• Two flow scenarios considered
		    o **Design Allowance**: Peak wet weather flow using the peaked dry weather flow plus the extraneous flow design allowance
		    o **5-Year Storm:** Modelled peak wet weather flow using the 5-year design storm
		• Peak flow capacity to meet design peak wet weather flow using the extraneous flow design allowance
		• Wet well and system storage considerations under 5-year storm to minimize basement flooding and overflow risks	

Forcemain	System Performance and Triggers	• Flag velocities less than 0.6 m/s • Flag velocities greater than 2 m/s • Upgrade when velocities exceed 2.5 m/s and considering condition and age	
	Upgrade Sizing	• Design velocity target between 1 m/s and 2 m/s • Forcemain twinning to increase capacity where feasible	
Trunk (>170 L/s peak dry weather flow[3])	System Performance and Triggers	• Design allowance peak wet weather flows, using the extraneous flow design allowance, to be managed within pipe • Freeboard (depth between hydraulic grade line and surface) greater than 1.8 m below surface in 5-year design storm • Flag pipes velocities less than 0.6 m/s • Flag pipes velocities greater than 3.0 m/s	
	Upgrade Sizing	• Sized for full flow under post-2051 design peak wet weather flow • Assess 5-year design storm performance to minimize basement flooding risks and overflows	

[3] Regional Municipality of Niagara Development Charge Background Study 2022 Appendix E

5.2.1. Sizing of Pump Stations

Although it is the Region's design philosophy to size sewage pumping stations (SPS) inline with the Region's extraneous flow design criteria, the Region's 2021 MSPU undertook a hybrid evaluation approach in an effort to acknowledge that SPSs are a major contributor to local wastewater system performance and that many legacy system's existing wet weather flows exceed the extraneous flow design allowance. The SPS hybrid performance evaluation and upgrade framework are summarized in **Table 5-3** and strives to balance the magnitude of capacity upgrades, potential cascading downstream upgrades, and managing the potential risk of local sewer surcharging and system overflows.

Under the hybrid performance evaluation and upgrade framework, the SPS capacity was sized to meet the lesser of peak wet weather flow (PWWF) using the extraneous flow design allowance, referred to as "Design Allowance PWWF" or the estimated 5-year storm PWWF. Further, consideration for the SPS actual performance under the estimated 5-year design storm peak wet weather flow was evaluated to determine if the available system storage including the wet well, storage tanks, and in-system capacity was sufficient to manage excess flows while maintaining the system hydraulic grade line (HGL) below the basement flooding level of 1.8 m below grade and/or below the local overflow level.

In instances where the 5-year storm PWWF flow exceeded the available system storage, additional system solutions such as wet weather management, system storage, and/or additional SPS capacity upgrades were incorporated into the servicing solution. The most efficient solution to manage capacity and flow reduction was determined through the assessment of calculated flows from the 2051 design allowance PWWF and modelled 5-year storm PWWF against the operational firm capacity of the station and system storage.

Table 5-3. SPS Assessment Framework

Case	2051 Design PWWF	2051 5 Year Storm PWWF	2051 5-Year Storm Storage Need	Preferred Solution	Upgrade Priority	Flow Monitoring Priority
Case 1	> Firm Capacity	> Firm Capacity	> Available Storage	Upgrade pumps to future design allowance flow with potential storage upgrades and wet weather management	High	Medium
Case 2	< Firm Capacity	> Firm Capacity	> Available Storage	Upgrade storage and wet weather management	High	High
Case 3	> Firm Capacity	> Firm Capacity	< Available Storage	Potential upgrade to design allowance flow and wet weather management	Medium	High
Case 4	< Firm Capacity	> Firm Capacity	< Available Storage	Potential wet weather management	Low	Medium
Case 5	> Firm Capacity	< Firm Capacity	< Available Storage	No upgrade, use actual peak flows	N/A	Low
Case 6	< Firm Capacity	< Firm Capacity	< Available Storage	No upgrade	N/A	Low

5.3. Wastewater Technical Level of Service Criteria Context

5.3.1. Wastewater Use Design Criteria

The basis of the growth wastewater system evaluation relies on appropriate estimates for per capita wastewater generation, peaking factors, and rates of inflow and infiltration. To estimate the growth flow under 2051 and buildout conditions, per capita flow rates, peaking factors, and extraneous flow allowance are defined based on historical data.

5.3.1.1. Per Capita Rate

As part of the 2021 MSPU, the per capita average dry weather flows was reassessed on a system scale to maintain a reasonable factor of safety within the consumption criteria while avoiding over-conservatism which ultimately impacts the capital projects that are triggered and when they are triggered. It was decided that the per capita flow criteria would be adjusted to match the median average dry weather flow across the Region while also applying the same ratio for residential and employment from the observed (local billing meter) water per capita rates.

The 2021 MSPU recommended design criteria to be utilized for per capita dry weather flows are as follows:

- Residential per capita rate: 255 L/c/d
- Employment per capita rate: 310 L/c/d

For the purposes of evaluating the wastewater flow criteria an in-depth review of a five-year period of records (2018-2022) was completed. **Table 5-4** presents the average per capita rate (combined population employment and tourism) that was calculated for the Niagara Falls WWTP (inclusive of the St. David's SPS Contributions from Niagara-on-the-Lake). To account for the influence of wet weather flows on the daily wastewater treatment plant flows, two additional average daily flows criteria were used:

- Dry average daily flows, which excluded days with greater than 5 mm of precipitation and preceding day
- Summer dry average daily flows: same as dry average daily flows but only accounted for flows within the month of June through to September.

The identification of appropriate wastewater per capita growth criteria was complicated due to:

- The observed inflow and infiltration which included:
  - Substantial local and seasonal variability in daily flows
  - Observed flows to the wastewater treatment plants exceeding the water generated from the water treatment plants
- Limited ability to complete detailed employment vs. residential-based analysis due to unmetered discharge.
- Difficulty in apportioning population demands by local WW sub-catchment.

Further to the WWTP based flow analysis, **Table 5-5** summarizes the dry weather flow per capita criteria by SPS utilizing the updated calibrated model results (2022-2023 flow monitoring data).

