Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

LITTLE ETOBICOKE CREEK FLOOD EVALUATION STUDY FLOOD REMEDIATION MODELLING AND ASSESSMENT PROGRESS REPORT NOS. 5 AND 6

Prepared for:
CITY OF MISSISSAUGA

Prepared by:
MATRIX SOLUTIONS INC.

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Guelph, Ontario

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LITTLE ETOBICOKE CREEK FLOOD EVALUATION STUDY

FLOOD REMEDIATION MODELLING AND ASSESSMENT

PROGRESS REPORT NOS. 5 AND 6

Prepared for City of Mississauga, February 2021

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VERSION CONTROL

Version	Date	Issue Type	Filename	Description
V0.1	26-Nov-2019	Draft	24603-531 PR5and6 R 2019-11-26 draft V0.1.docx	Issued to client for review
V0.2	27-Nov-2020	Revised Draft	24603-531 Progress Report 5_6 2020-11-27 draft V0.2.doc	Issued to client for review
V1.0	26-Feb-2021	Final	24603-531 Progress Report 5_6 2021-02-26 final V1.0.doc	Issued to client

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

1 INTRODUCTION

The Little Etobicoke Creek watershed in the City of Mississauga (the City) has experienced flooding and erosion concerns recorded back to at least the 1970s. The recent large flood event on July 8, 2013, which corresponded approximately to a 350-year storm (MMM 2015), resulted in many reports of flooding-related incidents and damage, particularly in the Dixie Road and Dundas Street East area. The focus of this flood evaluation study is to characterize flooding within the Little Etobicoke Creek watershed, identify preliminary flood cluster areas, and develop flood remediation options.

The Little Etobicoke Creek Flood Evaluation Study is being conducted in two phases as part of a final Master Plan for the City. Phase 1 was completed in January 2018 and expanded on previous studies of the overland spill from Little Etobicoke Creek, particularly focused on the Dixie-Dundas Special Policy Area, where flood flows spill from Toronto and Region Conservation Authority (TRCA) jurisdiction lands into Credit Valley Conservation jurisdiction lands. Phase 2 of the study is currently being ongoing and is the subject of this report. Phase 2 of the study is focused on the Little Etobicoke Creek watershed as a whole and includes characterization of overland urban flood risk as well as development, assessment, and recommendations for flood remediation measures. Figure 1 shows the study area, including the 2,260 ha Little Etobicoke Creek watershed.

1.1 Progress Report Purpose

This progress report summarizes the flood remediation options for flood clusters within Little Etobicoke Creek based on the previously developed two-dimensional (2D) PCSWMM model and a newly developed three-way coupled PCSWMM model for select areas. Six focus areas were identified for further flood evaluation and assessment of flood remediation solutions. Several options for each focus area were considered and, where applicable, solutions were simulated using the 2D and three-way coupled models.

To support the watershed-scale flood evaluation study for Little Etobicoke Creek, a minor system assessment was also completed to look at the level of service in the current sewer system (i.e., 2-, 5-, and 10-year). The level of service mapping in conjunction with the previous 2D surface modelling was used to understand urban flooding throughout each sewershed and will help the City select and carry out additional flood studies in the future.

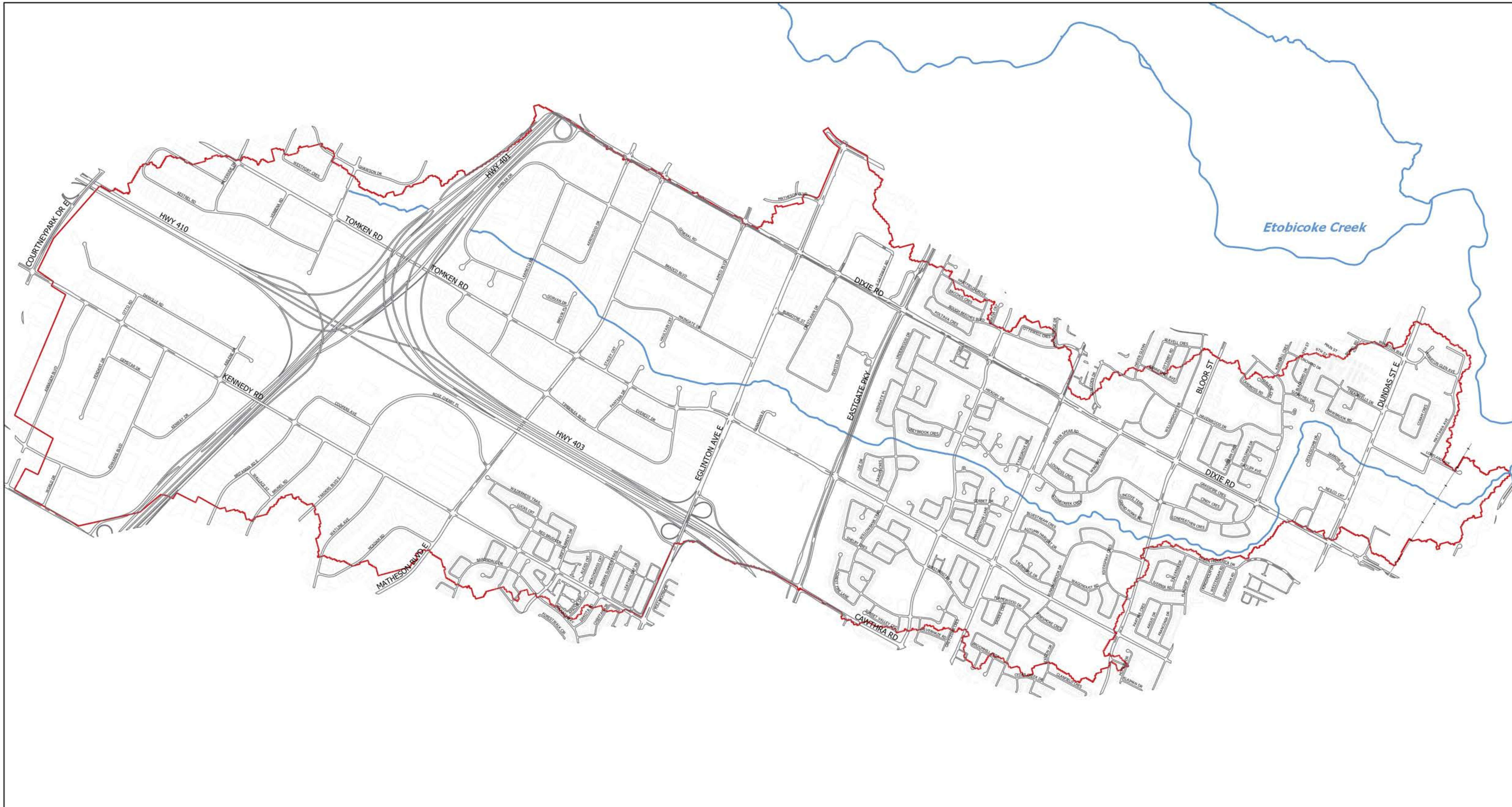


Figure Date: July 23 2020

- Roads
- Watercourse
- Railway
- Buildings
- Little Etobicoke Catchment

This drawing must be used in conjuction with the attached memorandum, 'Progress Report #5 and #6: FLOOD REMEDIATION MODELLING AND ASSESSMENT' (September 2019) and is subject to the same limitations and conditions stated in the memorandum.

T:\24603 - Little EtobicokeCr_Flood\531\05 Analysis\GIS\BaseMap_v3.qgs

N

0 500 1000 m

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Little Etobicoke Creek Phase 2
Flood Evaluation Study

24603-155562

Phase 2 Study Limit

P. Bishop
K. Hofbauer

Figure 1

Table 1 provides a summary list of the previous progress report and content.

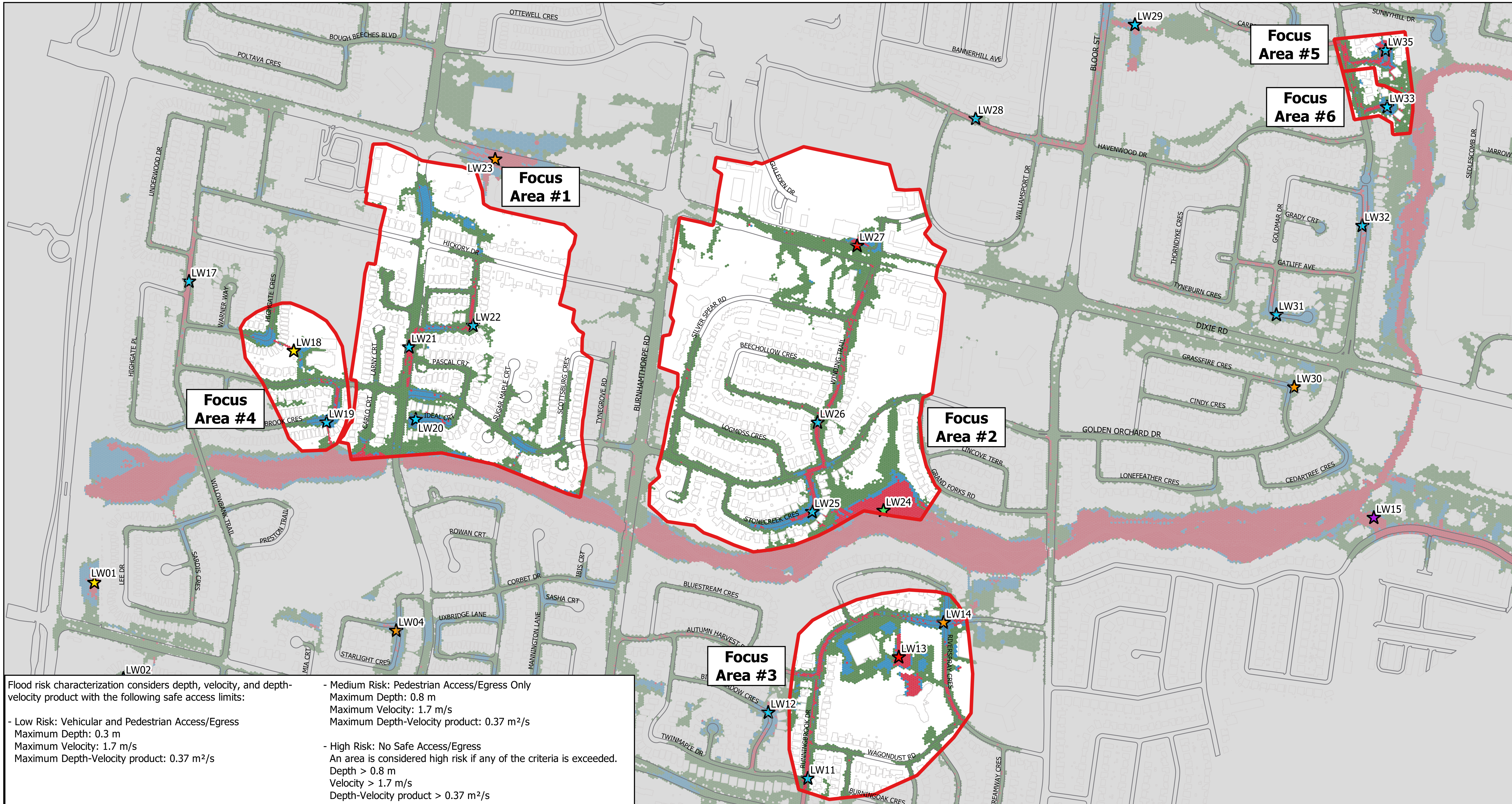
TABLE 1 Summary of Progress Reports

Progress Report No.	Topic	Content
1	Floodplain Spill Assessment (Matrix 2018)	• background review • Phase 1
2	Modelling for Flood Characterization and Analysis (Matrix 2020a)	• details of two-dimensional (2D) PCSWMM model development • 2D model validation • flood risk results
3 & 4	Flood Cluster Areas and General Causes of Flooding (Matrix 2020b)	• flood characterization • flood cluster identification • identifying mechanisms of flooding • recommending flood clusters for further assessment
5 & 6	Flood Remediation Modelling and Assessment	• minor system assessment (level of service modelling) • three-way coupled modelling methods • description and analysis of six focus areas

2 ASSESSMENT OF FOCUS AREAS

Over 70 flood clusters were identified in Progress Report Nos. 3 and 4 (Matrix 2020b). Many of these clusters were identified to be on private land and Matrix Solutions Inc. recommended that the City notify the property owners to monitor these areas and/or set private flood remediation measures. The remaining flood clusters required further analysis to confirm appropriate flood remediation alternatives. In some locations, the remediation of several flood clusters could potentially be accomplished by creating upstream storage, removing overland flow path barriers, or adding additional stormwater outlets. To address the greatest amount of flood cluster issues while considering cost and efficiency, an approach to look at focus areas and potential solutions was discussed with the City and carried out for the flood remediation alternatives assessment.

