AECOM

Appendix A

A.1 – Notice of Commencement

WARWICK AREA FLOODING STUDY

ENVIRONMENTAL ASSESSMENT ADDENDUM

NOTICE OF STUDY COMMENCEMENT

Background

The Norwich and Warwick Area Flooding Study Class Environmental Assessment was completed in July 2012 to address flooding of basements, yards, and local streets in the area.

The recommendations that came out of the environmental assessment included strategically located underground storage facilities and an upgrade of the Hughson Street storm sewer.

The City of Woodstock implemented solutions from the environmental assessment, including upgrades to the Hughson Street Storm sewer, construction of the Knightsbridge Park stormwater management facility (an underground facility at the Fairgrounds property), and the DM Sutherland facility.

Since then, flooding in the area has reduced and the City stopped receiving flooding complaints from area residents. The remaining stormwater management solution – the Cambridge/Warwick underground stormwater management facility - proceeded to the detailed design phase where the updated cost estimates proved to be much higher than estimated in the initial environmental assessment.

Due to the success of the management solutions already implemented and the higher-than-expected costs and severe impacts and disruption to local residents caused by construction, the City of Woodstock has asked AECOM to revisit the environmental assessment to investigate new alternative solutions that will be more cost effective and less disruptive to the local residents.

The Process

The Municipal Class EA study will be completed in accordance with the Ontario Environmental Assessment Act and will fulfill the requirements of the Municipal Class EA process (October 2000, as amended in 2007, 2011, 2015, and 2023) for Schedule B projects. The project team will examine a full range of alternatives and identify a preferred strategy for addressing the project needs. The project will include extensive public and agency consultation and require the completion of Project File Report.

How to Get Involved

The City would like anyone with an interest in this project to have an opportunity to provide input and help inform the decision-making process.

One Public Information Centres (PIC) will be held to provide information and receive feedback. The first PIC will present the background information, existing conditions, the alternative solutions being considered and evaluation criteria, in addition to providing next steps in the process.

WARWICK AREA FLOODING STUDY
ENVIRONMENTAL ASSESSMENT ADDENDUM
NOTICE OF STUDY COMMENCEMENT

Advanced notification of the PIC (Scheduled for the Winter 2023/2024) will be advertised on the City's website and in similar newspaper advertisements, in addition to being sent by mail or email to those on the study mailing list. For more information please visit:

https://warwickfloodingreview.ca/

Comments are encouraged now and throughout the study. If you have comments or questions, require further information or would like to be added to the study mailing list to receive future notifications, please contact:

Harold de Haan, P. Eng.,
City Engineer,
City of Woodstock
P.O. Box 1539
944 James Street
Woodstock ON, N4S 0A7
Tel: 519-539-2382 x3112
Email: hdehaan@cityofwoodstock.ca

Paul Adams
Environmental Planner,
AECOM Canada
250 York Street, Suite 410
London ON, N6A 6K2
Tel: 519-636-6448
Email: paul.adams2@aecom.com

With the exception of personal information, all comments will become part of the public record of the study. The study is being conducted according to the requirements of the Municipal Class Environmental Assessment, which is a planning process approved under Ontario's Environmental Assessment Act.

AECOM

Appendix A

A.2 –Public Information Centre

WARWICK AREA FLOODING STUDY

ENVIRONMENTAL ASSESSMENT ADDENDUM

NOTICE OF PUBLIC INFORMATION CENTRE

Background

The Norwich and Warwick Area Flooding Study Class Environmental Assessment was completed in July 2012 to address flooding of basements, yards, and local streets in the area.

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How to Get Involved

The City would like anyone with an interest in this project to have an opportunity to provide input and help inform the decision-making process.

An online Public Information Centre (PIC) is scheduled for **December 11th, 2023**. This PIC will present the background information, existing conditions, the alternative solutions considered, the evaluation summary and recommended solutions in addition to providing next steps in the process.

The online PIC format will be a video presentation that can be viewed at your leisure and will be available for the duration of the study. The video can be found at the following website starting on **December 11th, 2023**:

https://warwickfloodingreview.ca/

WARWICK AREA FLOODING STUDY
ENVIRONMENTAL ASSESSMENT ADDENDUM
NOTICE OF PUBLIC INFORMATION CENTRE

Comments are encouraged now and throughout the study. If you have comments or questions, require further information or would like to be added to the study mailing list to receive future notifications, please contact:

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City Engineer,
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Appendix A

A.3 –Notice of Completion

WARWICK AREA FLOODING STUDY
ENVIRONMENTAL ASSESSMENT ADDENDUM
NOTICE OF ADDENDUM

The City of Woodstock (the City) through their consultant AECOM Canada Ltd. has completed a Municipal Class Environmental Assessment Addendum for the Warwick Area Flooding Study, originally completed in July 2012. The original Environmental Assessment reviewed the cause of flooding in the Norwich and Warwick areas and evaluated alternative solutions. Six alternative solutions were evaluated, and the preferred alternative consisted of strategically located underground storage facilities and an upgrade of the Hughson Street storm sewer. All the recommended alternatives have been implemented except the Warwick Street / Cambridge Street underground storage facility. When this storage facility proceeded to detailed design, the updated cost estimates for the recommended underground storage facility proved to be much higher than initially estimated.

In 2022, the City initiated a study to identify new and more cost-effective solutions that could be evaluated against the previously recommended solution and complete an addendum to the Warwick Area Environmental Assessment Study. This addendum was completed following the 'Schedule B' process of the Municipal Class Environmental Assessment Process (2000, as amended in 2007, 2011, 2015, and 2023). The recommended solutions include localized protections for selected areas (**See Map 1**):

- Basement window protections
- Curb protections
- Grading modifications
- Low Impact Development (LID)
- Pumping

An addendum report has been prepared and a copy will be placed on public record on December 2nd, 2024, for thirty calendar days. The addendum report can be reviewed by members of the public and/or any other interested parties on the City of Woodstock's website:
https://www.cityofwoodstock.ca/en/city-governance/municipal-studies-and-plans.aspx.

If there are any outstanding concerns or issues with this project during the 30-day review period, please address them to the city staff listed below and we will attempt to seek a mutually acceptable resolution.

If no issues or concerns are raised by January 6th 2025, the project will be considered to have met the requirements of the Municipal Class Environmental Assessment and may proceed with the design as outlined in the addendum report.

To provide any comments, please contact either of the following team members no later than January 6th 2025.

WARWICK AREA FLOODING STUDY
ENVIRONMENTAL ASSESSMENT ADDENDUM
NOTICE OF ADDENDUM

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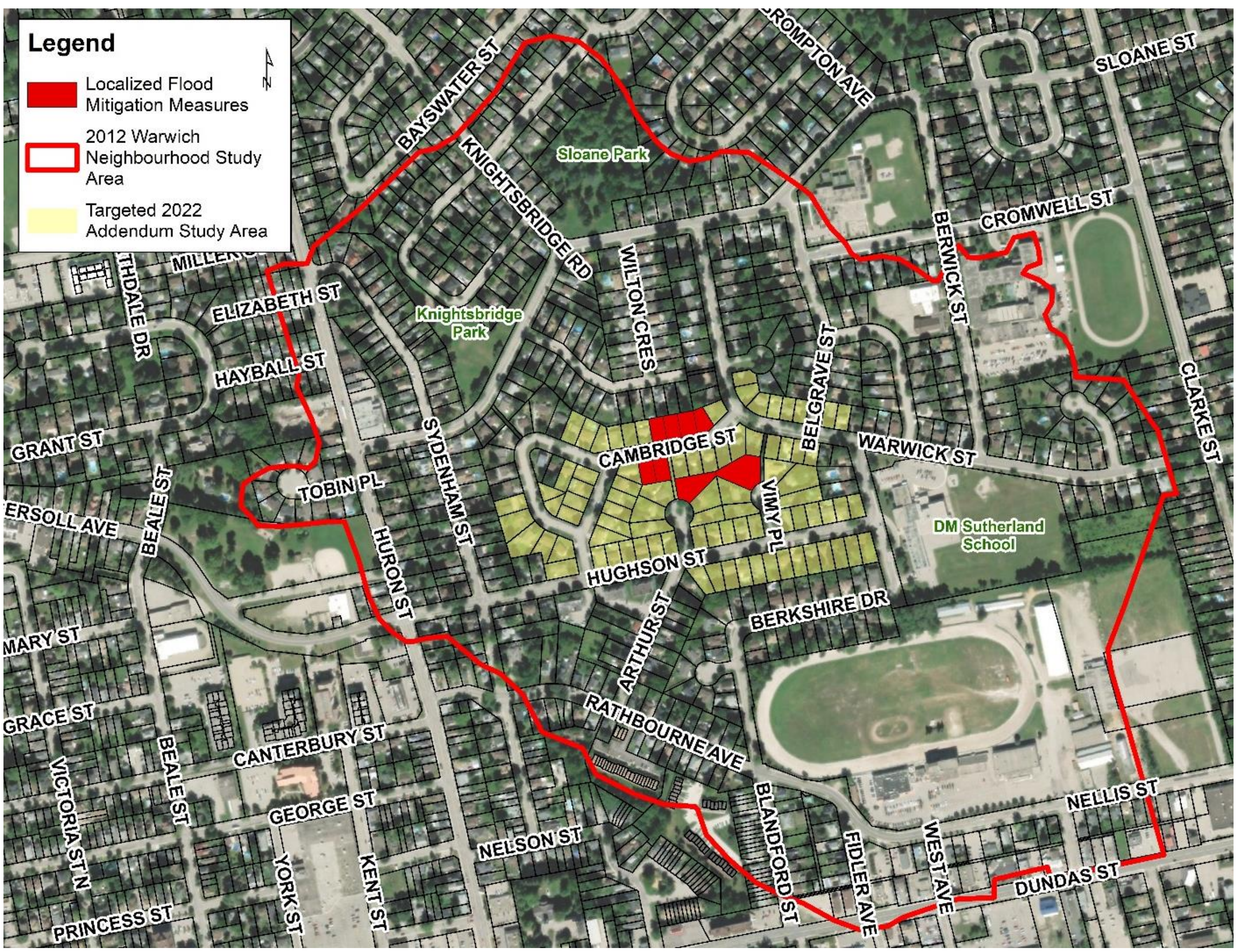

Map 1

With the exception of personal information, all comments will become part of the public record of the study. The study is being conducted according to the requirements of the Municipal Class Environmental Assessment, which is a planning process approved under Ontario's Environmental Assessment Act.

AECOM

Appendix B

B.1 – Warwick and Norwich Area Flooding Study (2012) – Under separate cover

AECOM

Appendix C

C.1 – Warwick Area Flooding Report

City of Woodstock

Warwick Area Flooding

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Date: February, 2021

Project #: 60612974

Distribution List

# Hard Copies	PDF Required	Association / Company Name
		City of Woodstock

Revision History

Rev #	Date	Revised By:	Revision Description

Statement of Qualifications and Limitations

The attached Report (the "Report") has been prepared by AECOM Canada Ltd. ("AECOM") for the benefit of the Client ("Client") in accordance with the agreement between AECOM and Client, including the scope of work detailed therein (the "Agreement").

The information, data, recommendations and conclusions contained in the Report (collectively, the "Information"):

- is subject to the scope, schedule, and other constraints and limitations in the Agreement and the qualifications contained in the Report (the "Limitations");
- represents AECOM's professional judgement in light of the Limitations and industry standards for the preparation of similar reports;
- may be based on information provided to AECOM which has not been independently verified;
- has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued;
- must be read as a whole and sections thereof should not be read out of such context;
- was prepared for the specific purposes described in the Report and the Agreement; and
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time.

AECOM shall be entitled to rely upon the accuracy and completeness of information that was provided to it and has no obligation to update such information. AECOM accepts no responsibility for any events or circumstances that may have occurred since the date on which the Report was prepared and, in the case of subsurface, environmental or geotechnical conditions, is not responsible for any variability in such conditions, geographically or over time.

AECOM agrees that the Report represents its professional judgement as described above and that the Information has been prepared for the specific purpose and use described in the Report and the Agreement, but AECOM makes no other representations, or any guarantees or warranties whatsoever, whether express or implied, with respect to the Report, the Information or any part thereof.

Without in any way limiting the generality of the foregoing, any estimates or opinions regarding probable construction costs or construction schedule provided by AECOM represent AECOM's professional judgement in light of its experience and the knowledge and information available to it at the time of preparation. Since AECOM has no control over market or economic conditions, prices for construction labour, equipment or materials or bidding procedures, AECOM, its directors, officers and employees are not able to, nor do they, make any representations, warranties or guarantees whatsoever, whether express or implied, with respect to such estimates or opinions, or their variance from actual construction costs or schedules, and accept no responsibility for any loss or damage arising therefrom or in any way related thereto. Persons relying on such estimates or opinions do so at their own risk.

Except (1) as agreed to in writing by AECOM and Client; (2) as required by-law; or (3) to the extent used by governmental reviewing agencies for the purpose of obtaining permits or approvals, the Report and the Information may be used and relied upon only by Client.

AECOM accepts no responsibility, and denies any liability whatsoever, to parties other than Client who may obtain access to the Report or the Information for any injury, loss or damage suffered by such parties arising from their use of, reliance upon, or decisions or actions based on the Report or any of the Information ("improper use of the Report"), except to the extent those parties have obtained the prior written consent of AECOM to use and rely upon the Report and the Information. Any injury, loss or damages arising from improper use of the Report shall be borne by the party making such use.

This Statement of Qualifications and Limitations is attached to and forms part of the Report and any use of the Report is subject to the terms hereof.

AECOM: 2015-04-13

Authors

Report Prepared By:

Yanzhen Ou, P.Eng.

Report Reviewed By:

Brian Richert, P.Eng.

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Appendix A- Flow Gauge Summary Table
Appendix B-Model Results for Calibration Events
Appendix C- Overland Flow Path Mapping

1. Introduction

1.1 Background

The Norwich and Warwick Area Flooding Study Class EA was completed in July 2012 (Dillon Consulting). The study was completed to address flooding of basements, yards, and local streets. The EA reviewed the cause of the flooding and evaluated alternate solutions. Flooding in the Warwick area included severe surface ponding in the low-lying area at the intersection of Warwick St. and Cambridge St., ponding at the Warwick St. and Belgrave St. intersection, and basement and backyard flooding in several low-lying areas. Six alternatives were evaluated in the EA. The preferred alternative consisted of strategically located underground storage facilities and an upgrade of the Hughson Street storm sewer.

When the EA preferred alternative proceeded to detailed design, the updated cost estimates for the recommended underground storage in the Warwick area proved to be much larger than estimated in the EA. The City of Woodstock approached AECOM to review the EA recommendations, collect additional data, and review the potential for other feasible solutions. The scope also includes an assessment of the current level of risk given that the EA solutions have now been partially implemented.

A monitor program was conducted by AECOM in 2019. The rainfall and level gauge monitoring suggest that runoff volume from the watershed (as indicated by the total volume of flow relative to the total volume of rainfall) is slightly smaller than the EA considered in sizing the storage solutions. This suggests that the EA storage solutions could potentially be slightly smaller and still provide a 100-year level of protection. Additional alternative, consisting of a large-diameter relief sewer from the Warwick/Cambridge sag location to Hughson, then westward to an appropriate location to convey 100-year flows beyond the ‘ridge’ in the topography, was identified during the initial flow monitoring analysis stage. This alternative could reduce or potentially eliminate some of the storage identified in the EA recommended solutions.

1.2 Scope of Study

The scope of this report is to:

- develop and calibrate a hydrologic and hydraulic model based on collected level data, rainfall data, and physical characteristics of the system and catchment;
- update the model for recently constructed above-ground storage in Fairgrounds area, based on available as-built drawings;
- update the model for new sewers recently constructed on Hughson Street from available drawings and GIS data;
- review storage required for the EA solution at Warwick and Cambridge Streets;
- assess flood risk for existing conditions (i.e. with the Fairgrounds/Hughson improvements, but without underground storage at Warwick/Cambridge);
- assess an alternate solution consisting of new connections to/from the Hughson Street storm sewer, forming a relief sewer from the low-lying area; review the feasibility of transferring additional flow in this way from the Warwick location to existing defined downstream overland flow routes; review the feasibility of the existing downstream overland flow routes as suitable outlets for overland flow.

1.3 Study Area

The subject site is located within a low-lying area of the City of Woodstock. The site topography is shown in **Figure 1-1**. The topography over the central portion of the study area is generally flat, with no overland flow route out of the study area.

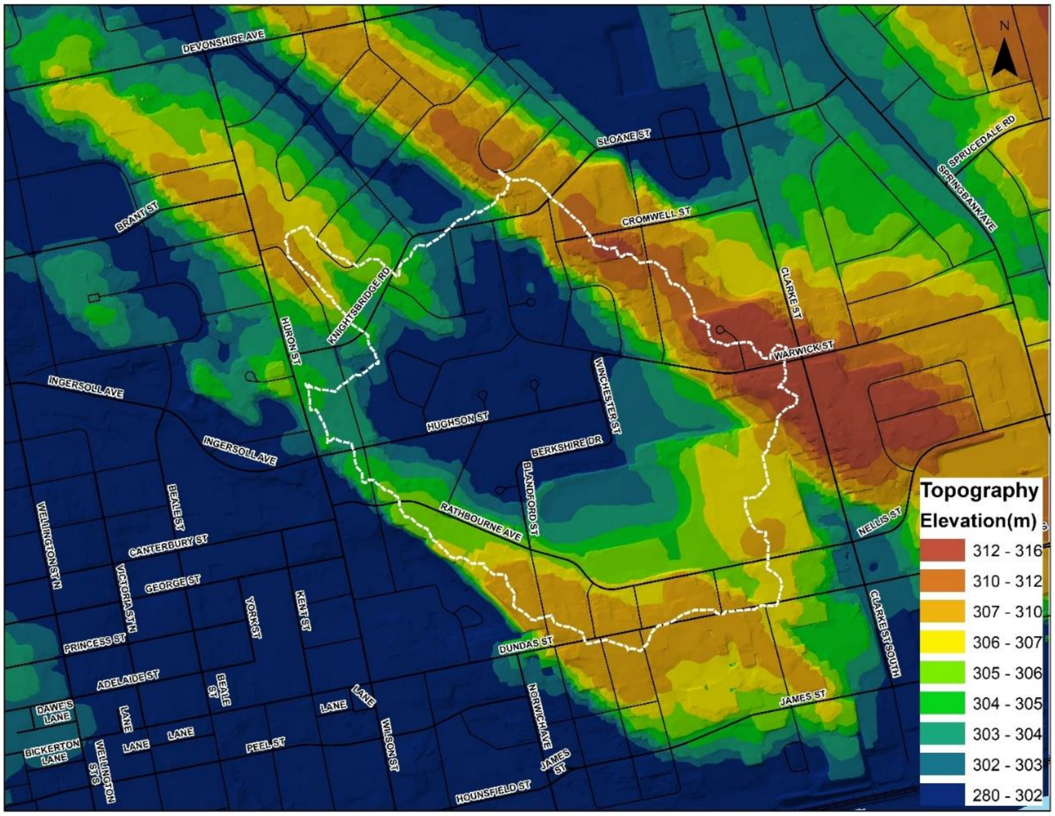

Figure 1-1: Topography of the Study Area

1.4 EA Solution Assessment

Strategic locations of underground storage and upgrades to the Hughson Street storm sewer (i.e. to the 'west outlet' from the study area) was the preferred solution identified in the original EA. The EA also identified the following refinement of the preferred alternative, to include the following details:

- Upgrading the storm sewer on Hughson to 1350-1800 mm, with sufficient capacity to convey the 100-year storm underground to the west outlet;
- Stormwater management facility in the Fairgrounds in the south part of the study area (2400 m3); and
- Surface flooding at Warwick/Cambridge addressed with:
    - underground storage at the DM Sutherland School, with added inlet capacity for the 100-year storm (1150 m^3)
    - additional underground storage at Cambridge/Warwick within the right-of-way (400 m^3), inlet controls at Knightsbridge Park, redirecting flows to the Hughson storm sewer

In this study AECOM focuses on the requirements/sizing for the underground storage, as well as reviewing feasibility of alternates to this storage.

1.5 Hughson Street STM Sewer Upgrades

The previous storm sewer on Hughson (from Cambridge to Winchester) was a 450 mm pipe discharging to Vimy Place storm sewers. Pipe upgrading on Hughson Street was completed in 2015. The existing STM sewer configuration is:

- From Winchester Street to Huron Street:525-1200 mm pipe, length of 250 m;
- From Cambridge Street to Jubillee Place: 750 mm pipe, length of 113 m;
- From Jubilee Place to Vimy Place: 600 mm pipe, length of 121 m;
- From Vimy Place to Winchester Street: 525 mm pipe, length of 138 m; and
- From Jubilee Place to Winchester Street: 300-375 mm pipe, length of 150m.

At the intersection of Vimy Place and Hughson Street a storm-to-storm overflow exists between two parallel storm sewer networks. The overflow links the 300-375 mm STM system constructed on Hughson Street along the north side of the right-of-way with a new 600mm STM system that was constructed on Hughson Street along the south side of the right-of-way to provide additional capacity and relieve the existing system. The storm sewer overflow is 450mm with the invert elevation approximately 1.5m above the invert of the outgoing storm pipe to Vimy Place and then discharging to the Warwick trunk sewer. The Cambridge sewer and the Fairground sewer are connected to the Hughson storm sewer.

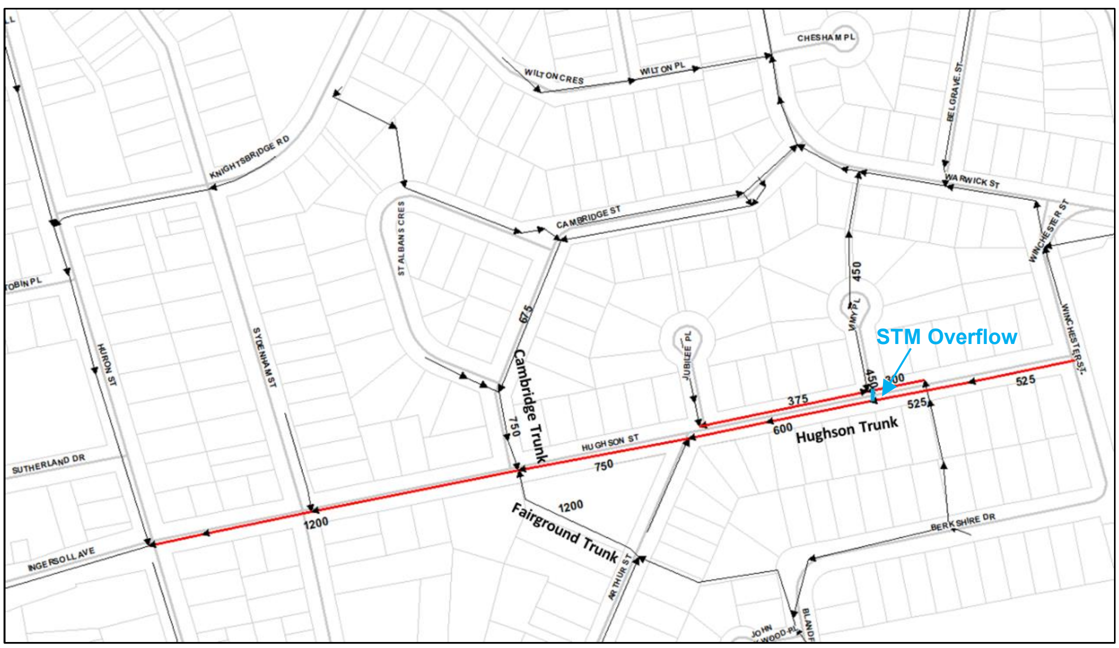

Figure 1-2: Upgraded Hughson Street STM Sewer

1.5.1 Fairground SWM Facility

An above ground SWM facility has been constructed within the Fairgrounds property at the south end of the study area. The Fairground SWM facility provides peak flow attenuation to the upstream catchment prior to discharging to the existing 300mm STM sewer. The outflow is controlled by the 100 mm orifice. The Fairground SWM facility provides a level of service above 100-year level, with a spill elevation of 302.88m to the backyards along Berkshire.

1.5.2 Underground Storage Alternatives

In addition to the above-ground storage in the fairgrounds, the EA solution recommended two additional underground storage alternatives to be implemented. These were:

- A 1150 m^3 underground storage tank on the property of the D M Sutherland School; and
- A 400 m^3 storage tank underground in the right-of-way near the Cambridge/Warwick intersection.

Only the above-ground storage tank in the fairgrounds as been constructed.

1.5.3 EA Recommended Flooding Remediation Alternative and Additional Assessment

The above solutions all formed part of the overall EA recommendation for flood remediation, which are summarized in **Table 1-1**. As part of the present assignment, AECOM is reviewing/updating these recommendations based on updated modeling, and reviewing some additional mitigation measures, as listed in **Table 1-1**.

Table 1-1: EA Solution and Proposed Additional Assessment

<table>
<tr><th></th><th>EA Solution</th><th>Proposed Additional Assessment</th></tr>
<tr><td rowspan="2">Storm sewer upgrades</td><td colspan="2">Sewer upgrades on Hughson St to convey 100yr flow westward</td></tr>
<tr><td>no other new STM sewers</td><td>Additional large diameter STM sewers to convey 100-year flow from Warwick/Cambridge to Hughson</td></tr>
<tr><td rowspan="3">Underground storage</td><td>Fairgrounds - 2400 m^3</td><td>To be reviewed</td></tr>
<tr><td>D M Sutherland school - 1150 m^3</td><td rowspan="2">Storage potentially reduced / eliminated with large diameter relief sewer connecting low point (Warwick/Cambridge) to Hughson</td></tr>
<tr><td>Warwick / Cambridge - 400 m^3</td></tr>
<tr><td>HGL Criteria</td><td>Not clear that it was addressed in the EA. Our model of the EA solution indicates that the storm sewers still surcharge to basement levels</td><td>Consider providing HGL relief to the storm sewers with a STM relief sewer (with no service connections to STM relief sewer)

Review major system capacity west of high point, and review feasibility of outlet (both STM trunk sewer flows and overland flows)</td></tr>
<tr><td>Overall recommendation</td><td>Underground tank</td><td>Review alternatives to tank, review potential flood proofing options In lieu of storage</td></tr>
</table>

2. Model Development

2.1 Storm Drainage System

Contours (half meter interval) were used to delineate the overland drainage system features such as surface drainage flow path and direction, surface ponding areas, and catchment area boundaries. **Figure 2-1** shows the storm sewer system and sewershed boundary, and **Figure 2-2** shows the overland flow path. The storm sewershed area is approximately 57 ha and drains via 2 storm outlets to the Thames River and Pittock Reservoir. All of the storm pipes are circular, and range in diameter from 150 mm to 1,950 mm.