Table 5-4. Historic Wastewater Per Capita Rates for WWTP

Year	Average Per Capita Rate (L/c/d)	Dry Weather Flow Per Capita Rate (L/c/d)	Summer Dry Weather Flow Rate (June to September) (L/c/d)
2018	311	290	242
2019	308	284	235
2020	261	247	200
2021	256	222	221
2022	No pop data		
Average	**292**	**260**	**225**
Current Design Criteria	450		
Region Design Criteria	255 (Residential) 310 (Employment)		

Table 5-5. Modelled Dry Weather Flow by SPS Catchment

SPS	Estimated Equivalent Population (2021) (inclusive)	Average Dry Weather Flow (L/s)	Modelled Per Capita Dry Weather Flow Rate (L/c/d)
Niagara Falls WWTP	134,414	450.1	289
└→Calaguiro SPS	329	2.0	532
└→Central SPS	33,759	158.9	407
└→Bender Hill SPS	5,517	97.4	1,336(1)
└→Muddy Run SPS	2,589	6.6	221
└→Seneca Street SPS	1,701	3.7	189
└→Dorchester Road SPS	12,407	56.6	394
└→Lundy's Lane SPS	1,697	7.3	374
└→Meadowvale SPS	1,287	3.3	362
└→Rolling Acres SPS	1,182	6.0	438
└→Royal Manor SPS	444	2.2	421
└→Drummond Road SPS	2,342	4.5	164
└→Kalar Road SPS	14,824	59.1	345
└→Mewburn SPS	134	0.6	376
└→Neighbourhood SPS	623	1.5	206
└→St. Davids #2 SPS	3,591	19.8	477
└→St. Davids #1 SPS	3,382	1.4	469
└→South Side High Lift SPS	50,837	163.9	279
└→South Side Low Lift SPS	8,740	25.7	254
└→Garner SPS	2,972	6.3	184
└→Oakwood SPS	396	1.1	249
└→Grassy Brook SPS	836	2.1	217
		Minimum	**164**
		Median	**353**
		Maximum	**1,336**

1. Bender Hill SPS services tourist core, population and employment number does not reflect tourism contributions

Based on the average dry weather flow observed at the WWTP, the average per capita wastewater generation of 292 L/s (**Table 5-4**), and the modelled per capita average dry weather flow of 289 L/s (**Table 5-5**) at the WWTP; which is significantly lower than the City's Design criteria of 450L/s and is within the boundaries of the Region's Design Criteria.

5.3.1.2. Peaking Factor

The City presently utilizes the Babbitt peaking factor approach in their current design criteria, however the Region 2021 MSPU utilizes Harmon's Peaking factor. It is recommended that the City adopts the Harmon's Peaking Factor approach, with values ranging from 2-4, to correspond with Region criteria.

5.3.1.3. Extraneous Flow Allowance

The City's current maximum extraneous flow allowance is 0.28 L/s/ha. 2021 MSPU design criteria for extraneous flows design allowance are:

- Existing areas: 0.4 L/s/ha
- Greenfield: 0.286 L/s/ha

Table 5-6 summarizes the peak wet weather flow by SPS utilizing the calibrated model results (2023 flow monitoring data) compared with the Region criteria. The existing observed flows are utilized to assess existing system wet weather flow contributions. The SPS catchments where the modelled 5-year and 10-year design storm peak exceeds the SPS capacity or Region design allowance PWWF are generally identified by an RDII exceeding 0.4 L/s/ha. These catchments require City and Region coordination to manage excess wet weather flows.

It is recommended that the City adopts the 2021 MSPU design criteria for extraneous flows to correspond with the Region criteria for the purpose of aligning the framework for SPS upgrades and system solutions to support growth.

Table 5-6. Observed Extraneous Flows

Pump Station Catchments	Inclusive Catchment Area (ha)	Existing SPS Operational Firm Capacity (L/s)	Region Design Allowance Peak Wet Weather Flow			Peak Existing Wet Weather Flow (L/s)		Peak Extraneous Flow (L/s/ha) (1 hour average)	
			Modelled Peak Dry Weather Flow (L/s)	Existing Region Extraneous Flow Allowance (L/s)	Total Design Allowance Peak Wet Weather Flow(1) (L/s)	5-year Design Storm	10-year Design Storm	5-year Design Storm	10-year Design Storm
Niagara Falls WWTP	5167	**N/A**	584.9	2,066.8	2,651.7	4073.1	4426.6	0.675	0.743
└→Calaguiro SPS	23	**5.5**	2.9	9.1	12.0	22.3	21.2	0.854	0.802
└→Central SPS	978	**800.0**	266.8	391.1	657.9	2848.3	3291.6	2.640	3.094
└→Bender Hill SPS	198	**237.0**	107.4	79.0	186.4	930.5	939.2	4.165	4.210
└→Muddy Run SPS	63	**77.0**	9.6	25.2	34.8	27.0	30.3	0.276	0.329
└→Seneca Street SPS	42	**63.0**	5.3	16.8	22.1	39.7	50.6	0.819	1.077
└→Dorchester Road SPS	576	**185.0**	84.1	230.4	314.5	390.1	385.7	0.531	0.524
└→Lundy's Lane SPS	97	**56.3**	12.4	38.9	51.3	48.1	54.6	0.368	0.434
└→Meadowvale SPS	36	**34.0**	7.4	14.4	21.8	67.5	73.3	1.673	1.837
└→Rolling Acres SPS	51	**52.3**	7.9	20.4	28.3	118.9	130.3	2.174	2.398
└→Royal Manor SPS	33	**8.8**	3.2	13.1	16.3	26.7	29.4	0.718	0.802
└→Drummond Road SPS	86	**56.7**	5.8	34.5	40.3	25.6	27.6	0.229	0.252
└→Kalar Road SPS	500	**463.0**	72.5	200.0	272.5	160.2	176.1	0.176	0.207
└→Mewburn SPS	9	**17.1**	0.8	3.6	4.4	2.2	2.2	0.159	0.159
└→Neighbourhood SPS	20	**29.0**	2.1	7.9	10.0	24.3	28.1	1.130	1.320
└→St. Davids #2 SPS	236	**42.9**	33.5	94.3	127.8	34.7	35.3	0.005	0.008
└→St. Davids #1 SPS	236	**28.8**	24.7	94.3	119.0	32.7	34.0	0.034	0.040
└→South Side High Lift SPS	2077	**609.0**	207.1	830.9	1,038.0	651.9	709.6	0.214	0.242
└→South Side Low Lift SPS	719	**392.1**	33.2	287.8	320.9	127.6	140.3	0.131	0.149
└→Garner SPS	98	**99.7**	7.9	39.2	47.1	25.2	25.2	0.177	0.177
└→Oakwood SPS	32	**13.0**	1.9	12.8	14.7	8.6	8.6	0.211	0.211
└→Grassy Brook SPS	53	**17.8**	2.2	21.2	23.4	25.2	25.2	0.433	0.433
							Current Region Design Criteria	**Existing Areas: 0.4** **New Areas: 0.286**	
							Current City Design Criteria	**0.28**	

1. May vary from 2021 Region MSPU Design Allowance Peak Wet Weather Flow due to updated modelled peak dry weather flow.
2. Red values denotes exceedance of current operational firm capacity or the Region extraneous flow allowance of 0.4 L/s/ha.

5.3.2. Starting Point Methodology

The modeled average day demand based on calibrated wastewater model (Calibrated to 2023 flow monitoring and Region SCADA records) was used to establish baseline system dry weather flows.

Table 5-5 summarizes the average dry weather flows to each Region SPS and to the WWTP.

5.3.3. Growth Flow Projections

Future system demands were developed using a starting point methodology, the standard approach within Southern Ontario and the one used in the Region 2021 MSPU for projecting future growth flows. Expected flows due to growth were added to the starting point demand to establish future flows. Example for 2051 growth scenario below:

2051 Flows = Baseline Average Day Demand Reduced to Account for Non-Revenue Water + (2051 total equivalent population[4]. – 2021 total equivalent population) × 270 L/c/d

5.3.4. Hydraulic Performance Criteria

The updated and calibrated hydraulic wastewater model was utilized in the analysis of existing wastewater system performance. This process detailed existing system performance without the application of growth demands and could be used as a guideline for potential system upgrades.