The City provided Matrix with map outlining the City's easements and open areas where potential flood remediation measures may be implemented. After reviewing the provided information, Matrix identified six areas where cost-effective solutions may address several flooding problems. These six focus areas (Figure 2), the associated flood clusters within these areas, and potential high-level solutions are outlined in Table 2.



Flood risk characterization considers depth, velocity, and depth-velocity product with the following safe access limits:

- Low Risk: Vehicular and Pedestrian Access/Egress
  Maximum Depth: 0.3 m
  Maximum Velocity: 1.7 m/s
  Maximum Depth-Velocity product: 0.37 m²/s

- Medium Risk: Pedestrian Access/Egress Only
  Maximum Depth: 0.8 m
  Maximum Velocity: 1.7 m/s
  Maximum Depth-Velocity product: 0.37 m²/s

- High Risk: No Safe Access/Egress
  An area is considered high risk if any of the criteria is exceeded.
  Depth > 0.8 m
  Velocity > 1.7 m/s
  Depth-Velocity product > 0.37 m²/s

Figure Date: July 6, 2020

Focus Areas

Risk (100-year Flood)
- Low
- Medium
- High

Progress Report #3 & 4 Clusters
- Additional Modelling/Assessment
- Channel Capacity
- Modification to Major Flow Route
- Monitor
- Notification

0 25 50 75 100 m

This drawing must be used in conjuction with the attached memorandum, Progress Report #7: Flood Alternatives Evaluation (June 2020) and is subject to the same limitations and conditions stated in the memorandum.

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Little Etobicoke Creek Phase 2
Flood Evaluation Study

Project #: 24603-155562

Focus Areas

M. Samson
A. McKay

Figure 2

TABLE 2 Focus Areas and Potential Solutions

Focus Area ID	Addressed Flood Clusters	Potential Solution
1	LW20, LW21, LW22	• storage pond in Golden Orchard Park, adjacent to cluster LW22 • inlet through Hickory Drive or Gryphon Mews pathways • outlet into Sugar Maple Court sewer (access road can be developed there as well)
2	LW24, LW25, LW26, LW27	• storage pond in Kennedy Park • inlet from Winding Trail through the easement • direct outlet to Little Etobicoke Creek via new sewer under Golden Orchard Drive
3	LW11, LW13, LW14	• outlet pipe connection from sewer on Runningbrook Drive through Cedarbrook Park; tie into existing sewer in the park or create additional outlet
4	LW18, LW19	• cut down the easement from Highgate Crescent to the school yard to allow major drainage pathway • cut down the easement on Greybrook Crescent to Little Etobicoke Creek to allow major drainage pathway
5	LW33	• cut down the easement on Taviton Crescent to Little Etobicoke Creek to allow major drainage pathway
6	LW35	• cut down the easement on Hedgestone Crescent to Little Etobicoke Creek to allow major drainage pathway

To evaluate each of the focus areas, separate modelling techniques were applied depending on the flood characterization identified in Progress Report Nos. 3 and 4 (Matrix 2020b) and the level of complexity of the potential solutions. For focus areas 3 through 6, solutions could be evaluated in the previously developed PCSWMM 2D model from Progress Report No. 2 (Matrix 2020a). However, some of the more complex solutions, such as those identified for focus areas 1 and 2, required the development of a three-way coupled model that included an explicit representation of the minor system network. Analysis of the minor system network is provided in Section 3, development of the three-way coupled model is provided in Section 4, and the alternative solutions assessment is summarized in Section 5.

3 MINOR SYSTEM ASSESSMENT

TRCA (2019) specifies that urban flooding includes “street flooding and basement flooding [which occur] when there is more water than the local drainage system (sewers and streets) can handle, or when there is a lack of a major overland flow route from a low-lying area. Urban storm infrastructure is the responsibility of municipalities.” Flood mechanisms causing urban flooding include undersized inlets (i.e., catch basins, ditch inlets, etc.), undersized sewers, ill-defined overland flow paths, low-lying areas with no outlet, and combinations thereof. To support the subwatershed-scale urban flood characterization for Little Etobicoke Creek, a “level of service,” or minor system sewer capacity assessment, was completed using MIKE URBAN to determine the existing condition level of service for the 2-year, 5-year, and 10-year design storm events using a 4-hour Chicago rainfall distribution. The development of the MIKE URBAN model is described in Appendix A.

3.1 Level of Service

Matrix performed a level of service assessment on the sewers and manholes in the study area using a one-dimensional (1D) MIKE URBAN model. The focus of this assessment was the storm sewer network; a 1D urban-only modelling approach was considered appropriate because the effect of tailwater conditions at the outfalls is considered minimal for the design storm (10-year). The 25-year storm, which is the current municipal design standard for trunk sewers, was not considered in this analysis.

3.1.1 Level of Service in Pipes

The pipe level of service represents the largest storm for which the pipe peak flow does not exceed its design capacity. That is, the pipe level of service was considered by reviewing the ratio of maximum modelled pipe flow (Q_{max}) to the pipe full flow capacity (Q_{full}). Where Q_{max}/Q_{full} is less than 80%, the pipe is considered below capacity; where Q_{max}/Q_{full} is between 80% and 120%, the pipe is considered at capacity; and where Q_{max}/Q_{full} is greater than 120%, the pipe is considered above capacity. These ratios were developed with the understanding that assumptions inherent in a modelled pipe network may result in a level of uncertainty of the simulated flows and reflected in the ranges used to assess the pipe capacity.

The pipe level of service results are summarized in Table 3. While most pipes in the study area (81%) have a level of service that exceeds the 10-year design guideline for the storm sewer system (non-trunk sewer; City of Mississauga 2009), approximately 19% of pipes do not meet the standard. To assess the capacity limitation in an area, the results of the pipe analysis must be considered in conjunction with the node level of service analysis (Section 3.1.2).

TABLE 3 Sewer Level of Service

Level of Service (years)	Rainfall Depth (mm)	Count (Percentage of Total; %)
≤2	<34	106 (5%)
2 to 5	34 to 45	145 (7%)
5 to 10	45 to 55	142 (7%)
10+	>55	1,645 (81%)

Pipe level of service is shown on Maps 1.1 and 1.2 (Appendix B). Peak pipe flow relative to design capacity for the 2-year, 5-year, and 10-year storms are shown on Maps 1.3 to 1.8 (Appendix B). The level of service analysis considers many dynamic factors in the minor system network, including pipes that are influenced by backwater conditions. When flow in a pipe is restricted by backwater downstream, the peak flow in the given pipe is shown to be very small (close to zero). This means, by looking at the ratio of maximum modelled flow (Q_{max}) in the pipe relative to the pipe capacity, there is an indication that the pipe has additional capacity when that is not the case. Using the results of the node level of service analysis in conjunction with the results for the sewer capacity analysis provides a holistic understanding of the pipe system and can indicate when a pipe is actually at capacity due to backwater when the Q_{max}/Q_{full} ratio indicates that it is not.

3.1.2 Level of Service in Nodes

The node level of service analysis considers the largest storm event for which the node does not surcharge to surface. Node level of service is shown on Maps 1.9 and 1.10 (Appendix B). Node hydraulic grade line (HGL) relative to ground surface for the 2-year, 5-year, and 10-year storms are shown on Maps 1.11 to 1.16 (Appendix B). Under a backwater condition, a raised water elevation in a given manhole may be a result of a downstream constriction and not directly related to the adjacent pipe. Consequently, the results of the node level of service analysis should be interpreted in conjunction with the pipe level of service analysis (Section 3.1.1). The node level of service results are summarized in Table 4.

TABLE 4 Summary of Node Level of Service

Level of Service (years)	Rainfall Depth (mm)	Number of Nodes (Percentage of Total; %)
≤2	<34	413 (8%)
2 to 5	34 to 45	230 (4%)
5 to 10	45 to 55	400 (8%)
10+	>55	4,235 (80%)

3.2 Level of Service Summary

The level of service mapping shows there are some capacity limitations within the minor system during the 2-year, 5-year, and 10-year design storms within the Little Etobicoke Creek sewersheds. Where the level of service limitation and previously identified flood clusters align, there is likely to be an issue with urban flooding that warrants consideration and perhaps remediation within the sewer network. Areas where the sewer system has a level of service less than 10-year design storm on five or more consecutive sewers are summarized in Table 5.

TABLE 5 Areas with <10-year Level of Service

<table>
<tr><th>Service Map</th><th>Description</th></tr>
<tr><td>


</td><td>
Neighbourhood east of Kennedy Road, between Matheson Boulevard East and Eglinton Avenue East (Upper Model Area).

Affected streets:

Wilderness Trail
Drift Current Drive
Cosentino Gardens
Beachgrass Court
Indian Summer Trail

Manholes
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service
Sewer
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service
Swale
</td></tr>
<tr><td>


</td><td>
Neighbourhood west of Hickory Drive, between Willowbank Trail and Rathburn Road East (Lower Model Area).

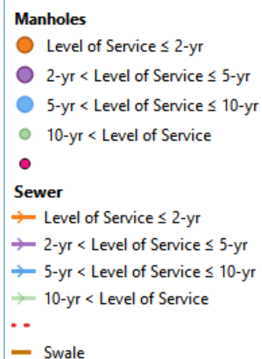
Affected streets:

Willowbank Trail
Highgate Crescent
Golden Orchard Drive
Greybrook Crescent

Manholes
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service
Sewer
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service
Swale
</td></tr>
</table>

<table>
<tr><th>Service Map</th><th>Description</th></tr>
<tr><td>
</td><td>Neighbourhood west of Hickory Drive, between Rathburn Road East and Burnhamthorpe Road East (Lower Model Area).

Affected streets:
• Pascal Court
• Golden Orchard Drive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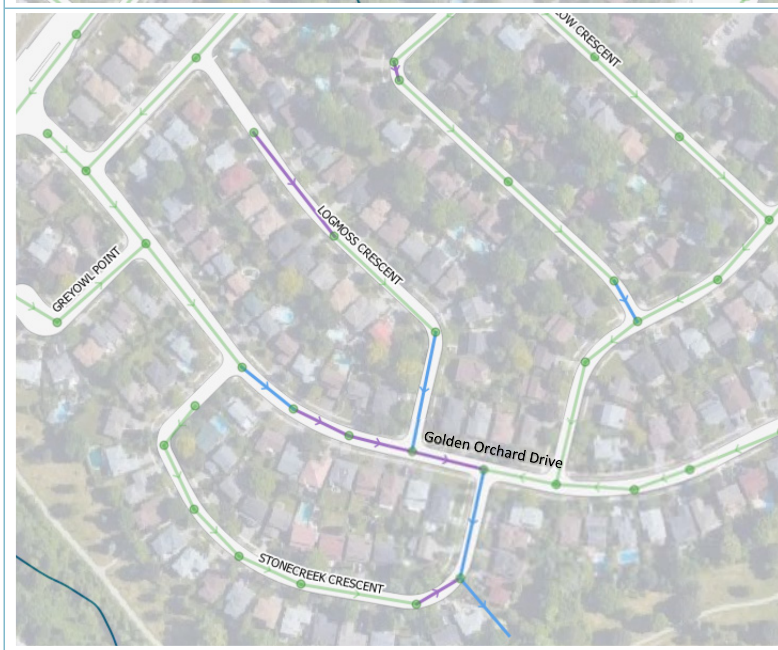
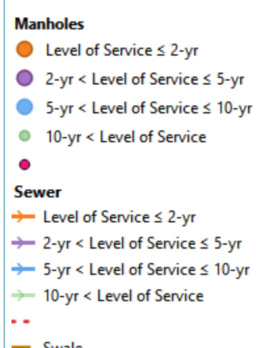
<tr><td>
</td><td>Neighbourhood west of Dixie Road, between Burnhamthorpe Road East and Bloor Street (Lower Model Area).

Affected streets:
• Logmoss Crescent
• Golden Orchard Drive
• Stonecreek Crescent


</td></tr>
</table>

<table>
<tr><th>Service Map</th><th>Description</th></tr>
<tr><td>
</td><td>Neighbourhood east of Dixie Road (Lower Model Area).

Affected streets:
Havenwood Drive
Williamsport Drive
Manholes
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service

Sewer
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service

Swale</td></tr>
<tr><td>
</td><td>Neighbourhood south of the Bloor Street and Dixie Road intersection (Lower Model Area).