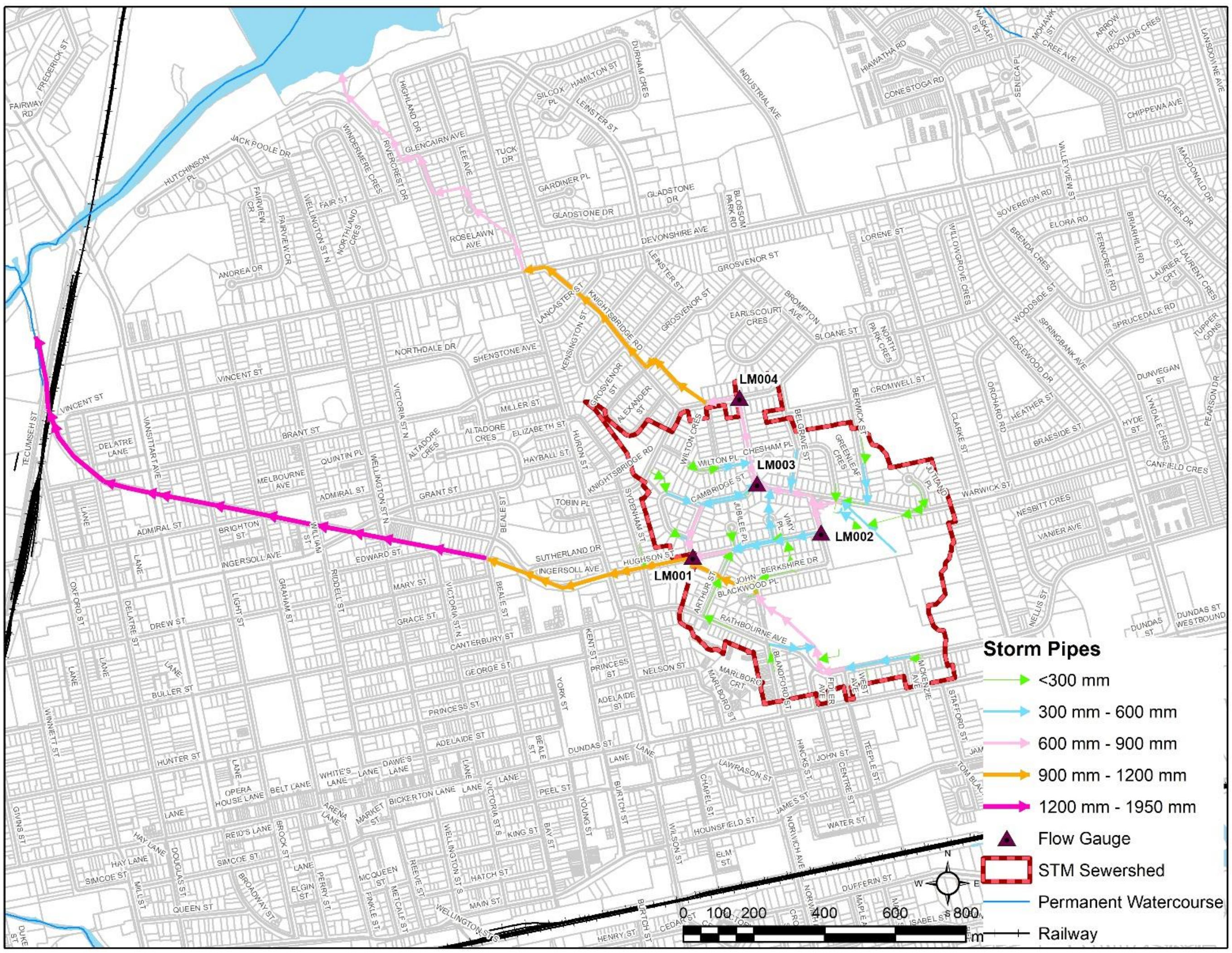

Figure 2-1: Existing Storm Sewer System

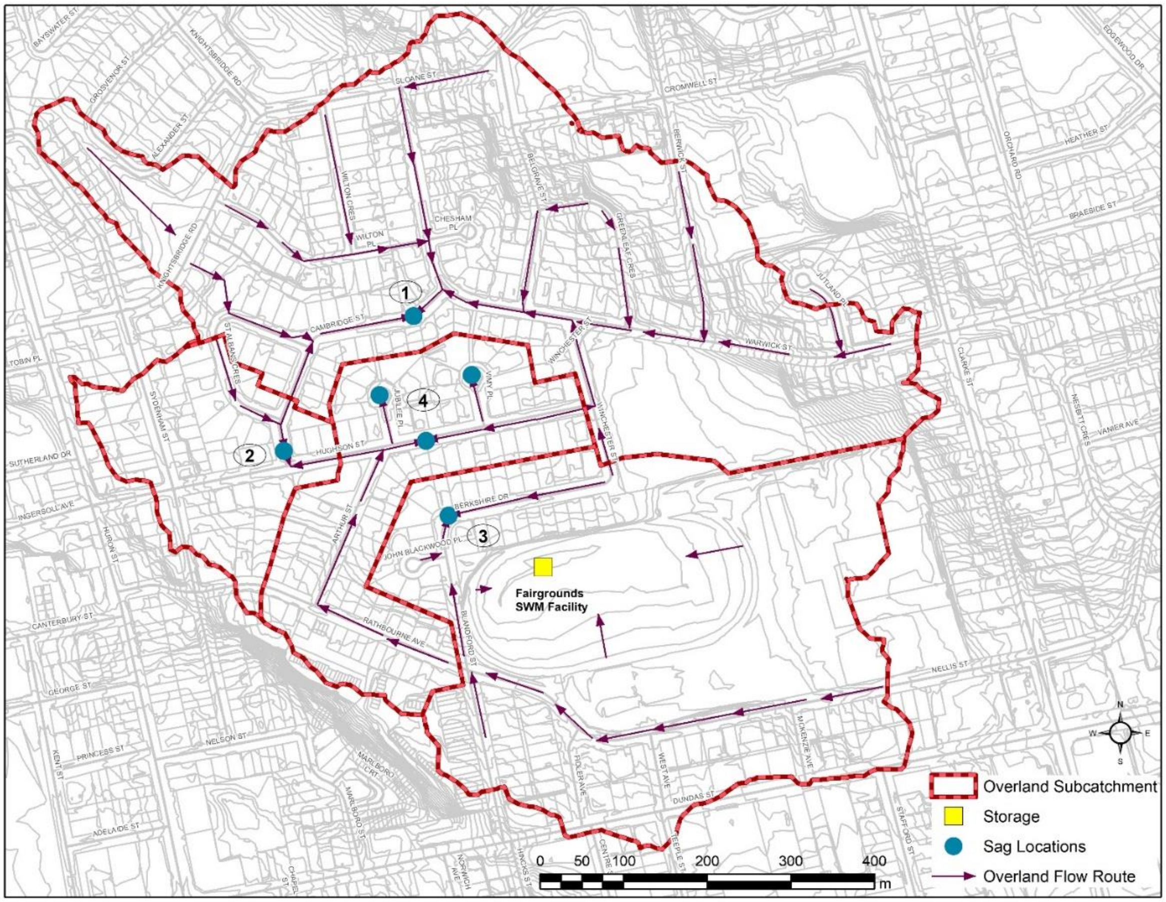

Figure 2-2: Overland System

2.2 Model Development

2.2.1 Model Network

A hydrologic/hydraulic model assessment of the storm drainage system was undertaken using PCSWMM with the following objectives:

- To define the magnitude and extent of surcharging in the sewer system as well as represent surface flooding depths for a range of design storms; and
- To aid in the development and evaluation of alternatives based on the target level of service/performance.

The interconnection between the minor and major system is modelled following dual drainage principles:

- The minor system is composed of the underground network of pipes designed to convey stormwater runoffs from typical storm events.
- The major system consists of overland pathway of the roads that carry flows beyond what the minor system can handle to the sag locations.

The storm sewer model was assembled using the GIS database provided by the City. A data gap analysis was conducted to determine the completeness of the provide data. Anomalies identified include connectivity errors, missing pipe inverts, and missing manhole ground elevations. Data gaps and checks were filled through a series of inference assumptions based on surrounding infrastructure and engineering judgement.

2.2.2 Subcatchment Delineation

The subcatchment areas were delineated based on topographic grades and overland flow direction implied by grades. The distribution between pervious, impervious in each subcatchment was estimated from aerial photos.

2.2.3 Rainfall and Flow Monitoring Data

Precipitation and flow monitoring were carried out from August to November 2019. Data collected were used for model calibration. **Figure 2-3** shows the monitoring locations and the drainage area for each flow monitor.

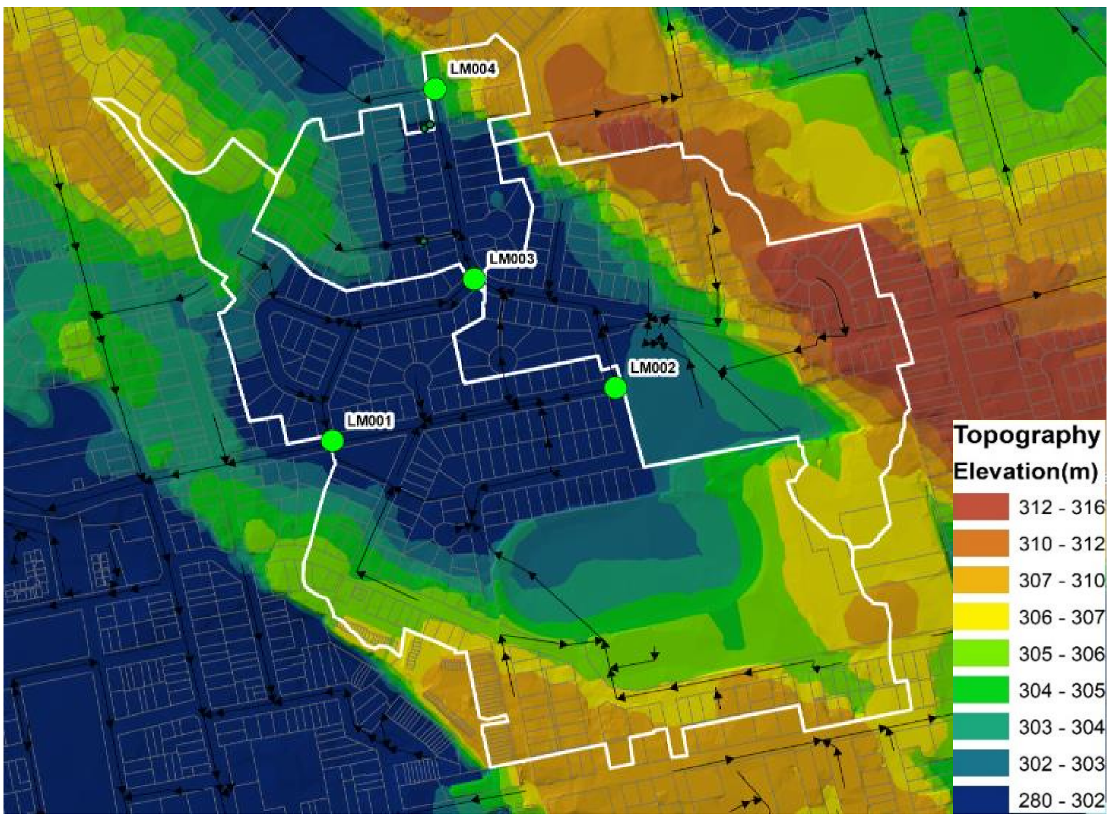

Figure 2-3: Flow Gauge Locations

One rain gauge was installed during the monitoring period. The recorded rainfall events are shown in **Table 2-1**. Storm events were identified with a minimum total depth of 10 mm.

Table 2-1: Summary of Rainfall Events

Rainfall Event Date	Total Precipitation (mm)	5-min Peak Precipitation Intensity (mm/hr)	Storm Duration (hr)
17-Aug	16.8	45.7	2
18-Aug	15.0	51.8	2
21-Aug	7.1	39.6	0.5
11-Sep	11.7	27.4	3
11-Sep	21.3	79.2	2
13-Sep	11.2	45.7	2
1-Oct	16.8	36.6	2.5
2-Oct	11.4	18.3	3
31-Oct	52.6	9.1	30

Four flow monitoring stations were installed in the storm sewer system during the flow monitoring period. Appendix A summarizes the peak runoff rates and volumetric runoff coefficients measured at each of the four storm monitoring stations. Volumetric runoff coefficients in urban areas are typically greater than 25% and as high as 70%. The average runoff coefficients for LM001, LM002, LM003, and LM004 are 34%, 33%, 37%, and 43% respectively.

2.3 Model Calibration

Model calibration is achieved by changing model parameters to produce results matching the flow monitoring data within a reasonable accuracy. The model was calibrated by matching as best as possible the modelled results to the monitored records.

The subcatchment areas were delineated based on topographic grades and overland flow direction implied by grades. The impervious portion in each subcatchment was estimated from aerial photos. The runoff volume was then adjusted in the model to match observed runoff volumes by routing a portion of the impervious area onto pervious areas. Conceptually, this represents areas such as roofs discharging onto grass surfaces, or sidewalks/patios/driveways draining to adjacent pervious areas. Once volume was determined, AECOM calibrated subcatchment width and slope to provide the best fit for peak flows. Model calibration was performed with the nine gauged events included in **Table 2-1**. **Figure 2-4** shows the final calibrated parameters for each subcatchment.

Table 2-2 shows the calibrated peak flow and volume with the monitored records. Graph reports of model results for calibration events at the 3 monitoring locations are shown in Appendix B.

The calibrated model accurately reflects monitored data. Matching the volume was given a higher priority over matching peak flow because the primary objective of this study is to evaluate the EA's storage alternatives.

Of all stations, the calibration at Gauge LM004 was the best with seven event differences of -17% to 11% on volumes between modelled results and monitored records. Discrepancies and relatively high percentage differences in flow peak and flow volume in the results could be attributed to the spatial variability of rainfall within the study area.

Table 2-2: Model Calibration Results

Gauge LM001						
Date	Volume (m3)			Peak Flow (m3/s)		
	Monitor	Model	Diff	Monitor	Model	Diff
17-Aug	1434	1573	10%	0.8	1.1	36%
18-Aug	1588	1562	-2%	1.0	1.1	9%
21-Aug	996.4	716.3	-28%	0.6	0.4	-26%
11-Sep	1385	1032	-25%	0.5	0.4	-3%
11-Sep	2367	2584	9%	1.5	1.8	23%
13-Sep	1463	1510	3%	0.7	0.8	13%
1-Oct	1948	1570	-19%	0.7	0.6	-9%
2-Oct	1480	1170	-21%	0.4	0.3	-23%
31-Oct	9982	5255	-47%	0.2	0.2	-26%
Gauge LM003						
Date	Volume (m3)			Peak Flow (m3/s)		
	Monitor	Model	Diff	Monitor	Model	Diff
17-Aug	841	1191	42%	0.4	0.7	71%
18-Aug	864	1213	40%	0.5	0.7	49%
21-Aug	531	560	5%	0.3	0.4	26%
11-Sep	679	797	17%	0.2	0.4	54%
11-Sep	1774	1784	1%	0.9	0.8	-14%
13-Sep	725.8	1153	59%	0.3	0.6	87%
1-Oct	1171	1209	3%	0.3	0.5	37%
2-Oct	957.4	891.5	-7%	0.2	0.3	12%
31-Oct	6109	4020	-34%	0.1	0.1	10%
Gauge LM004						
Date	Volume (m3)			Peak Flow (m3/s)		
	Monitor	Model	Diff	Monitor	Model	Diff
17-Aug	1490	1648	11%	0.73	0.9343	29%
18-Aug	1488	1669	12%	0.79	0.93	18%
21-Aug	928	768	-17%	0.50	0.477	-5%
11-Sep	1142	1118	-2%	0.41	0.46	13%
11-Sep	2663	2457	-8%	1.18	1.2	2%
13-Sep	1090	1586	46%	0.55	0.807	47%
1-Oct	1865	1634	-12%	0.61	0.64	6%
2-Oct	1490	1233	-17%	0.43	0.358	-17%
31-Oct	8408	5538	-34%	0.16	0.17	4%

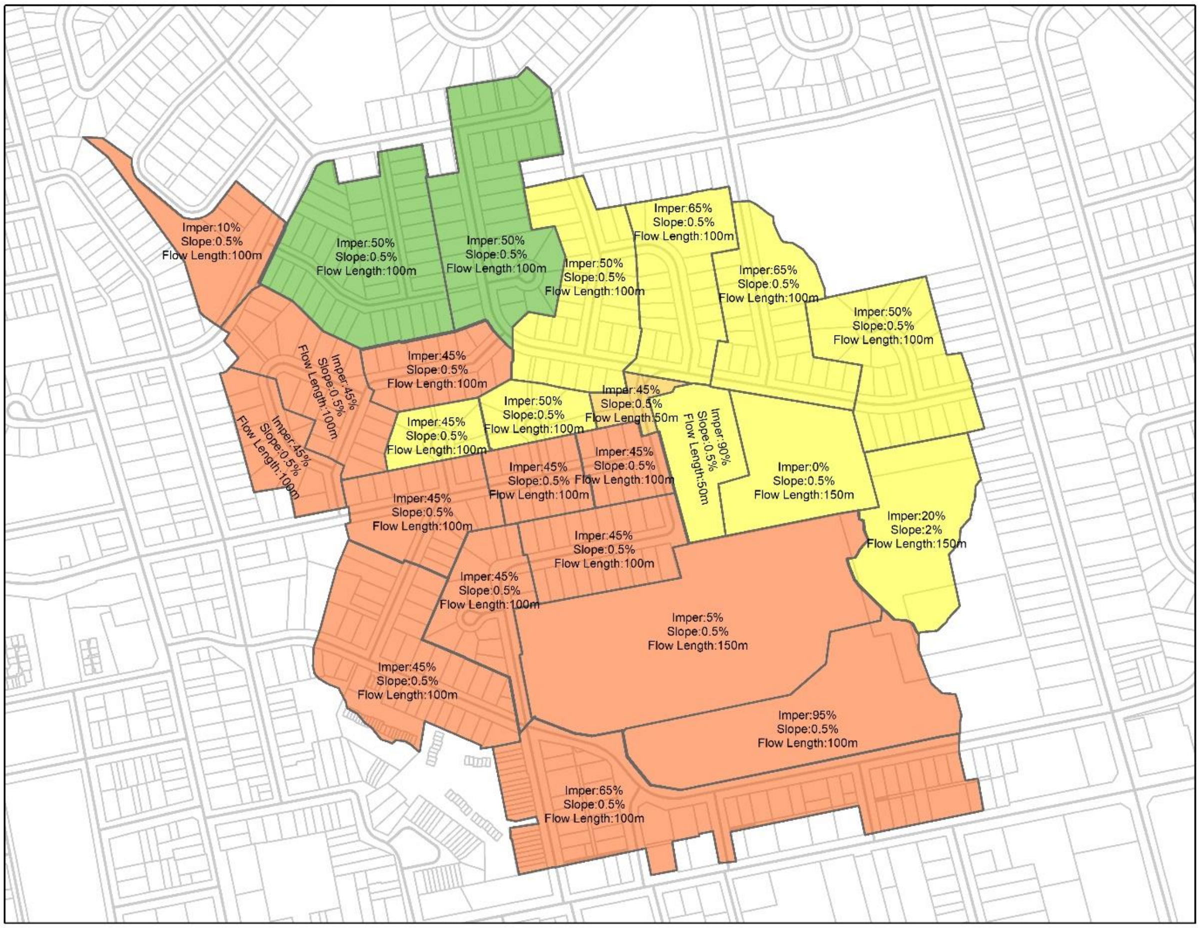

Figure 2-4: Subcatchments with Calibrated Parameters

3. Evaluation of Existing Flood Risk

3.1 Surface Ponding

As shown in **Figure 3-2,** there are four low-lying areas with no surface outlet where water will pond. Of these areas, the low-lying area on Cambridge St. west of Warwick St. has the greatest overland catchment area and the greatest risk of surface flooding. AECOM ran the model to generate the total runoff in this overland catchment. With no overland outlet, the flow out of this overland catchment is limited to the capacity of the storm outlet. The volume that remains will pond on the surface at the low point.

The calibrated model was used to simulate the 2-year, 5-year,10-year, 25-year, 50-year and 100-year design storm events for the drainage system under existing conditions. The design storms that were utilized were based on the City of London 2-year through 100-year events. The 24-hour Chicago storm distribution with 10 minute time steps was applied; since the recommended measures is storage, a 24-hour storm is used to consider the critical storage volumes that would occur for large-duration storms. The model results indicates that the storm sewers along Warwick Street, between Cambridge Street and Jutland Place, have less than 2 year conveyance capacity and the HGL is surcharged above ground during the 2-year storm.

Figure 3-1 shows the overland ponding limits and volumes at Cambridge/Warwick when the water level (a) fills the ROW and (b) ponds high enough to reach a building.

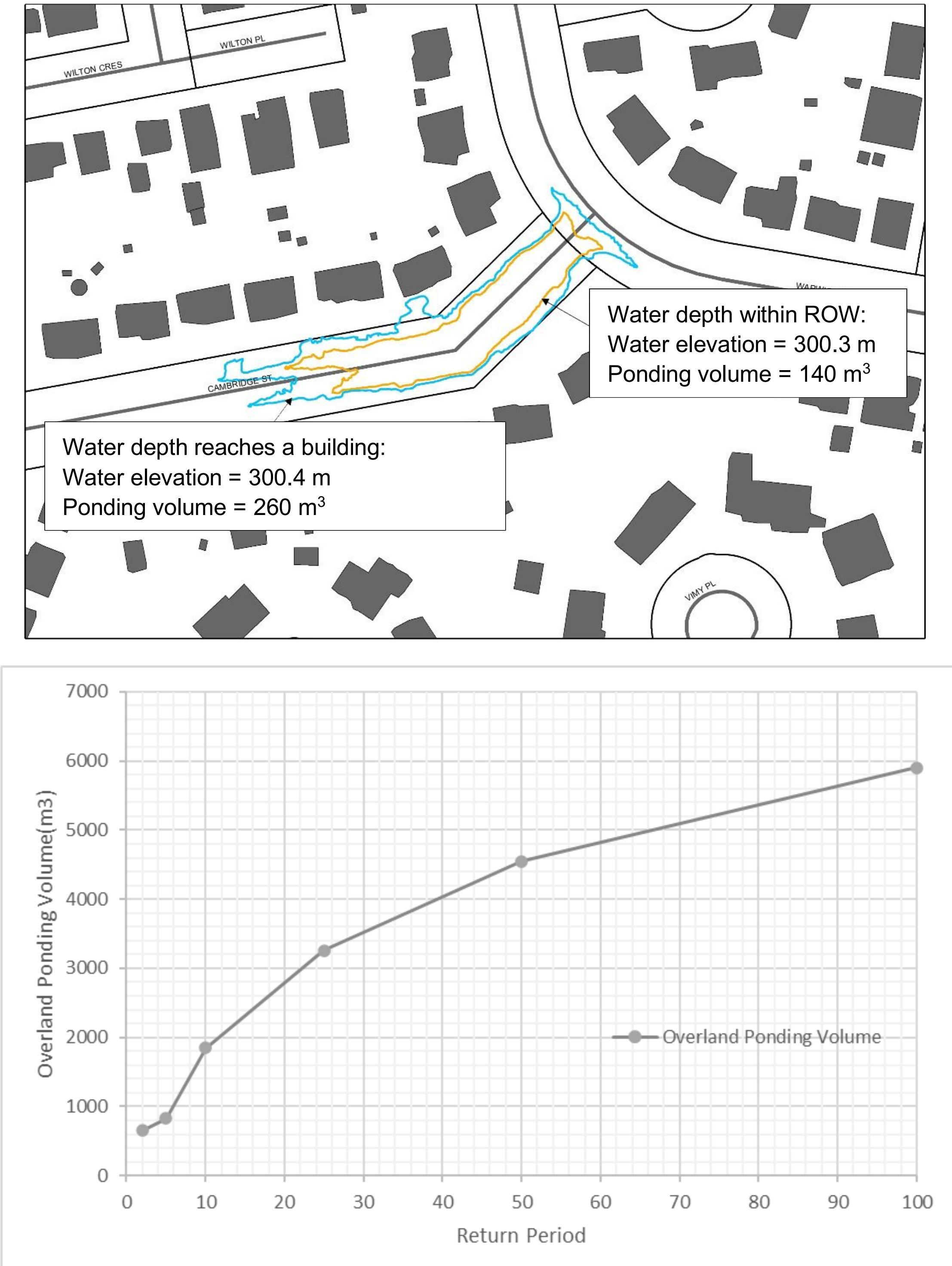

Figure 3-1: Overland Ponding Volume at Cambridge/Warwick

Table 3-1 shows the surface ponding volume for different ponding depths. **Figure 3-2** takes this information and plots the extent of surface flooding for specific events. The results show that 8 houses are subject to surface flooding as a result of 100-year surface ponding elevation and 2 houses are subject to surface flooding for the 2-year surface ponding elevation.