Causes system surcharging leading to basement flooding are:

- Peak rain derived inflow and infiltration exceeding pipe capacity;
- Structural deficiencies such as pipe deflection;
- Operational deficiencies such as debris build up and blockages;
- Pumping station deficiencies resulting in system backups.

The model assumes the system is functioning as designed and does not reflect structural or operational constraints in the gravity system.

5.3.4.1. Gravity Sewer System Capacity

Table 5-7 summarizes the percentage of the system meeting various sewer performance criteria as measured:

3. d/D: the ratio of hydraulic depth over full pipe depth;
4. HGL: The hydraulic grade line of a surcharging sewer is below road center line ground surface.

[4] Equi. Pop – Total of the combined people and employment population

A system is deemed to be as risk of basement flooding when the hydraulic grade line (HGL) exceeds a freeboard below road center line ground surface(represented by the symbol 'X m' in **Figure 5-1** which is higher than the standard basement's elevation.

Figure 5-1. Example of Sewer Capacity and Freeboard

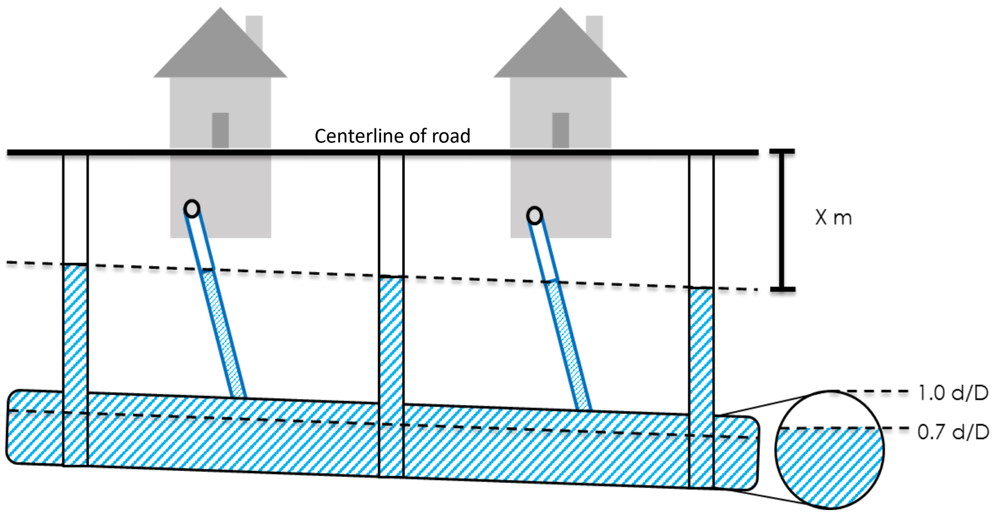


Table 5-7. Gravity Sewer Performance

Design Storm	d/D		Surcharging		
	<0.8	0.8-1	Freeboard <1.8 m	Freeboard <2.1 m	Freeboard <2.4 m
DWF	99.8%	0.2%	0.0%	0.0%	0.0%
2-Year	96.6%	3.4%	1.6%	1.7%	1.9%
5-Year	94.9%	5.1%	2.2%	2.5%	2.8%
10-Year	93.9%	6.1%	2.6%	3.0%	3.4%
25-Year	93.1%	6.9%	3.1%	3.4%	3.7%
50-Year	92.3%	7.7%	3.6%	4.1%	4.4%
100-Year	91.4%	8.6%	4.3%	4.5%	4.7%

Industry standards for basement elevations range from 1.7 to 2.1 m below ground levels, with municipal standards typically achieving a minimum of 1.8 m. Based on the existing system performance, there is an opportunity to apply a more conservative 2.1 m freeboard without substantially increasing existing system upgrade needs.

5.3.4.1.1. Gravity Sewer Performance Objective

The objective for upgrades to gravity sewers will be assessed using the City's current Standards for Site Planning consisting of:

- Minimum and maximum velocity at full pipe capacity shall be 0.6 and 3.0 m/s, respectively;

- The minimum pipe size for sanitary sewers shall be 200 mm diameter (with the exception of top end/low flow sewers which can be sized to 150 mm to maintain minimum velocity targets); and
- The minimum HGL shall be 2.1 meters cover below final grade at centreline of road.

5.3.4.1.2. Gravity Sewer Capacity Assessment

The performance of the gravity sewers will be evaluated on three criteria in order to classify sewer capacity assessment of surplus capacity, restrained capacity, surcharging from downstream capacity limitation and capacity limitation causing basement flooding risk:

1. d/D: the ratio of hydraulic depth over full pipe depth;
2. q/Q: the ratio of pipe flow to Manning's Capacity flow based on diameter, slope; and
3. HGL: The hydraulic grade line of a surcharging sewer is below the City's basement protection freeboard of 2.1 m under the design storm (this is more conservative than the Region's 1.8 m freeboard criteria)

The gravity system performance criteria and classifications are detailed in **Table 5-8**.

Table 5-8. Gravity System Performance Criteria

Sewer Classification	Hydraulic Criteria	Description
Surplus Capacity	• d/D <1 • q/Q <1	• Pipe not surcharging • Flow within pipe capacity
Restrained Capacity	• d/D <1 • q/Q = 1	• Pipe not surcharging • Flow exceeding pipe capacity
Surcharging – Downstream Limitation	• d/D > 1 • HGL ≤ 2.1 m freeboard • q/Q = 1	• Pipe surcharging • HGL depth not exceeding criteria • Flow exceeding pipe capacity
Exceeds Capacity and Basement Flooding Risk	• d/D > 1 • HGL > 2.1 m freeboard • q/Q = 1	• Pipe surcharging • HGL depth exceeding criteria • Flow exceeding pipe capacity

5.3.5. Combined and Sanitary Sewer Overflows

MECP F-5-1: Determination of Treatment Requirements for Municipal and Private Sewage Treatment Works Discharging to Surface Waters[5] states that:

"All sewage treatment works shall provide secondary treatment or equivalent as the "normal" level of treatment, unless individual receiving water assessment studies indicate the need for higher levels of treatment"

The procedure also contains recommendations for sewage by-pass from nominally separate systems.

Meeting the goals of total containment and treatment of sewage flows per the MECP Procedure F-5-1 in the MSP-WWMS are considered in the long-term strategies, however, the study will focus on continuing to achieve the objectives of Procedure F-5-5 with the consideration of the significant growth anticipated within the City (detailed in Section 11 of the Procedure).

MECP F-5-5: Determination of Treatment Requirements for Municipal and Private Combined and Partially Separated Sewer Systems[6] goals are stated as follows:

1. Eliminate the occurrence of dry weather overflows;
2. Minimize the potential for impacts on human health and aquatic life resulting from Combined Sewer Overflows;
3. Achieve as a minimum, compliance with body contact recreational water quality Provincial Water Quality Objectives for Escherichia coli at beaches impacted by Combined Sewer Overflows for at least 95% of the four-month period (June 1 to September 30) for an average year.