Affected streets:
Cedartree Crescent
Golden Orchard Drive
Grassfire Crescent
Tyneburn Crescent
Thorndyke Crescent
Goldmar Drive
Fieldgate Drive
Manholes
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service

Sewer
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service

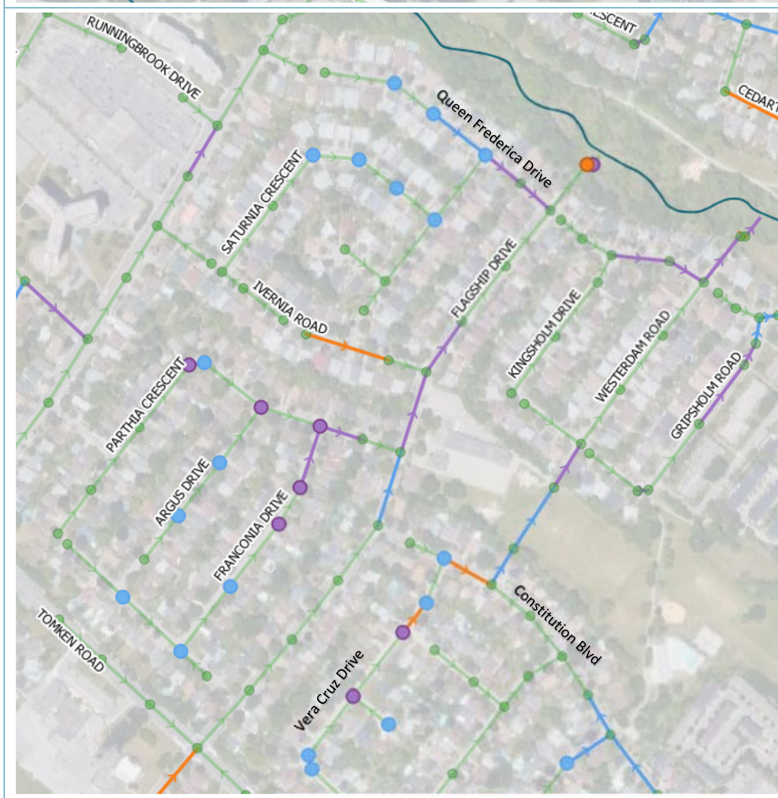
Swale</td></tr>
</table>

<table>
<tr><th>Service Map</th><th>Description</th></tr>
<tr><td>
</td><td>Neighbourhood north of Dundas Street East (Lower Model Area).

Affected streets:
• Fairfox Crescent
• Nawbrook Road

Manholes
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service

Sewer
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service

Swale</td></tr>
<tr><td>
</td><td>Neighbourhood south of Bloor Street, east of Tomken Road East (Lower Model Area).
Affected streets:
• Vera Cruz Drive
• Franconia Drive
• Argus Drive
• Parthia Crescent
• Flagship Drive
• Saturnia Crescent
• Queen Frederica Drive
• Gripsholm Road
•

Manholes
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service

Sewer
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service

Swale</td></tr>
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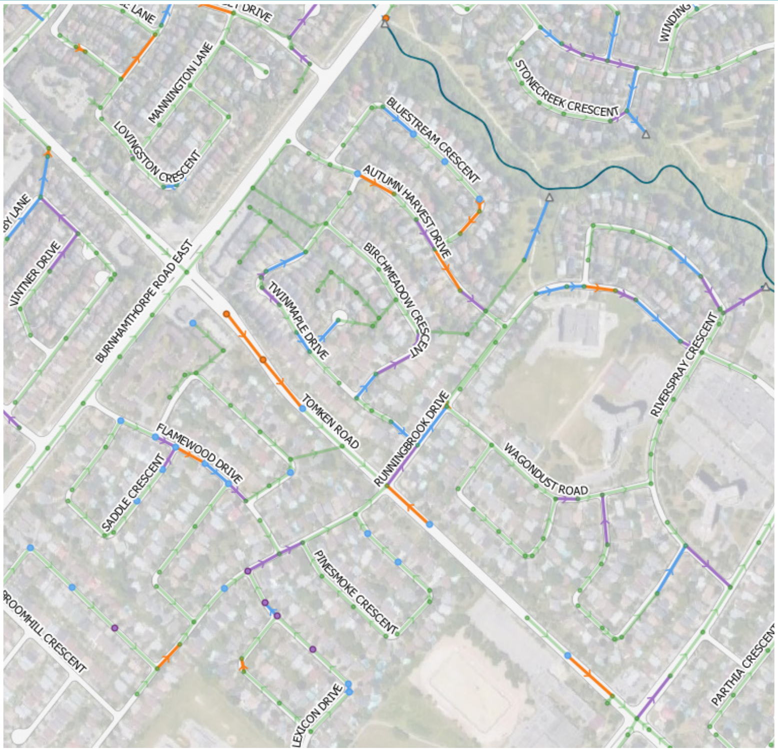
<table>
<tr><th>Service Map</th><th>Description</th></tr>
<tr><td>
</td><td>Neighbourhood between Burthamthorpe Road East and Bloor Street (Lower Model Area).

Affected streets:
• Lexicon Drive
• Broomhill Crescent
• Runningbrook Drive
• Flamewood Drive
• Tomken Road
• Twinmaple Drive
• Birchmeadow Crescent
• Autumn Harvest Drive
• Bluestream Crescent
• Riverspray Crescent

Manholes
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service

Sewer
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service

Swale</td></tr>
<tr><td></td><td></td></tr>
<tr><td>
</td><td>Neighbourhood north of Burhamthorpe Road between Cawthra Road and Tomken Road (Lower Model Area).

Affected streets:
• Lingfield Crescent
• Torino Crescent
• Westminster Place
• Rathburn Road East
• Sunset Valley Court
• Wetherby Lane
• Vintner Drive

Manholes
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service

Sewer
Level of Service ≤ 2-yr
2-yr < Level of Service ≤ 5-yr
5-yr < Level of Service ≤ 10-yr
10-yr < Level of Service

Swale</td></tr>
</table>

3.3 Riverine Flooding Impacts

During high flow events, water elevation in the Little Etobicoke Creek can be high enough to submerge sewer system outlets along the banks, creating backwater in the minor system. The backwater impact will potentially reduce the level of service in the sewer systems, as any storm sewers that are partially full, or completely full, from riverine (Little Etobicoke Creek) water will have a reduced capacity for stormwater conveyance. Matrix performed a riverine flooding impact assessment to identify sewers that will be partially full or completely full during the riverine design storms (2-year through 350-year) and Regional events based on the water levels in Little Etobicoke Creek. The riverine backwater assessment identified areas where urban runoff may not be effectively drained by the sewer system during some riverine return period events, which could influence potential flood remediation solution effectiveness.

Matrix used the existing Little Etobicoke Creek 1D HEC-RAS model (TRCA 2016) to export water surface elevations for each storm event. Sewer outlets at the banks of Little Etobicoke Creek were assigned water surface elevation values from the exported layer. By comparing sewer invert and obvert elevations with water surface elevations assigned at the outlet, each sewer was classified as one of the following:

- Full capacity: invert elevation at the lower end of storm sewer segment is higher than water surface elevation (i.e., the pipes are empty and there is no backwater in the sewer).

- Some capacity: water surface elevation is between the invert and obvert elevations at the lower end of storm sewer, so the storm sewer is partially filled with backwater.

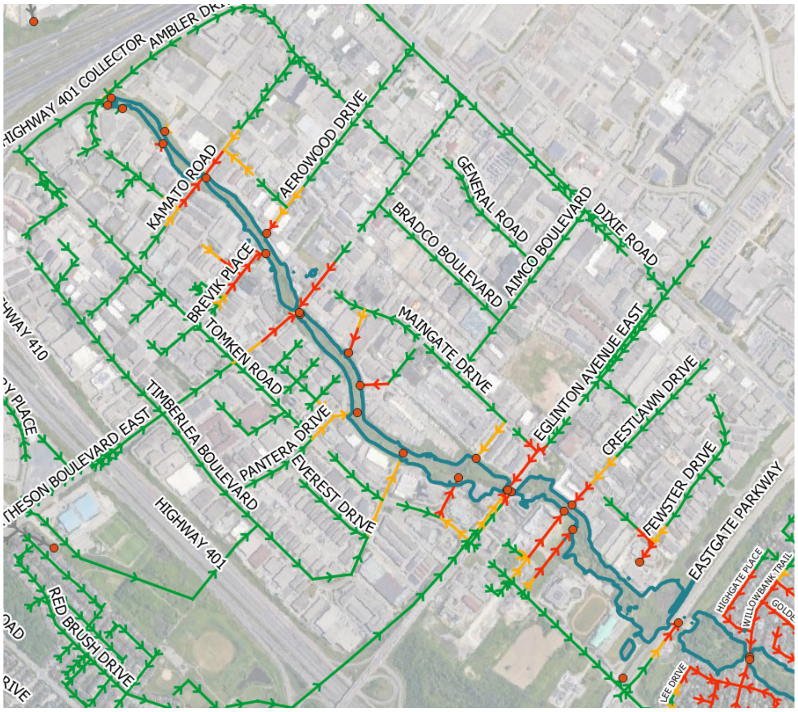
- No capacity: water surface elevation is higher than obvert elevation at the lower end of storm sewer, so the sewer is filled with backwater at the lower end.

Storm sewers that do not outlet directly to Little Etobicoke Creek, such as the areas west of Highway 403 and Highway 410, which outlet to open ditches or stormwater ponds, were not considered in the analysis. Also, storm sewers outside the modelling domain of the existing HEC-RAS model, such as the areas north of Highway 401, were not considered in the analysis, as no water surface elevation is available.

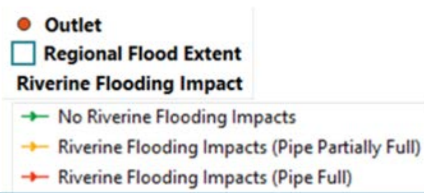
In general, results of impacted storm sewers show that backwater effects in the storm sewer system in the Lower Model area have significantly more impacts than backwater effects in the Upper Model areas. The existing HEC-RAS model shows that average water depth in the Lower Model areas is much higher than in the Upper Model areas. The differences in water depth contribute different backwater impacts between the Upper Model and Lower Model areas.

The result maps of riverine flooding impact during the design storms (2-year through 350-year) and Regional storm events can be found in Appendix B (Maps 2.1 to 2.16). Table 6 provides a summary of riverine flooding impacts for areas in the Little Etobicoke Creek watershed. Descriptions and images in Table 6 show the riverine impacts on the storm sewer system during the Regional event (from Maps 2.13 and 2.14; Appendix B), which is considered the worst-case condition for this site.

TABLE 6 Riverine Flooding Impacted during the Regional Event

<table>
<tr><th>Riverine Flooding Affected Area</th><th>Description</th></tr>
<tr><td>
</td><td>Upper model areas: industrial and commercial area between Highway 401 (north end) and Eastgate Parkway (south end).