Table 3-1: Depth and Volume – Surface Ponding at Warwick/Cambridge

Ponding Depth above low point on Cambridge (m)	Surface Ponding Volume (m3)	Comment
0.1	15	
0.2	60	
0.3	140	Water depth reaches edge of ROW
0.4	260	Water depth reaches a building
0.5	640	
0.6	1070	
0.7	1630	
0.8	4760	Ponded water spills towards Hughson
0.9	8530	

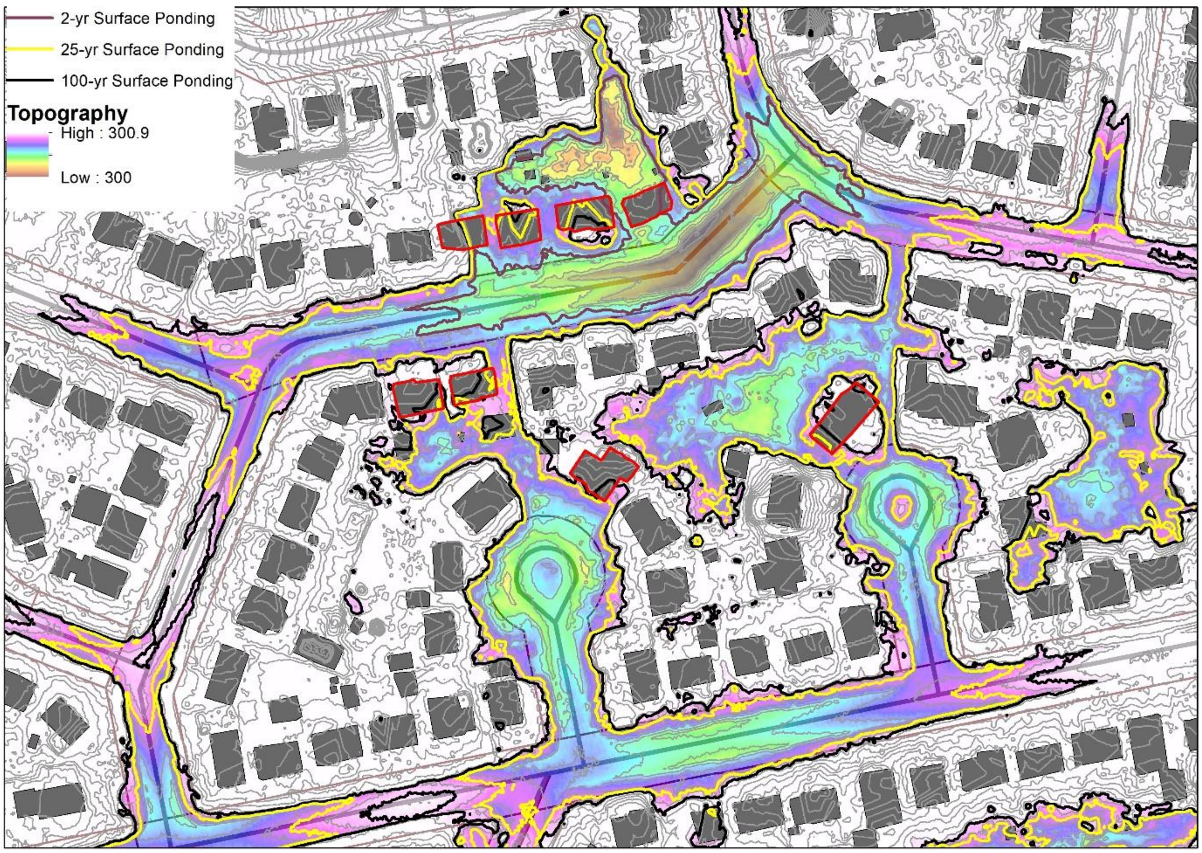

Figure 3-2: Overland Ponding Limits at Cambridge/Warwick

3.1.1 Storm Sewer Surcharge

A key question is whether historic flooding is due to overland ponding or surcharging storm sewers, and whether historic basement flooding is due to sanitary or storm sewer surcharging. According to the best available information for grades, surface flood risk is limited to 8 properties shown in **Figure 3-2** . More widespread basement flooding from the storm system could be related to storm sewer surcharge. Surcharging storm sewers can potentially cause basement flooding through service connections to the storm sewer; if foundation drains are connected to storm sewers, the surcharged storm sewer could eventually cause basement flooding through cracks in basement walls and the basement floor.

The extent and nature of existing private service connections to the storm sewers is not entirely clear for the Warwick area. The 2012 Class EA investigated this question in two ways: through CCTV inspections, and through questionnaires distributed to residents. The conclusions in the EA were:

- CCTV inspections were conducted in several storm sewers in the study area to determine if direct connections to the storm sewers from the foundation drains existed. Several do exist in the Cambridge/St Albans areas. CCTV inspections along the Warwick St storm sewer did not observe direct foundation drain connections. AECOM draws the conclusion that foundation drains are generally not directly connected to the storm sewer, but they are in a small number of cases.
- The questionnaire focused on the nature of flooding for affected residences. **Almost all of the responses who experienced basement flooding indicated that the source was sanitary backup** through floor drains, basement toilets, showers, and laundry tubs. A small number indicated that flooding was through cracks in foundation walls, basement floors, and sump pump wells. Four out of 55 responses indicated that flooding was from sump pump wells.

It is known that the storm sewer outlet servicing the Warwick and Cambridge area surcharges for storm events as small as a 2-year storm. The profile of the outlet storm sewer is shown below for (a) the observed HGL during the September 11, 2019 rain event; (b) the calibrated model HGL for the same event; and (c) the calibrated model for a 2-year rainfall event. The extent of potential basement flooding due to storm sewer surcharge is mapped by highlighting all areas where the surcharge level is within 1.8 m of the ground level (i.e., higher than basement levels). This is shown on **Figure 3-3** for both the 2-year storm and the surcharge level observed for the September 10, 2019 storm.

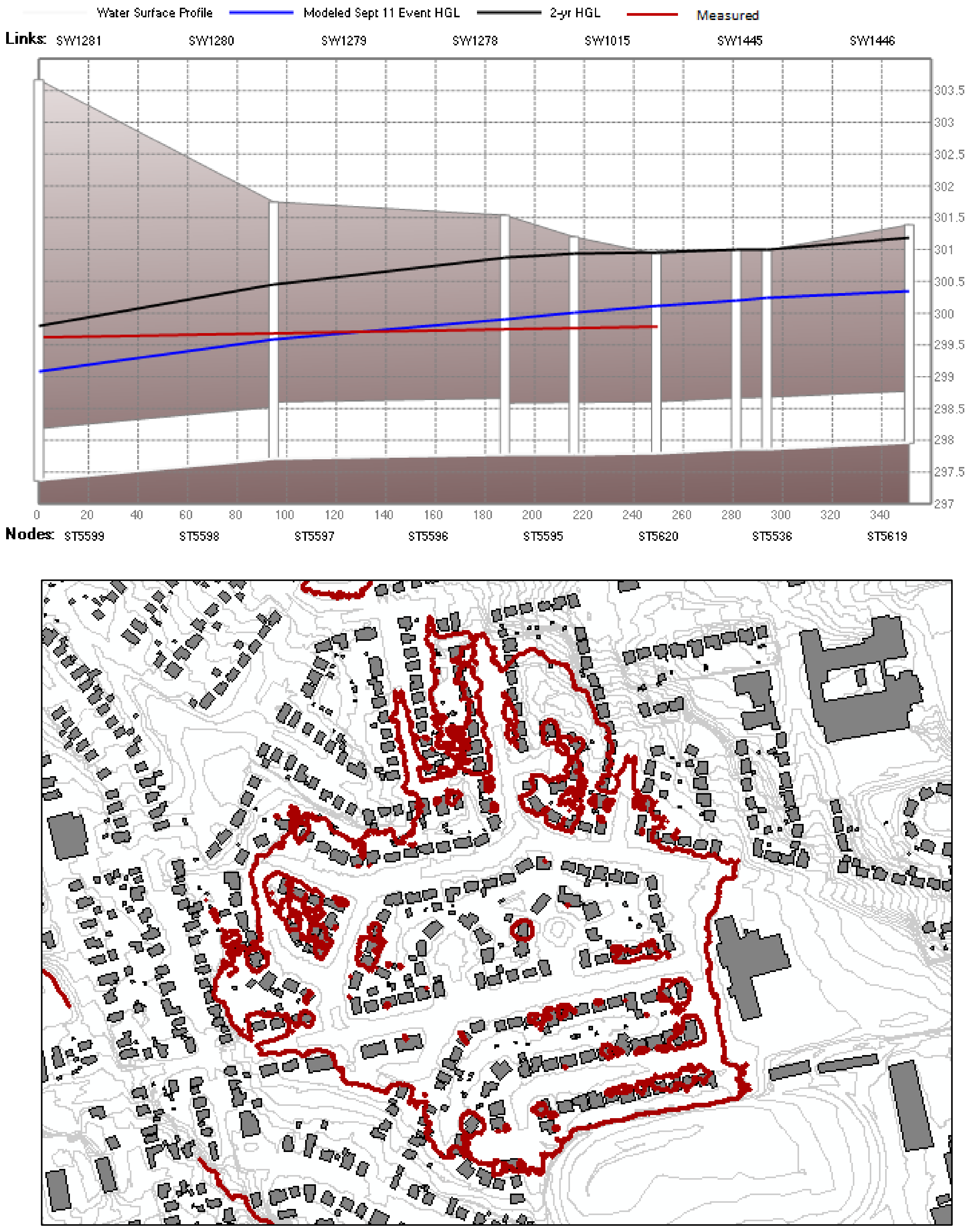

Figure 3-3: Area Subject to Potential Basement Flooding Risk from Foundation Drain or Private Drain Connections to Storm Sewers (HGL within 1.8 m of the ground, 2-year storm)

Both the monitored and modeled results show that the HGL is routinely higher than estimated basement elevations for a very large area, encompassing dozens of properties. The observed HGL for the September 11, 2019 event was between 301.5 m and 301.9 m at all four gauged locations. If basements were hydraulically connected to the storm sewers, this event would have caused basement flooding at dozens of properties. The short duration rainfall intensity measured for this event (27 mm/hr over a 5-minute duration) is far lower than a 2-year storm event, which means that the area in **Figure 3-3** experiences surcharged storm sewers (higher than basement levels) on a regular basis (several times every year). Since there is no history of repeated widespread storm sewer related basement flooding over this wide an area, it implies that there are few direct hydraulic connections between the basements and storm sewers. AECOM recommends additional investigations to confirm this and recommends proceeding with a solution that addresses surface flooding concerns. Given the evident low number of properties with direct connections to the storm sewer via foundation drains, these could potentially be addressed individually (e.g. through incentives/subsidies for private-side measures such as sump pumps and backflow preventors) rather than through large public infrastructure measures.

3.2 Existing Flood Risk

The flood risk in the Warwick area has two components: surcharging storm sewers (i.e. risk of basements to be flooded due to potential direct private connections to the storm sewers), and surface ponding in low lying areas. The flood risk for surcharging storm sewers exists for all storm events, for all mitigation alternatives. The storage alternatives in the EA do not prevent the storm sewers from surcharging to basement levels several times per year. The surface flooding risk, however, is mitigated to some degree by the storage options.

The surface flooding risk under various scenarios is described in the Table below.

Table 3-2: Summary of Flood Risk from Surface Ponding – Cambridge and Warwick

Event									
	Ponding Volume (m^3)	Ponding depth (m)	Number of properties	Ponding Volume (m^3)	Ponding depth (m)	Number of properties	Ponding Volume (m^3)	Ponding depth (m)	Number of properties
2-year	830	0.54	2	630	0.50	2	220	0.37	0
5-year	990	0.58	3	810	0.54	2	310	0.41	0
10-year	2890	0.74	4	1810	0.71	4	970	0.58	3
25-year	5100	0.81	8	3300	0.75	8	1400	0.66	4
50-year	6600	0.85	8	4500	0.79	8	3000	0.74	4
100-year	8800	0.91	8	6000	0.83	8	4100	0.78	8

Note:1. Reference model: Warwick Project_Existing_Final

2. Reference mode: Warwick Project_Future with Cambridge Storage and Sutherland

4. Downstream Overland Flow Capacity

The original EA has assessed that the causes of flooding in the Warwick area as:

- lack of capacity in the storm drainage system;
- inlet capacity deficiencies; and
- most importantly, a lack of an overland flow route out of the lowest parts of the study area

An alternative relief sewer route along the 'west' outlet (downstream of LM001) was considered. This has the advantage of being (a) a shorter distance until surface grades are below 300.0 m, and (b) larger diameter pipes already exists along downstream routes. Ideally, once the 100-year flow was conveyed below the high-point to the west in the storm sewer, any capacity constraints for the 100-year flow would create surcharging to the ground and overland flow along a safe flow route to the ultimate outlet. The intent of the relief sewer would be to convey the 100-year flow out of the trapped low-lying area, potentially to an existing major overland flow route to the west. This section assesses whether the 100-year flows could be conveyed to the west without impacting private properties.

4.1 Downstream Overland Flow Route Alternative

There are two downstream overland flow routes was evaluated in this study:

- Alternative1: storm relief sewer connected to the downstream west storm trunk sewer; and
- Alternative2: storm relief sewer connected to the downstream south storm trunk sewer.

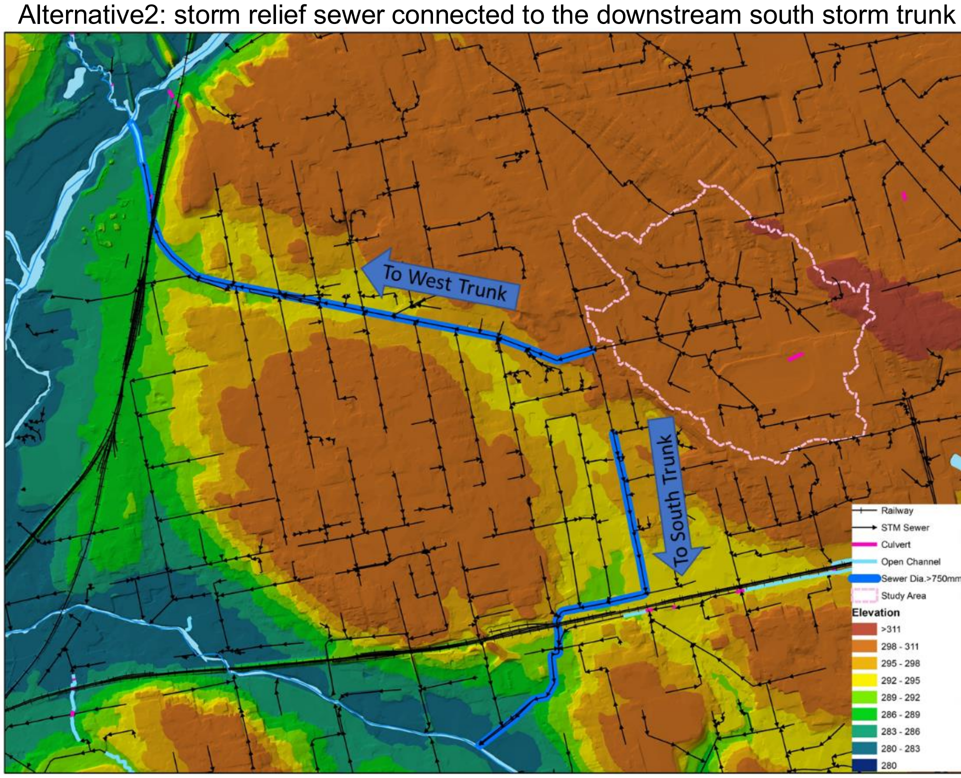

Figure 4-1: Downstream Overland Flow Route

4.2 Downstream West Storm Trunk Sewer

The downstream west trunk is located between Huron Street and Tecumseh Street with a pipe diameter of 1200-1950mm and a total length of 2090m. It is the primary outlet considered for a potential Warwick storm relief trunk. The west trunk flows westward along the low-lying easement, and outlets to Thames River.

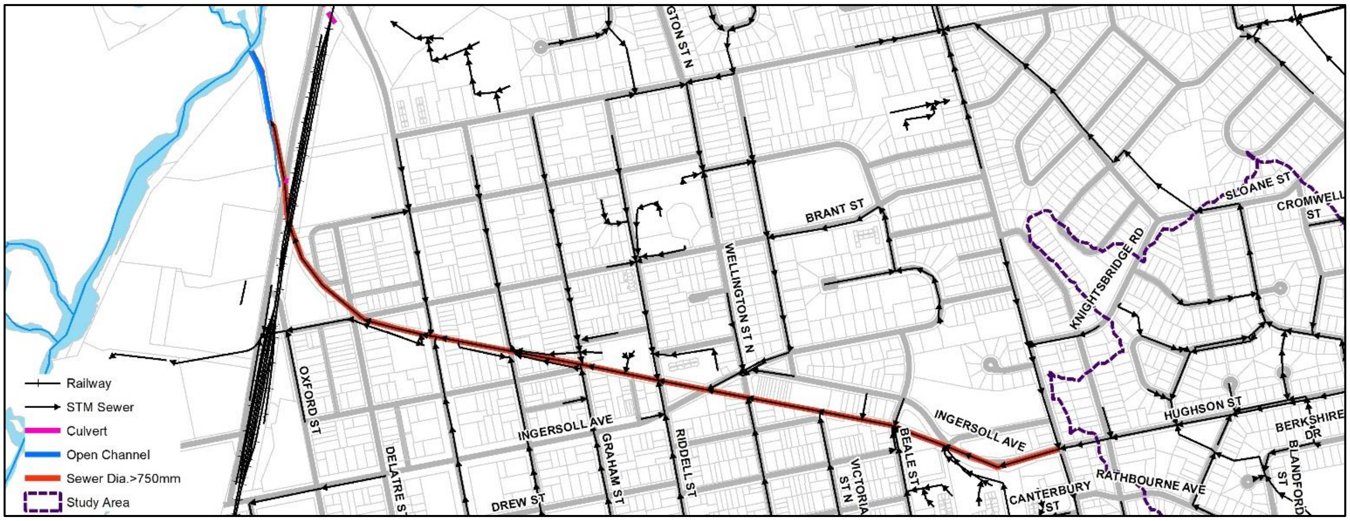

Figure 4-2: West Storm Trunk Sewer

Catchments tributary to the west storm trunk were delineated as shown in **Figure 4-3**. A storm model was used to perform capacity analysis of the west trunk in terms of HGL in the sewer system. A 2-year design event with 15-min duration having an intensity of 62 mm/hr was utilized to generate the flow from subcatchments. It is recognized that not all of the impervious area generates direct runoff to the storm sewer system. Impervious area of each subcatchment was estimated based on the land use data with assumption of: commercial area-95%, institutional area-50%, open space-0%, residential area-50% , and road-100%. It is assumed 50% of the impervious area was 'directly connected' to the storm collection system. A constant flow rate from Hughson trunk was applied, and this rate was 'ramped' incrementally higher to determine system bottlenecks.

The water surface profile of the existing west storm trunk sewer is presented **Figure 4-4**. With a flow of 2.7 m^3/s coming from the Hughson trunk, the HGL is above ground elevation at manhole **ST5375.**

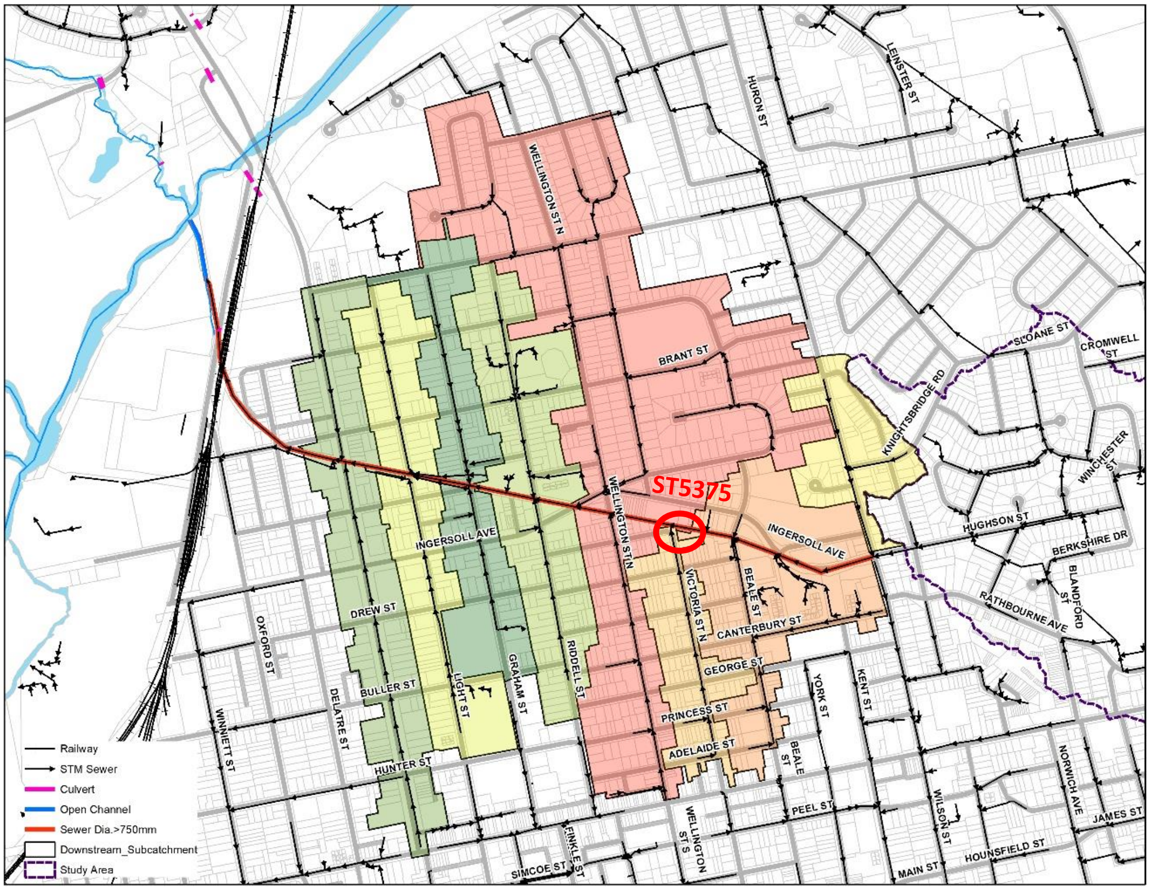

Figure 4-3: West Trunk Servicing Area

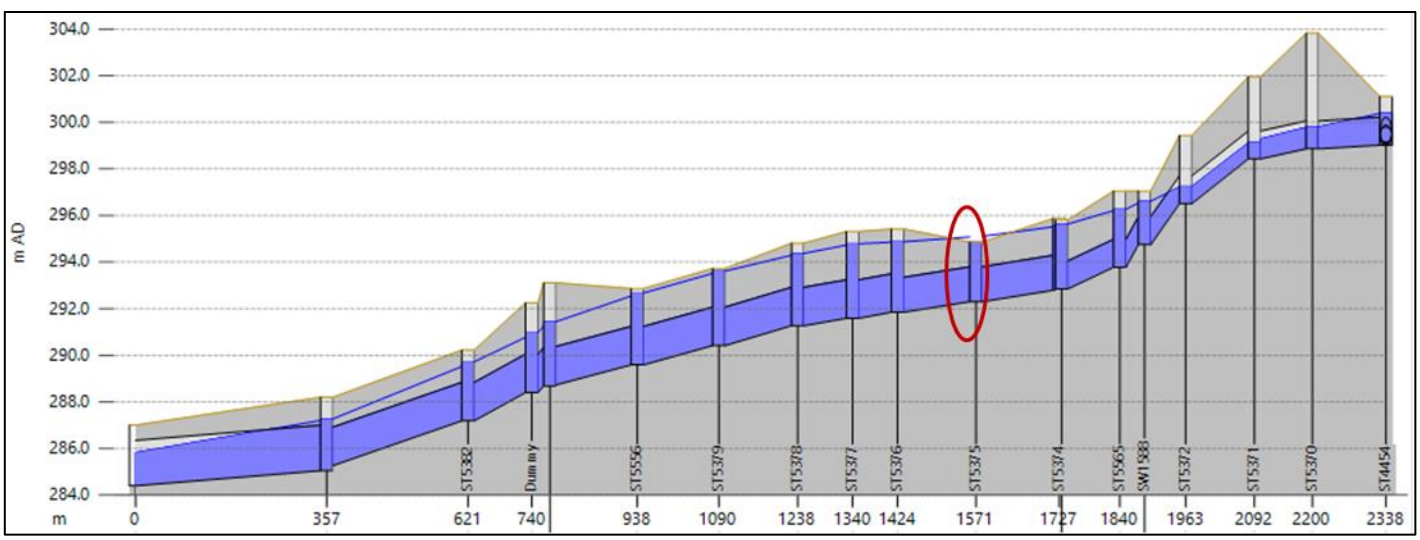

Figure 4-4: Water Surface Profile of West Storm Trunk Sewer

4.2.1 Overland Flow Route

A detailed overland flow path and direction, and surface ponding areas along the west trunk was derived from an analysis of the topography based on the City's contour data. The lid elevations of manhole were also reviewed to determine the route taken by stormwater as it concentrates during a rainfall event and makes its way downslope. The overland flow path mapping of the west trunk can be found in Appendix C. The overland flow paths generally travel towards the west and south flowing across the public and private properties and outletting to the Thames River and Cedar Creek.