The Technical Criteria from MECP Procedure F-5-5 that are required for the Study are as follows:

- No overflows during dry weather;
- Maximize the use of the collection system for the storage of wet weather flows when capacity is available; and
- During a seven (7) month period commencing within 15 days of April of an average year, provide 90% volumetric control of wet weather in addition to all of the dry weather flow.

Additionally, Section 11 of the F-5-5 Regulation mandates that:

"When and where significant combined sewer system deficiencies exist, the Regional Office of the Ministry shall require that the provision of sanitary servicing for additional development tributary to the deficient system be curtailed to prevent aggravation of the problem until the necessary upgrading, as

[5] MECP F-5-1 Website: https://www.ontario.ca/page/f-5-1-determination-treatment-requirements-municipal-and-private-sewage-treatment-works
[6] MECP F-5-5 Website: https://www.ontario.ca/page/f-5-5-determination-treatment-requirements-municipal-and-private-combined

outlined by a Pollution Prevention and Control Plan is carried out in keeping with the requirements of this Procedure. Some development is allowed as upgrading proceeds, conditional upon its progress. The staged upgrading should at a minimum provide for the transmission and treatment of all flows from the additional development. This provision applies to significant development i.e. not to simple, one lot infill cases."

To align with the Procedure and Region approach, the MSP-WWMS assesses solutions such that growth does not increase system wet weather flows, City-wide. Development approvals will not be limited in advance of the I&I removal but it is encouraged that the City remove I&I at a similar rate of development.

5.4. Assessment of an Average Precipitation Year

This section is intended to outline the City of Niagara Falls precipitation, allocation approach and assumptions which will be used to support the City's F-5-5 analysis. Selecting a suitable rainfall year as representative of an 'average year' sets up a transparent and repeatable framework for analysis and forecasting. The growth projections will be used to estimate future system demands and ultimately determine growth related infrastructure needs.

Long term precipitation analysis was completed using data from the Region's Niagara Falls WWTP Precipitation Station 1998 to 2022. Long term trends were established for several variables including the total number of rainfall events, total annual precipitation depth, total duration of rainfall, average event duration, and median event intensity which are summarized in **Table 5-9**. The average year was determined by determining the least rank sum to the average across all variables. 2022 was determined to be the most representative of an "average year" for the F-5-5 time period and will be utilized for the average year assessment of the system.

Table 5-9. Long-term Annual Rainfall Trends (F-5-5) at Niagara Falls WWTP Precipitation Station

Year	Number of Rainfall Events	Annual Precipitation (mm)	Total Duration (hrs)	Average Event Duration (dd:hh:mm)	Average Event Precipitation (mm)	Median Peak 1-hr Intensity (mm/hr)
1998	54	365.5	433.6	8.0	6.8	2.0
1999	50	452.75	556.3	11.1	9.1	3.1
2000	52	567.25	708.2	13.6	10.9	2.9
2001	56	391.5	595.3	10.6	7.0	1.8
2002	61	497	580.6	9.5	8.1	2.3
2003	64	590	647.9	10.1	9.2	2.0
2004	58	619.5	713.3	12.3	10.7	2.5
2005	42	562.25	484.0	11.5	13.4	3.1
2006	55	534.25	626.1	11.4	9.7	3.0
2007	47	229.25	403.5	8.6	4.9	1.3
2008	65	451	614.1	9.4	6.9	2.8
2009	51	540.5	551.4	10.8	10.6	3.0
2010	54	479	489.5	9.1	8.9	3.1
2011	52	600.75	729.6	14.0	11.6	3.3
2012	44	436.5	483.8	11.0	9.9	2.6
2013	56	678.25	630.8	11.3	12.1	2.5
2014	55	429.75	473.6	8.6	7.8	2.3
2015	50	485.75	419.6	8.4	9.7	2.5
2016	48	289.75	362.9	7.6	6.0	2.5
2017	63	624.25	634.7	10.1	9.9	2.5
2018	49	437.5	639.7	13.1	8.9	2.5
2019	64	601	635.1	9.9	9.4	3.4
2020	52	373	527.7	10.1	7.2	2.5
2021	57	626	650.8	11.4	11.0	2.5
2022	***53***	***463.75***	***577.4***	***10.9***	***8.8***	***2.8***
2023	56	471.25	549.1	9.8	8.4	2.4
Average	***54***	***492.2***	***566.1***	***10.5***	***9.1***	***2.6***
Median	***54***	***482.4***	***579.0***	***10.4***	***9.1***	***2.5***

5.5. Wastewater System Technical Level of Service Criteria

Table 5-10 summarizes the draft wastewater system technical level of service criteria that will be utilized as the decision-making rationale related to wastewater system capacity needs and triggers for upgrades.

Table 5-10. Summary of Wastewater Technical Criteria

<table>
<tr><th colspan="3">Criteria</th><th>Performance Target</th></tr>
<tr><td rowspan="5">Wastewater Flows</td><td rowspan="2">Per Capital Rate</td><td>Residential</td><td>255 L/c/d</td></tr>
<tr><td>Employment</td><td>310 L/c/d</td></tr>
<tr><td colspan="2">Peaking Factor</td><td>Harmon’s Peaking Factor</td></tr>
<tr><td rowspan="2">I/I Allowance</td><td>Existing Areas</td><td>0.4 L/s/ha</td></tr>
<tr><td>Greenfield</td><td>0.286 L/s/ha</td></tr>
<tr><td rowspan="3">System Performance</td><td colspan="2">Peak Wet Weather Design Flows</td><td>10-Year Design Storm</td></tr>
<tr><td colspan="2">Existing Infrastructure</td><td>• d/D < 1
• HGL <2.1 m</td></tr>
<tr><td colspan="2">New/Upgraded Infrastructure</td><td>• Full capacity velocity between 0.6-3.0 m/s
• Minimum sewer size of 200 mm diameter (with the exception of top end/low flow sewers which can be sized to 150 mm to maintain minimum velocity targets)
• HGL <2.1 m at centreline of road</td></tr>
<tr><td colspan="3">Overflows</td><td>MECP’s F-5-5 Regulations:
• No overflows during dry weather;
• During a seven (7) month period commencing within 15 days of April of an average year, provide 90% volumetric control of wet weather in addition to all of the dry weather flow.

Additionally, Section 11 of the F-5-5 Regulation mandates that:

“When and where significant combined sewer system deficiencies exist, the Regional Office of the Ministry shall require that the provision of sanitary servicing for additional development tributary to the deficient system be curtailed to prevent aggravation of the problem..”</td></tr>
</table>

6. Stormwater System

6.1. Stormwater Level of Service Framework

Based on the MSP-WWMS vision statement and the identified Policy statements, the following customer service statement for the City's stormwater system was developed to guide the selection of Level of Service objectives and design criteria:

"To provide an efficient, sustainable, and reliable stormwater management system that minimizes environmental impacts and protects public health and property"

Table 6-1 details objectives intended to evaluate the existing and future performance of the stormwater system in terms of technical and customer key performance indicators.