In general, storm sewers within 150 m of Little Etobicoke Creek are affected by backwater.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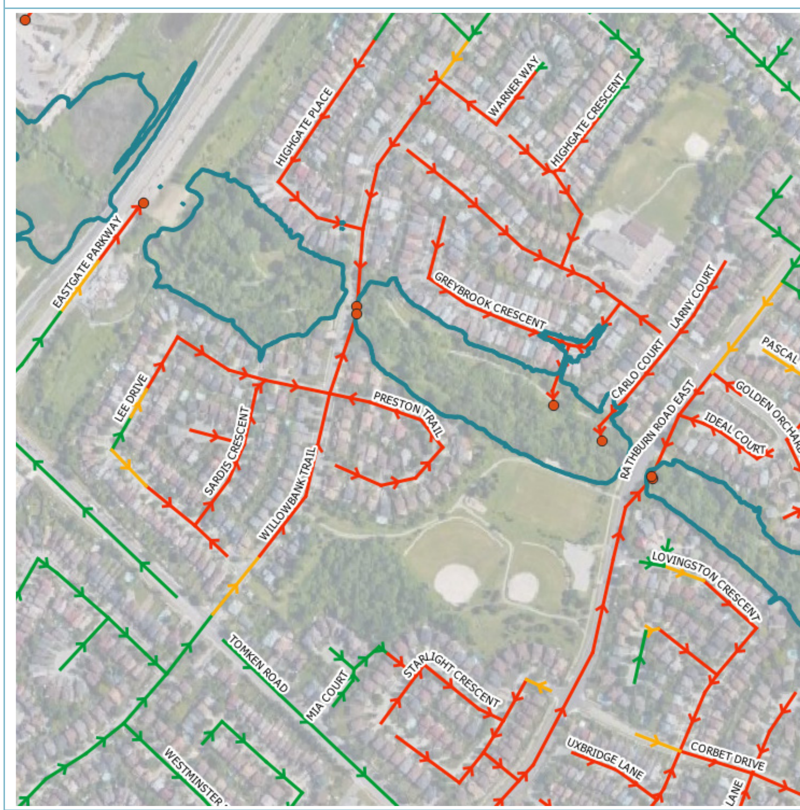
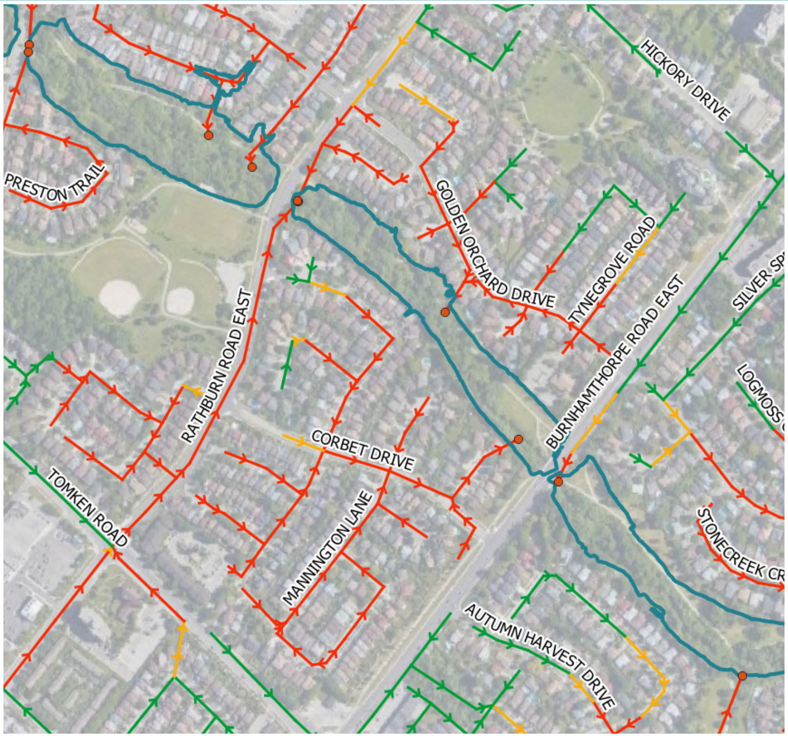
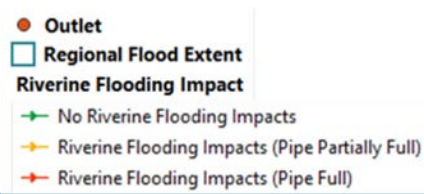
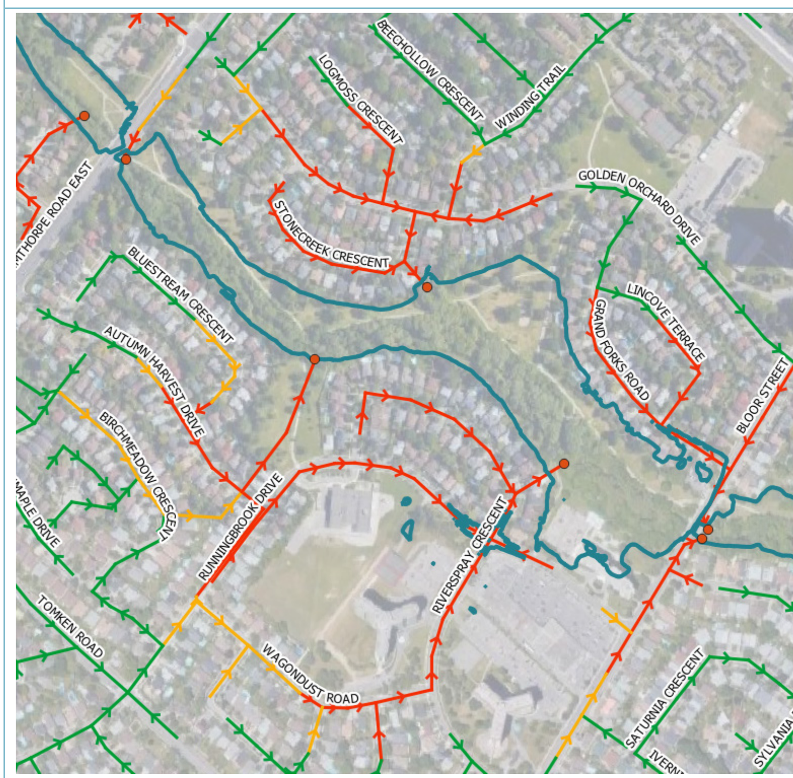
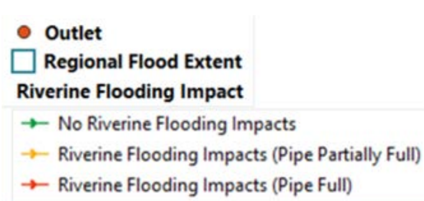
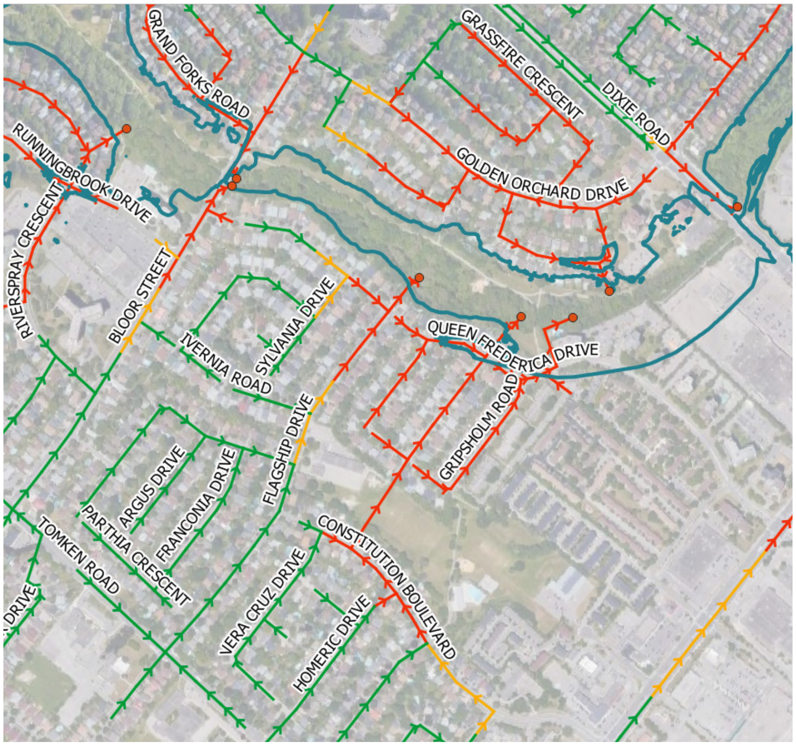
<tr><td>
</td><td>Neighbourhood between Eastgate Parkway (north end) and Rathburn Road East (south end).

East neighbourhoods: storm sewers within 250 m of Little Etobicoke Creek are affected by backwater.

West neighbourhoods: storm sewers are affected up to Tomken Road. Storm sewers are also affected on Starlight Crescent, 500 m away from the outlet.

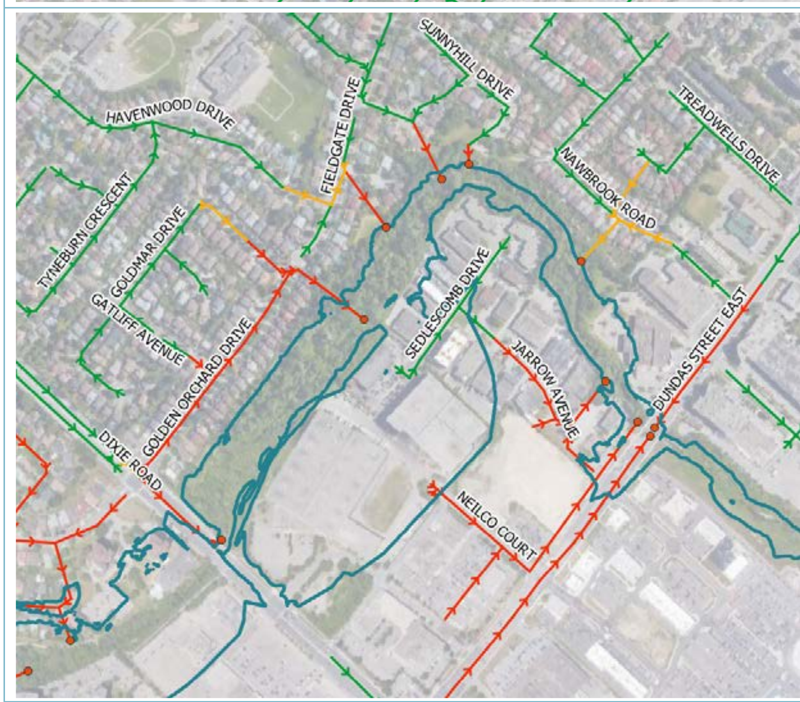

</td></tr>
</table>

Riverine Flooding Affected Area	Description
	Neighbourhood between Rathburn Road East (north end) and Burnhamthorpe Road East (south end). East neighbourhood: storm sewers within 200 m of Little Etobicoke Creek are affected by backwater. West neighbourhood: storm sewers within 500 m of Little Etobicoke Creek are affected by backwater. Storm sewers along with Rathburn Road East are full for 800 m until Westminster Place. 
	Neighbourhood between Burnhamthorpe Road East (north end) and Bloor Street (south end). East neighbourhood: storm sewers within 150 m of Little Etobicoke Creek are affected by backwater. West neighbourhood: storm sewers on Riverspray Crescent, parts of Autumn Harvest Drive, and the circle road surrounding St. Teresa of Calcutta Catholic Elementary School and Westwood Luxury Apartments building are affected by backwater. 

<table>
<tr><th>Riverine Flooding Affected Area</th><th>Description</th></tr>
<tr><td>
</td>
<td>Neighbourhood between Bloor Street (west end) and Dixie Road (east end).

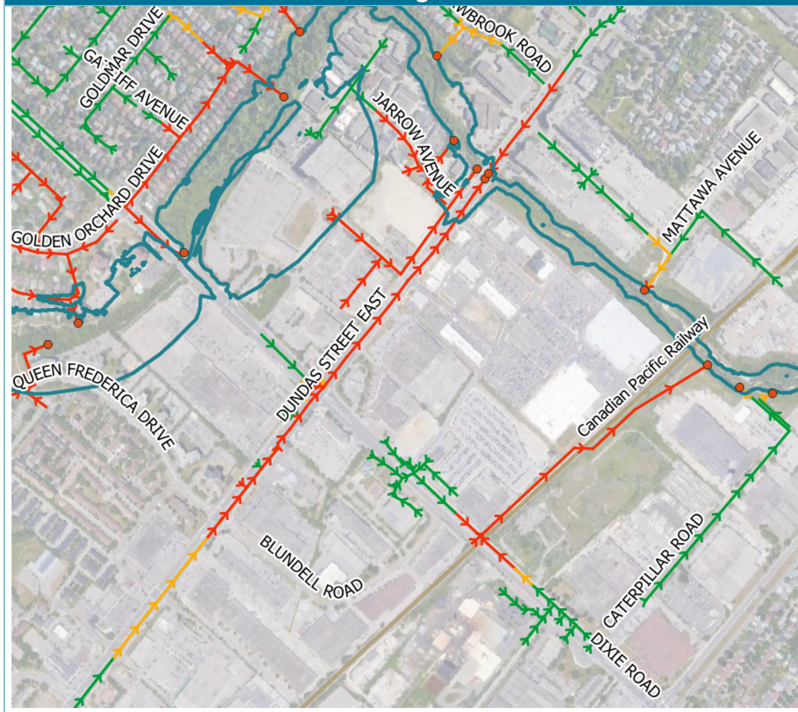
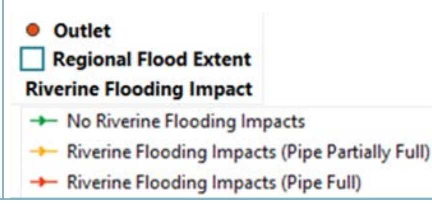
North neighbourhood: most storm sewers are affected by backwater.

South neighbourhood: storm sewers within 600 m of Little Etobicoke Creek are affected by backwater. The full sewer capacity aligns with overbank flooded area near Queen Frederica Drive and Westerdam Road.

Outlet
Regional Flood Extent
Riverine Flooding Impact
No Riverine Flooding Impacts
Riverine Flooding Impacts (Pipe Partially Full)
Riverine Flooding Impacts (Pipe Full)</td></tr>
<tr><td>
</td>
<td>North neighbourhood between Dixie Road (west end) and Dundas Street East (east end).

Only a few storm sewers are affected by backwater in this area. Sewers directly connected to the outlet on Golden Orchard Drive are full.