With a proposed Warwick storm relief sewer connected to the downstream west trunk, during intense rainfall events when the flow exceeds the capacity of the west trunk, the pipe system starts to surcharge above the ground elevation and overland flow of stormwater occurs at manhole **ST5375. ST5375** is located the north of Edward Street within private property. Overflow from ST5375 travels south-east crossing private properties and conveying the bulk of flows to the lower topographical depressions as shown in the figure below:

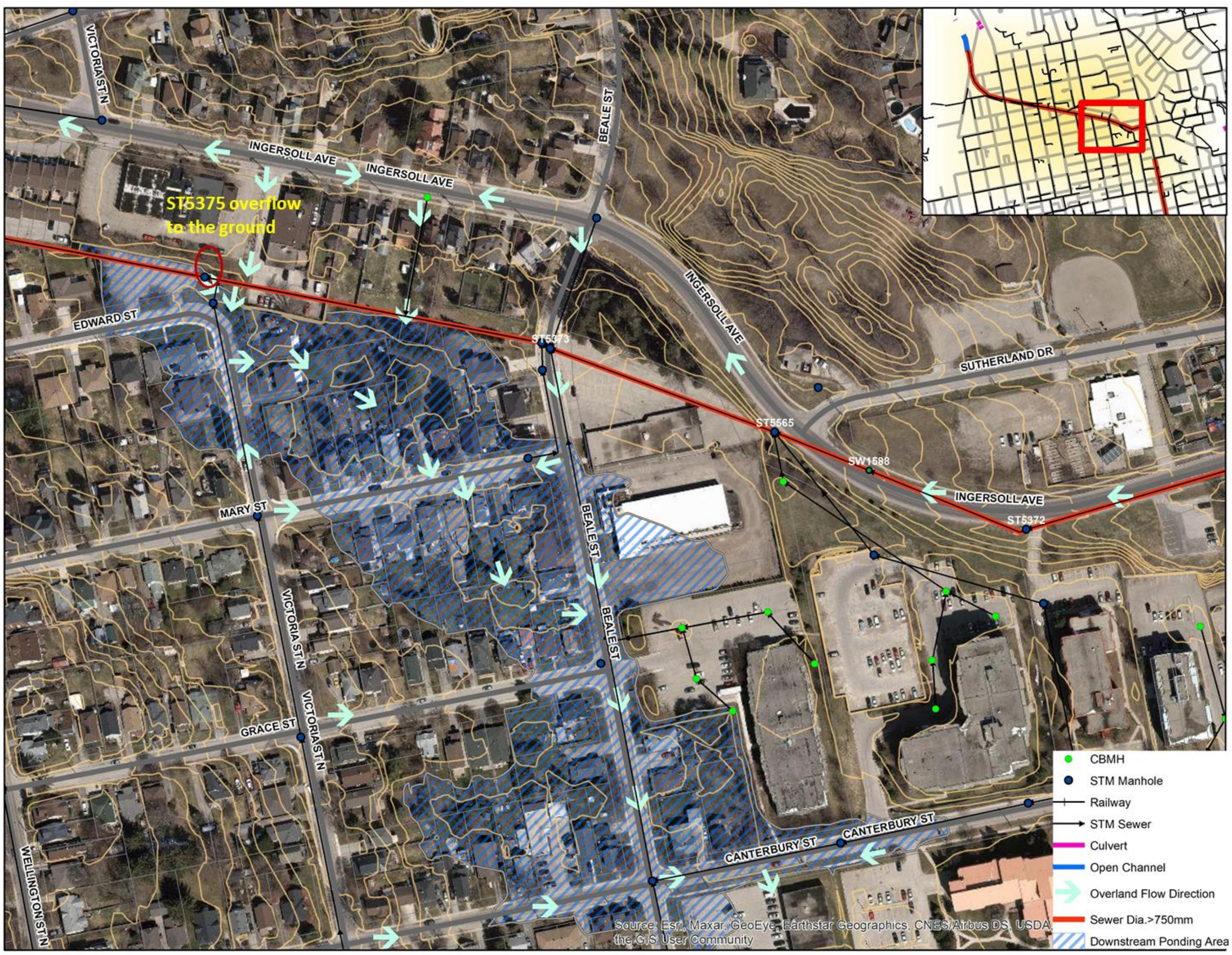

Figure 4-5: Overflow Path from MHST5375

In the vicinity of MHST5375 there is a local depression in the terrain where water would pond. Surface ponding would occur at north of Canterbury Street, south of Ingersoll Avenue, and east of Victoria Street North.

The assessment concludes that the west storm trunk sewer (route described above) does not serve as an adequate outlet for a potential relief sewer constructed in the Warwick area. The additional flows to this outlet would cause the storm sewer to surcharge to the ground surface, and there is no adequate overland flow path or outlet for these surface flows that would not create a flooding impact on private properties.

4.3 Downstream South Storm Trunk Sewer

The downstream south storm trunk sewer was also evaluated as an alternative outlet for a storm relief sewer from the Warwick area. The storm trunk sewer travels south along Huron Street and Wilson Street, then continues west besides CN railway, and travels towards the south-west crossing railway and private properties before entering Cedar Creek. The trunk has a pipe diameter of 900mm to 1950mm with a totally length of 1536m.

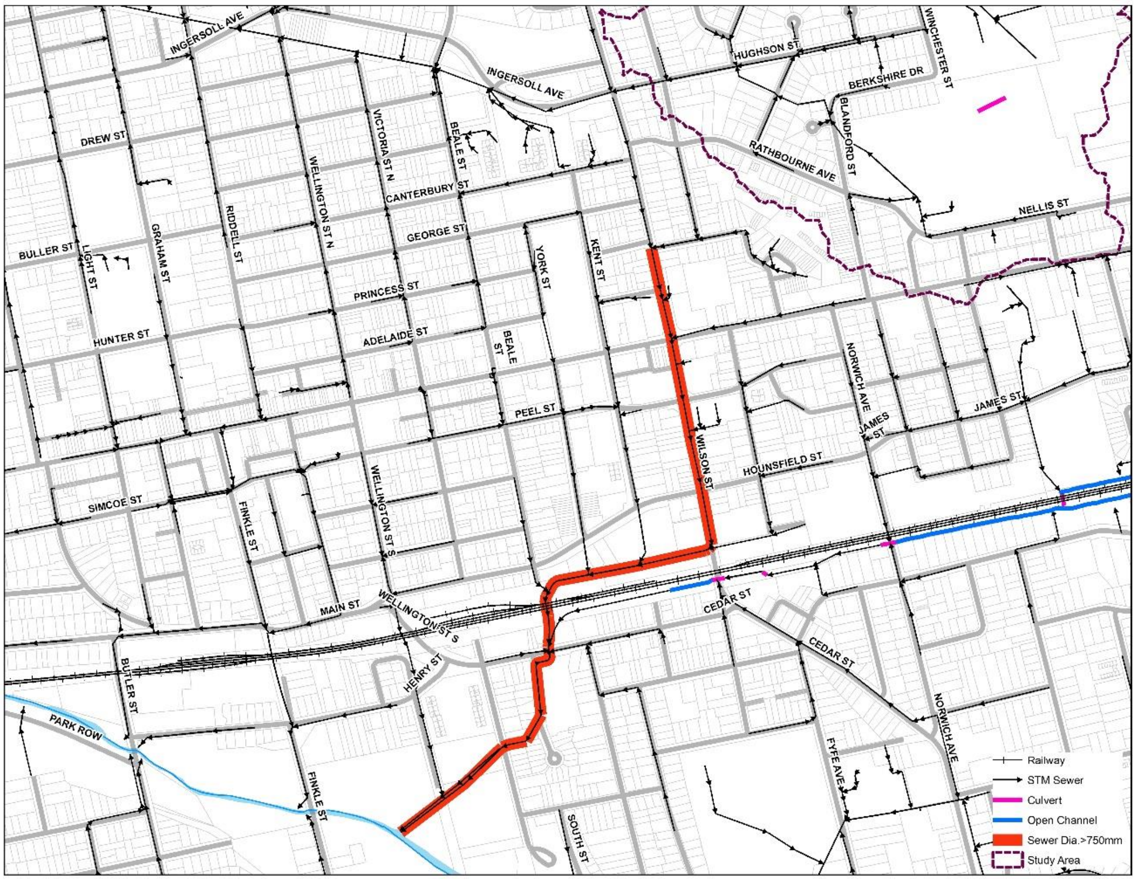

Figure 4-6: South Storm Trunk Sewer

4.3.1 Overland Flow Route

A detailed overland flow path and direction, and surface ponding areas along the south trunk was derived from an analysis of the topography based on the City's contour data and the lid elevations of manhole. The overland flow path mapping of the south trunk can be found in Appendix C. The overland flow path generally travels towards the south-west, flowing across the public and private properties and outletting to Cedar Creek.

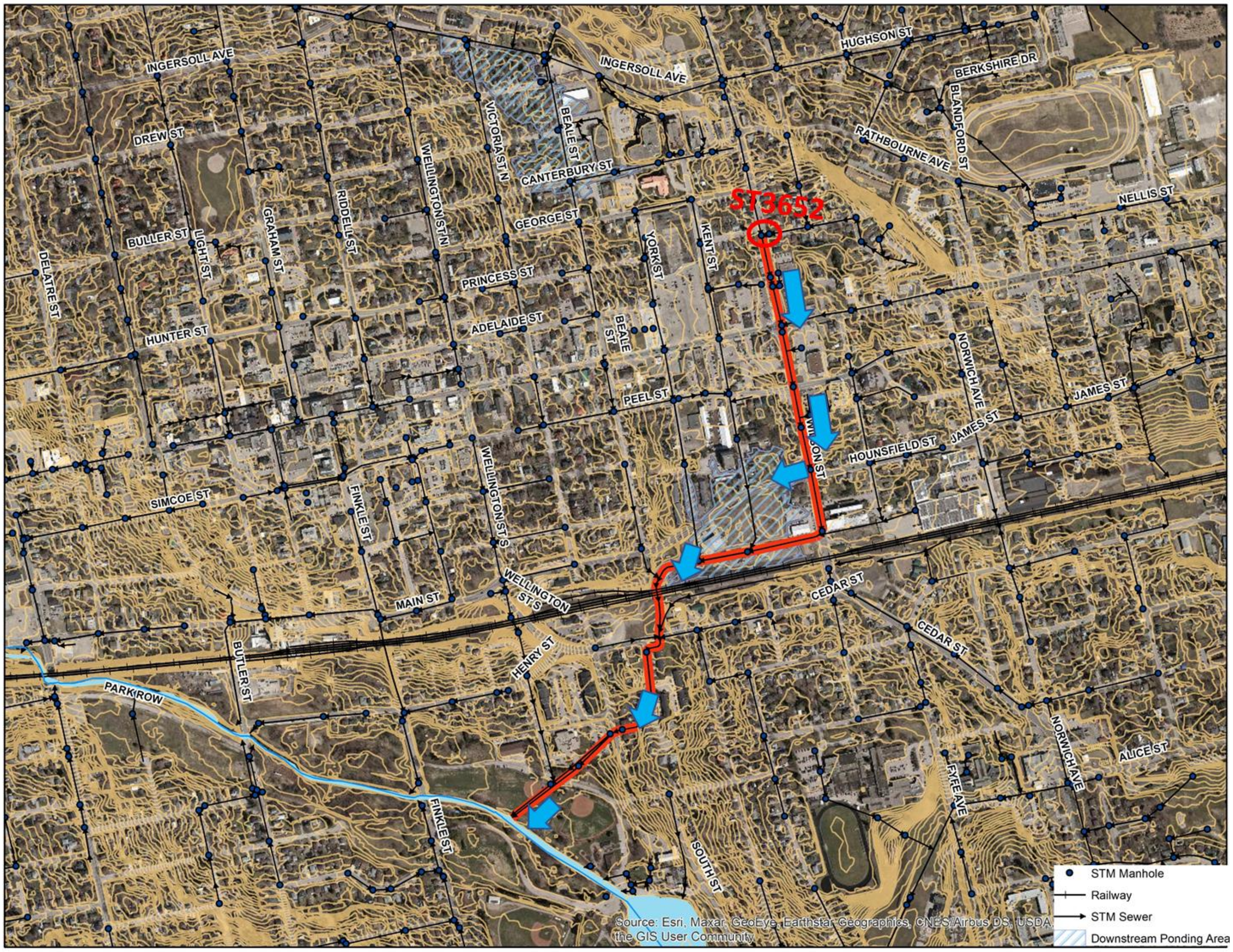

Figure 4-8：Overland Flow Direction for South Trunk

With the proposed Warwick storm relief sewer connected to the downstream south trunk, during intense rainfall events when the flow exceeds the capacity of the south trunk, the pipe system starts to surcharge above the ground elevation and overland flow of stormwater occurs at manhole **ST3652.** Overflow from ST3652 travels south along Wilson Street and Burtch Street crossing private properties and conveying the bulk of flows to the lower topographical depressions. The major constraint of this route is the local depression bounded by Peel Street, CN Rail tracks, Young Street, and Wilson Street. The maximum ponding depth may reach 1.5 m at private property backyards before it spills to the downstream side.

The assessment concludes that the south storm trunk sewer (route described above) also does not serve as an adequate outlet for a potential relief sewer constructed in the Warwick area. The additional flows to this outlet would cause the storm sewer to surcharge to the ground surface, and there is no adequate overland flow path or outlet for these surface flows that would not create a flooding impact on private properties.

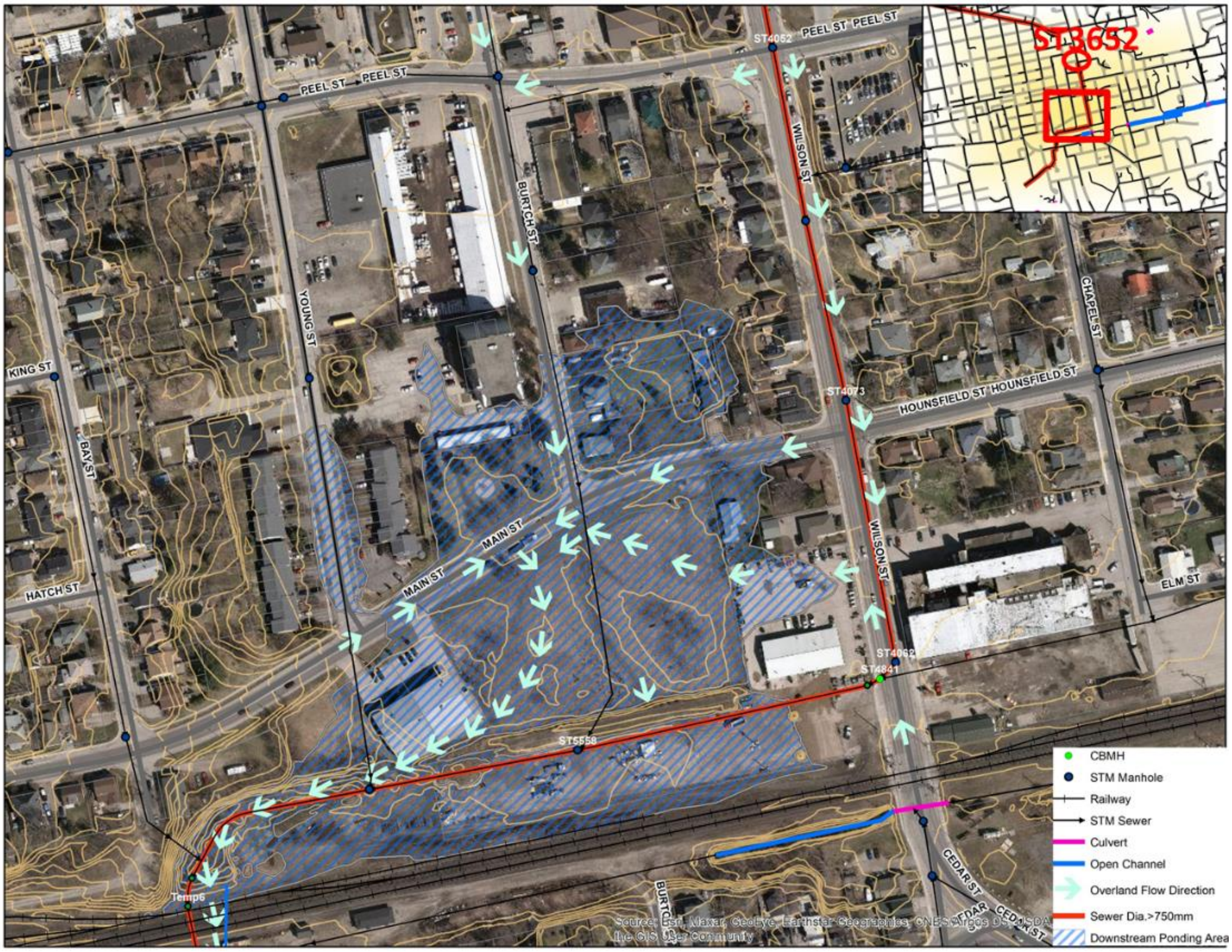

Figure 4-9: Overland Ponding Area

4.4 Downstream Overland Capacity Conclusion

The Warwick storm relief sewer is considered not a feasible option due to the identified overland capacity constraints of both the downstream west and south trunks. The additional flows to either outlet would cause the storm sewer to surcharge to the ground surface, and there is no adequate overland flow path or outlet for these surface flows that would not create a flooding impact on private properties.

5. Evaluation and Conclusions

The alternative actions at this point are generally as follows:

- Option 1- Implement the full EA solution
- Option 2 – Accept existing conditions and existing level of risk – i.e. partial implementation of the EA solution
- Option 3 – Pursue a solution that updates the EA solution (e.g. updates storage volumes based on a re-calibrated model)
- Option 4 - Pursue a new solution (e.g. storm relief sewer to an existing storm / overland outlet outside the local low-lying catchment), or different mitigation strategies.

AECOM's evaluation of Options 1, 2, and 3 is summarized in **Table 3-2** of this report. AECOM's modeling of the EA solution (Option 1) indicates that 4 residential buildings would still be subject to surface flooding at a 50-year return interval event. Under existing conditions (Option 2), 2 residential buildings would be flooded for a 2-year event, 8 residential buildings for a 50-year event, and 8 buildings for a 100-year event. Our assessment is that construction of the 2 underground storage tanks (at D M Sutherland school and at Cambridge/Warwick) only provide marginal benefits at an extremely high cost. AECOM considered revising the storage volume (Option 3), but smaller volumes provide negligible benefits, and full protection from surface flooding would require substantially larger volume of storage than is currently proposed.

AECOM evaluated some additional alternatives under Option 4. The primary large infrastructure improvement considered in detail was a large diameter relief sewer from the Cambridge/Warwick area, connecting to the Hughson storm sewer, discharging to an existing trunk storm sewer beyond the overland catchment limits of the study area. The features of this solution would be

- Providing relief from surface flooding by providing conveyance capacity away from the sag locations in the study area
- Providing surcharge relief for the storm sewer system
- Providing sufficient conveyance capacity to discharge 100-year flows in the relief storm sewer to a point that is beyond the overland catchment limits; this would ensure that any additional surcharge in the further downstream trunk which caused additional overland flow would be able to be conveyed along existing overland flow paths outside the study area

In our review of this alternative, the primary drawback which makes this option unfeasible is the lack of an overland flow route along any feasible downstream outlet. AECOM determined that the existing overland flow paths are in many areas not along existing rights-of-way, and there are existing overland flooding concerns for private property along each potential overland flow path. Since the increased conveyance of a relief sewer would contribute to overland flow and make this existing surface flooding worse, the alternative is considered not feasible.

Under Option 4, AECOM reviewed additional lower cost flood mitigation / flood proofing alternatives that only address the specific properties at flood risk.

AECOM's conclusions are:

1. Construction of additional underground storage identified in the EA (D M Sutherland School and at Cambridge/Warwick) only provides marginal benefits to reduce surface flooding risk at a couple properties, and is likely prohibitively costly to achieve these marginal benefits.

2. A storm relief sewer that only extends just beyond the overland catchment limits of the study area (i.e. just conveys drainage out of the general 'sag' area) is not feasible due to increased risk of flooding to private property along overland flow routes downstream.
3. Flood proofing measures addressed at the specific properties at risk of surface flooding can mitigate the risk of damages at these properties. This can be either measures targeted for the home owner's to pursue (such as sealed basement windows, raised sills, property grading), or measures on public property (such as a raised sill along the driveways / front yards along the curb that prevents the ponding water from spilling into the lot). The latter alternative may also require private drainage measures to discharge or retain stormwater on each property (e.g. pumping, rain gardens/retention, etc).
4. Neither the EA solution nor the potential additional surface flood proofing measures will remove the risk caused by frequently surcharging storm sewers. Both the modeling and the monitored water levels indicate that the storm sewers in the area frequency surcharge to levels that are above basement elevations. There has not been widespread basement flooding complaints every year in the area, which suggests that most basements are not directly connected to the storm sewers; the foundation drains may discharge via sump pumps to the ground, or they may be protected by check valves on the storm service connection, or the storm service connection may not exist. The small number of direct storm connections via foundation drains in borne out in CCTV investigations and home owner questionnaires completed during the EA. AECOM recommends that any future basement flooding in the area that is attributed to storm sewer backup should be addressed through public education and/or subsidies for measures on private lots.

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AECOM

Appendix A

Flow Gauge Summary Table

LM001

Gauge	LM001
Location:	
Catchment Area (ha)	33
Summary	

					5 minute		10 minute		15 minute		20 minute		25 minute	
Date	rainfall volume	runoff volume	calculated C	Peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow
	(mm)	(m3)		(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)
17-Aug	16.8	1393	0.25	0.77	45.7	1.41	45.7	1.41	43.7	1.35	34.3	1.06	29.3	0.90
18-Aug	15.0	1533	0.31	0.99	51.8	1.60	50.3	1.55	38.6	1.19	31.2	0.96	26.2	0.81
21-Aug	7.1	933	0.40	0.59	39.6	1.22	29.0	0.89	23.4	0.72	18.3	0.56	15.2	0.47
11-Sep	11.7	1334	0.35	0.45	27.4	0.85	19.8	0.61	16.3	0.50	16.8	0.52	17.1	0.53
11-Sep	21.3	2313	0.33	1.48	79.2	2.45	71.6	2.21	53.8	1.66	43.4	1.34	38.4	1.19
13-Sep	11.2	1404	0.38	0.74	45.7	1.41	38.1	1.18	34.5	1.07	27.4	0.85	22.6	0.70
1-Oct	16.8	1825	0.33	0.66	36.6	1.13	33.5	1.03	31.5	0.97	27.4	0.85	23.2	0.71
2-Oct	11.4	1373	0.36	0.44	18.3	0.56	16.8	0.52	13.2	0.41	13.7	0.42	13.4	0.41
31-Oct	52.6	5585	0.32	0.22	9.1	0.28	9.1	0.28	7.1	0.22	3.0	0.09	3.0	0.09

LM002

Gauge	LM002
Location:	
Catchment Area (ha)	1.2
Summary	

					5 minute		10 minute		15 minute		20 minute		25 minute	
Date	rainfall volume	runoff volume	calculated C	Peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow
	(mm)	(m3)		(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)
17-Aug	16.8	50	0.25	0.04	45.7	0.05	45.7	0.05	43.7	0.05	34.3	0.04	29.3	0.03
18-Aug	15.0	49	0.27	0.04	51.8	0.06	50.3	0.05	38.6	0.04	31.2	0.03	26.2	0.03
21-Aug	7.1	27	0.31	0.03	39.6	0.04	29.0	0.03	23.4	0.03	18.3	0.02	15.2	0.02
11-Sep	11.7	53	0.38	0.02	27.4	0.03	19.8	0.02	16.3	0.02	16.8	0.02	17.1	0.02
11-Sep	21.3	91	0.35	0.09	79.2	0.09	71.6	0.08	53.8	0.06	43.4	0.05	38.4	0.04
13-Sep	11.2	49	0.36	0.04	45.7	0.05	38.1	0.04	34.5	0.04	27.4	0.03	22.6	0.02
1-Oct	16.8	69	0.34	0.03	36.6	0.04	33.5	0.04	31.5	0.03	27.4	0.03	23.2	0.03
2-Oct	11.4	49	0.35	0.02	18.3	0.02	16.8	0.02	13.2	0.01	13.7	0.01	13.4	0.01
31-Oct	52.6	583	0.92	0.01	9.1	0.01	9.1	0.01	7.1	0.01	3.0	0.00	3.0	0.00

LM003

Gauge	LM003
Location:	
Catchment Area (ha)	17.8
Summary	

					5 minute		10 minute		15 minute		20 minute		25 minute	
Date	rainfall volume	runoff volume	calculated C	Peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow
	(mm)	(m3)		(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)
17-Aug	16.8	841	0.28	0.42	45.7	0.84	45.7	0.84	43.7	0.80	34.3	0.63	29.3	0.54
18-Aug	15.0	864	0.32	0.48	51.8	0.95	50.3	0.92	38.6	0.71	31.2	0.57	26.2	0.48
21-Aug	7.1	531	0.42	0.29	39.6	0.73	29.0	0.53	23.4	0.43	18.3	0.34	15.2	0.28
11-Sep	11.7	649	0.31	0.23	27.4	0.50	19.8	0.36	16.3	0.30	16.8	0.31	17.1	0.31
11-Sep	21.3	1756	0.46	0.94	79.2	1.45	71.6	1.31	53.8	0.99	43.4	0.80	38.4	0.70
13-Sep	11.2	700	0.35	0.33	45.7	0.84	38.1	0.70	34.5	0.63	27.4	0.50	22.6	0.41
1-Oct	16.8	1113	0.37	0.35	36.6	0.67	33.5	0.61	31.5	0.58	27.4	0.50	23.2	0.42
2-Oct	11.4	925	0.45	0.24	18.3	0.34	16.8	0.31	13.2	0.24	13.7	0.25	13.4	0.25
31-Oct	52.6	3348	0.36	0.12	9.1	0.17	9.1	0.17	7.1	0.13	3.0	0.06	3.0	0.06