6.2. Region Stormwater System Technical Level of Service Criteria

The Region MSPU did not include recommendations for the stormwater system performance; however, Niagara Region released Region-wide Stormwater Management Guidelines in 2022 which contain level of service criteria for Regional infrastructure and to be used where lower-tier municipalities do not have defined technical criteria. The following is a brief summary of the relevant components:

- Flood Control – post-development to pre-development for 2-year through 100-year storms
- Water Budget – Pre-development levels maintained with a minimum of zero runoff for the first 5mm of rainfall
- Quality Control – 80% TSS removal (MECP "Enhanced" criteria)
- Climate Change – Assessed using one of the three approved online tools or alternative method:
    - University of Western Ontario IDFCC Tool
    - Ontario Climate Change Data Portal (OCCDP) IDF Rainfall Tool
    - MTO IDF Curve Lookup
    - Alternative method – stress test scenario with increased rainfall percentages

Table 6-1. Stormwater Level of Service Objectives

Service Objective	Supporting Policy Statements		Technical Objective	Key Performance Indicators - Technical	Key Performance Indicators - Customer
Efficient	G.08	SW.02 SW.08	• Full life-cycle costing • Renewal of aging infrastructure • Optimization of system operations • Source control • Minimize directly connected downspouts	• SOGR program • Performance of existing conveyance and treatment infrastructure • Prevalence of on-site SWM controls • No new direct connected roof leaders	• Number of complaints (cost, flooding, etc.) • Number Basement flooded • Number road flooding/ closure • Amount of damage and insurance claims • Emergency relief cost • Regular cost (property tax)
Sustainable	G.07 G.11	SW.02	• Full life-cycle costing • Renewal of aging infrastructure • Costs associated with obtaining funding	• SOGR program • Age of infrastructure • Replacement/rehab costs • O&M costs	
Safe and Reliable	G.04 G.05 G.07 G.10	SW.01	• Capacity to meet specified design storm (major and minor systems) • Minimal flooding events • Resiliency to climate change • Condition of sewer system (CCTV) • Minimize cross-connections	• Percent of system meeting capacity needs under minor storm • Percent of system meeting capacity needs under major storm • System's ability to meet performance targets under existing and climate change scenarios • Sufficiency of outlets • Number of cross connections to sanitary system	• Number of complaints (cost, flooding, etc.) • Number Basement flooded • Number road flooding/ closure • Amount of damage and insurance claims • Emergency relief cost • Regular cost (property tax)
Environmental and Regulatory	G.02	SW.03 SW.04 SW.05 SW.07	• Compliance with Provincial Water Quality Objectives • Ontario Water Resources Act • The Clean Water Act and Source Protection Plan • MECP Stormwater Planning and Design Guidelines, Future LID Guidelines • Adaptability to the effect of climate change • Water balance and provision of baseflow to streams • Protecting aquatic habitat	• Percent of system with adequate flooding and erosion control practices (stabilization or retention/detention) • Percent of system with adequate water quality treatment • Imperviousness • Prevalence of LIDs/ recharge areas • Pond and OGS sediment removal needs • Critical receiver water quality • Critical receiver stability • Critical receiver ecological changes	• Compliance with MECP Standards • Alignment with the source water protection plan amendments to the Official Plan and Zoning By-law 79-200 • Number of complaints: park/trail and watercourse cleanliness, water quality, sport fisheries • Number of severe weather events

6.3. Design Storms Climate Change Consideration

Several different approaches have been undertaken by municipalities to account for climate change when evaluating or planning their stormwater management system, including the following:

- Undertake a statistical study to update local intensity-duration-frequency (IDF) parameters based on the most up-to-date precipitation data to determine the current impact of climate change. Where old IDF parameters have been found to be more conservative than the updated parameters (which may occur if the old parameters were calculated form a shorter data set including an extreme storm event), old parameters are retained to implicitly account for future climate change.
- Apply an increase factor (e.g. 15%) to existing IDF parameters based on assumptions regarding the effect of climate change on rainfall depths.
- Utilize modified IDF parameters based on specific local predictions of a global climate model, if available.
- Utilize a more conservative return period when designing new infrastructure (e.g. 10 year storm instead of 5 year storm).

Due to the inherent uncertainty and lack of site-specific information regarding the current and future impact of climate change on the City of Niagara Falls, the recommended approach is as follows:

- Conservative IDF parameters (as included in the new Linear Design Guidelines) and design storms will be used to assess existing storm sewer capacity and design new storm sewers
- Target level of service for storm sewer capacity in existing areas will consider financial and technical feasibility of upgrading deficiencies, and major system evaluation study will be recommended to ensure that storms exceeding minor system capacity can be adequately conveyed to outlets
- During MSP-WWMS process, alternative approaches will be evaluated based on resiliency to climate change by assessing the solutions capacity to accommodate more conservative return period storms.

6.3.1. IDF Curve

The City's current IDF curves were updated in 1989 (Falcone Smith Associates) as part of the Shriners Creek Watershed Study. During a Level of Service Workshop with City staff (September 11, 2023), it was noted that the City's IDF curves were reviewed as part of the Master Drainage Plan Update (Aquafor Beech, 2017). A review of the Master Drainage Plan Update results indicated inconsistencies in the reported data. The results of the Master Drainage Plan Update indicated that a 5% - 10% increase in rainfall was appropriate to account for climate change.; however, the City have indicated that the IDF analysis from this study was not carried forward into an updated IDF curve.

As discussed during the Level of Service Workshop, GEI noted that other Niagara Region lower-tier municipalities have reviewed IDF curves against the Ministry of Transportation (MTO) IDF Curve Lookup Tool[7], which developed location-specific IDF curves based on statistics from 352 Meteorological Service of Canada and National Oceanic and Atmospheric Administration stations with an average record length of 30 years. As recommended during the workshop, the current day (2010 MTO data) and climate change projected (extrapolated to 2050) MTO IDF curves will be used in evaluating both the existing system performance and future infrastructure performance respectively.

Table 6-2, Table 6-3, and **Table 6-4** provide the MTO IDF parameters, rainfall intensity (mm/hr), and rainfall depth (mm) for 2010, which will be used to assess existing system performance. **Figure 6-1** provides a graphical representation of the intensity vs duration associated with the 2010 MTO IDF curve.