Outlet
Regional Flood Extent
Riverine Flooding Impact
No Riverine Flooding Impacts
Riverine Flooding Impacts (Pipe Partially Full)
Riverine Flooding Impacts (Pipe Full)</td></tr>
</table>

Riverine Flooding Affected Area	Description
 	Industrial and commercial area on Dundas Street East and Dixie Road; south bank of Little Etobicoke Creek. Storm sewers on Dundas Street East are extensively affected by backwater within 970 m of the creek. Storm sewers aligned with Canadian Pacific Railway are also full for 600 m upstream. 

4 THREE-WAY MODEL DEVELOPMENT

Two focus areas in Little Etobicoke Creek, identified in Section 2, were further assessed using a three-way coupled model, which included explicit representation of the urban sewer system, ground surface, and watercourse network. These areas were chosen based on the high-risk trigger from the original model in Progress Report Nos. 3 and 4 (Matrix 2020b), coupled with the potential to implement a storage facility in City-owned lands in Golden Orchard Park and Kennedy Park.

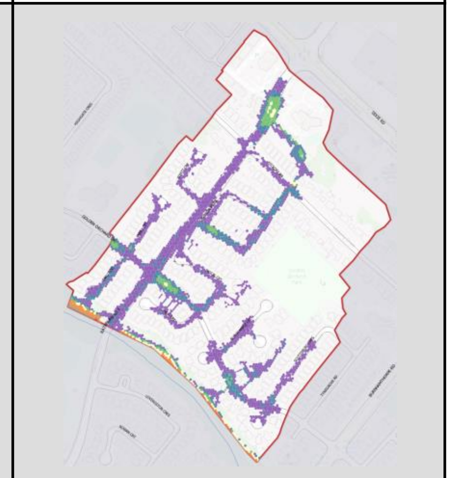
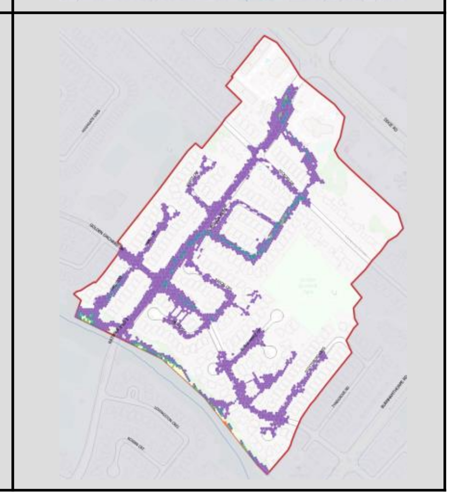
The extents of focus areas 1 and 2 were individually delineated to sufficiently contain overland flooding with minimal influence from outside flows. The three-way model integrated the 1D minor system from Progress Report No. 1 (Matrix 2018) and the PCSWMM 2D model from Progress Report Nos. 3 and 4 (Matrix 2020b) for the two specific focus areas.

Results show consistent flooded areas between the standalone 2D and the integrated three-way models (Figure 3 for Focus Area 1 and Figure 4 for Focus Area 2). Areas in the three-way model that do not show surface flooding or display a reduction in velocity where the 2D model had shown higher values is an indication that the sewer system is more effective at capturing and conveying minor flows than the assumptions applied in the original 2D model (i.e., maximum capacity of 19 mm/hour and 44 mm/hour). In contrast, flooding in the three-way model where there is none in the 2D model is a possible indication of backup in the underlying sewer from Little Etobicoke Creek or due to sewer capacity limitations.

The three model scenarios (2D model 19 mm/hour assumption; 2D model 44 mm/hour assumption; and three-way model) displayed similar results under the 100-year storm as shown in Figures 3 and 4. For both focus areas 1 and 2, there was less flood risk shown in the three-way model under the 100-year storm than the previous 2D models (Figures 3 and 4). The high-risk areas (red) were consistent with those previously identified in Progress Report Nos. 3 and 4 (Matrix 2020b) with the exception of Ideal Court in Focus Area 1. This area moved from a moderate-risk to low-risk area, as the minor system captured more surface water than previously assumed and there is less spillover across the properties from Golden Orchard Drive. Overall, the close match between the 2D and three-way models displayed in Figure 5 validates the results of the 2D model.

In Focus Area 1, the 10-year storm generated a similar flooding extent to the 100-year storm with lower risk (Figure 5). There were a few areas on Rathburn Road East and Gryphon Mews that were flagged as high-risk areas under the 10-year storm. In Focus Area 2, the flooding extent of the 10-year storm is much smaller than the 100-year storm results. High-risk flood areas for the 100-year storm were located along Winding Trail and Stonecreek Crescent, as well as in the Little Etobicoke Creek floodplain.

The developed three-way model was used to evaluate more detailed causes of flooding and potential flood remediation efforts for focus areas 1 and 2 (Section 4). It should be noted that when conducting a flood risk analysis, PCSWMM outputs overall maximum depth and velocity regardless of the time step. The product of depth x velocity applied to the risk maps assumes that these localized maximums happen at the same time. As such, these maps demonstrate the most conservative estimate of risk.

	2D Surface Model 19 mm/hr assumption (100-yr, 4-hr)	2D Surface Model 44 mm/hr assumption (100-yr, 4-hr)	Three-Way Model includes minor system (100-yr, 4-hr)
Max Depth			
Max Velocity			
Max Depth x Max Velocity			

Legend

Maximum Depth (m)	Maximum Velocity (m/s)	Maximum Depth x Velocity (m²/s)
<= 0.10	<= 0.10	<= 0.10
0.10 - 0.30	0.10 - 0.25	0.10 - 0.25
0.30 - 0.50	0.25 - 0.50	0.25 - 0.37
0.50 - 0.80	0.50 - 1.00	0.37 - 1.00
0.80 - 1.50	1.00 - 1.70	1.00 - 1.50
1.50 - 2.00	1.70 - 2.00	1.50 - 2.00
> 2.00	> 2.00	> 2.00

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Little Etobicoke Creek Phase 2
Flood Evaluation Study

Problem Area 1
100-year Model Comparisons

Date:	Project:	Submitter:	Reviewer:
October 2020	24603 - LEC Phase 2	M. Samson	A. McKay

Figure 3

	2D Surface Model 19 mm/hr assumption (100-yr, 4-hr)	2D Surface Model 44 mm/hr assumption (100-yr, 4-hr)	Three-Way Model includes minor system (100-yr, 4-hr)
Max Depth			
Max Velocity			
Max Depth x Max Velocity			

Legend

Maximum Depth (m)	Maximum Velocity (m/s)	Maximum Depth x Velocity (m^2/s)
<= 0.10	<= 0.10	<= 0.10
0.10 - 0.30	0.10 - 0.25	0.10 - 0.25
0.30 - 0.50	0.25 - 0.50	0.25 - 0.37
0.50 - 0.80	0.50 - 1.00	0.37 - 1.00
0.80 - 1.50	1.00 - 1.70	1.00 - 1.50
1.50 - 2.00	1.70 - 2.00	1.50 - 2.00
> 2.00	> 2.00	> 2.00

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Little Etobicoke Creek Phase 2
Flood Evaluation Study

Problem Area 2
100-year Model Comparisons

Date:	Project:	Submitter:	Reviewer:
October 2020	24603 - LEC Phase 2	M. Samson	A. McKay

Figure 4

	2D Surface Model 19 mm/hr assumption (100-yr, 4-hr)	3-Way Model includes minor system (10-yr, 4-hr)	3-Way Model includes minor system (100-yr, 4-hr)
Problem Area 1			
Problem Area 2			

Legend

Risk

- Low
- Medium
- High

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Little Etobicoke Creek Phase 2
Flood Evaluation Study

100-year Risk Maps

Date:	Project:	Submitter:	Reviewer:
October 2020	24603 - LEC Phase 2	M. Samson	A. McKay

Figure 5

5 FLOOD REMEDIATION OPTIONS, ANALYSIS, AND EVALUATION

Six focus areas (Figure 2) in the Lower Little Etobicoke Creek watershed were further evaluated for flood remediation options. In general, the causes of high-risk flooding in these areas include:

- Channel capacity limitations backing into settlement areas: the flooding from Little Etobicoke Creek extends beyond the channel boundaries and into adjacent lands and properties.
- Sewer capacity limitations: sewer pipes are overwhelmed by the amount of water that is received; the sewers cannot convey water from the surface storm events.
- Riverine backwater in sewer network: high water levels in Little Etobicoke Creek causes backwater into the outlet pipes, which does not allow water to be conveyed out of the minor system.
- Ineffective inlets: the low number or lack of inlets cause flooding on the surface. In some locations, the inlets may not coincide with depression areas making them less effective at capturing flow.
- Localized depressions: the site topography induces localized flooding areas. Many areas flow to a large depression area creating high-risk due to flood depths.
- Obstruction of overland flow path: the overland flow is obstructed by a barrier, such as a curb or property development. In an ideal scenario, major flows are conveyed through roadways and easements, allowing water to reach Little Etobicoke Creek with limited damage to adjacent properties.

It should be noted that the storm sewer system (i.e., minor system) is designed for smaller storm events (5-year and 10-year storms) and pipes at capacity and surface flooding along roadways is expected during larger storm events (e.g., 100-year event).

5.1 Overview of Flood Remediation Options

Different remediation solutions were assessed and evaluated for each focus area. Flood risk remediation measures were focused on practical high-level opportunities that would reduce flood risk with a reasonable cost-benefit solution. The flood remediation measures that were considered in this analysis generally included:

- Do nothing: as part of the Class Environmental Assessment process, this alternative is an evaluation requirement and may be the most suitable option in some cases. The “do nothing” option in this assessment would mean the identified flood issue is left to continue.

- Additional sewer inlets: install additional catch basins/double catch basins, or convert catch basins to double catch basins, to capture more surface water. If done, upsizing downstream sewers may need to be considered.

- Increase sewer capacity: upsize sewers to increase capacity in opportune locations as indicated by the model. Assessment of this type of measure requires confirmation that flooding is not transferred to downstream locations.

- Storage areas: install storage facilities in strategic locations (e.g., City-owned parks) to reduce peak flow in downstream sewers and reduce HGLs.

- Outlet pipe: install an additional outlet pipe from the sewer network to Little Etobicoke Creek to increase capacity.

- Regrading of depression areas: reduce depression areas to decrease potential flood depths.

- Modification of overland flow routes: optimize overland flow routes in the urban areas using curb cuts and regrading.

- Education: provide information for residents living in the flood-risk areas about ways to further protect their homes from flood damage, such as the importance of ensuring catch basins are clear of leaf litter and debris.

5.2 Analysis and Evaluation of Remediation Options

As mentioned in Progress Report No. 2 (Matrix 2020a), flood risk characterization is typically undertaken with consideration of three risk factors: depth, velocity, and depth x velocity product. In accordance with current Ontario Ministry of Natural Resources and Forestry (MNRF) practices, the following risk mapping criteria apply (Table 7). Low-risk areas are inundated, but where vehicle and pedestrian access and egress are still feasible. Medium-risk areas do not permit vehicle access and egress, but pedestrian access and egress is possible. High-risk areas do not facilitate safe access of any kind.

The flood risk of each grid cell in the study area was categorized as a low-, medium-, or high-risk flood area based on current MNRF practices (Table 7).

TABLE 7 Flood Risk Criteria

Parameter	Risk Level		
	Low	Medium	High*
Depth	≤0.3 m	>0.3 m and ≤0.8 m	>0.8 m
Velocity	≤1.7 m/s	≤1.7 m/s	>1.7 m/s
Depth x Velocity Product	≤0.37 m^2/s	≤0.37 m^2/s	>0.37 m^2/s

* Exceedance of any one of the criteria results in high risk.

Evaluating remediation effort effectiveness for this progress report was conducted using the 100-year storm event. The flood risk improvement was measured in terms of the remediation measure's ability to reduce flood risk; categorized as high, medium, and low risk to life (MNR 2002; Figure 6). The flood risk improvement was quantified based on the 2D cells in PCSWMM (average of 25 m^2 each) between the existing conditions and proposed solutions. For each focus area, both the total areas with improved/eliminated flood risk and increased flood risk were tallied to support the technical analysis. Flood risk improvement was deemed as a reduction if areas reduced in risk level, such as moving from a medium- to a low-risk level. These areas were summed altogether to estimate the total improved area. Alternatively, increase in residual flooding was evaluated as an increase in flood risk, such as moving from a medium- to a high-risk level.