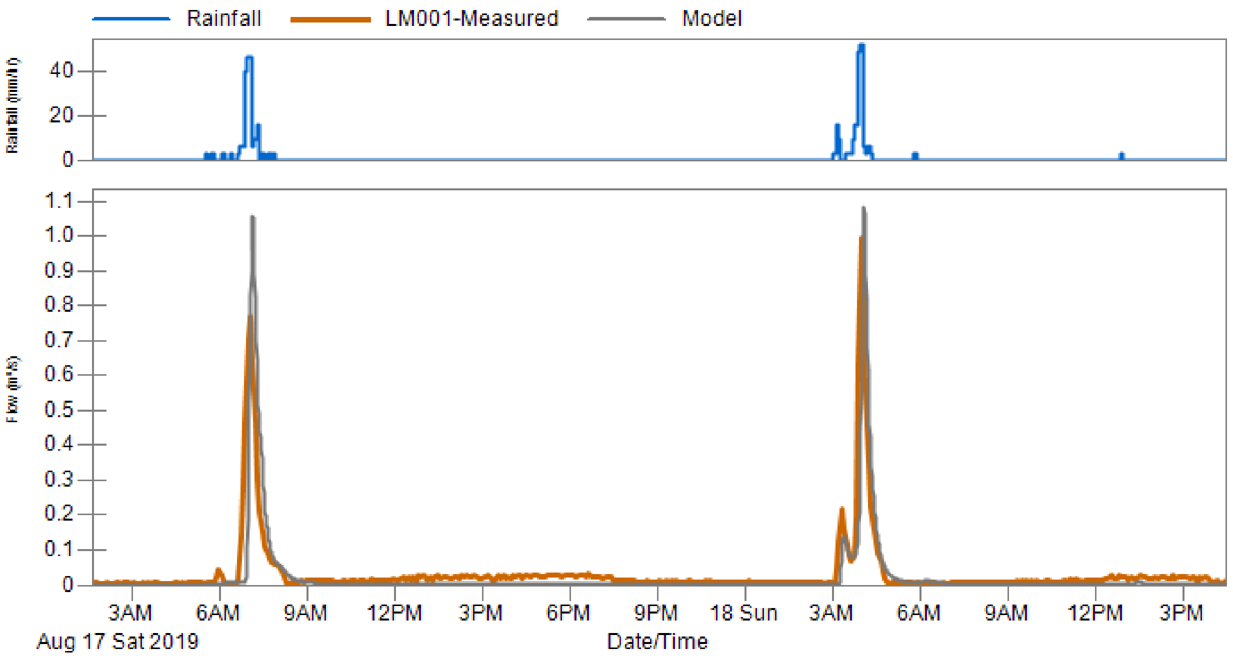
LM004

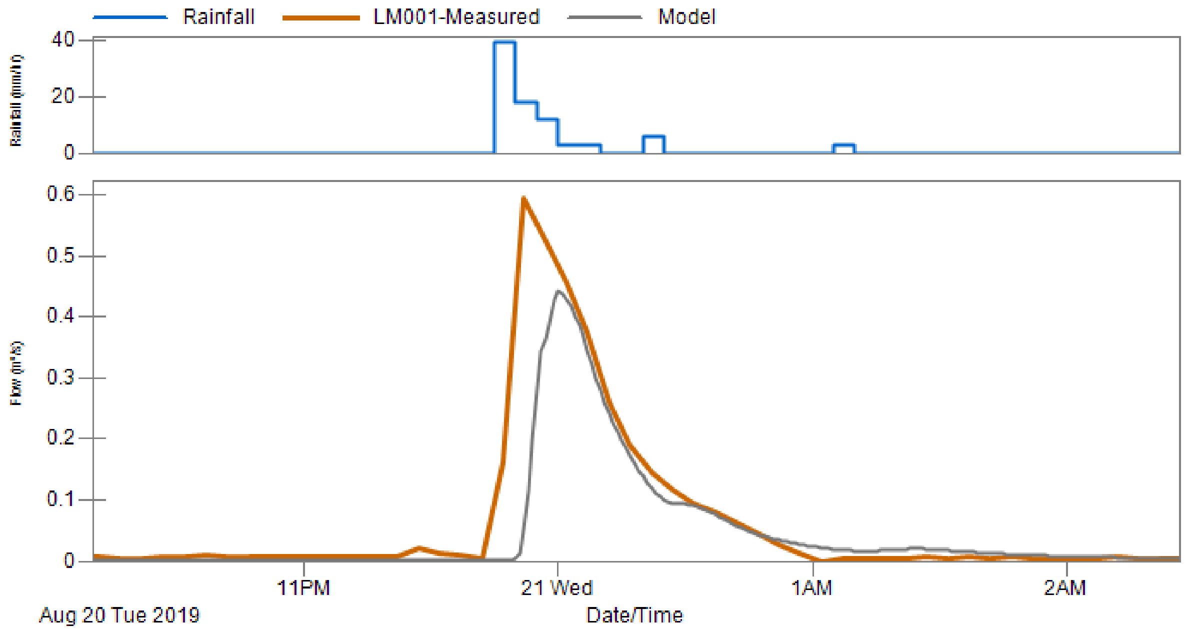
Gauge	LM003
Location:	
Catchment Area (ha)	23.9
Summary	

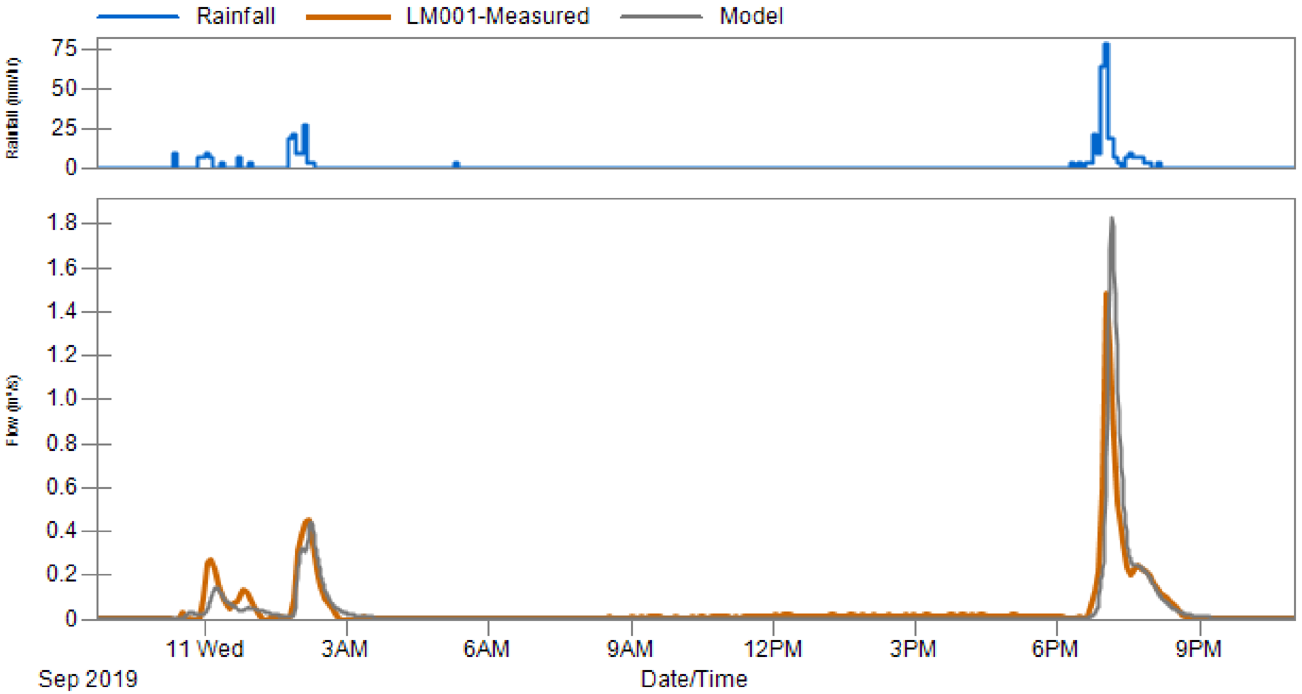
					5 minute		10 minute		15 minute		20 minute		25 minute	
Date	rainfall volume	runoff volume	calculated C	Peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow	Peak rainfall intensity	Rational Method peak flow
	(mm)	(m3)		(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)	(mm/hr)	(m3/s)
17-Aug	16.8	1413	0.35	0.73	45.7	1.31	45.7	1.31	43.7	1.25	34.3	0.98	29.3	0.84
18-Aug	15.0	1397	0.39	0.79	51.8	1.49	50.3	1.44	38.6	1.11	31.2	0.90	26.2	0.75
21-Aug	7.1	880	0.52	0.50	39.6	1.14	29.0	0.83	23.4	0.67	18.3	0.52	15.2	0.44
11-Sep	11.7	1081	0.39	0.41	27.4	0.79	19.8	0.57	16.3	0.47	16.8	0.48	17.1	0.49
11-Sep	21.3	2602	0.51	1.18	79.2	2.27	71.6	2.05	53.8	1.54	43.4	1.25	38.4	1.10
13-Sep	11.2	1085	0.41	0.55	45.7	1.31	38.1	1.09	34.5	0.99	27.4	0.79	22.6	0.65
1-Oct	16.8	1682	0.42	0.61	36.6	1.05	33.5	0.96	31.5	0.90	27.4	0.79	23.2	0.66
2-Oct	11.4	1434	0.52	0.43	18.3	0.52	16.8	0.48	13.2	0.38	13.7	0.39	13.4	0.38
31-Oct	52.6	4777	0.38	0.16	9.1	0.26	9.1	0.26	7.1	0.20	3.0	0.09	3.0	0.09

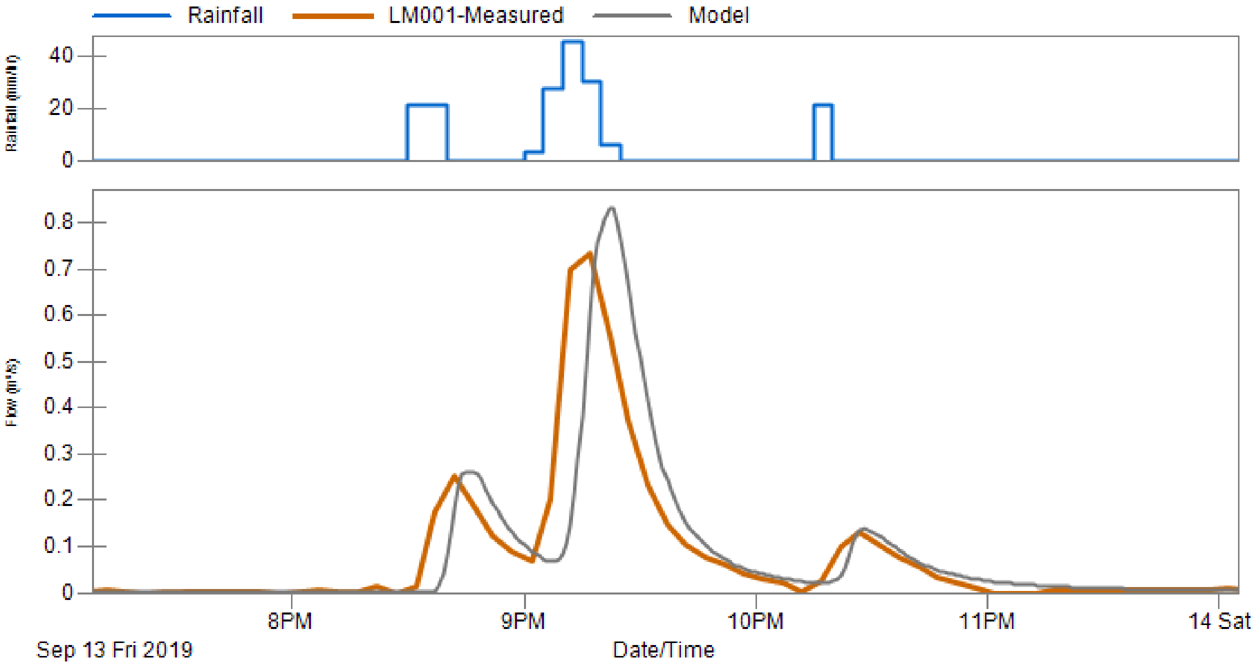
Appendix B

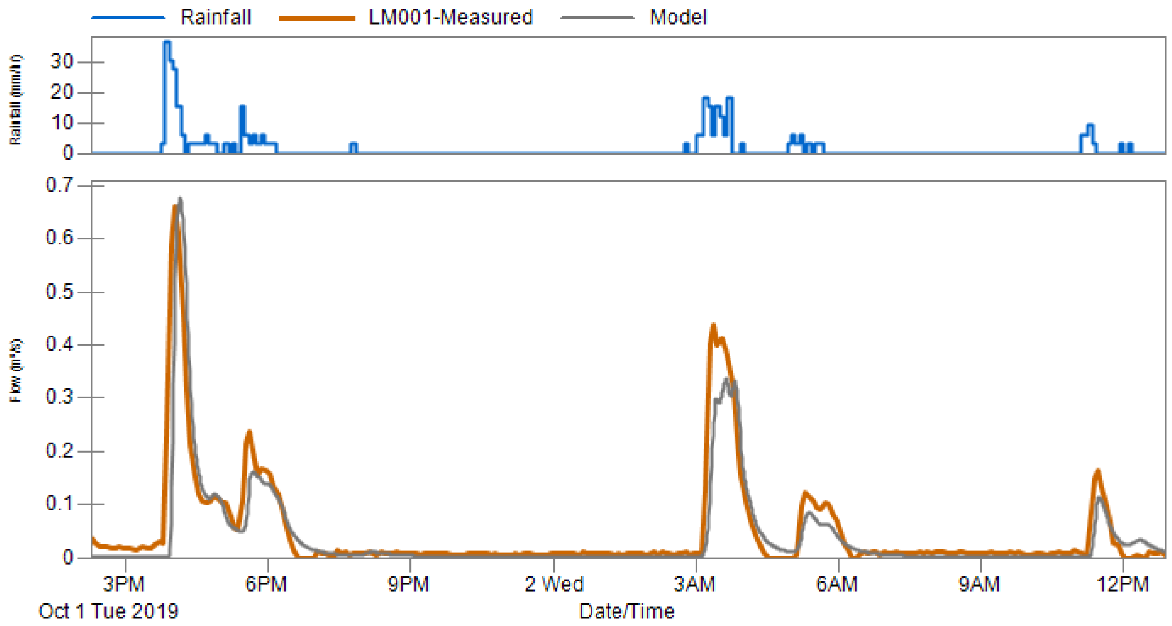
Model Results for Calibration Events

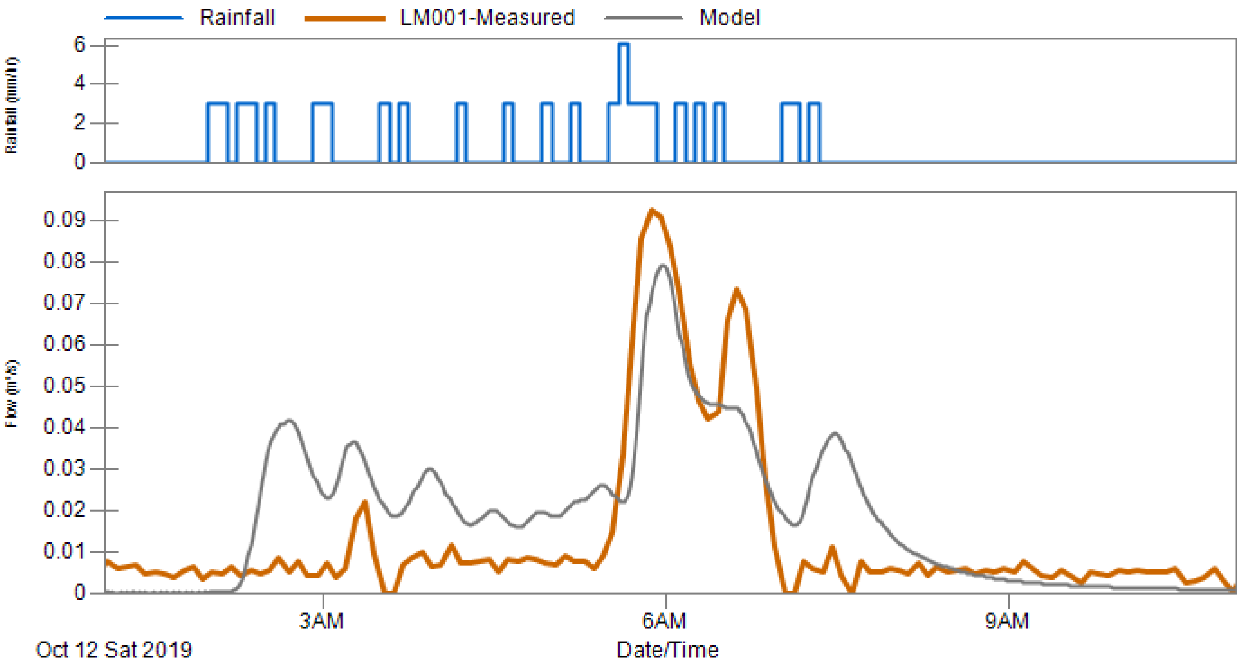

Rainfall
LM001-Measured
Model
Rainfall (mm/hr)
Flow (m³/s)
3AM
6AM
9AM
12PM
3PM
6PM
9PM
18 Sun
3AM
6AM
9AM
12PM
3PM
Aug 17 Sat 2019
Date/Time

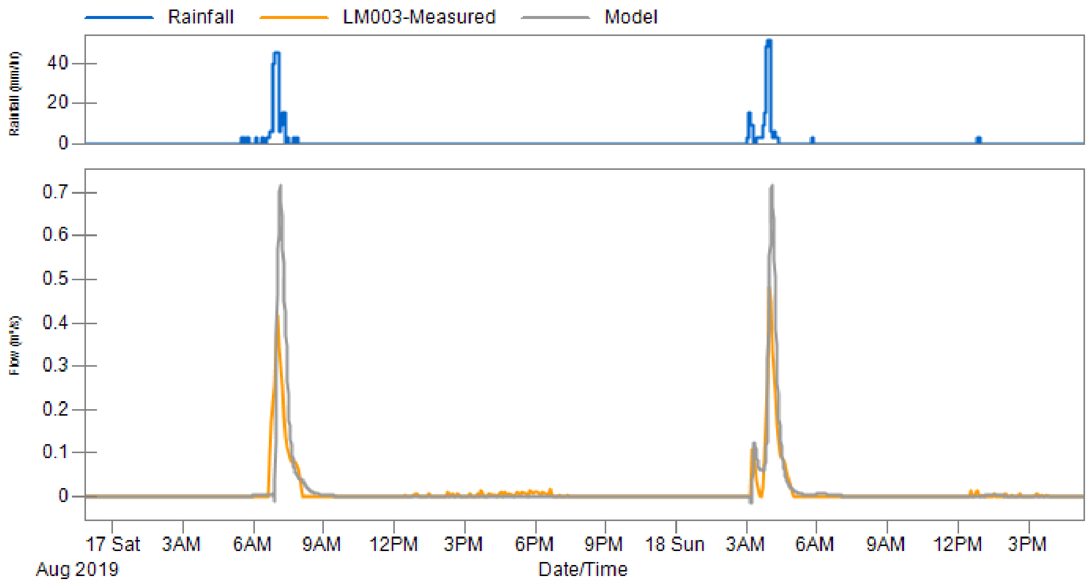

Rainfall
LM001-Measured
Model
Rainfall (mm/hr)
Flow (m³/s)
11PM
21 Wed
1AM
2AM
Aug 20 Tue 2019
Date/Time

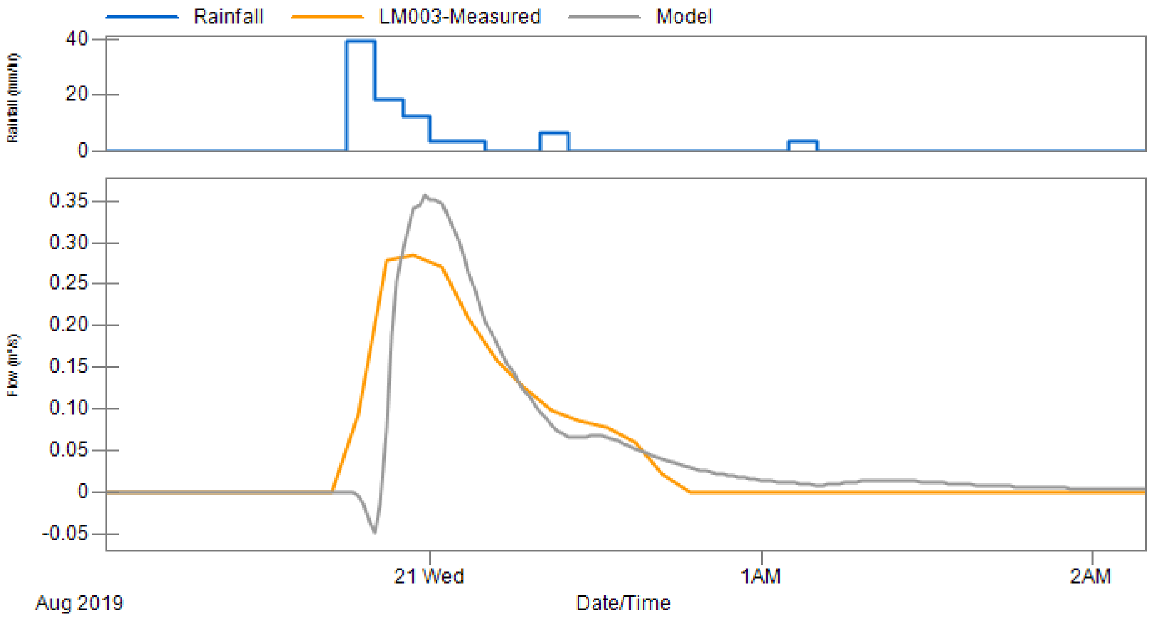

Rainfall
LM001-Measured
Model
Rainfall (mm/hr)
75
50
25
0
Flow (m³/s)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
11 Wed
3AM
6AM
9AM
12PM
3PM
6PM
9PM
Sep 2019
Date/Time

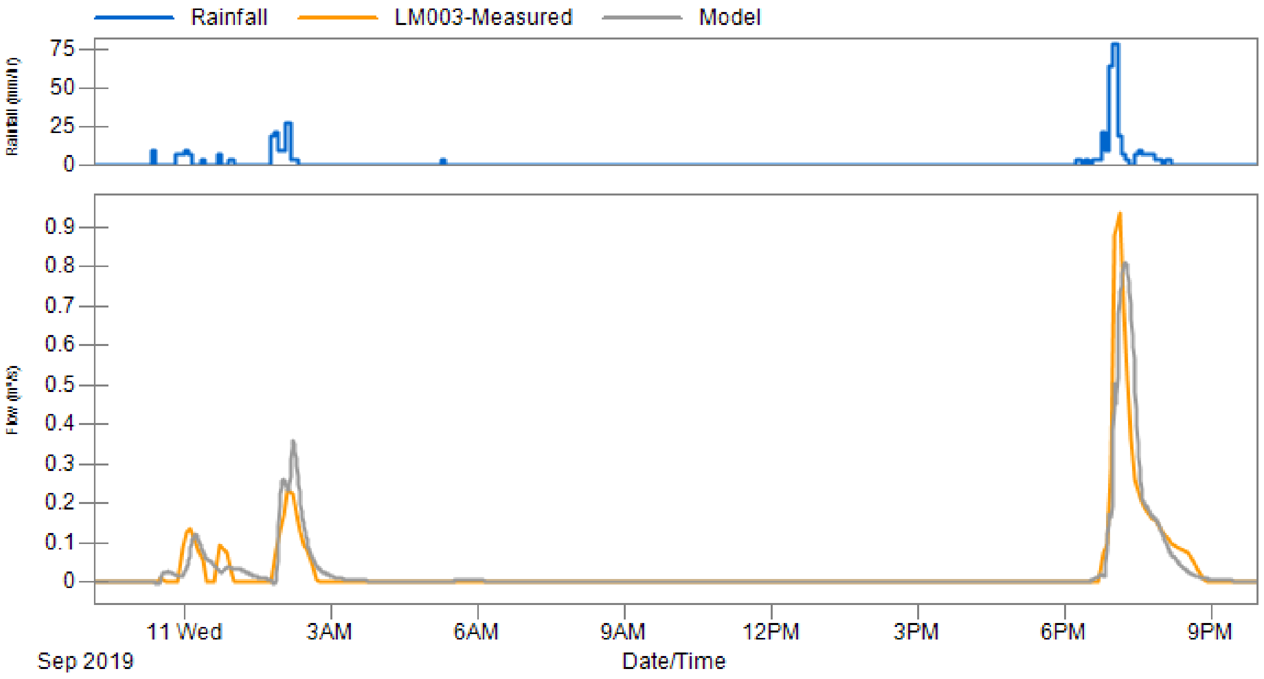

Rainfall
LM001-Measured
Model
Rainfall (mm/hr)
40
20
0
Flow (m³/s)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
8PM
9PM
10PM
11PM
14 Sat
Sep 13 Fri 2019
Date/Time

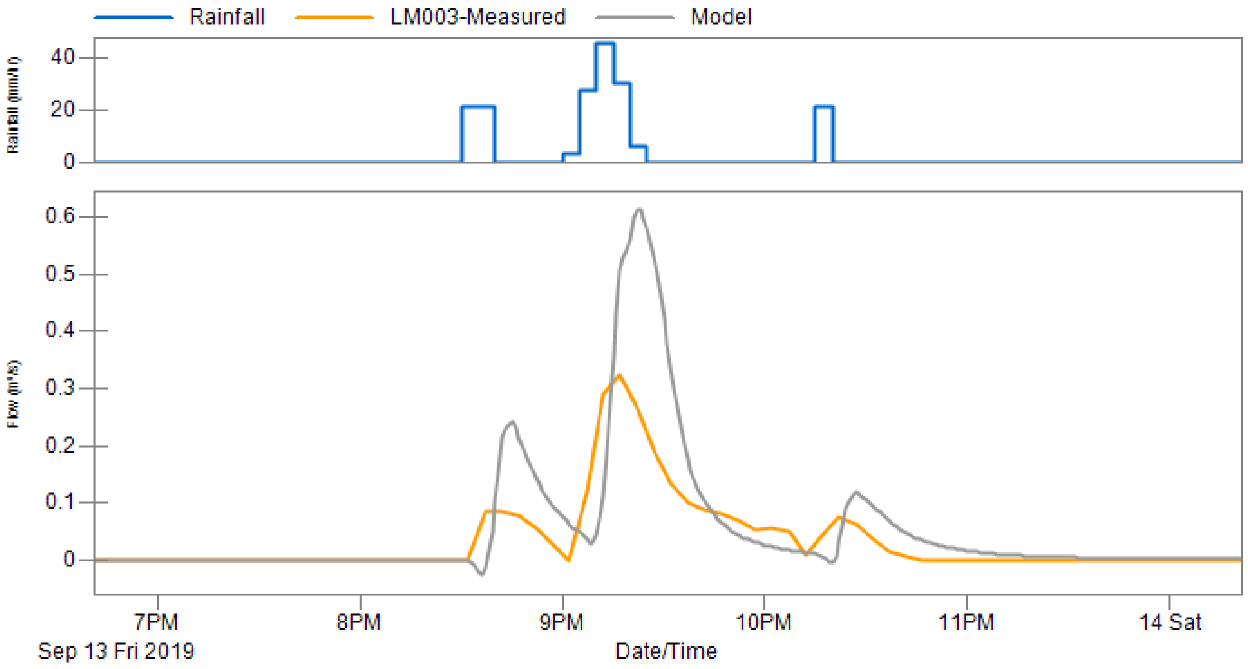

Rainfall
LM001-Measured
Model
Rainfall (mm/hr)
30
20
10
0
Flow (m³/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
3PM
6PM
9PM
2 Wed
3AM
6AM
9AM
12PM
Oct 1 Tue 2019
Date/Time