Table 6-2. 2010 MTO IDF Parameters

Return Period	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
A	22.4	29.7	34.4	40.5	45	49.4
B	-0.699	-0.699	-0.699	-0.699	-0.699	-0.699

Table 6-3. 2010 MTO IDF Rainfall Intensity (mm/hr)

Duration	5-min	10-min	15-min	30-min	1-hr	2-hr	6-hr	12-hr	24-hr
2-yr	127.2	78.4	59	36.4	22.4	13.8	6.4	3.9	2.4
5-yr	168.7	103.9	78.3	48.2	29.7	18.3	8.5	5.2	3.2
10-yr	195.4	120.4	90.7	55.8	34.4	21.2	9.8	6.1	3.7
25-yr	230	141.7	106.7	65.7	40.5	24.9	11.6	7.1	4.4
50-yr	255.6	157.4	118.6	73.1	45	27.7	12.9	7.9	4.9
100-yr	280.6	172.8	130.2	80.2	49.4	30.4	14.1	8.7	5.4

Table 6-4. 2010 MTO IDF Rainfall Depth (mm)

Duration	5-min	10-min	15-min	30-min	1-hr	2-hr	6-hr	12-hr	24-hr
2-yr	10.6	13.1	14.8	18.2	22.4	27.6	38.4	47.3	58.3
5-yr	14.1	17.3	19.6	24.1	29.7	36.6	50.9	62.7	77.3
10-yr	16.3	20.1	22.7	27.9	34.4	42.4	59	72.7	89.5
25-yr	19.2	23.6	26.7	32.9	40.5	49.9	69.5	85.6	105.4
50-yr	21.3	26.2	29.6	36.5	45	55.4	77.2	95.1	117.1
100-yr	23.4	28.8	32.5	40.1	49.4	60.9	84.7	104.4	128.6

[7] MTO IDF Curve Lookup Tool: https://idfcurves.mto.gov.on.ca/terms.shtml

Figure 6-1. Intensity vs. Duration for 2010 MTO IDF Curve

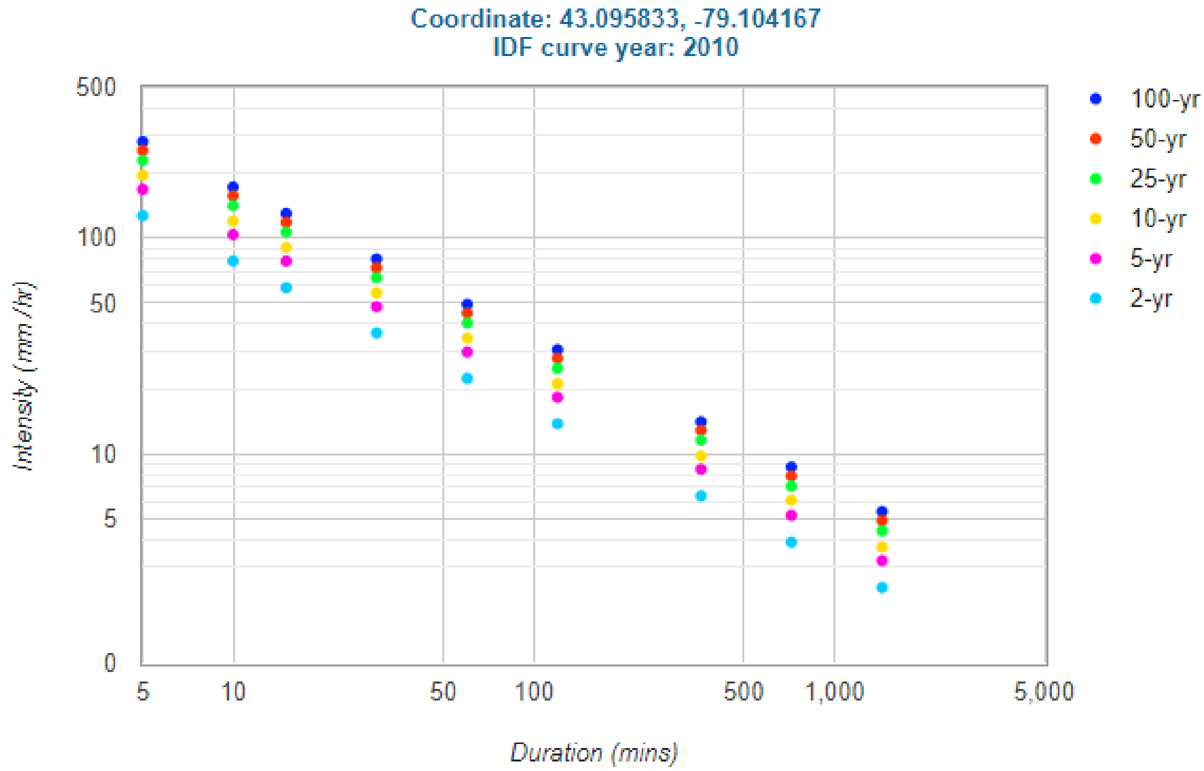


Table 6-5and **Table 6-6** provide the extrapolated rainfall intensity (mm/hr), and rainfall depth (mm) for 2050, which will be used to assess existing system performance. **Figure 6-2** provides a graphical representation of the intensity vs duration associated with the 2050 MTO IDF curve.

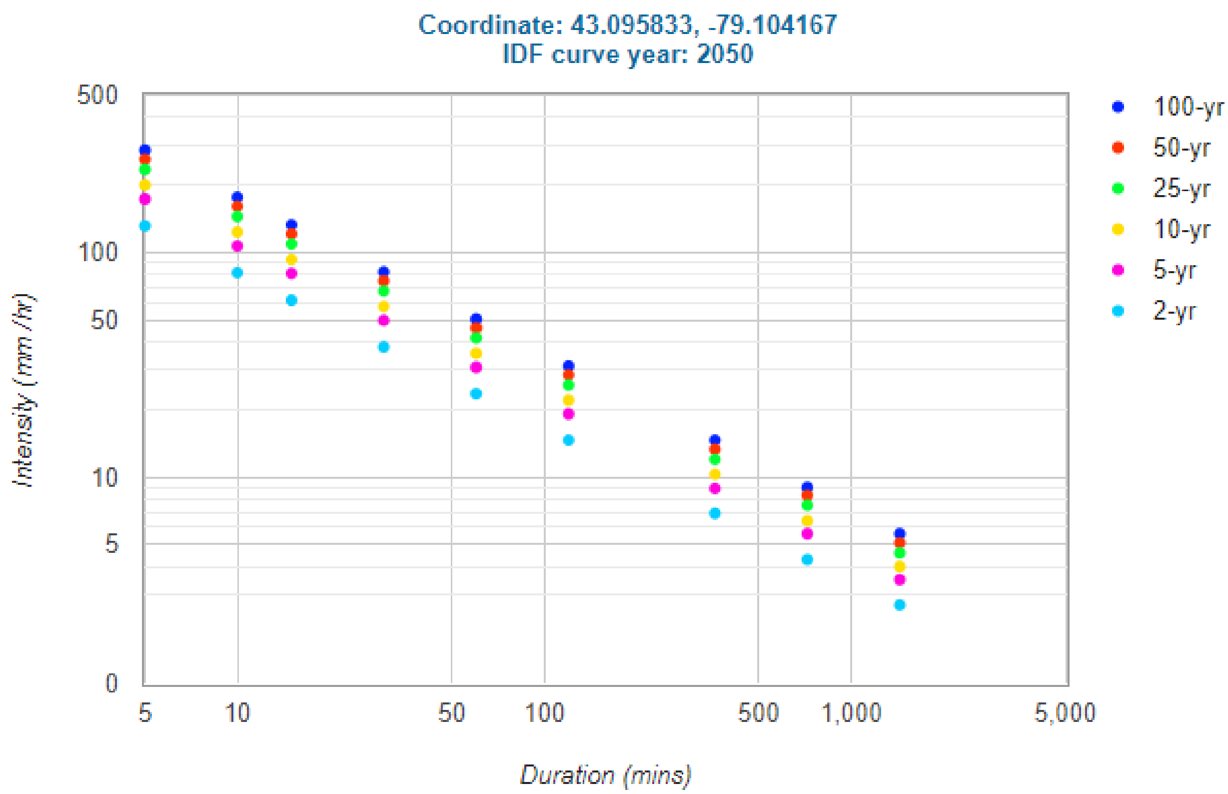
Table 6-5. 2050 MTO IDF Rainfall Intensity (mm/hr)