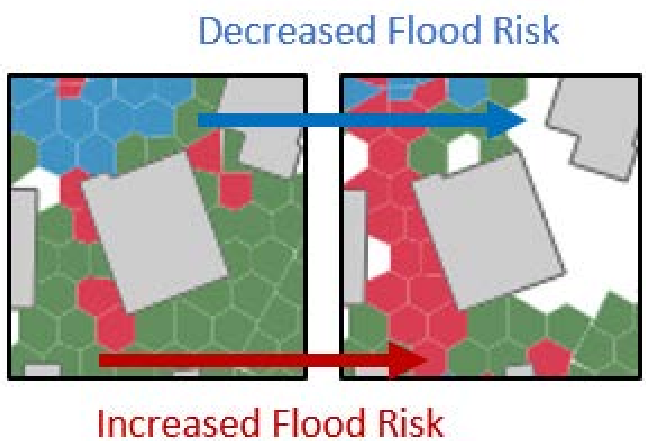

FIGURE 6 Flood Improvement Analysis

Qualitative observations were also considered in the evaluation. For instance, minor improvements in flood risk on private property or municipal services (such as fire halls) was considered an important improvement. Further detail on localized flooding, as well as flood remediation options, are provided for each of the six focus areas in the following subsections.

5.3 Focus Area 1: Rathburn Road East and Golden Orchard Drive

5.3.1 Existing Conditions

Focus Area 1 includes three flood clusters that have the potential to be remediated by creating overflow storage in Golden Orchard Park, a City-owned park north of Sugar Maple Court. There is wide-spread moderate- and high-risk flooding on the surface through this focus area starting during the 10-year storm.

Characterization of the previously identified flood clusters (LW20, LW21, and LW22; Figure 2) using the three-way model is as follows:

- LW20: this cluster was initially identified as a high-risk area on Ideal Court and Golden Orchard Park; however, the three-way model demonstrated that the minor system on Ideal Court can effectively convey surface water during the 100-year storm from this area thus reducing the flood risk to low. Despite having two double catch basins at this location on Golden Orchard Park, there is still a medium-risk of ponding. This area is depressed relative to the adjacent overland flow route on Rathburn Road East. Flooding at LW20 affects 14 households, and multiple reports of flooding were received from these properties during the July 8, 2013 flood (Matrix 2020a).

- LW21: beginning with the 10-year storm event, there are high velocities on Rathburn Road East due to localized depressions. The limited number of inlets on Rathburn Road further contribute to the flooding in LW20, posing a concern to the access/egress for the adjoining streets.

- LW22: similar to LW21, there is high velocity on Gryphon Mews under the 10-year storm event and a topographic low contributing to the flooding issue. There is evidence of sufficient inlets in the area and capacity in the sewer system; however, the high velocities and subsequent ponding in one area does not coincide with the location of the inlets.

In addition to the three flood clusters, there are two more areas with elevated flood risk identified through the three-way model within Focus Area 1. These areas include:

- North of the intersection of Rathburn Road East and Hickory Drive: a relatively flat area in comparison to the rest of Rathburn Road East contributes to localized flooding. The three catch basins in this section do not have enough inlet capacity to capture the flow.

- North of the intersection of Gryphon Mews and Hickory Drive: the property located in this area has a localized depression area that inevitably floods beginning with the 2-year storm. The provided data did not identify any inlets in this location. Further assessment is required in this location to determine if there is unidentified infrastructure conveying water out of the depression.

5.3.2 Remediation

A storage facility in Golden Orchard Park was simulated with a connection through the easement from Gryphon Mews. Under the current sewer configuration, it was found that the storage facility would only capture a small portion of the flooding volume (1,070 m^3), with costs exceeding the benefit the facility would provide. Different upgrades and configurations to the sewer network were investigated to convey additional flow to the storage facility, but no option was found to be particularly effective. With the current sewer configuration, the trunk sewer on Rathburn Road East cannot practically connect to the sewer running parallel to Hickory Drive due to a significant invert elevation difference (approximately 2 m). Similarly, the sewers on the northeast section of Gryphon Mews are unable to connect with the south section where the easement to the park is located due to the invert elevation difference (1 m).

Focus Area 1 has many areas of localized depressions that fill quickly during high-intensity rainfall events such as the 100-year storm (Figure 7). The velocity induced high-risk areas (LW21 and LW22) could not be remediated without major changes to the topography, which is not likely feasible given the extent of the surrounding residential development. Furthermore, the proximity of Little Etobicoke Creek creates significant sewer backwater during storm events, which increases flooding at the intersection of Rathburn Road East and Golden Orchard Drive. The flooding will remain until Little Etobicoke Creek levels recede, relieving the sewer capacity.

Ultimately, upgrading the inlets to double catch basins and creating three additional inlets in the flood-prone areas north of the intersection Rathburn Road East and Hickory Drive was more effective than rerouting minor flow to a storage facility. The additional catch basins also caused negligible downstream issues. Additionally, simulations of upsizing the storm pipes (850 to 1,000 mm) just upstream at Rathburn Road East demonstrated minor improvement flood risk on Golden Orchard Drive where backwatering was seen. Much of the high-risk area at LW21 was reduced to low-risk and the widespread medium-risk flooding extent north of the intersection of Rathburn Road East and Hickory Drive was reduced in area as well as flood risk. Additionally, the overland flow in the backyards parallel to Hickory Drive, and the flooded area at the intersection of Rathburn Road East and Golden Orchard Drive, are significantly reduced. Overall, approximately 8,080 m^2 within Focus Area 1 was reduced to a lower flood risk category. The minimal head difference between the sewer inverts and the Little Etobicoke Creek water levels during storm events limits the ability to further mitigate flooding in Focus Area 1.

FIGURE 7 Impact of Focus Area 1 Inlet Upgrades

5.4 Focus Area 2: Winding Trail and Golden Orchard Drive

5.4.1 Existing Conditions

Focus Area 2 contains four flood clusters (LW24, LW25, LW26, and LW27) located along Winding Trail and Golden Orchard Drive. Elevated flood risk extends from Dixie Road (the upper boundary limit of Focus Area 2) to the outlet on Stonecreek Crescent.

The three-way model was used to characterize previously identified flood clusters (LW24, LW25, LW26, and LW27; Figure 2) as follows:

- LW24: under the 2-year storm, LW24 is identified as a high-risk area based on both depth and velocity. LW24 is caused by riverine flooding and is located in an open park space within the defined TRCA floodline. Remediation efforts are the responsibility of TRCA and were not considered as part of this study.

- LW25**:** flood cluster LW25 presents high-risk flooding starting during the 5-year storm. The model results indicate there are 12 properties impacted by flooding in this area, which corresponds to the flood reports from the July 8, 2013 storm. There is limited conveyance capacity within the right-of-way on Stonecreek Crescent due to the riverine backwater conditions in the sewer beginning at the 5-year storm event.

- LW26: high velocities on Winding Trail limit the capability for storm sewer inlets to capture flow along this road beginning with the 5-year storm, and the extent of the high-risk areas grows as rainfall intensity increases. Portions of the sewer along Winding Trail are also at capacity, which limits the ability for additional catch basins to convey more water into the storm system.

- LW27: this area is deemed high-risk under the 5-year storm due to flood depth. LW27 is located in a parking lot with a lower elevation relative to Dixie Road. As the parking lot is private property, it could contain additional private catch basins, which would reduce the extent of surface flooding.

5.4.2 Remediation

Flooding in Focus Area 2 has the potential to be remediated using an overflow storage facility in the City-owned Kennedy Park. This park contains easements that may be used to connect the storage facility to the existing stormwater infrastructure. The effects of adding a storage facility in Kennedy Park were simulated using a connection to the trunk sewer on Winding Trail through an easement near the intersection of Winding Trail and Silver Spear Road. The simulation shows that during the 100-year storm, the storage facility was only able to capture a small amount of volume (1,470 m^3) from the sewer and did not significantly reduce flood risk in any of the areas up or downstream.

Additional remediation solutions were simulated at Focus Area 2 in lieu of the storage facility. An upgrade in sewer pipe size (from 525 to 825 mm) was attempted along the intersection of Dixie Road and Winding Trail. Minimal change in flood risk was seen on the surface, though the capacity of the minor system was improved. Alternative simulations were completed by upgrading catch basins to double catch basins and ensuring that these double catch basins were located at low points on Dixie Road and Winding Trail (both with and without downstream pipe upgrades). Again, the pipe upgrades did little to address local surface flooding issues; the regrading and upgrades of the catch basins was much more affective at reducing surface flooding in this area.

With the upgraded double catch basins, the pedestrian entrance to the Mississauga fire station off Dixie Road was graded higher to contain overland flow on the road. Regrading created more opportunities to capture flow into the minor system by ensuring that the catch basin locations corresponded to depressions. This allowed ponded water to enter the storm sewer, reducing flood risk through Focus Area 2 (Figure 8). The model results shows that increasing the number of inlets within this area reduced 6,370 m^2 to a lower flood risk category. The areas with risk reduction are mostly comprised of parking lots at the intersection of Dixie Road and Winding Trail, with less benefit along roadways and at residential buildings. There was some increase in flood risk downstream due to the remediation efforts, which amounted to an area of 650 m^2.

An additional alternative was simulated, which facilitated overland drainage through Kennedy Park by creating strategic curb cuts and regrading (less than 1 m deep). Creating this additional flow path reduced the flows on Winding Trail and resulted in an overall reduced flood risk by 8,280 m^2. Residual flooding amounted to 2,850 m^2; however, the increased risk is concentrated in low-risk areas, such as the park and the grassed area within the floodplain.

The portion of Focus Area 2 closer to Little Etobicoke Creek would require more extensive upgrades and complex sewer configurations to reduce flood risks. The riverine backwater effect from Little Etobicoke Creek, combined with the low-lying depression area at the corner of Stonecreek Crescent, limits the ability to store or convey stormwater effectively. During the 5-year storm, the sewer at Stonecreek Crescent is at capacity and cannot receive more flow; therefore, additional inlets in this area would not be beneficial. A larger easement could be created from Stonecreek Crescent to Little Etobicoke Creek to allow more overland flow; however, the City would need to acquire property for this alternative and is, therefore, not currently considered a feasible option.

FIGURE 8 Impact of Focus Area 2 Inlet Upgrades and Regrading

5.5 Focus Area 3: Runningbrook Drive and Riverspray Crescent

5.5.1 Existing Conditions

Focus Area 3 is located on the western side of Little Etobicoke Creek between Burnhamthorpe Road and Bloor Street. During the July 8, 2013 events, multiple reports were received from this area due to flooding on properties (Progress Report No. 2; Matrix 2020a). The level of service mapping (Section 3), shows many pipes in this area at a level of service below the 10-year design storm (Maps 1.1 and 1.2; Appendix B). The level of service at each manhole (Maps 1.9 and 1.10; Appendix B) does not indicate that there is any surcharging during the 2-year through 10-year storms; however, the storm sewers on Riverspray Crescent display riverine backup as early as the 2-year storm event.

In Focus Area 3, there are three flood clusters identified (LW11, LW13, and LW14; Figure 2), which are characterized as follows:

- LW11: flood cluster LW11 was identified as a high risk due to high velocities along Runningbrook Drive. The minor system assessment demonstrated that there are capacity issues, creating a level of service at this flood cluster that is less than the 10-year design storm. Several flood reports were received around this flood cluster during the July 8, 2013 event.

- LW13: a topographic low point behind St. Teresa of Calcutta Catholic Elementary School and an underground parking for the Westwood Luxury Apartments causes high-risk flood depths beginning during the 10-year storm event. The flooding during the 100-year storm event in this area affects the access/egress of people living in the apartment complex and the school.

- LW14: this medium-/high-risk flood cluster that begins during the 10-year event is located on a topographic low at the intersection of Runningbrook Drive and Riverspray Crescent. The sewers are flowing full adjacent to this cluster under low-intensity storms (one section under the 2-year storm), indicating that this stretch may be undersized as it meets the trunk sewer on Riverspray Crescent.

5.5.2 Remediation

A feasible remediation option for this focus area would be to provide an outlet pipe connection from the sewer on Runningbrook Drive through Cedarbrook Park that directly outlets to Little Etobicoke Creek. The outlet pipe may be able to tie into the existing sewer outlet in the park or may require an additional outlet; further study is required for this detail. This new outlet connection will convey flow on Runningbrook Drive to Little Etobicoke Creek, redirecting flow that would have continued toward the Riverspray intersection. The additional pipe would alleviate some capacity on the Runningbrook Drive sewer (improving flooding at LW13 and LW14). An alternative that provided an overland outlet from Runningbrook Drive through Cedarbrook Park was also considered but would require significant earthworks to create a sufficient flow route since portions of the park are higher in elevation than Runningbrook Drive.