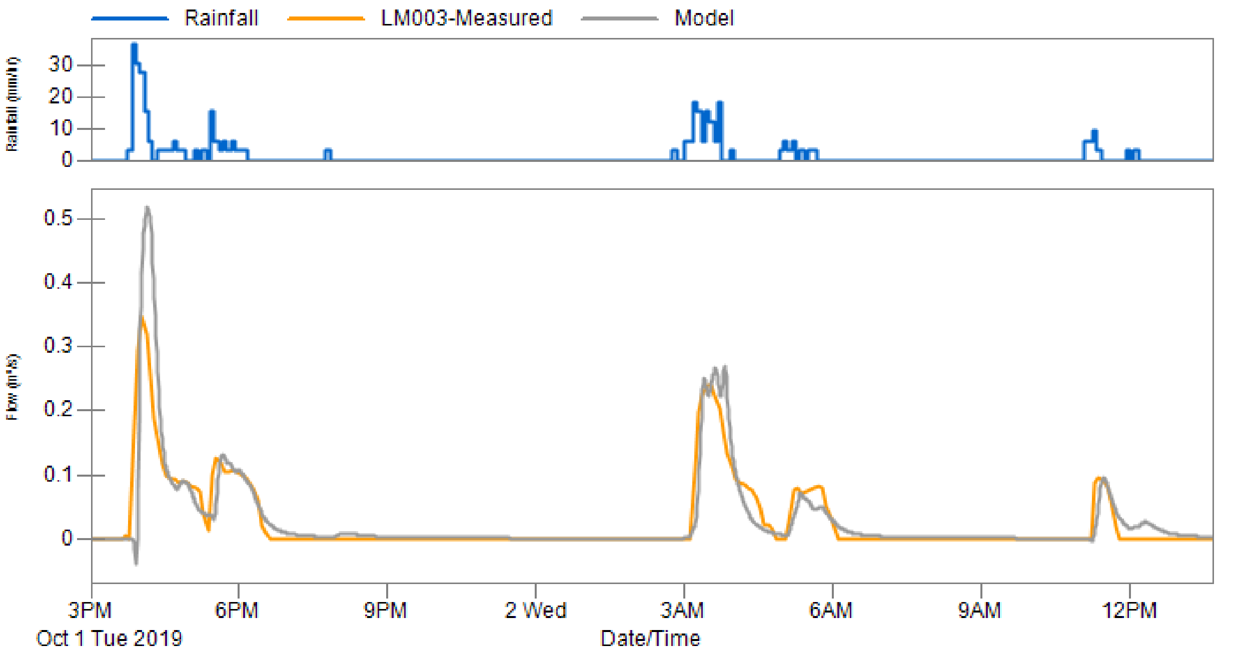

Rainfall
LM001-Measured
Model
Rainfall (mm/hr)
6
4
2
0
Flow (m³/s)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
3AM
6AM
9AM
Oct 12 Sat 2019
Date/Time


Rainfall
LM003-Measured
Model
Rainfall (mm/hr)
Flow (m³/s)
17 Sat
3AM
6AM
9AM
12PM
3PM
6PM
9PM
18 Sun
3AM
6AM
9AM
12PM
3PM
Aug 2019
Date/Time

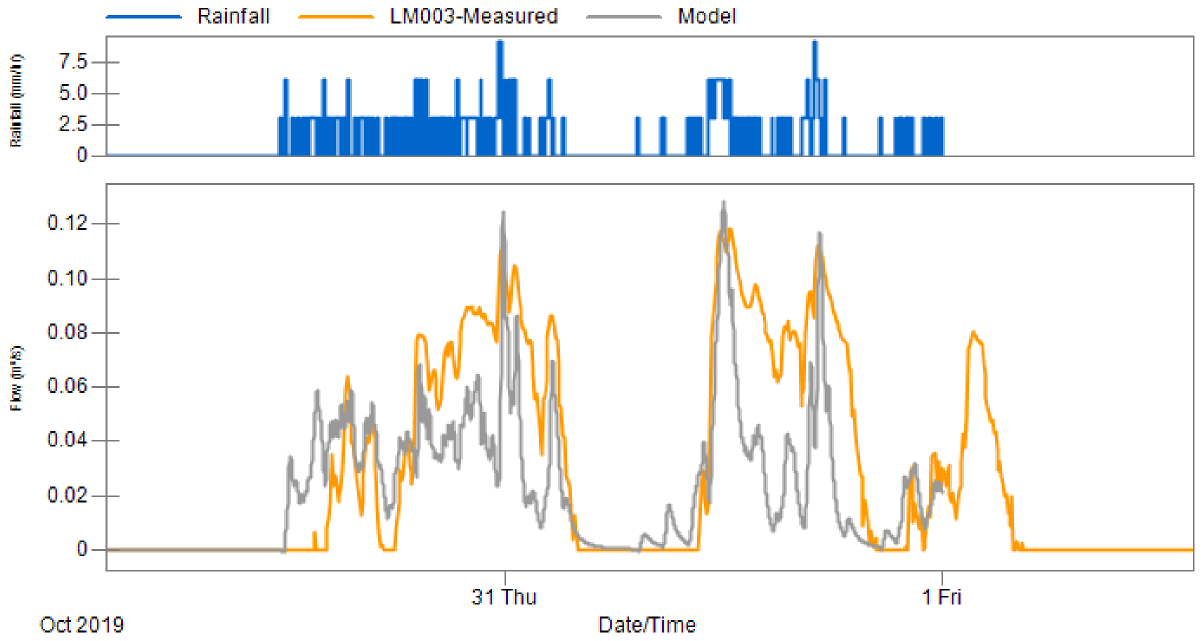

Rainfall
LM003-Measured
Model
Rainfall (mm/hr)
Flow (m³/s)
21 Wed
1AM
2AM
Aug 2019
Date/Time


Rainfall
LM003-Measured
Model
75
50
25
0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
11 Wed
3AM
6AM
9AM
12PM
3PM
6PM
9PM
Sep 2019
Date/Time

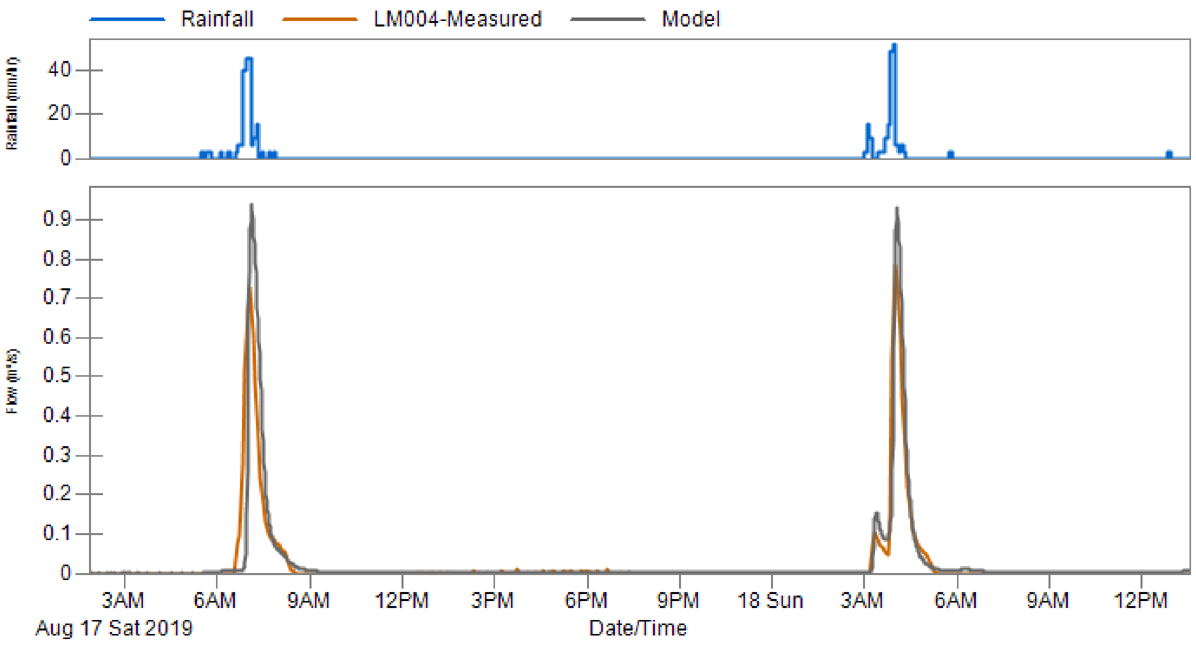

Rainfall
LM003-Measured
Model
40
20
0
0.6
0.5
0.4
0.3
0.2
0.1
0
7PM
8PM
9PM
10PM
11PM
14 Sat
Sep 13 Fri 2019
Date/Time

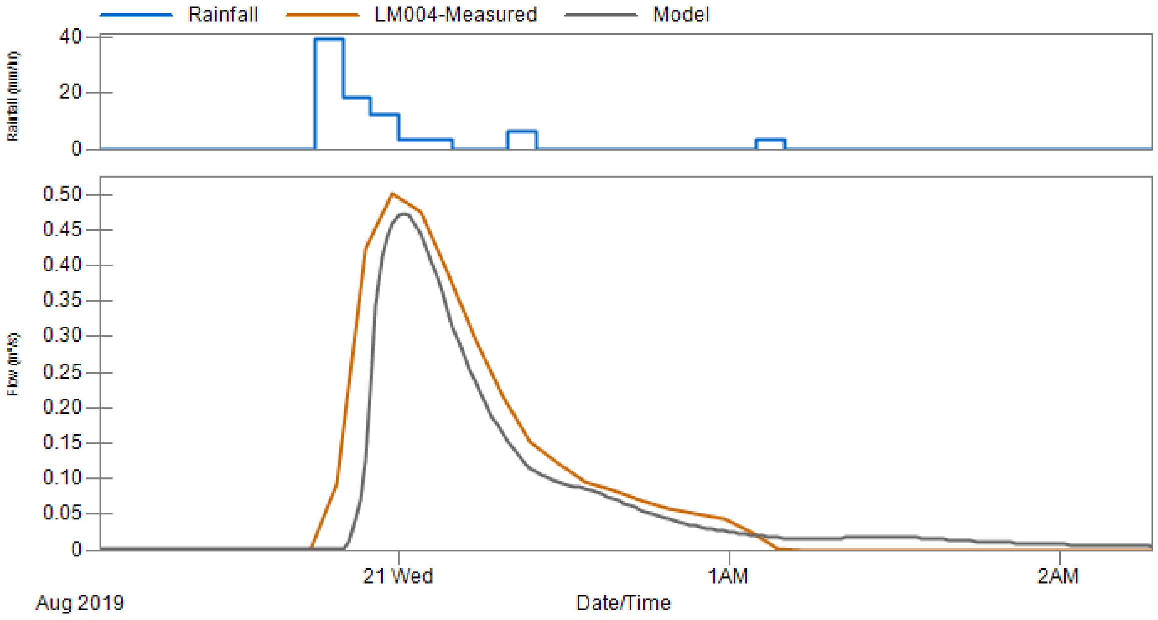


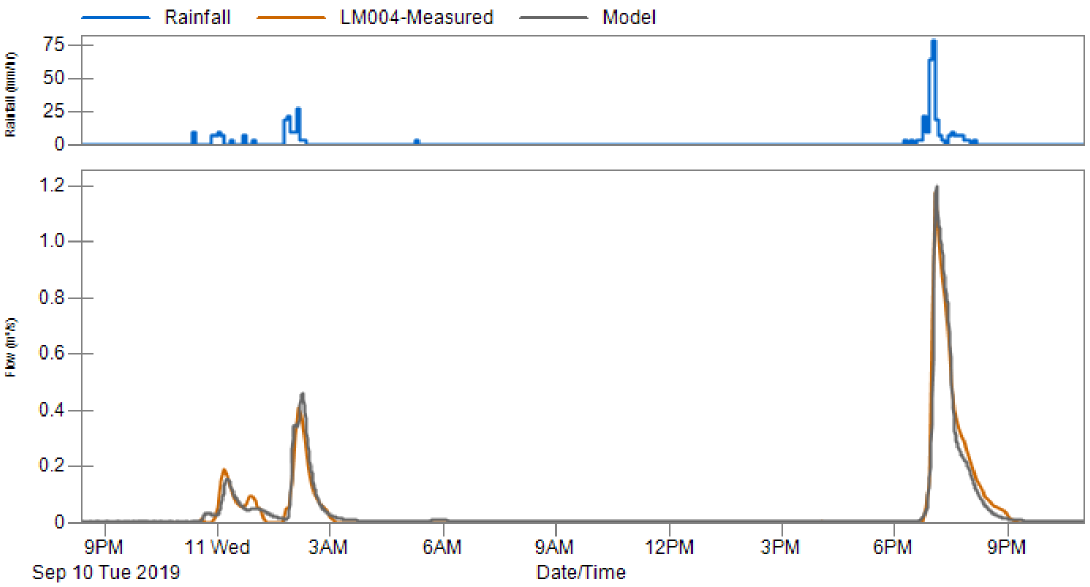
Rainfall
LM003-Measured
Model
30
20
10
0
0.5
0.4
0.3
0.2
0.1
0
3PM
6PM
9PM
2 Wed
3AM
6AM
9AM
12PM
Oct 1 Tue 2019
Date/Time



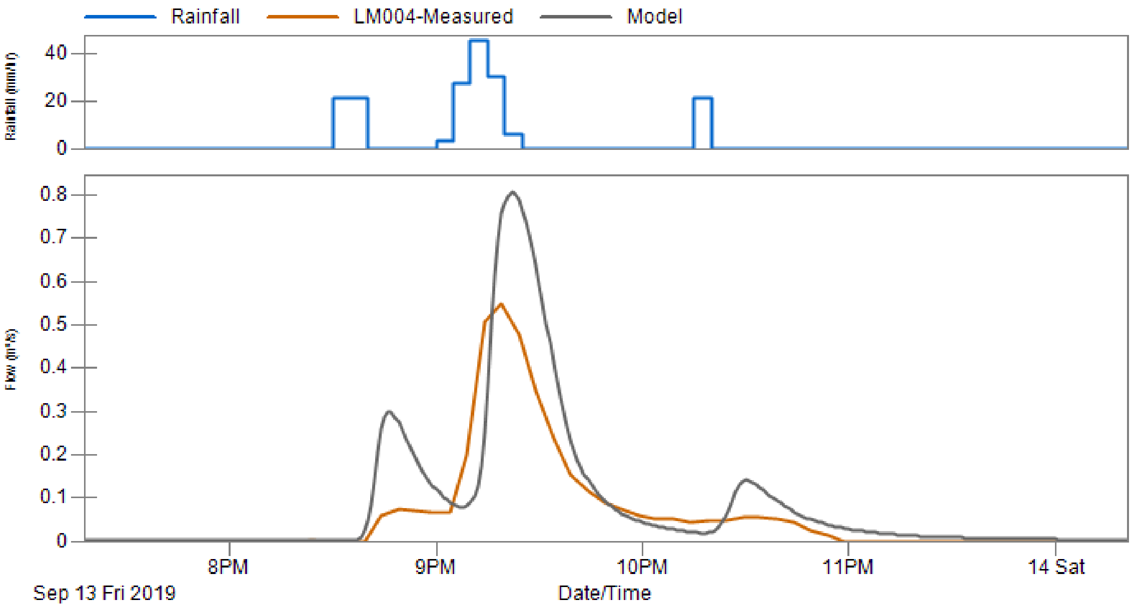
Rainfall
LM003-Measured
Model
7.5
5.0
2.5
0
0.12
0.10
0.08
0.06
0.04
0.02
0
31 Thu
1 Fri
Oct 2019
Date/Time


Rainfall
LM004-Measured
Model
40
20
0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
3AM
6AM
9AM
12PM
3PM
6PM
9PM
18 Sun
3AM
6AM
9AM
12PM
Aug 17 Sat 2019
Date/Time

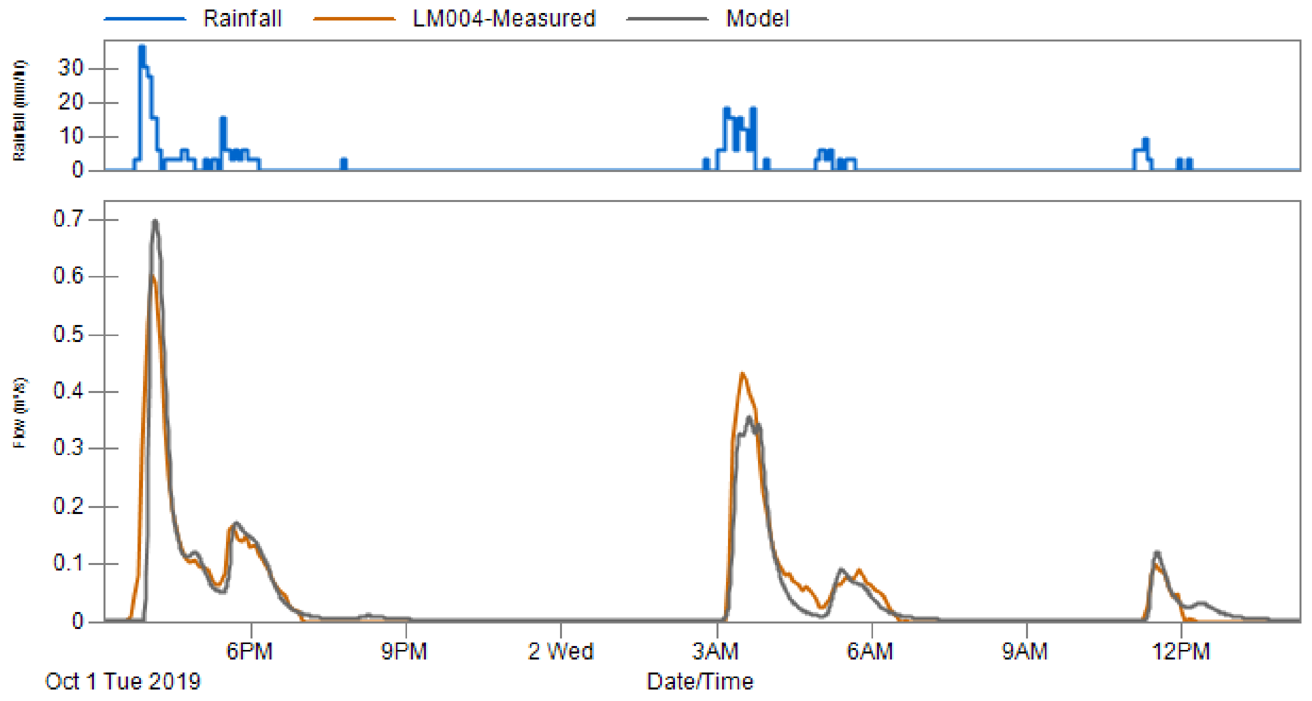

Rainfall
LM004-Measured
Model
40
20
0
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
21 Wed
1AM
2AM
Aug 2019
Date/Time



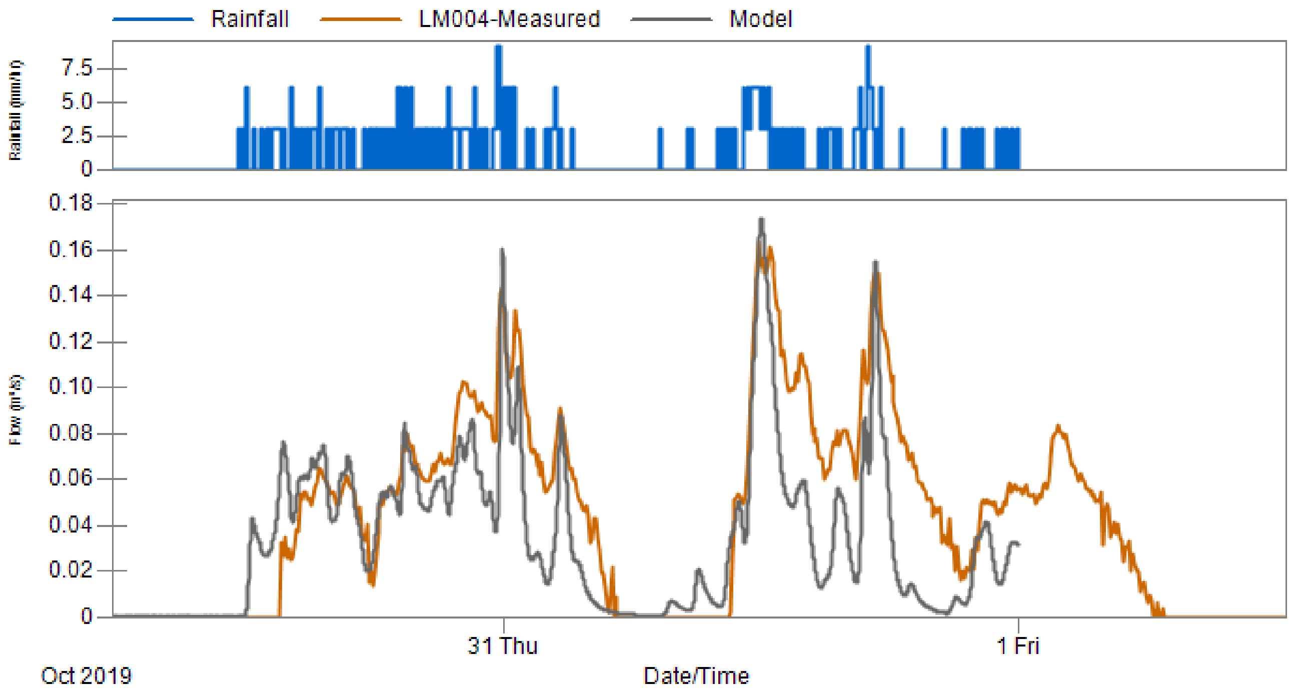
Rainfall
LM004-Measured
Model
Rainfall (mm/hr)
Flow (m³/s)
9PM
11 Wed
3AM
6AM
9AM
12PM
3PM
6PM
9PM
Sep 10 Tue 2019
Date/Time



Rainfall
LM004-Measured
Model
Rainfall (mm/hr)
Flow (m³/s)
8PM
9PM
10PM
11PM
14 Sat
Sep 13 Fri 2019
Date/Time



Rainfall
LM004-Measured
Model
30
20
10
0
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
6PM
9PM
2 Wed
3AM
6AM
9AM
12PM
Oct 1 Tue 2019
Date/Time



Rainfall
LM004-Measured
Model
7.5
5.0
2.5
0
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
31 Thu
1 Fri
Oct 2019
Date/Time

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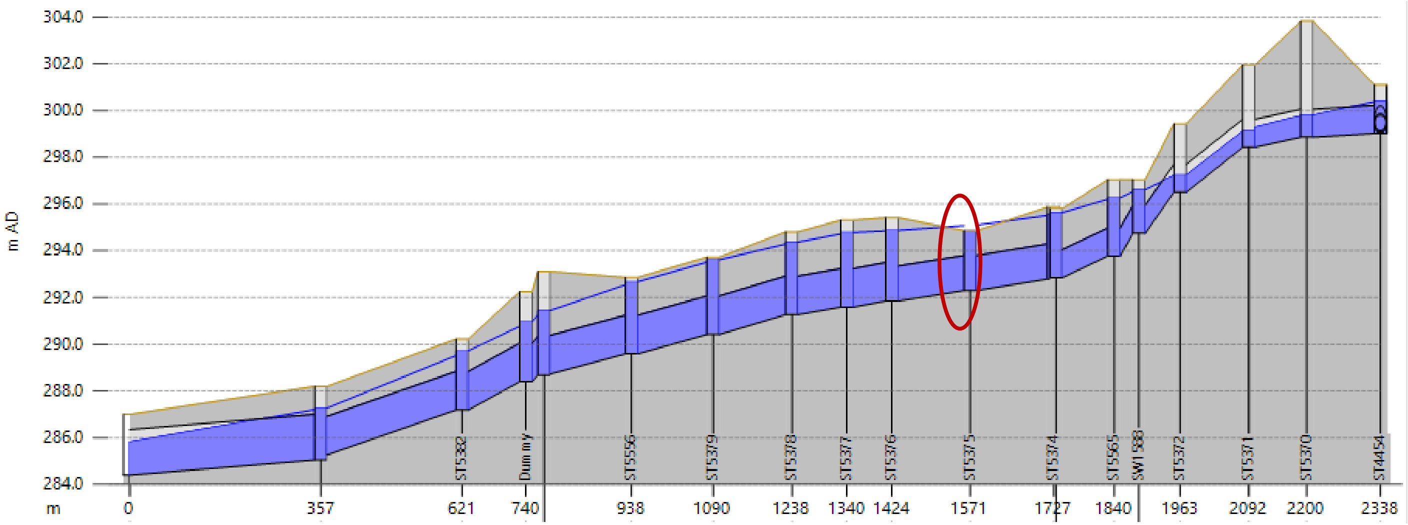
Appendix C