Duration	5-min	10-min	15-min	30-min	1-hr	2-hr	6-hr	12-hr	24-hr
2-yr	131	81.1	61.2	37.9	23.5	14.6	6.9	4.3	2.7
5-yr	172.5	106.6	80.5	49.8	30.8	19.1	8.9	5.6	3.5
10-yr	199.2	123.1	92.9	57.4	35.5	22	10.3	6.4	4
25-yr	233.8	144.4	108.9	67.3	41.6	25.7	12	7.5	4.6
50-yr	259.4	160.2	120.8	74.6	46.1	28.5	13.3	8.3	5.1
100-yr	284.4	175.5	132.4	81.8	50.5	31.2	14.6	9	5.6

Table 6-6. 2050 MTO IDF Rainfall Depth (mm)

Duration	5-min	10-min	15-min	30-min	1-hr	2-hr	6-hr	12-hr	24-hr
2-yr	10.9	13.5	15.3	18.9	23.5	29.2	41.4	51.6	64.8
5-yr	14.4	17.8	20.1	24.9	30.8	38.2	53.4	67.2	84
10-yr	16.6	20.5	23.2	28.7	35.5	44	61.8	76.8	96
25-yr	19.5	24.1	27.2	33.6	41.6	51.4	72	90	110.4
50-yr	21.6	26.7	30.2	37.3	46.1	57	79.8	99.6	122.4
100-yr	23.7	29.3	33.1	40.9	50.5	62.4	87.6	108	134.4

Figure 6-2. Intensity vs. Duration for 2050 MTO IDF Curve Extrapolated



6.3.2. *Design Storms*

The 3-hour Chicago distribution will be used for the minor and major system storm system analysis. The 5-year design storm will be used to assess the performance of the minor system, while the 100-year design storm will be used to assess the performance of the major system.

6.4. Stormwater Technical Level of Service Context

There is no prescribed level of service in the Stormwater Management Planning and Design Manual (MECP, 2003) for minor system (storm sewer and ditch) performance. The MECP manual notes that storm sewers are generally sized to convey runoff from storms ranging from 2 year to 10-year return periods, and that during the design phase the Rational Method is typically used to calculate the required capacity of sewers.

The recommended approach to evaluate the existing stormwater system performance is as follows:

- Utilize all-pipes model with catchment characteristics calibrated to observed flow monitoring data and apply 3-hour Chicago design storm of various return periods in existing and post-development scenarios. For growth and intensification areas, subcatchment parameters typical to the type of land use will be applied.
- Recommended minor system evaluation utilizing the 5-year storm event.
- Recommend major system evaluation study to ensure that storms exceeding minor system capacity can be adequately conveyed to outlets.

New infrastructure in greenfield areas should follow the City of Niagara Falls Standards for Site Planning.

6.4.1. Stormwater Hydraulic Performance Criteria

The updated and calibrated PCSWMM model was utilized in the analysis of existing stormwater system performance with the historical 3-hour Chicago design storm applied. This process detailed existing system performance without the application of growth or climate change and could be used as a guideline for potential system upgrades.

6.4.2. Storm Sewer System Capacity

Storm sewer capacity conditions will be defined and assessed when peak system HGL within a pipe satisfies the following conditions:

- The HGL is maintained below the ground surface elevation (i.e. stormwater system surcharges to the road) at either end of each storm sewer.

Level of service, in terms of design storm return period, is to be based on observed performance/ characteristics, providing an appropriate balance of risk and financial feasibility:

- 5 Year level of service across the entire City's minor system

6.4.3. Stormwater Facilities

There are several types of stormwater management facilities within the City of Niagara Falls:

- End-of-pipe detention ponds, including dry ponds, wet ponds, and wetlands. Typically designed for quantity control (flooding and/or erosion control) and quality control.
- Oil grit separator (OGS) units; quality control only.

The recommended approach is to evaluate the existing stormwater system in terms of coverage, with the required amount of coverage and design criteria for various stormwater management objectives to be subcatchment specific depending on the characteristics of the receiver. 100% of outfalls to sensitive watercourses are to have upstream or downstream control measures unless the subwatershed study confirms that they are not required. Further, direct outfalls to the Hydro Canal, the Welland River, and the Niagara River do not require quantity control, however they do require quality control as follows:

- Existing system coverage requires a minimum of 50% of the impervious areas to be captured and treated via a water quality facility
- New system coverage requires 100% of the impervious area drains to have a water quality facility

Further, each quality control facility is to target an 80% total suspended solids removal (to be confirmed by subwatershed studies) and 70% suspended solids removal into the Hydro Canal, Welland River, and the Niagara River.

6.4.4. New Development Sites

Servicing of new development with the MSP-WWMS will be evaluated using the Standards for Site Planning. Approval of future development applications will be subject to the City criteria and policy in place at the time of the application and may differ to those outlined below.

6.4.4.1. Stormwater Runoff and Imperviousness

Table 6-7 details the percent impervious, by land use, which was used by the MSP-WWMS to evaluate the potential runoff rated from greenfield and infill development. These impervious percentages are derived from the runoff coefficients provided in the Niagara Region Stormwater Management Guidelines (2022). The Guidelines provide a runoff coefficient of 0.95 for impervious area and 0.25 for pervious area.

Table 6-7. Stormwater Perviousness

Land use	Runoff Coefficient	Impervious Percentage (%)
Parks and Open Spaces	0.35	14%
Single Family Residential	0.6-0.65	50% - 57%
Semi-detached Residential	0.7	64%
Townhouses	0.75	71%
Apartments	0.85	86%
Schools	0.75	71%
Industrial	0.9	93%
Commercial	0.9	93%
Churches	0.75	71%

6.4.4.2. Depression Storage

Table 6-8 summarizes the depression storage that was used by the MSP-WWMS.

Table 6-8. Depression Storage Recommendation

Perviousness	Depression Storage
Pervious	4 mm
Impervious	1.5 mm

6.4.4.3. Flow Control Targets

Unless otherwise stated under area specific stormwater planning studies, new development / redevelopment areas will be expected to manage stormwater runoff to the following criteria:

- Post development peak flow to match pre-development peak flow under both minor flow system level of service objective (5 year design storm) and major system level of service objective (100 year design storm)
- Manage post development runoff volumes to the greater of:
  - Match pre-development flows under both minor system level of service objective (5 year design storm) and major system level of service objective (100 year design storm)
  - Capture and manage the first 25 mm of site runoff.