Matrix completed a simulation of the outlet pipe connection from the storm sewer on Runningbrook Drive through Cedarbrook Park to Little Etobicoke Creek for the 100-year storm event using the 2D model. The results of the model, shown on Figure 9, demonstrate that the outlet pipe would be effective at lowering the flood risk in the area and reducing the flood extents at LW13 and LW14. The outlet pipe removed enough flow such that the high-risk areas on Runningbrook Drive downstream of the connection were removed and only medium-risk flooding persists at LW14 during the 100-year storm. There is still high-risk flooding shown at LW13; however, this is due to the reversed sloped parking lot, which likely connects to a private storm sewer system. Overall, there was a 9,830 m^2 reduction in flood severity and a negligible 50 m^2 increase in residual flood risk from implementing this alternative.

The high-risk areas at LW11 do not change despite the addition of the pipe outlet. A three-way model was not developed for Focus Area 3; however, increasing inlet capacity, adding additional inlets, or upsizing the sewer in this area could help alleviate flooding in cluster LW11. A detailed model should be developed to confirm that adjustments to the minor system in these areas would not increase flood risk to adjacent or downstream locations. However, the outlet pipe through Cedarbrook Park would be more effective if the minor system capacity upstream was maximized.

FIGURE 9 Focus Area 3 Risk Mapping with a Flood Remediation Solution

Additional flood remediation options to further alleviate flooding in cluster LW14 is more difficult, as this location is adjacent to Little Etobicoke Creek and increasing sewer or inlet capacity may not be effective given riverine backups into the minor system during low-intensity storms (<10 years). Ensuring that there is an effective overland flow path from Runningbrook Drive directly to Little Etobicoke Creek may be the most practical remediation solution for this area to further reduce flooding.

5.6 Focus Area 4: Highgate Crescent and Greybrook Crescent

5.6.1 Existing Conditions

Focus Area 4 is located on the east side of Little Etobicoke Creek between Willowbank Trail and Rathburn Road East. In this area, there are two depressions without sufficient overland flow paths at the corner of Highgate Crescent (LW18) and Greybrook Crescent (LW19), which causes localized flooding. These two areas are contained within the same sewershed and show insufficient servicing from the minor system assessment (Maps 1.9 and 1.10; Appendix B). The level of servicing mapping for this area demonstrates that the pipes in the area are under capacity and there is surcharging in the manholes during the 2-year, 5-year, and 10-year storm events.

The two flood clusters identified in Focus Area 4 (LW18, LW19; Figure 2) are characterized as follows:

- LW18: Highgate Crescent, which currently has medium- and high-risk flooding that starts during the 10-year storm event, is in a topographic low with curbs impeding the overland flow path toward Greybrook Crescent and Little Etobicoke Creek. The minor system in this area is surcharging during the 5-year storm event. The overland flow from LW18 contributes to further issues at LW19.

- LW19: similar to LW18, the high-risk areas on Greybrook Crescent are caused by a combination of the depression area and a blockage of the overland flow by the road curb. The minor system at this location is surcharging during the 2-year storm. Riverine backwater begins at this outlet as early as the 2-year storm event.

5.6.2 Remediation

The most straightforward solution for these areas would be to regrade the existing easements from Highgate Crescent to the school yard, as well as the easement off the corner of Greybrook Crescent to Little Etobicoke Creek, to allow for a more defined major overland flow path. This alternative was assessed using the 2D model and the risk mapping results for the 100-year storm are provided in Figure 10. As shown, regrading the existing easement at Highgate Crescent decreases the flood risk at LW18 as flow is able to travel overland through the easement. There are some downstream impacts, including increased flood risk along Golden Orchard and Greybrook Crescent.

The results of the assessment, including both easement cuts, indicated that 2,900 m^2 were reduced to a lower flood risk category. The curb cut on Highgate Crescent caused an area of 710 m^2 to increase in flood risk downstream, with the most notable increases on Golden Orchard Drive. These increases can be further mitigated with refinement during future project phases (i.e., detailed design). Regrading the easement on Greybrook Crescent provided some localized improvement to flood risk, without any downstream increases in flood risk.

To reduce flood risk on Highgate Crescent and to avoid exacerbating issues downstream, another option would be to create storage on the St. Basil School property. Storing storm sewer and overland flows would be more effective in reducing the flood risk downstream than providing an overland flow path alone. However, Matrix recognizes that there would be significant challenges to creating a storage facility within the school property, and this would likely involve property acquisition.

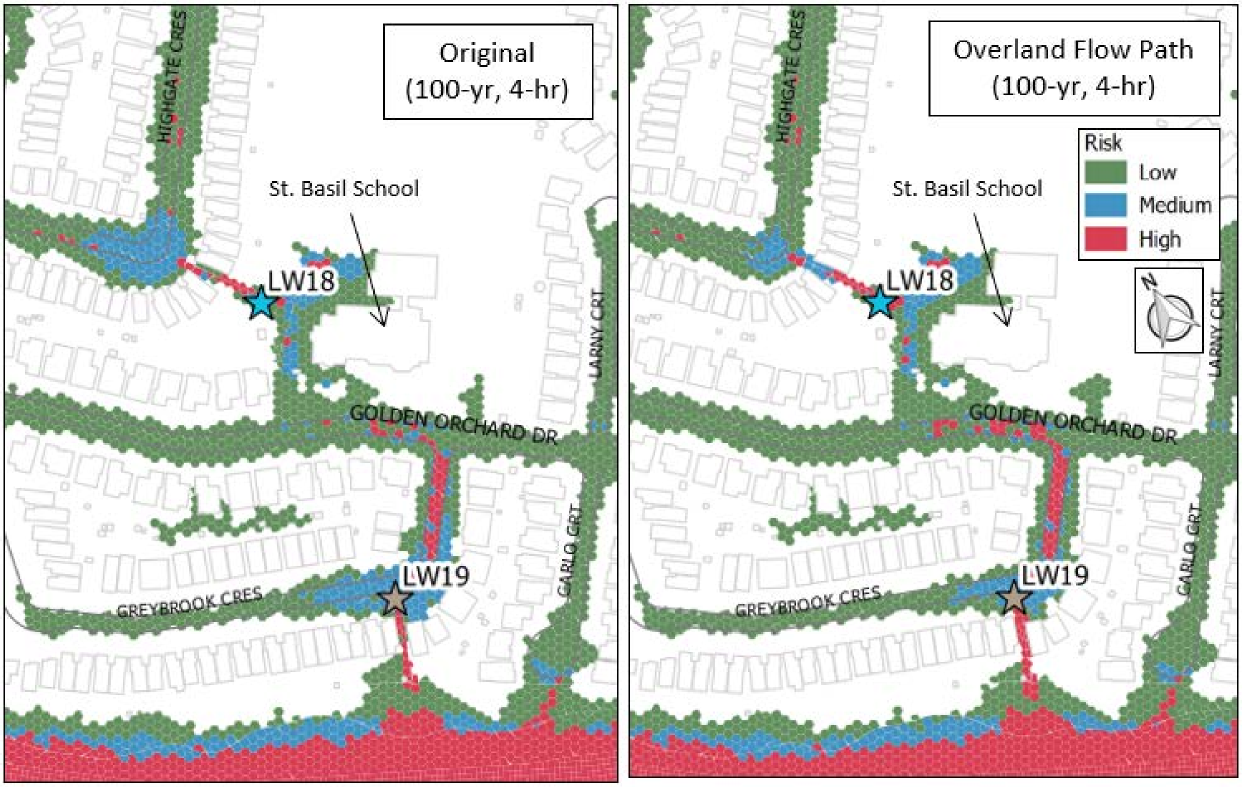

FIGURE 10 Focus Area 4 Risk Mapping with a Flood Remediation Solution

5.7 Focus Area 5: Hedgestone Court

5.7.1 Existing Conditions

Focus Area 5 is located on Hedgestone Court off Fieldgate Drive. This court is located along a major overland flow route from the upstream Cardross Road and Marlene Court. High- and medium-risk flooding in this area is caused by high velocities, depth, and combined depth x velocity starting at the 5-year storm event. Overland flow travels down Hedgestone Court to the cul-de-sac (LW35) that is surrounded by residential properties with reverse sloped driveways, which can be prone to flood damage during high-flow events. Although there is an easement through this area to Little Etobicoke Creek, the easement is not currently maintained as a primary overland flow route. No reports of flooding were received in this area during the July 8, 2013 flood event, although two reports were received from Cardross Road and Marlene Court.

The minor system assessment showed that the pipes from Hedgestone Court have a level of service comparable to the 5- to 10-year storm, and the adjacent sewers on Fieldgate Drive have a level of service less than the 5-year storm. No manholes in the cul-de-sac are surcharging during the 2-year through 10-year storms. The 750 mm outlet pipe from Hedgestone Court has greater than a 10-year level of service.

5.7.2 Remediation

A potential remediation solution for this area would be to regrade the existing easement from Hedgestone Court to Little Etobicoke Creek to create an unimpeded primary overland flow route. This remediation solution was assessed using the 2D model by modifying the surface to simulate regrading. The results of the analysis are shown on Figure 11, which indicates that this solution would be successful in reducing some of the flood risk through Hedgestone Court. The model results for this solution show 1,780 m^2 were reduced to a lower flood risk category during the 100-year storm event. Residual flooding shows a 180 m^2 increase in flood risk. These increases in flood risk can likely be mitigated through further refinement during future project phases (i.e., detailed design). Special consideration should be provided for the property directly impacted by the change in direction of the drainage path, such as considering the presence or position of basement windows.

High-risk flooding remains in some areas and in the reverse sloped driveways. This is in part due to modelling methods that did not consider the inlets at the bottom of these driveways. However, further public education about floodproofing (such as sealing garage doors and basement cracks) should be provided to residents living in this area, especially those with reverse sloped driveways.

High-risk flooding may still exist in Hedgestone Court, even with the implemented remediation measures. The minor system assessment indicated that there may be available capacity between the 5-year and 10-year storm event in the sewer system. Currently, there is only one double catch basin in Hedgestone Court. Additional inlets could be placed on Hedgestone Court to capture more flow in this area.

If the primary overland flow route is not modified through Hedgestone Crescent or if additional remediation is required to further reduce flood risk, it is recommended that upgrades to the minor system could be considered for the area. Additional inlets can be placed on Hedgestone Court to capture flow before travelling overland. If additional inlets reduce the sewer system capacity, the City should also consider upsizing the current 750 mm outlet to Little Etobicoke Creek.

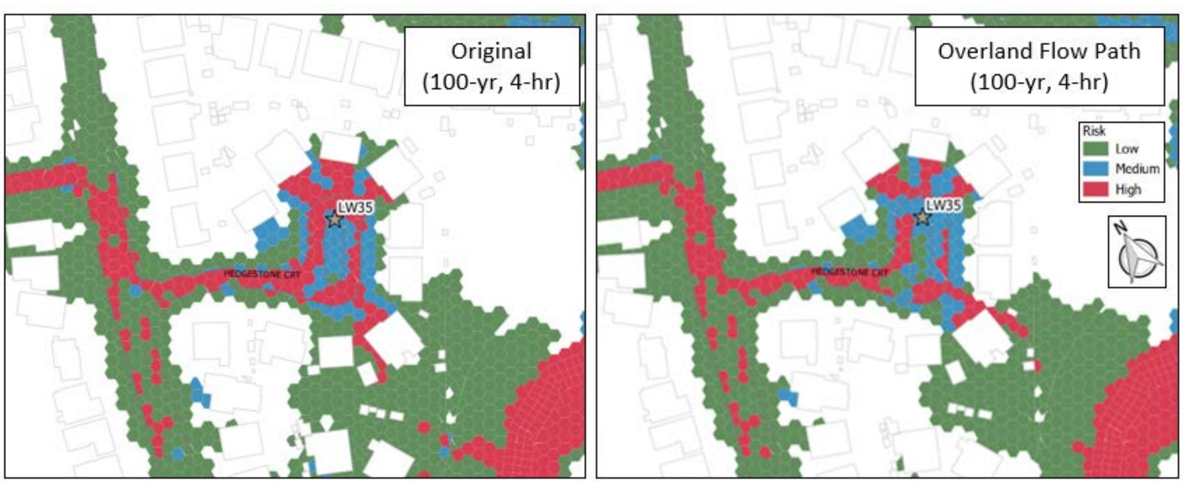

FIGURE 11 Focus Area 5 Risk Mapping with a Flood Remediation Solution

5.8 Focus Area 6: Taviton Court

5.8.1 Existing Conditions

Focus Area 6 is located adjacent to Focus Area 5 on Taviton Court off Fieldgate Drive. Overland flow on Fieldgate Drive that does not enter Hedgestone Court accumulates on the Taviton Court cul-de-sac (LW33), which is surrounded by residential properties. This surface flow creates high depths and velocities that lead to medium- and high-risk flooding in the area that starts during the 10-year storm event. No flood reports were received in this area during the July 8, 2013 event.