Overland Flow Path Mapping

Alternative 1: Warwick STM relief sewer connected to the downstream west trunk, between HURON ST and Thames River
Pipe Size: 1200-1950 mm
Total Length: 2090 (m)

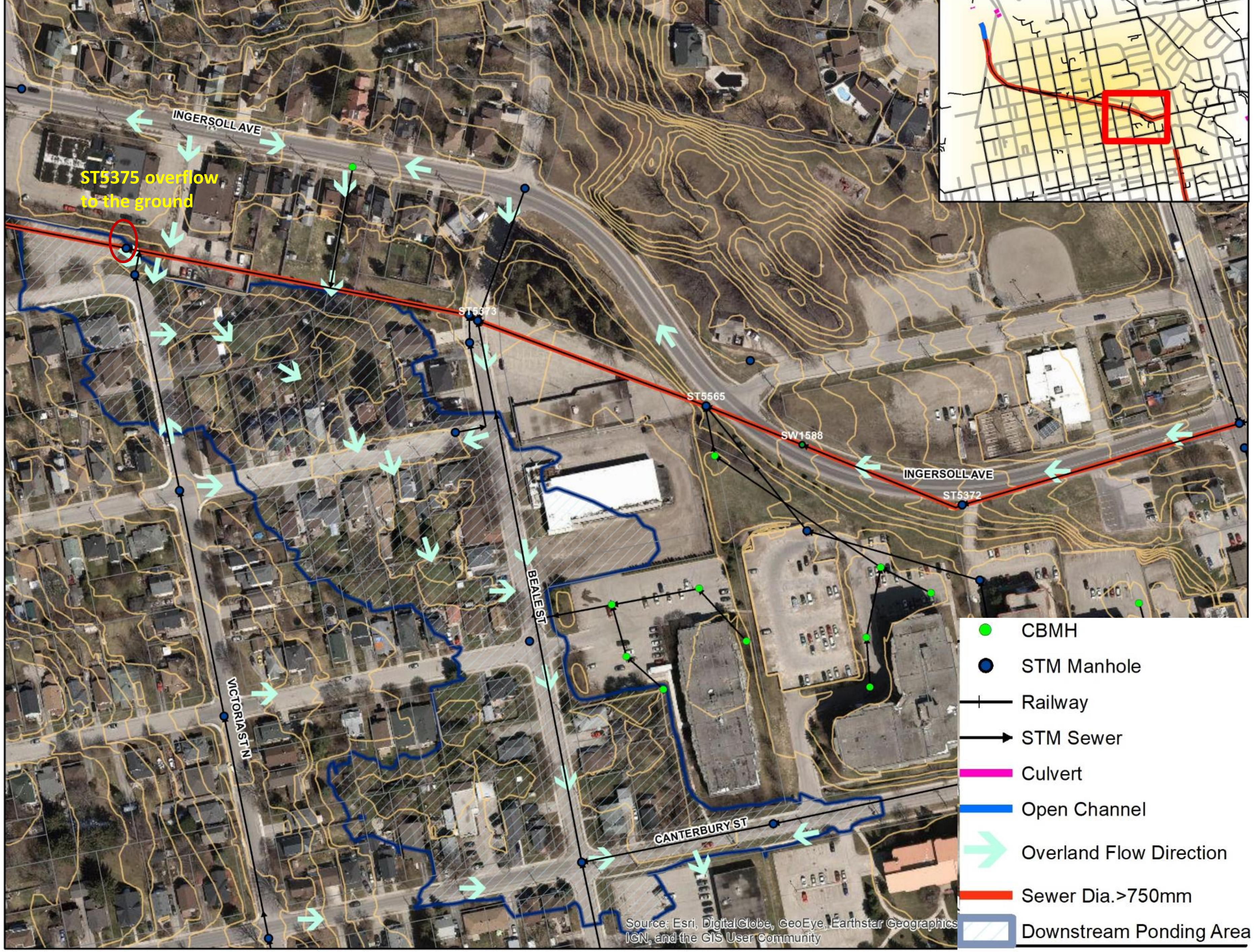


Water surface profile scenario:

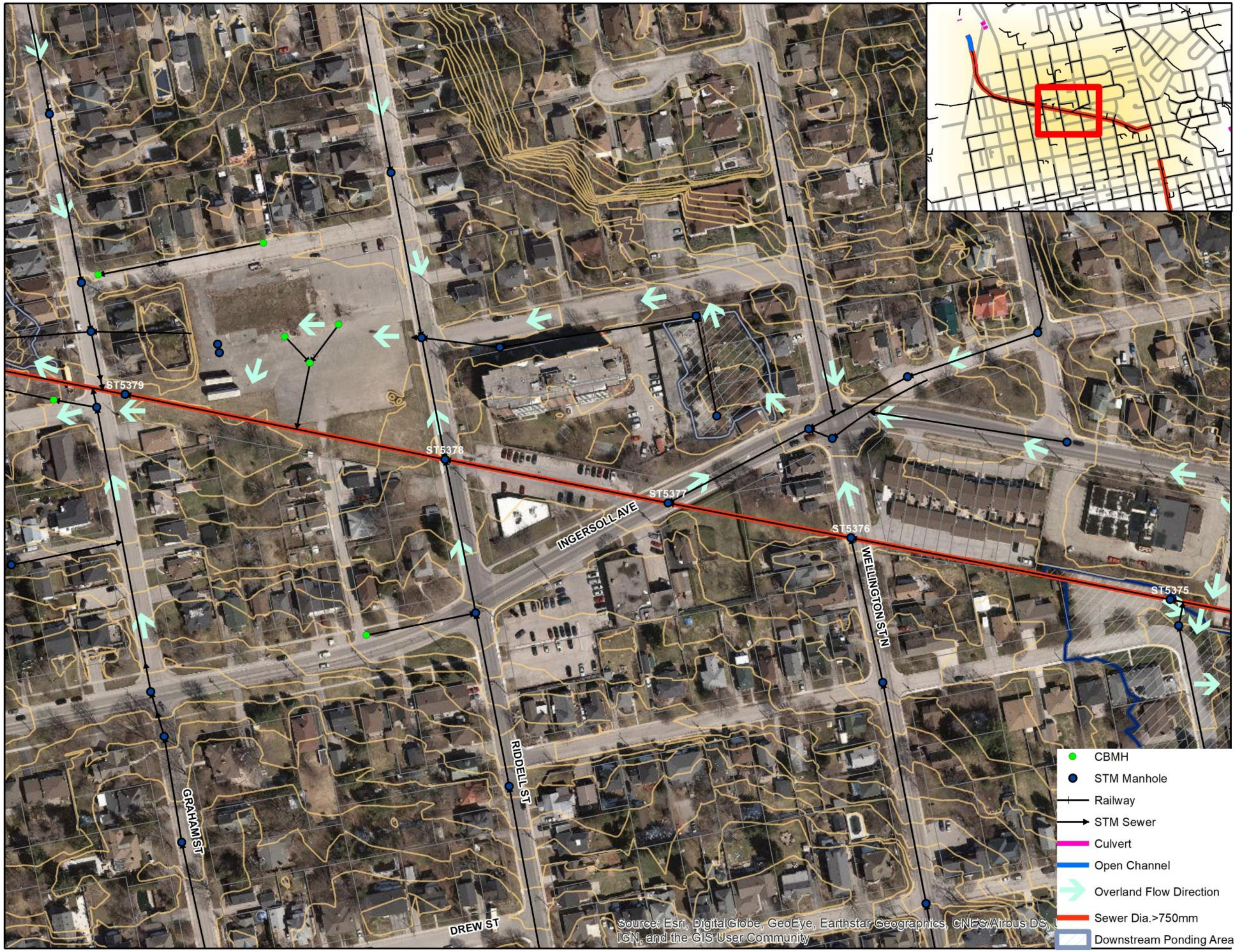
- 2.7 m3/s from Warwick West Trunk
- A 2-yr design event with 15-min duration having an intensity of 62 mm/hr was utilized together with impervious area to generate the flow from downstream subcatchments. A runoff coefficient of 0.8 was applied. Assumed 50% of the impervious area was 'directly connected' to the storm collection system.

System Constrain: ST5375

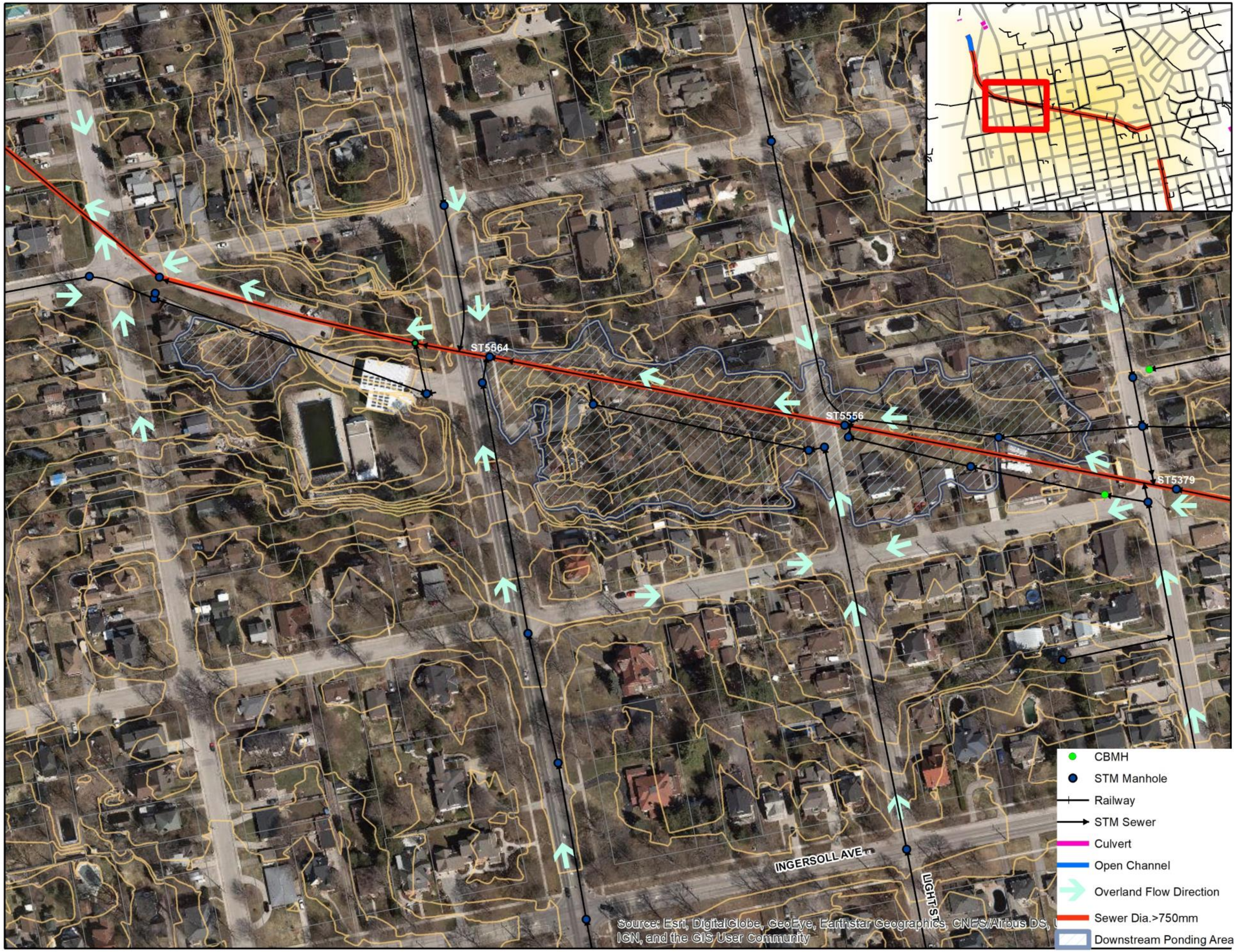
With more flow discharged to the West trunk, the STM sewer may surcharge to above the ground at ST5375



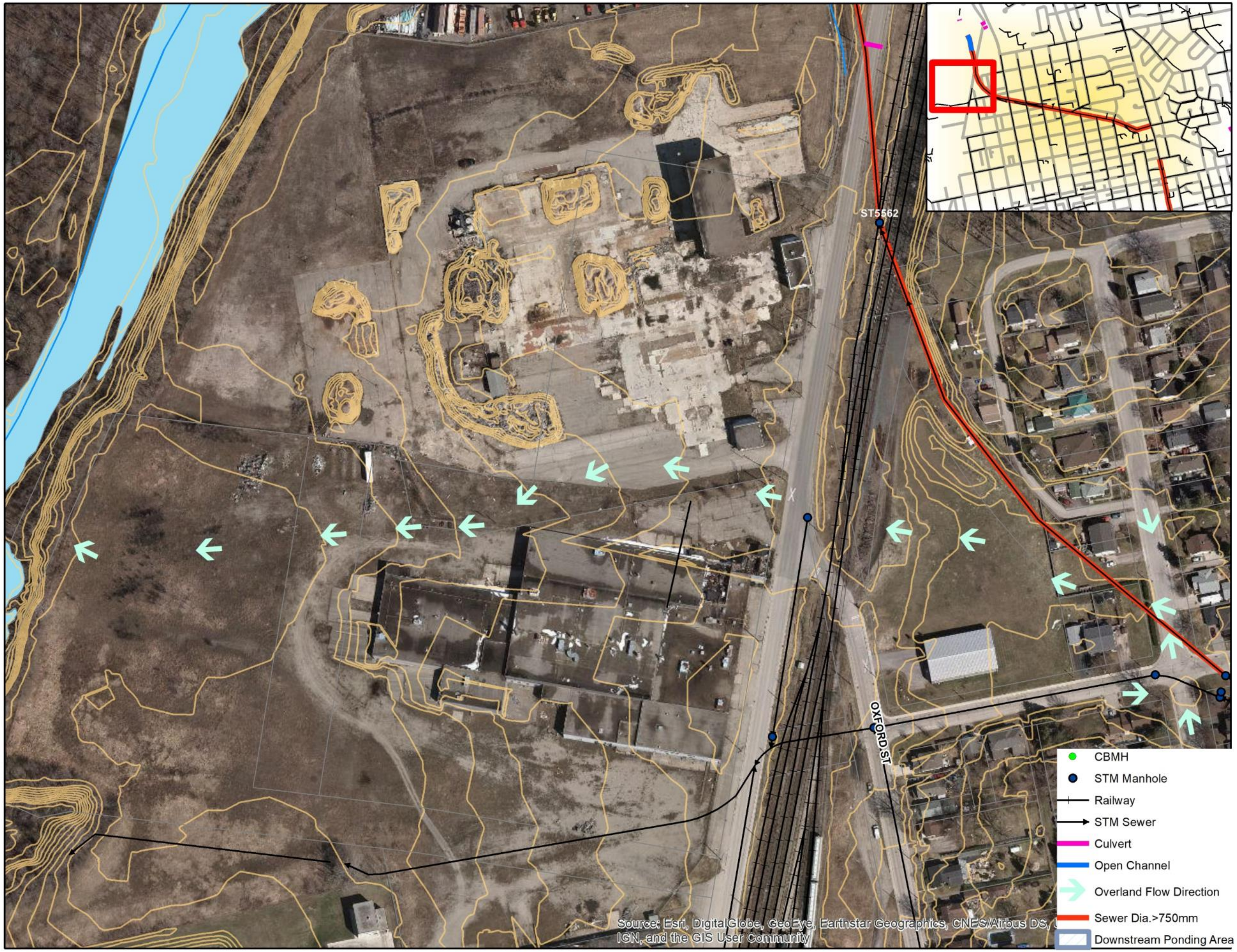
- **ST5375 overflow will impact the local private property**

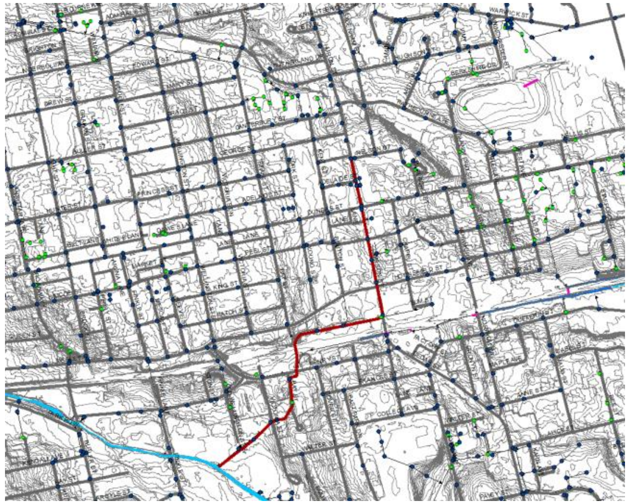


ST5379
ST5378
ST5377
ST5376
ST5375
INGERSOLL AVE
WELLINGTON ST N
RIDDELL ST
GRAHAM ST
DREW ST
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS,
IGN, and the GIS User Community
CBMH
STM Manhole
Railway
STM Sewer
Culvert
Open Channel
Overland Flow Direction
Sewer Dia.>750mm
Downstream Ponding Area

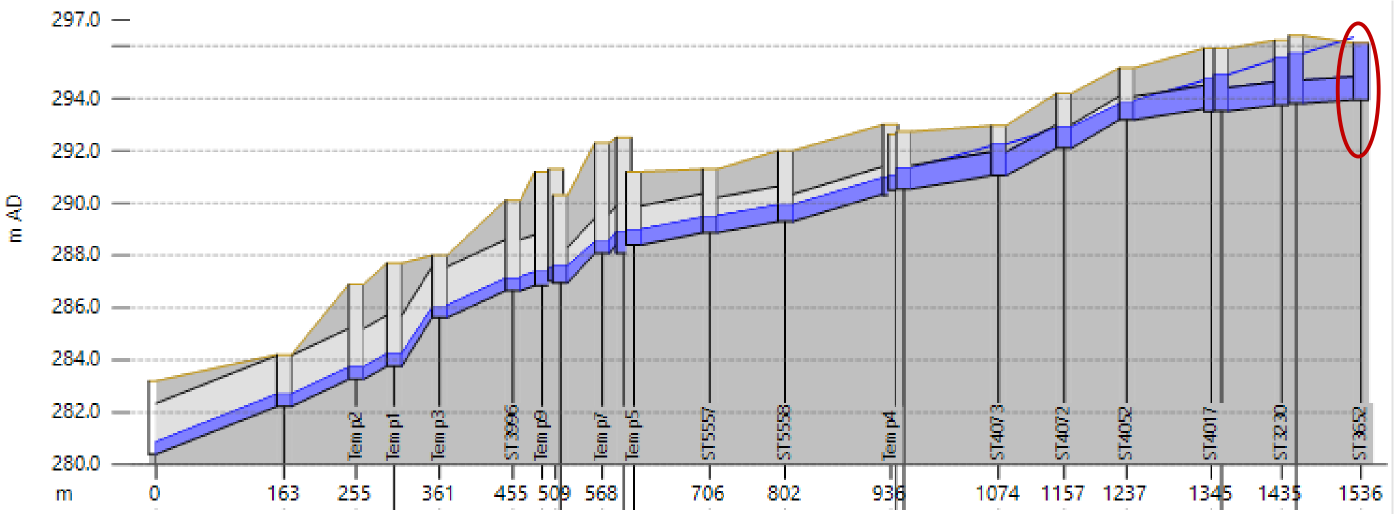


ST5564
ST5556
ST5379
INGERSOLL AVE
LIGHT ST
CBMH
STM Manhole
Railway
STM Sewer
Culvert
Open Channel
Overland Flow Direction
Sewer Dia.>750mm
Downstream Ponding Area
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS,
IGN, and the GIS User Community


ST5562
OXFORD ST
CBMH
STM Manhole
Railway
STM Sewer
Culvert
Open Channel
Overland Flow Direction
Sewer Dia.>750mm
Downstream Ponding Area
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS,
IGN, and the GIS User Community



Alternative 2: Warwick STM relief sewer connected to the downstream south trunk, on WILSON ST, from NELSON ST to Cedar Creek
Pipe Size: 900-1950 mm
Total Length: 1535 (m)

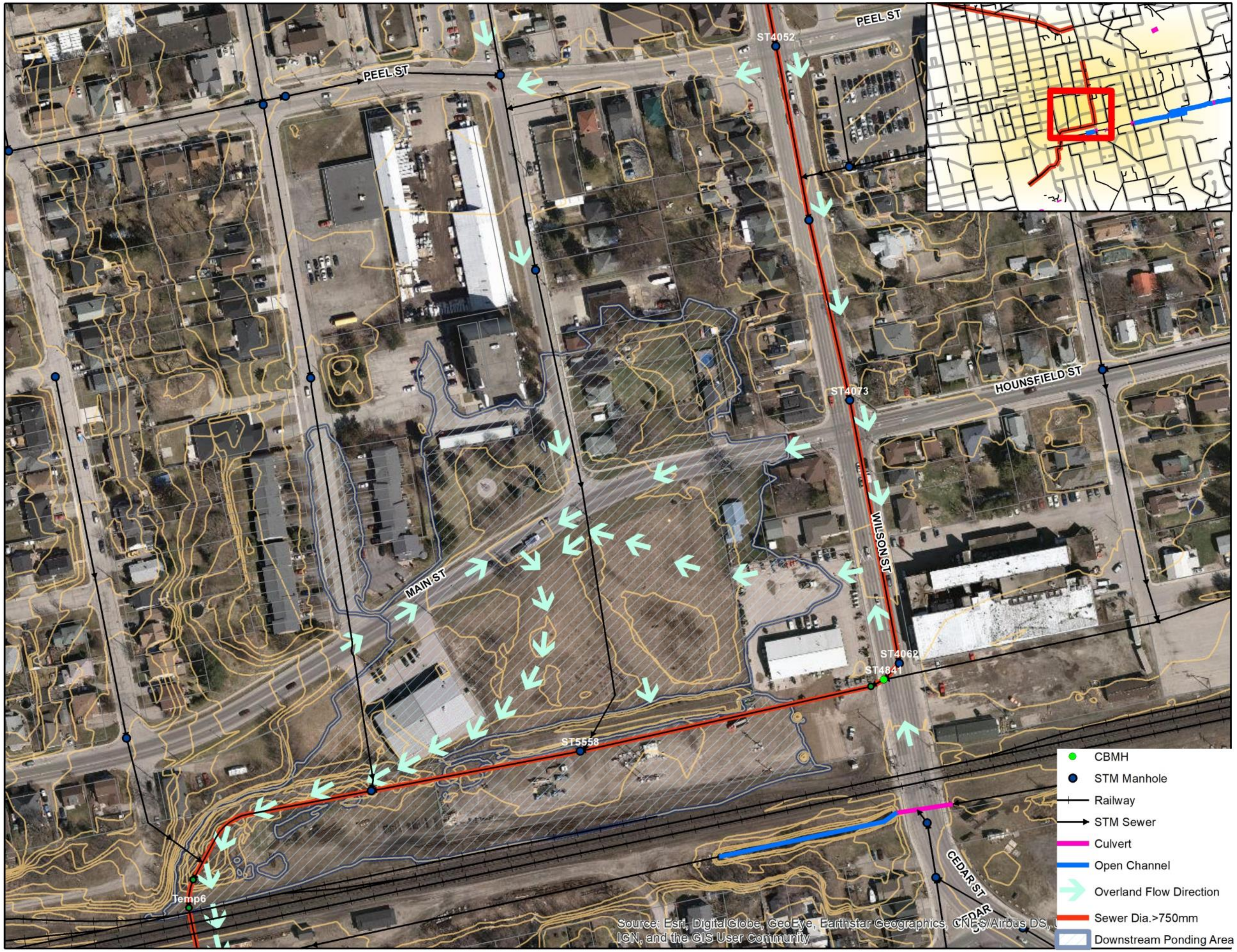


Water surface profile scenario:

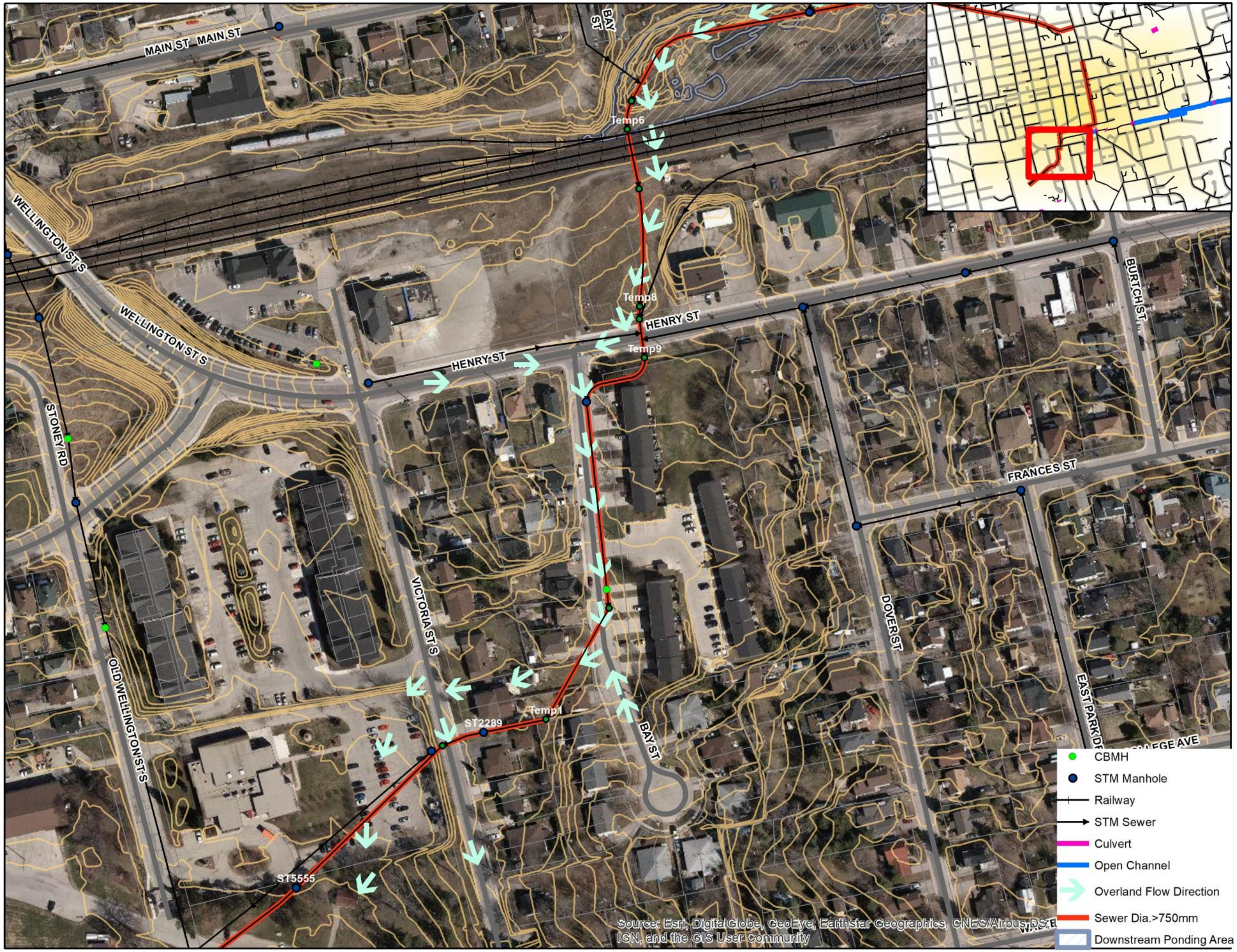
- 2.7 m3/s from Warwick West Trunk

System Constrain: ST3652
With more flow discharged to the South trunk, the STM sewer may surcharge to above the ground at ST3652, the 900 mm pipe section with a capacity of 1.5m3/s