Further, allowable peak flows will be subject to the available capacity in the downstream minor and major stormwater conveyance systems.

6.4.4.4. Major Flow System

Unless otherwise stated under area specific stormwater planning studies, new development / redevelopment area will require a clearly defined major storm outlet, with adequate capacity, discharging to the City’s riverine system, the Hydro Canal, Welland River, or the Niagara River.

6.5. Stormwater System Technical Level of Service

Table 6-9 summarizes the draft stormwater system technical level of service criteria that will be utilized as the decision-making rationale related to stormwater system capacity needs and triggers for upgrades.

Table 6-9. Summary of Stormwater Technical Criteria

Criteria		Targets
Stormwater Flows	Minimum Runoff Coefficient "R" for Rational Method	Parks and Open Spaces - 0.35 Single Family Residential - 0.6-0.65 Semi-detached Residential - 0.7 Townhouses - 0.75 Apartments - 0.85 Schools - 0.75 Industrial - 0.9 Commercial - 0.9 Churches - 0.75
	Depression Storage	1.5 mm for impervious areas 4 mm for pervious areas
	Synthetic Design Storm	3-hour Chicago (minor system)
	Velocity	Minimum velocity – 0.8 m/s Maximum velocity – 6.0 m/s
Sewer System Performance	Design Return Period	Minor System – 5 Year Major System – 100 Year
	HGL Target (existing)	Below ground level
	d/D Target (new)	d/D = 1.0
Facility Assessment – Quantity Control/ Erosion Control	Coverage	100% of outfalls to sensitive watercourses have upstream control or downstream control measures. – Matching Post to Pre-development flows and duration Not required for outfalls to the Hydro Canal, Welland River, or the Niagara River provided there is sufficient capacity in the conveyance system.
Facility Assessment – Quality Control	Coverage (existing)	Minimum 50% of impervious area drains to water quality facility
	Coverage (new)	100% of impervious area drains to water quality facility
	Target	70% Total suspended solids removal into the Hydro Canal, Welland River, and the Niagara River 80% Total suspended solids removal into a quality control facility
	Thermal Mitigation	Per Subwatershed Studies or individual studies if a subwatershed study is not available
Facility Assessment – Water Balance		Per Subwatershed Studies or individual studies if a subwatershed study is not available

Appendix C Stormwater Capital Program Summary

Project No.	Description	Prioritization	Project Type	Project Timeline	Length (m)	Total Cost ($)	DC Cost ($)	OB Cost ($)	City (Benefit to Existing) Cost ($)
1	Sewer Upgrade - Stanley-405	Existing Risk: Exceeds Level of Service	Sewer Upgrade	10+	833	$2,868,000	-	-	$2,868,000
2	Sewer Upgrade - Dorchester Road	Existing Risk: Exceeds Level of Service	Sewer Upgrade	10+	1655	$7,009,000	-	-	$7,009,000
3	Sewer Upgrade - Olden & Casey	Existing Risk: Exceeds Level of Service	Sewer Upgrade	10+	1486	$10,199,000	-	-	$10,199,000
4	Sewer Upgrade - Mount Carmel	Existing and Medium-Term Growth Needs	Sewer Upgrade	10+	512	$1,227,000	$122,700	-	$1,104,300
5	Sewer Upgrade - Cardinal Drive	Existing Risk: Exceeds Level of Service	Sewer Upgrade	10+	313	$748,000	-	-	$748,000
6	Sewer Upgrade - Rolling Acres	Existing Risk: Exceeds Level of Service	Sewer Upgrade	10+	2235	$6,572,000	-	-	$6,572,000
7	Sewer Upgrade - Keith Street Catchment	Existing Risk: Exceeds Level of Service	Sewer Upgrade	10+	1124	$3,753,000	-	-	$3,753,000
8	Sewer Upgrade - QEW South of Thorold Stone Road	Existing Risk: Exceeds Level of Service	Sewer Upgrade	10+	2901	$17,007,000	-	-	$17,007,000
9	Sewer Upgrade - Lundy's Lane and Kalar Road	Existing and Medium-Term Growth Needs	Sewer Upgrade	10+	1673	$8,897,000	$889,700	-	$8,007,300
10	Sewer Upgrade - Kalar Road	Existing and Medium-Term Growth Needs	Sewer Upgrade	10+	390	$1,443,000	$144,300	-	$1,298,700
11	Sewer Upgrade - Chippawa Local	Existing Risk: Exceeds Level of Service	Sewer Upgrade	10+	2528	$5,595,000	-	-	$5,595,000
DC-1	Beaverdams SWM Facility - Land Purchase, Design & Construction	Supports/Triggered By Growth	SWM Pond	0-2	0	$2,868,000	$573,600	-	$2,294,400
DC-3	New Sewer - Biggar Road Trunk Storm Sewer Phase 2	Supports/Triggered By Growth	New Storm Sewers	5-10	850	$800,000	$720,000	$80,000	-
DC-4	New Sewer - Corwin EA Trunk Sewer and Outfall	Existing and Short-Term Growth Needs	Sewer Separation	5-10	1180	$14,613,250	$2,922,650	-	$11,690,600
Corwin Drive	Sewer Separation - Corwin Drive	Completed EA	Sewer Separation	5-10	4150	$43,120,000	-	-	$43,120,000
DC-7	Portage Road (Norton Street - Macklem Street) - Upsize Storm Outlet	Existing and Short-Term Growth Needs	Sewer Upgrade	5-10	480	$1,247,500	$249,500	-	$998,000
DC-10	New Sewer - Thorold Stone Road Extension	Existing and Short-Term Growth Needs	New Storm Sewers	5-10	700	$1,000,000	$1,000,000	-	-
DC-11	Thompson Creek EA/Design	Supports/Triggered By Growth	Study	5-10	0	$250,000	$250,000	-	-
DC-12	Sewer Separation - Valley Way Phase 1A, 1B, 2	Existing and Short-Term Growth Needs	Sewer Separation	0-2	1480	$12,692,750	$2,538,550	-	$10,154,200
DC-13	New OPG Outlets	Supports/Triggered By Growth	New Outfall	5-10	0	$430,200	$430,200	-	-
DC-14	Stormwater Master Plan	Existing Risk: Exceeds Level of Service	Study	5-10	0	$250,000	-	-	$250,000
DC-15	Stormwater Model Update	Existing Risk: Exceeds Level of Service	Study	5-10	0	$100,000	-	-	$100,000
DC-16	New Sewer - Allendale Avenue (Ferry Street - Robinson Street)	Existing and Short-Term Growth Needs	New Storm Sewers	0-2	370	$1,178,400	$589,200	-	$589,200
DC-17	New Sewer - Robinson Street (Stanley Avenue to East Limit)	Existing and Short-Term Growth Needs	New Storm Sewers	0-2	440	$560,500	$280,250	-	$280,250