The minor system assessment indicated a sewer capacity along Fieldgate Drive equal to or below the 2-year storm event in some locations, with surcharging between the 5-year and 10-year storm event in the Fieldgate Drive cul-de-sac. The 1,350 mm outlet pipe at this location has a level of service between the 5-year and 10-year event. Currently, there is only a single catch basin on Taviton Court and a double catch basin at the Fieldgate Drive and Taviton Court intersection to collect minor system flow.

5.8.2 Remediation

Regrading of the easement from Taviton Court to Little Etobicoke Creek to allow a more direct major conveyance route was reviewed as an option to alleviate flood risk in the area. The option was simulated using the 2D model (Figure 12), by modifying the surface to simulate regrading. The model results for this solution indicated 2,320 m^2 were reduced to a lower flood risk category for the 100-year storm event, with four properties experiencing significantly lower flooding extent. Although much of the medium-risk flood areas were mitigated within this area, the high-risk flood area increases due to the increase in velocities as water moves from the court through the easement during the 100-year storm event. This increase in residual flooding amounts to 610 m^2; however, increases can likely be localized to the easement and not impact the adjacent properties through detailed design, making it acceptable.

Additional options to mitigate flooding in this area include increasing inlet capacity on Taviton Court by adding catch basins or upsizing the single catch basin on Taviton Court to a double catch basin. The 1,350 mm outlet pipe would also need to be upsized to accommodate the additional inflows as it currently shows a reduce level of service.

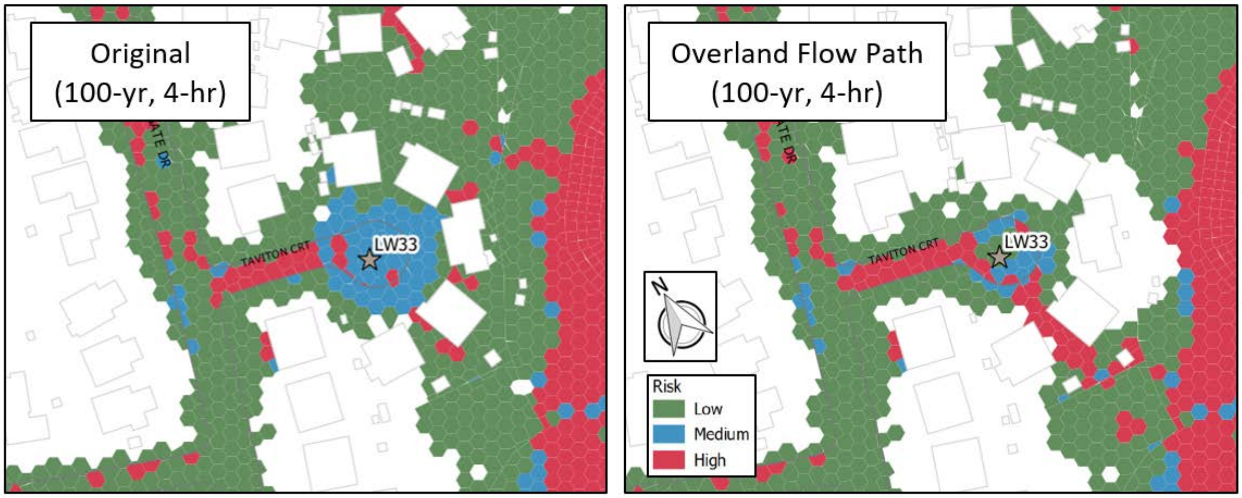

FIGURE 12 Focus Area 6 Risk Mapping with a Flood Remediation Solution

6 NEXT STEPS

Focus areas and flood cluster areas were identified based on the flood risk characterization and the results of the 2D and three-way coupled models. Each solution will be assessed and a decision-making matrix will be developed to consider:

- flood risk reduction potential:
  - total reduction in flood risk severity (e.g., change from high to low risk)
- social impacts:
  - anticipated disruption during construction (e.g., traffic delays, loss of park space)
  - level of long-term impact to people and property (e.g., loss of park space)
  - public perception and stakeholder acceptance
- downstream impacts/residual flooding:
  - potential transferal of the flood risk to another location
  - increase risk of basement flooding
- capital costs

A Public Information Centre will also be held to present and obtain feedback on a decision-making matrix that reflects the goals and objectives of the City and community.

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APPENDIX A
MIKE URBAN Model Development

APPENDIX A

MIKE URBAN MODEL DEVELOPMENT

1 INTRODUCTION

To support the subwatershed-scale urban flood characterization for Little Etobicoke Creek, a “level of service,” or minor system sewer capacity assessment, was completed using MIKE URBAN to determine the existing condition level of service for the 2-year, 5-year, and 10-year design storm events using a 4-hour Chicago rainfall distribution. The following appendix outlines the development of the one-dimensional (1D) MIKE URBAN model for the Little Etobicoke Creek sewersheds.

2 MIKE URBAN MODEL DEVELOPMENT

The MIKE URBAN model was developed by Matrix Solutions Inc. and included the following steps:

- delineating and importing urban catchments and assigning appropriate hydrologic parameters
- compiling and importing sewer network data (catch basins, manholes, pipes, and outlets)
- connecting catchments to the sewer network
- representing the storage ponds
- assigning boundary conditions at outfalls

2.1 Data Review

Matrix reviewed the land use, storm sewer network and survey data provided by the City of Mississauga (the City) and identified the following:

- Catch basin leads were included in the storm sewer database but were missing invert data. These leads were incorporated into the model as orifices with a 250 mm diameter, connecting catch basins to the nearest manholes. These catch basin-manhole connections were compared against the City’s lateral links layer and any inconsistencies were addressed (e.g., when the catch basin is not associated with the nearest). Catch basin inverts were assumed to be 1 m below ground surface.

- Manhole and catch basin lid elevations were not provided and were determined using light detection and ranging (LiDAR).

- Data gap filling of the permeable land use (reviewed aerial imagery and classified as permeable, distinct from woodlot [lawns and parks]).

- Sewers along a newly constructed road at Eglinton Avenue East and Canadian Place had no invert data and were not modelled.

2.2 One-dimensional Urban Model Development

2.2.1 MIKE URBAN Urban Catchments

The process of subcatchment delineation is described in Progress Report No. 2 (Matrix 2020). Only catchments draining to the storm network were included in the MIKE URBAN model. Catchments were reviewed and compared against LiDAR data, and minor adjustments were made along the edges of the model domain where parts of catchments were identified as draining to an adjacent sewershed.

Hydrologic attributes were assigned to each urban catchment, including percent impervious area, percent pervious area, catchment length, slope, and roughness. The catchments were subdivided into pervious and impervious land use types consistent with MIKE URBAN modelling practice as follows:

- Pervious areas were split into three categories based on land use classification: woodlots, permeable urban areas (lawns and parks), gravel parking lots/roads.
- Impervious areas were classified as either steep (small buildings, residential roofs) or flat (large buildings, roads, parking lots, etc.).

Manning's n values for the urban catchments were grouped and assigned based on land use categories defined, as shown in Table 1.

TABLE 1 Urban Catchment Pervious and Impervious, Land Use Type, and Manning's n

MIKE URBAN Land Use Type	Land Use	Manning's n
Pervious Low	Gravel Parking	0.012
Pervious Medium	Natural Areas (parks, lawns)	0.150
Pervious High	Woodlot	0.400
Impervious Steep	Urban Impervious (buildings, residential roofs)	0.012
Impervious Flat	Urban Impervious (road, paved parking, water features)	0.012

Note:

1 The urban pervious land use includes residential driveways as there is no shapefile available for these features.

Source:
Water resources Engineering (Chin 2006)

Catchment lengths were determined using the impervious overland flow length equation, as presented in the *Visual OTTHYMO Reference Manual Version 5.0* (Civica 2017):

$$Length = \sqrt{\frac{Area}{1.5}}$$

The mean slope for each catchment was calculated from the LiDAR data.

2.2.2 MIKE URBAN Hydrology

The urban catchment shapefile was imported to MIKE URBAN. The kinematic wave surface runoff computation method available in MIKE URBAN was used to simulate rainfall runoff from the urban catchments. This method provides a comprehensive representation of the main processes influencing rainfall runoff to the sewer system, including losses from impervious areas and losses and infiltration from pervious areas. The volume of runoff is controlled by the hydrological losses and the catchment areas. The shape of the runoff hydrograph is controlled by the catchment parameters including the length, slope, and roughness of the catchment surface. These parameters form a basis for the kinematic wave computation using the Manning's n equation. A summary of the parameters used in the MIKE URBAN hydrology model is provided in Table 2.

TABLE 2 Summary of Kinematic Wave Hydrologic Model Parameters

Parameter	Description
Calculated Catchment Parameters	
Length (m)	Length of surface drainage path.
Slope (%)	Average slope of surface drainage as shallow laminar sheet flow.
Impervious Area (%)	Fraction of catchment surface containing impervious surfaces (e.g., rooftops, roads, and parking lots). Comprised of both flat and steep impervious areas.
Pervious Area (%)	Fraction of catchment surface consisting of permeable surfaces (e.g., yards, parks, woodlot, etc.). Comprised of low, medium, and high permeable areas.
Kinematic Wave Parameters	
Wetting Loss (mm)	Initial wetting of the catchment surface
Storage Loss (mm)	Precipitation depth required for filling the depressions on the catchment surface prior to occurrence of runoff.
Start Infiltration (mm/hour)	The maximum rate of infiltration (Horton).
End Infiltration (mm/hour)	The minimum rate of infiltration (Horton).
Horton's Exponent (/hour)	The rate of reduction of the infiltration rate reduction over time during rainfall.
Inverse Horton's Exponent (/hour)	The rate of recovery of the infiltration rate over time after rainfall has stopped.
Manning's n	Roughness of the catchment surface.

2.2.3 1D Model Validation

The results of the hydrology model were compared to the existing Visual OTTHYMO (VO) model, provided by Credit Valley Conservation (CVC), for the Applewood Creek subwatershed (Civica 2015).As shown in Table 3 average runoff coefficients from the catchments match within 3% between the MIKE URBAN, Applewood VO, and PCSWMM models.

TABLE 3 Summary of Runoff Coefficients across Programs

Storm Event	Runoff Coefficient (Runoff/Rainfall)		
	ID MIKE URBAN (Matrix)	Applewood VO (CVC)	PCSWMM (Matrix PR Nos. #3 and #4)
2-year	0.65	0.67	0.65
5-year	0.70	0.72	0.71
10-year	0.75	0.75	0.75

2.2.4 MIKE URBAN Storm Network

The City's storm network was imported into MIKE URBAN. The previously delineated catchments (Section 2.2.1) were connected to their associated catch basin. Catchment connections were reviewed and minor adjustments were performed. Catch basins were connected to manholes via orifice connections, as described in Section 2.1. A small number of profiles with erroneous profiles were fixed (e.g., a pipe's obvert connects to downstream pipe's invert). Networks draining the Ontario Ministry of Transportation (MTO) highway corridor (Highway 401, Highway 403, and Highway 410) were removed. Ditches were represented as trapezoidal channels, with typical sections cut from LiDAR data.

Reports for four stormwater management (SWM) facilities in the study area were provided by the City (Cosburn Patterson Wardman Limited 1995, Greenland 2001, Philips Engineering 2006), shown in Table 4. SWM Facility 4301 (Highway 401 at Highway 410) was not represented because it outlets to the MTO highway drainage network, which is not represented in this model.

TABLE 4 Stormwater Management Facilities Represented in the MIKE URBAN Model

Stormwater Management Pond ID	Location Description
3601	Eglinton Avenue East at Highway 403
3602	Eglinton Avenue East at Highway 403
4302	Highway 401 at Highway 410

The SWM ponds were represented as basins with associated stage-area curves, which were estimated from data provided in the SWM pond reports. These relationships are shown in Tables 5 through 7.

TABLE 5 Stormwater Management Facility 4302 Basin Geometry

Stage (m)	Area (Cross-sectional) (m^2)	Area (Surface) (m^2)
0.17	0	9,032
1.67	190	14,091

TABLE 6 Stormwater Management Facility 3602 Basin Geometry

Stage (m)	Area (Cross-sectional) (m²)	Area (Surface) (m²)
0	0	1
3.64	109	8,550

TABLE 7 Stormwater Management Facility 3601 Basin Geometry

Stage (m)	Area (Cross-sectional) (m²)	Area (Surface) (m²)
0	0	3,520
2.40	115.2	8,224

2.3 Rainfall and Level of Service Analysis

A 4-hour Chicago distribution was simulated in the MIKE URBAN model for the 2-year, 5-year, and 10-year design storm events. The level of service analysis, which represents the largest storm for which the pipe peak flow does not exceed its design capacity was completed for all sewersheds in the study area. Further description of the level of service analysis and results are provided in Progress Report Nos. 5 and 6.

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APPENDIX B
Results Maps

(see companion digital files)