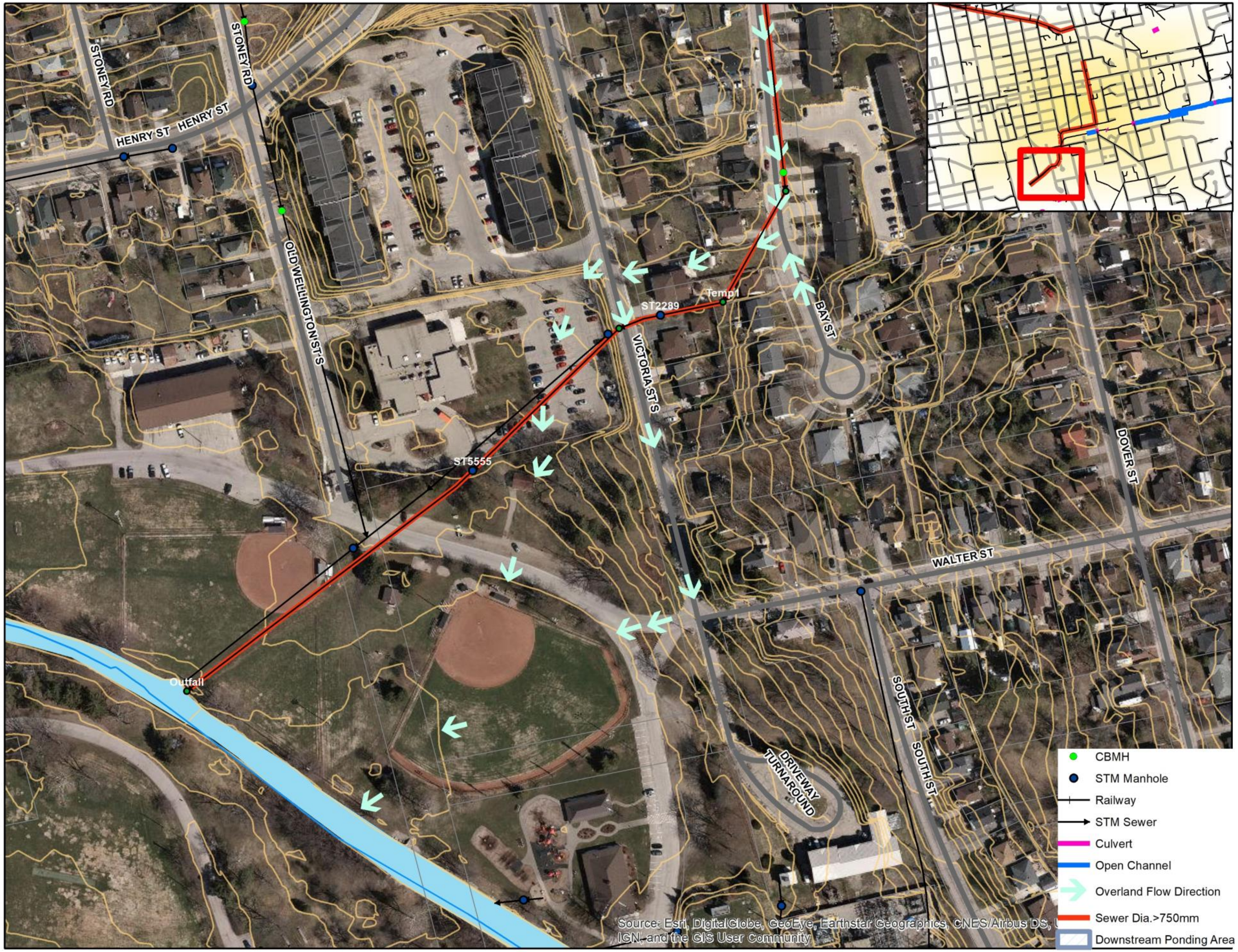
ST3652
ST3230
ST4017
ST4052
YORK ST
KENT ST
WILSON ST
PEEL ST
PEEL ST
CBMH
STM Manhole
Railway
STM Sewer
Culvert
Open Channel
Overland Flow Direction
Sewer Dia.>750mm
Downstream Ponding Area
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS,
IGN, and the GIS User Community



Overflow from ST3652 may impact local private properties and railway.



Over flow from ST3652 may impact local private properties.


STONEY RD
STONEY RD
HENRY ST
HENRY ST
OLD WELLINGTON ST S
VICTORIA ST S
BAY ST
DOVER ST
WALTER ST
SOUTH ST
SOUTH ST
DRIVEWAY TURNAROUND
ST2289
Temp1
ST5555
Outfall
CBMH
STM Manhole
Railway
STM Sewer
Culvert
Open Channel
Overland Flow Direction
Sewer Dia.>750mm
Downstream Ponding Area
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS,
IGN, and the GIS User Community

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Appendix C

C.2 – Warwick Area Flooding Study Supplemental Drainage Assessment

Final Warwick Area Flooding Study Supplemental Drainage Assessment

City of Woodstock

Project number: 60677774

April 12 2024

Statement of Qualifications and Limitations

The attached Report (the "Report") has been prepared by AECOM Canada Ltd. ("AECOM") for the benefit of the Client ("Client") in accordance with the agreement between AECOM and Client, including the scope of work detailed therein (the "Agreement").

The information, data, recommendations and conclusions contained in the Report (collectively, the "Information"):

- is subject to the scope, schedule, and other constraints and limitations in the Agreement and the qualifications contained in the Report (the "Limitations");
- represents AECOM's professional judgement in light of the Limitations and industry standards for the preparation of similar reports;
- may be based on information provided to AECOM which has not been independently verified;
- has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued;
- must be read as a whole and sections thereof should not be read out of such context;
- was prepared for the specific purposes described in the Report and the Agreement; and
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time..

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AECOM: 2015-04-13

Quality information

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Revision History

Revision	Revision date	Details	Authorized	Name	Position

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Table of Contents

Figures

1. Introduction

1.1 Project Background

The Norwich and Warwick Area Flooding Study Municipal Class EA was completed in July 2012 (Dillon Consulting). The study was completed to address flooding of basements, yards, and local streets. The EA reviewed the cause of the flooding and evaluated alternate solutions. Flooding in the Warwick area included severe surface ponding in the low-lying area at the intersection of Warwick St. and Cambridge St., ponding at the Warwick St. and Belgrave St. intersection, and basement and backyard flooding in several low-lying areas. Six alternatives were evaluated, and the preferred alternative consisted of strategically located underground storage facilities and an upgrade of the Hughson Street storm sewer.

When the preferred alternative proceeded to detailed design, the updated cost estimates for the recommended underground storage in the Warwick area proved to be much larger than initially estimated. The City of Woodstock approached AECOM to identify ay new solutions that could be evaluated against the previously recommended solution.

In addition to the analysis, AECOM conducted a monitoring program and assessment of the partially implemented recommendations. The results of the assessment are provided in the Warwick Area Flooding Report (AECOM, 2021). The location of the study area is shown in Figure 1. This report serves to summarize the findings of the prior report and provide additional information regarding costing and feasibility.

2. Problem Statement

The residents of the Warwick study area within the City of Woodstock have suffered from chronic flooding of basements and yard over the past 30 years. Recent high-intensity rainfall events and the continuously changing impact of climate change have resulted in wide-spread street, yard and basement flooding during high-intensity rainfall events. The street, yard and basement flooding is a result of poorly defined major overland flow routes and deficient storm drainage system capacity currently servicing Warwick study area.

Future development or urban intensification of open space within the Warwick study area are limited due to the lack of storm and sanitary servicing capacity. Based on these considerations the study area requires short- and long-term storm servicing improvements, an overall plan to implement these improvements, and localized flood protection measures in areas of high risk.

Figure 1. Study Area

3. Existing Environmental Conditions

3.1 Technical

The Warwick study area is located within the North Woodstock Watershed (Upper Thames River Conservation Authority, 2007). Its stormwater drainage system is composed of two separate trunks draining towards two different Watersheds.

The system's current configuration is the result of iterative improvements or modifications throughout time, having portions of older drainage systems dating back to early twentieth century infrastructure. The Hughson trunk storm sewer conveys flow in a south-westerly direction and ultimately discharges directly to the Thames River within the South Thames Watershed and the Warwick trunk storm sewer conveys flow in a north-westerly direction and ultimately discharges into Pittock Lake within the North Woodstock Watershed.

At the west study area boundary, the Hughson trunk consists of a 1200 mm diameter storm sewer, the ultimate outlet at the Thames River is approximately 1,950 m downstream.

At the north study area boundary the Warwick trunk consists of a 900 mm diameter storm sewer, the ultimate outlet at Pittock Lake is approximately 1,350 m downstream.

The two Warwick study area storm drainage systems fall within a low-lying area of the City of Woodstock. Topographically, the major system flows towards the intersection of Warwick Street and Cambridge Street. On the other hand, the minor systems are designed to drain the centre areas towards Pittock Lake and Thames River, on the perimeter of the study areas.

Consequently, the governing topography challenges the minor's systems ability to convey storm water flows away from the area by moving overland and underground storm flows in opposite directions. In addition, the two storm drainage systems present various interconnections, splitting stormwater flows between both North Woodstock and South Thames Watersheds, while adding complexity to the prevalent drainage paths under large storm events.

The sanitary system, on the other hand, presents two clearly separated systems draining North and West of the Warwick study area. With exception to the potential of basement flooding allowing the systems to interact, the storm and sanitary systems are entirely separated through the study area and their performance is expected to be unrelated to each other under normal dry weather flow conditions.

3.2 Terrestrial and Aquatic Resources

Typical of other urbanized areas within the City of Woodstock, the Warwick study areas can be characterized as having limited natural vegetation. However, several remnant woodlots exist within the study area, included an old-growth deciduous tree stand located in Sloane Park along the northerly limit of the Warwick study area. The Warwick study area falls within the 'North Woodstock' subwatershed, within the Upper Thames River (South Branch) watershed, under the jurisdiction of the Upper Thames Valley Conservation Authority (UTRCA). Secondary source information and a letter obtained from UTRCA confirmed the Warwick study area does not contain any Areas of Natural and Scientific Interest (ANSIs), Environmentally Sensitive Areas (ESAs), significant wetlands or any other lands regulated by the conservation authority.

3.3 Geology and Surficial Soils

The study area is located within the physiographic region of Southwestern Ontario known as the Oxford Till Plain. The till plain has well-marked valleys cut by glacial meltwater streams, including both Cedar Creek and the South Branch of the Thames River. The surface is drumlinized, notably in the area south of Woodstock, where the glacier overrode an older moraine and faint drumlins and fluting further north are evident. The drumlins within the City of Woodstock have a northwest alignment. The Woodstock drumlins are underlain by Bois Blanc limestone. The till is pale brown and there is some dolomite in it. The south branch of the Thames River rises in the long swamp west of Tavistock, flows east and then swings south eventually finding a spillway through Woodstock and Ingersoll. The Thames valley is about 2 km wide in this after and over 30 m deep, cut to bedrock. Cedar Creek, at Woodstock, is the only important tributary entering this section of the Thames River. It drains an area of inter-morainal swamp to the south of the city and at times creates minor flood conditions (Chapman & Putman, 1984).

3.4 Topography and Major Overland Flow Routes

Much of Woodstock is characterized by moraines and faint drumlins aligned in a northwest direction, the Thames River valley and the Cedar Creek River valley. The entire Warwick study area falls between two drumlins aligned in a north-westerly orientation. The highest ridges of the drumlin to the northeast of the Warwick study area are approximately 10 m higher than the trough in which the study area lies. To the southwest the drumlin ridge rises approximately 5 m above the lowest point in the trough before falling away to the southwest towards Cedar Creek.

The regional topography surrounding the Warwick study area has a significant impact on the drainage characteristics within each area. The natural and man-made topographic features within each study area result in discontinuous major overland flow routes that effect drainage patterns and conveyance of flows that exceed the capacity of local storm sewers. The entire Warwick study area lies within a depressed zone within two drumlins. Although the overall topography falls in a southeast to northwest direction the local topography does not allow for a continuous overland flow route out of the lowest portions of the depression near the intersection of Cambridge and Warwick Street.

3.5 Fill Areas and Former Landfill Sites

The County of Oxford Official plan provides constraint mapping that shows the location of existing and former landfill areas within the City of Woodstock. One former waste disposal site is located near the Fairgrounds property south of Warwick Street.

3.6 Cultural Resources

The community was first settled in 1800 after Sir John Graves Simcoe, Governor of what was then known as Upper Canada, determined that the area was well suited as a town site. Simcoe envisioned Oxford as one of several town sites linked by a military road and a system of rivers and canals. Other town sites included London, Chatham and Dorchester, with London as the defensible capital. The military road stretching from Burlington Bay through Woodstock to London, provided an overland supply route for the safe movement of troops and settlers. This would offer inland access during an era when commerce and settlements depended on major waterways. Simcoe named this road Dundas Street after Henry Dundas, Viscount Mellville, Secretary of State for War and the Colonies. The early settlers were American immigrants from New York State. Increased immigration from Great Britain followed in the 1820s and 1830s. Woodstock was incorporated as a town in 1851.

The Stage 1 Archaeological Assessment (AECOM, 2023) for the Warwick Area Flooding Study has determined that the potential for the recovery of pre- and post-contact Indigenous and 19th century Euro-Canadian archaeological resources within the study area is high, within areas not subject to previous disturbance.

3.7 Socio-Economic Environment

The County of Oxford is composed of eight municipalities and covers an area of 2,028 km^2, having the City of Woodstock as its main urban centre. In 1979, the County of Oxford adopted its Official Plan (the Plan) which contains goals, objectives and policies established primarily to manage and direct change and the effects on the social, economic and natural environment of the municipality (County of Oxford, 2022). The plan has been amended regularly since, with the current version being updated in 2022, to reflect the present challenges and future opportunities within Oxford County.

Specifically, the Plan establishes land use planning principles, coordinating the current and future strategies for environmental and socioeconomic sustainable development. Among their land use objectives, the Plan states the following principles:

- Maximizing the use of existing services and infrastructure
- Promoting energy efficiency and protecting natural areas
- Land use intensification
- Integration of environmental considerations into land use planning
- Improving community livability, function and design
- Committing to public environment.

The City displays a higher density in its historic central area, west of the Warwick study area, progressively reducing its density towards the edges. The dominant land uses towards the centre and north of the City are residential R1 and R2 (low density single-detached and semi-detached dwellings respectively).

Woodstock also displays extensive industrial and commercial areas on the southeastern quadrant, adjacent to Highway 401 and Oxford Road 4. Throughout time, the study area has experienced organic intensification and redevelopment, increasing the built area extents and affective the infrastructure level of service and natural environments.

The Warwick Study area consists primarily of low density residential land uses. On the south side, it presents community facilities through the Fairgrounds Complex. The Warwick area is a fully-developed mature community without clear opportunities for large redevelopment.

4. Evaluation of Alternative Solutions

4.1 Original Proposed Solution

Strategic locations of underground storage and upgrades to the Hughson Street storm sewer was the preferred solution identified in the original EA. The solution consisted of the following elements:

- Upgrading the storm sewer on Hughson to 1350-1800 mm, with sufficient capacity to convey the 100-year storm underground to the west outlet;

- Stormwater management facility (SWMF) implemented in the Fairgrounds in the south part of the study area (2400 m^3); and
- Surface flooding at Warwick/Cambridge addressed with:
  - expansion of the existing (107 m^3) underground storage at the DM Sutherland School, with added inlet capacity for the 100-year storm (1150 m^3); and,
  - additional underground storage at Cambridge/Warwick within the right-of-way (400 m^3), inlet controls at Knightsbridge Park, redirecting flows to the Hughson storm sewer.

The upgrade of the Hughson Street storm sewer and the construction of the Fairgrounds SWMF were completed, but detailed design of the proposed underground storage at the DM Sutherland School and at Cambridge/Warwick resulted in significantly higher cost estimates than originally presented in the EA. As a result, progress toward the proposed underground storages was halted in order to further investigate alternative approaches and identify a cost-effective option.

4.2 Data Collection and Modelling

Monitoring of the partially implemented original solution was carried out by AECOM in 2019, and modelling and assessment of the new conditions was completed and is detailed in the Warwick Area Flooding Report (AECOM, 2021). The alternatives considered in the report are as follows:

- Option 1 – Implement the full EA solution;
- Option 2 – Accept existing conditions and existing level of risk – i.e. partial implementation of the EA solution;
- Option 3 – Pursue a solution that updates the EA solution such as updated storage volumes based on a re-calibrated model; or,
- Option 4 – Pursue a new solution in the form of flood mitigation measures localized to the specific properties at risk.

A fifth option involving non-property specific controls such as a large diameter relief sewer from the Cambridge/Warwick area discharging to an existing trunk storm sewer beyond the overland catchment limits of the study area was also initially considered, but deemed infeasible. The existing overland flow paths are in many areas beyond the Warwick study area not along existing rights-of-way, and there are existing overland flooding concerns for private property along each potential overland flow path. Since the increased conveyance of a relief sewer would contribute to overland flow and make this existing surface flooding worse, the fifth option was not modelled.

Modelling of the area identified a total of 8 properties at risk of being impacted by overland flooding under existing conditions.

The modeling of the EA solution (Option 1) indicates that 4 residential buildings would still be subject to surface flooding at a 50-year return interval event, and 8 buildings would be subject to flooding during the 100-year return interval event.

Under existing conditions (Option 2), 2 residential buildings would be flooded for a 2-year event, 8 residential buildings for a 50-year event, and 8 buildings for a 100-year event. The assessment indicates that construction of the 2 underground storage tanks (at D M Sutherland school and at Cambridge/Warwick) only provide marginal benefits at an extremely high cost.

Modelling revised underground storage tank volumes (Option 3), indicate that smaller volumes provide negligible benefits, and full protection from surface flooding would require substantially larger volume of storage than is currently proposed.

Under Option 4, AECOM reviewed additional lower cost flood mitigation / flood proofing alternatives that only address the specific properties at flood risk. Flood proofing measures addressed at the specific properties at risk of surface flooding can mitigate the risk of damages at these properties. This can be either measures targeted for the homeowners to pursue (such as sealed basement windows, raised sills, property grading), or measures on public property (such as a raised sill along the driveways / front yards along the curb that prevents the ponding water from spilling into the lot). The latter alternative may also require private drainage measures to discharge or retain stormwater on each property (e.g. pumping, rain gardens/retention, etc).

4.3 Assessment of Alternatives

The 2021 Warwick Flooding Study report indicates that, under existing conditions with partial EA recommendation implementation (Option 2), there are only 8 properties that are identified to be at risk of being impacted by overland flooding, and that the risks to all 8 properties are only partially mitigated by full implementation of the EA solution.

Due to this, the implementation of property-specific controls for the at-risk buildings (Option 4) is considered to be the most cost-effective control of flood risks and has therefore been identified as the preferred alternative.

All of the assessed alternatives only address the risks of overland flood impacts to properties. Neither the EA solution nor the potential additional surface flood proofing measures will remove the risk caused by frequently surcharging storm sewers. Both the modeling and the monitored water levels indicate that the storm sewers in the area frequency surcharge to levels that are above basement elevations. There have not been widespread basement flooding complaints every year in the area, which suggests that most basements are not directly connected to the storm sewers; the foundation drains may discharge via sump pumps to the ground, or they may be protected by check valves on the storm service connection, or the storm service connection may not exist. The small number of direct storm connections via foundation drains in borne out in CCTV investigations and homeowner questionnaires completed during the EA. It is recommended that any future basement flooding in the area that is attributed to storm sewer backup should be addressed through public education and/or subsidies for measures on private lots.

5. Preferred Alternative

The revised assessment and evaluation of alternative solutions indicated that implementing localized flood controls to protect specific properties at risk (Option 4) is the preferred alternative solution.

As indicated previously this involves supplementing the recommended EA measures which have already been implemented with measures targeted for the homeowners to pursue (such as sealed basement windows, raised sills, property grading), or measures on public property (such as a raised sill along the curb that prevents the ponding water from spilling into the lot). The latter alternative may also require private drainage measures to discharge or retain stormwater on each property (for example, pumping, rain gardens/retention, etcetera).

5.1 Environmental Implications of the Proposed Changes

The potential environmental effects and mitigation measures outlined in this section focus only on the differences between the preferred alternative and the original EA solution. Potential environmental effects and associated mitigation measures will be further addressed as part of the detailed design phase.

5.1.1 Infrastructure and Safety

Implementation of Option 4 instead of the full EA solution may result in higher flood risks to up to 8 properties within the Warwick Study area, but the proposed property-specific controls will mitigate damages which may have otherwise occurred.

The implementation of localized controls will require localized construction efforts and will no longer require construction impacts and disturbance to the Warwick and Cambridge intersection or the D M Sutherland school parking lot.

5.1.2 Technical

There will no longer be service level improvements which would have otherwise been provided by the Warwick and D M Sutherland underground storage facility.

The technical complexity and constructability requirements for the localized controls will be significantly lower than those required for the underground storage facilities. However, co-operation from the owners of the identified buildings will likely be required in order to implement the localized controls.

5.1.3 Financial

The implementation of localized flood controls at the at-risk properties will be significantly more affordable and cost-effective when compared to the construction and maintenance of two additional underground storage systems which would provide partial flood protection to eight residential buildings up to the 50-year event.

5.2 Cost Estimate

The specifics of the localized flood controls for the eight at-risk properties will be dependent on the lot-specific conditions and determined in detailed design. As such, the costs of the solution will be dependent on the protections selected. This section serves to provide rough estimations of the general costs for lot protection options.

5.2.1 Design

The first steps in refining the design of the localized protections will require detailed topographic surveys of the properties at risk. The information of interest includes:

- Corners of properties / property lines;
- Corners of buildings;
- Top of foundation;
- Finished first floor elevation;
- Any and all building opening elevations and dimensions of openings below finished first floor elevation; and,
- Location of sump pump outlet (i.e., elevation, discharge to grade or PDC).

Costs of the initial surveys are estimated to be in the range of $1000 per property. Once the most vulnerable areas and flow routes have been identified, the most effective options can be refined. Detailed design and pursuit of homeowner approval can be carried out following this step, but as the design will be dependent on the information obtained during the survey, there is currently insufficient information available to provide an estimate on the level of effort.

It is possible that survey results may allow for narrowing of the areas and locations required to be impacted by the controls. The following sections provide estimations of supply and construction costs for some protection options, assuming that all eight properties will be involved.

5.2.2 Basement Window Protections

The supply and install cost for sealed window wells is estimated to be $2500 per window. Assuming four basement windows per home, the costs of this option are expected to be in the range of $80,000.

5.2.3 Curb Protections

The supply and install costs of standard and mountable curbs are typically in the ranges of $45-$80 per meter. The costs of specialized curbs with sills to provide overland flood protection will be dependent on the supplier, but approximately twice the price of more typical curbs has been initially estimated. The length of curb and driveway along the 8 properties of interest has been assumed to be 220 m, and at a price of $150/m to supply and install, and $7/m for removal of the existing curb, the costs of this option are expected to be in the range of $35,000.

5.2.4 Grading Modifications

The costs involved in grading the front lawns of the 8 properties to prevent overland flows impacting the buildings will depend on the area required to be disturbed and how much material is required to be brought in or excavated. Assuming front lawn dimensions of 25 m x 10 m, the estimated grading and re-sodding costs for the eight properties is estimated to be in the range of $60,000.

5.2.5 Low Impact Development

If curb protection and grading measures are implemented to prevent overland flows from encroaching on the properties, drainage paths away from the properties will also be blocked. Measures to manage the trapped runoff will be required, and one potential option would be to utilize rain gardens or soakaways. Implementing a basic clear-stone soakaway to infiltrate runoff from the 8 properties is estimated to be in the range of $20,000. However, additional costs are expected as the soakaway would need to be located on private property and permission from the owner would be required. Splitting the soakaways into individual units is anticipated to have similar total installation costs, but landscaping materials to improve the aesthetics of the soakaways would increase the pricing.

5.2.6 Pumping

If curb protection and grading measures are implemented to prevent overland flows from encroaching on the properties, drainage paths away from the properties will also be blocked. Measures to manage the trapped runoff will be required, and one potential option would be to pump the runoff out of the trapped area. The costs of implementing a pumping solution will be dependent on the extent of new infrastructure required, maintenance and operating costs for the system, and costs involved in acquiring areas for the pump(s) to be installed in; there is currently insufficient information available to provide an estimate.

6. References

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